Towards an Integrated Management of Tropical Coastal Resources

Proceedings of the ASEAN/US Technical Workshop
on Integrated Tropical Coastal Zone Management
28-31 October 1988
Temasek Hall, National University of Singapore
Singapore

Edited by

Chou Loke Ming, Chua Thia-Eng, Khoo Hong Woo, Lim Poh Eng, James N. Paw, Geronimo T. Silvestre, Mark J. Valencia, Alan T. White and Wong Poh Kam

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Foreword

The coastal waters of Southeast Asia have some of the world's richest ecosystems and are characterized by extensive coral reefs and dense mangrove forests. Blessed with warm tropical climate and high rainfall, these waters are further enriched with nutrients from the land, which enable them to support a wide diversity of marine life. Because economic benefits could be derived from them, the coastal zones in these countries teem with human settlements. Over 70% of the population in the region lives in coastal areas where resources have been heavily exploited. This situation became apparent between the 1960s and 1970s when socioeconomic pressures increased. Large-scale destruction of the region's valuable resources has caused serious degradation of the environment, thus affecting the economic life of the coastal inhabitants. This lamentable situation is mainly the result of ineffective or poor management of the coastal resources.

Coastal resources are valuable assets that should be utilized on a sustainable basis. Unisectoral overuse of some resources has caused grave problems. Indiscriminate logging and mining in upland areas might have brought large economic benefits to companies undertaking these activities and, to a certain extent, increased government revenues, but could prove detrimental to lowland activities such as fisheries, aquaculture and coastal-tourism dependent industries. Similarly, unregulated fishing effort and the use of destructive fishing methods, such as mechanized push-nets and dynamiting, have seriously destroyed fish habitats and reduced fish stocks. Indiscriminate cutting of mangroves for aquaculture, fuel wood, timber and the like has brought temporary gains in fish production, fuel wood and timber supply but losses in nursery areas of commercially important fish and shrimp, coastal erosion and land accretion.

The coastal zones of most nations in the Association of Southeast Asian Nations (ASEAN) are subjected to increasing population and economic pressures manifested by a variety of coastal activities, notably, fishing, coastal aquaculture, waste disposal, salt-making, tin mining, oil drilling, tanker traffic, construction and industrialization. This situation is aggravated by the expanding economic activities attempting to uplift the standard of living of coastal people, the majority of whom live below the official poverty line.

Some ASEAN nations have formulated regulatory measures for their coastal resources management (CRM) such as the issuance of permits for fishing, logging, mangrove harvesting, etc. However, most of these measures have not proven effective due partly to enforcement failure and largely to lack of support for the communities concerned.

Experiences in CRM in developed nations suggest the need for an integrated, interdisciplinary and multisectoral approach in developing management plans that will provide a course of action usable for the daily management of the coastal areas.

The ASEAN/United States (US) Coastal Resources Management Project (CRMP) arose from the existing CRM problems. Its goal is to increase existing capabilities within ASEAN nations for developing and implementing CRM strategies. The project, which is funded by the US Agency for International Development (USAID) and executed by the International Center for Living Aquatic Resources Management (ICLARM) in cooperation with ASEAN institutions, attempts to attain its goals through these activities:

- analyzing, documenting and disseminating information on trends in coastal resources development;
- increasing awareness of the importance of CRM policies and identifying, and where possible, strengthening existing management capabilities;
- providing technical solutions to coastal resources use conflicts; and
- promoting institutional arrangements that bring multisectoral planning to coastal resources development.

In addition to implementing training and information dissemination programs, CRMP also attempts to develop site-specific CRM plans to formulate integrated strategies that could be implemented in the prevailing conditions in each nation. To date, these management plans have essentially reached the final phase of completion and require approval, endorsement and funding for implementation.

The Technical Workshop on Integrated Tropical Coastal Area Management, held in Singapore on 28-31 October 1988, aimed to foster regional cooperation among scientists through an exchange of ideas, information, experiences and expertise on CRM and to provide a venue for them to present their scientific findings and discuss coastal resources issues, planning and management.

Jointly sponsored by the National University of Singapore, Science Council of Singapore and the ASEAN/US CRMP of ICLARM, the technical workshop was the first regional meeting of scientists involved in CRM since the project's inception in 1986.

A total of 103 participants composed of project personnel and observers from the six ASEAN member-countries and the United States (i.e., from the the East-West Center, the University of Hawaii and the University of Rhode Island) presented 77 papers covering these areas: coastal resources assessment, environmental degradation, socioeconomics of coastal resources and communities, legal and institutional arrangements in coastal area management, environment/habitat enhancement and production, and resource planning and management. The papers were based on research made and secondary data gathered by the various project task groups.

These proceedings are a concrete expression of the participants' commitment to the regional effort of properly managing, protecting and conserving the coastal resources.

We would like to express gratitude to the editorial staff of the ASEAN/US CRMP: Marie Sol M. Sadorra, Romeo J. Santos, Mari Assunta A. Carigma, Pamela P. del Rosario, Cecille Legazpi and Katherine I. Chua for copyediting the papers; Rachel C. Josue and Eloisa Espiritu for typing them; and Rachel Atanacio for drawing the figures and preparing the layout. Appreciation is extended to Mr. Len Garces of ICLARM and Dr. Richard Tobin of the State University of New York, Buffalo, U.S.A., who contributed valuable technical and editorial comments; and to USAID which funded the workshop and the publication of these proceedings.

The editors

Session I
Coastal Resources Assessment

An assessment of the coastal environment of Phangnga Bay, Thailand

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LIMPSAICHOL, P. and N. BUSSARAWIT. 1991. An assessment of the coastal environment of Phangnga Bay, Thailand, p. 3-11. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

Phangnga Bay in southern Thailand is one of the six pilot sites of the ASEAN/US Coastal Resources Management Project (CRMP). General environmental and oceanographic parameters were monitored in Phangnga Bay which covered mariculture sites, fishery potentials and mangal outfall areas. Outflowing water of net tidal transport dominated the surface water while the dense seawater flowed underneath. During the southwest monsoon with heavy rainfall, large variations in salinity (>5 ppt) extended more than 5 km offshore because of the outflow of very low saline water (<10 ppt) from mangal canals. Coliform bacteria and other biological parameters were determined to assess the environmental changes diurnally and seasonally. The relatively calm seas during the northeast monsoon caused the build up of high hydrogen sulfide in the sediment while opposite patterns were observed during the southwest monsoon when seas were rough. The deterioration of economically important bivalve beds (*Paphia* sp.) was observed to be related to the concentrations of hydrogen sulfide. The degree of environmental variation and the extent of affected areas are prerequisite information that will provide a guideline for the appropriate management of marine resources in the bay.

INTRODUCTION

Phangnga Bay is located in the Upper South region of Thailand facing Andaman Sea. The bay is surrounded by 196,428 ha of mangrove swamps (Aksornkoae 1988).

The hydrodynamics of the bay is mainly influenced by semidiurnal tides and two seasonal regimes, the northeast and southwest monsoons. The dry northeast monsoon is from November to April, with an average annual rainfall of 290 mm. It is characterized by a calm sea and weather. The wet southwest monsoon prevails from May to September and is characterized by a strong southwesterly or westerly wind, which brings an average annual rainfall of 1,970 mm (Yasaki and Jantarapagdee 1981).

The hydrodynamics of the bay was studied from January 1987 to 1988 under the CRMP. The information derived from the study is vital in assessing such issues as larvae recruitment, mariculture potential areas, pollution load, water quality and sedimentation characteristics in relation to mining operations and the resuspension process.

STUDY AREAS

Seven sampling stations were established. Three stations were located at the inner bay within Phangnga Province where intensive aquaculture was established. The inner bay is shallow, largely influenced by runoff, with extensive mudflats and fringing mangroves. Two stations, located on the eastern coast of the bay near Krabi Province, have mud and sandy substrates. The coast is rocky, relatively deep and has open sea characteristics. The other two stations, located on the western coast of the bay within Phangnga Province, have the intermediate characteristics of the above five stations.

RESOURCE MANAGEMENT PROBLEMS

Phangnga Bay is rich in coastal resources that support a broad range of economic activities. However, the use of these resources contributes to environmental degradation and overexploitation.

Tin mining, for instance, contributes to high water turbidity in the bay due to the discharge of mine tailings. Large areas of mangroves are denuded due to conversion for agricultural, industrial, aquaculture and urban developments (Aksornkoae 1988). Increasing population and tourism activity in the area contribute to poor water quality due to the discharge of untreated sewage into the bay. Agricultural and industrial discharges also compound the water quality management problems. And there is overfishing in the bay. These issues stem from inadequate management guidelines and implementation.

Currents affect the distribution of larvae. Thus, knowledge of current patterns is needed to locate the optimum areas for larvae recruitment.

With regard to variations in water quality parameters due to meteorological influences, these add stress on mariculture development. For instance, the high mortality of parent cockles was associated with abrupt drops in salinity from runoff during the wet southwest monsoon period (PPFO 1987).

METHODOLOGY

In addition to the collection and analysis of secondary information on the coastal environment of Phangnga Bay, several primary data were collected from the seven sampling stations established along the bay. Parameters determined included soil and water quality and plankton/shellfish identification (Table 1).

Current speeds and directions were measured hourly for 25 hours throughout the water column over two tidal cycles in each station. Meteorological conditions were also recorded.

Aside from soil and water samplings, interviews were also conducted. Local artisanal fishermen were interviewed for catch data analysis that could indicate possible environmental stress on some species.

Fish larvae density and identification were based on samples taken in 1984. The oblique towing technique was used with a plankton net of the WP-3 type (UNESCO 1986). Samples were preserved in 4% neutralized formaldehyde prior to analysis.

RESULTS AND DISCUSSION

Water currents and tides

Surface water moved counterclockwise (maximum speed of 1.126 m/s) during the northeast monsoon. The subsurface water intruded into the bay with a relatively strong flow (maximum speed of 0.109 m/s) from the east coast. This subsurface intrusion turned counterclockwise along with the surface's circulation. A minor inflow of subsurface water (maximum speed of 0.014 m/s) was observed on the west coast (Fig. 1).

Patterns changed during the southwest monsoon when the surface water moved (maximum speed of 0.220 m/s) northeasterly into the bay along the west coast in a clockwise motion. It was influenced by the strong winds of this monsoon. A minor surface pattern of inflowing water (maximum speed of 0.093 m/s) was observed on the east coast. Similarly, subsurface water moved into the bay (maximum speed of 0.185 m/s) along the east coast while a minor subsurface flow was observed (maximum speed of 0.179 m/s) along the west coast (Fig. 1).

During the northeast monsoon, a minor surface current (maximum speed of 0.099 m/s) moved the east coast water south while a circulating pattern moved it (maximum speed of 0.206 m/s) southwest and counterclockwise. The subsurface water then reversed its flow from flood tide. Other currents are shown in Fig. 1. During the southwest monsoon, minor surface and subsurface currents had variable patterns (Fig. 1).

The inner bay surface runoff moved southwest in a circulating pattern. This affected most of the west side's runoff areas. This pattern changed to the east during the southwest monsoon.

During the southwest monsoon, the residual surface's circulating pattern reversed its flow to a clockwise motion (maximum residual speed of 0.072 m/s). Winds from the ocean caused a subsurface counterclockwise circulation (maximum residual speed of 0.063 m/s) from the east coast.

Water quality

The results of the water quality assessment (Tables 1 to 4 and Figs. 2 and 3) showed different regimes in three areas: the east coast, the west coast and the inner bay area.

Total suspended solid (TSS) concentrations were identical (12.8±3.2 ppm) on both coasts while the inner bay value was higher (18.1±5.0 ppm). The pH values in the inner bay water, affected by runoff, were lower (pH 8.23±0.09) compared to those (pH 8.35±0.10) on both coasts (Table 2).

Values of salinity, temperature, dissolved oxygen (DO) and total alkalinity were 32.0±0.8 ppt, 28.6±0.4°C, 6.5±0.5 ppm and 134.0±32.0 ppm

$CaCO_3$, respectively, which were identical in the three areas. The salinity in the inner bay was lower.

Nearshore DO slightly exceeded that of the offshore water (6.3±0.05 ppm), which may indicate a higher primary productivity. In general, the water quality of the outer sites of both coasts was characteristic of the open sea (Limpsaichol et al. 1987).

Table 3 presents the hydrological conditions observed during the northeast and southwest monsoons while the typical water quality parameter variation along the upstream and offshore stretch is shown in Figs. 2 and 3.

The TSS patterns were closely related to water circulation in the bay. During the northeast monsoon, the relatively high TSS (14.0±2.0 ppm) of the inner bay water was probably transported, partially settling off and being diluted along the counterclockwise path to the west coast, while a relatively low TSS (10.1±1.3 ppm) was observed along the east coast, where the partial mixing of runoff and seawater occurs.

Similar patterns of TSS were observed in the southwest monsoon. The magnitude was higher due to strong winds, a clockwise circulation and the strong flow of the subsurface's counter circulation. Thus, a very high value of TSS (96.8±13.2 ppm) was recorded in the inner bay with an intermediate value of 10.8±2.0. A comparatively low value (20.8±2.2 ppm) was observed on the west where the partial mixing occurred. The TSS in the inner bay varied greatly from 615.0 ppm during the southwest monsoon to 41 ppm during the northeast monsoon.

The inner bay TSS had a low organic content. This implies that the sediment consisted of loosely combined silt and clay derived from mine tailings. The subsurface TSS during ebb tides generally contained a lower organic load than the surface TSS, which supports the above pattern.

During the northeast monsoon, the TSS content in the bay was relatively uniform (14.0±2.0 ppm) throughout ebb and flood tides. In contrast, the strong southwest monsoon's resuspending action occurred typically along a stretch about 1 km before and behind the coastline. Thus, a very high TSS content was observed upstream during flood tides and vice versa as well as during ebb tides. This showed that the majority of TSS in the bay was derived mainly from the resuspension of deposited sediment along the shore.

Similar salinity (31.93±0.27 ppt) was recorded during the northeast monsoon at flood and ebb tides in the bay, implying uniform circulation. Southwest monsoon subsurface inflow on the west coast resulted in a slightly higher salinity than on the east coast (32.28±0.04 ppt) while relatively low salinity prevailed in the inner bay water (31.06±0.5 ppt). Diurnal variation (4.3 ppt) was considerably higher during the northeast monsoon (1.6 ppt). An upstream salinity variation of 11.9 ppt was observed.

During the northeast monsoon, the east coast's salinity varied by 1.20 ppt (Table 4). This extended 2 km from the coastline beyond which the salinity remained uniform throughout (32.94±0.27 ppt) and relatively stable. Such a salinity variation was greatly enlarged during the southwest monsoon. During a prolonged dry period, a 3.5 ppt variation extended for 5 km offshore while an upstream variation of 12.0 ppt was enhanced during heavy rainfall periods.

The buffering property of the coastal bay waters was relatively high, as indicated by the total alkalinity shown in Table 3.

The northeast monsoonal water temperature (28.62±0.40°C) in January was relatively lower than the southwest monsoonal value (32.3±0.5°C) in June. These values prevailed uniformly in the coastal waters where a 3°C diurnal variation was recorded regardless of ebb or flood tides.

High nutrient contents (PO_4 and NO_3) were generated in the mangal upstream area during the northeast monsoon. They were diluted by the downstream water and moved into the bay during ebb tide. The nutrient-rich stream water was then pushed backwards upstream during flood tide. Thus, high nutrient contents were again recorded in the upstream water. Although the southwest monsoon caused a fluctuation in nutrient contents as runoff from various sources, a similar circulation pattern was observed.

Aquaculture activities, chiefly cage culture, are increasing and one of the sites (KK site), about 3 km upstream of Park Lao River called *kokekrai* affected the water quality in the area. This intensive cage-mariculture site usually associated with human settlements (with 400 cages) caused very turbid water (TSS 106 mg/l) and had exceeded the threshold value (NTAC 1972). The TSS consisted of a high organic fraction (OF) of up to 63 ppm, which was mainly the remainder of fishmeal (Table 3).

The microbial decomposition caused very low DO (<3 ppm), which further decreased at night. Thukhvinars et al. (1983) reported the DO content in heavy culture areas to be as low as 1.5 ppm at night, thus causing high mortalities due to hypoxia.

Massive culture cages restricted the water movement from dispersing pollutants; this led to a drastic drop in total alkalinity value (<60 ppm $CaCO_3$). Such a low value is favorable for bacterial development to which culture fish becomes vulnerable (Dharnchalarnukij et al. 1982). Thus, a high coliform bacteria (1,700 MPN/100 ml) was recorded, which exceeded the acceptable value of 1,000 MPN/100 ml (Unkulvasapaul and Simachaya 1986).

High levels of coliform bacteria (1,400 MPN/100 ml) were also recorded in the site where the sewage from the *kokekrai* village was discharged (Table 3).

Primary productivity

Relatively high primary production was observed in the bay. The average annual production rate was 384 gC/m^2/year from a range of 287-956 gC/m^2/year (Sündstrom et al. 1987) which was related to the high production of mangrove swamps (Christensen 1978). As a result, the maximum primary production of 13.5-70.0 mgC/m^3/hour and a high chlorophyll-a content was noted in coastal waters (1-5 m depth). In deeper waters, relatively lower values of both parameters were observed.

Zooplankton sampled by Boonruang (1985) in 1981-1982 consisted of an average of 682 individuals/m^3 with an average biomass of about 20 mg/m^3. Copepods were the most abundant group (30.3%). Other zooplanktonic larvae were crabs, shrimps and bivalves, which shared the proportion ranges of 1.2-10.7%, 0.9-2.6% and 0.2-5.5%, respectively.

High densities of zooplankton were recorded during the northeast monsoon in the inner bay. Their abundance and distribution were complicated but the hydrodynamic regimes and feeding obviously regulated their fate.

Coastal sediment

Coastal sediment cores recovered along Phangnga Bay (40 cm in depth) consisted of three layers. The top layer was mainly oxidized silt and clay, with low organic content. The depth of this layer depended entirely on monsoonal influences. The second layer was 11-14 cm in depth, consisting of very fine silt clay sand in a high organic matrix. A mixture of fine shell fragments was also observed in some locations. The third layer consisted of fine and coarse sand and was low in organic content with coarse shell fragments. The texture and depth of the second and third layers, which indicated little or no monsoonal influence, were significantly uniform throughout the year regardless of site.

Microbial decomposition of organic material occurred in the sediment layers typically under anaerobic condition that leads to the intensive generation of H_2S. Sulfide level in the sediment was as high as 306.6 mg/kg wet wt. during the northeast monsoon compared to 223.9 mg/kg wet wt. during the southwest monsoon. Significantly high sulfide content was recorded in the the sediments on both coasts. High sulfide content was likewise noted throughout the depth range of the inner bay sediment cores and occasionally at certain depths of the east coast sediment. In contrast, relatively low values were observed in the west coast sediment where there were mostly sand and shell fragments.

Shrimp catch

A survey of shrimp fishermen showed that during the northeast monsoon, 30 long-tailed shrimp fishing boats were in operation. Shrimp gill nets were operated during early morning hours, with an average catch of 2-6 kg/day, mainly of penaeid and metapenaeid shrimps. The average catch yield was 4.0±1.2 kg/day at a size range of 6-15 cm in length. Catch comparison with 15 boats during the southwest monsoon yielded 1-5 kg/day. Similar species were recorded but the catch yield average was only 2.7±1.1 kg/day. A significant decline in yield occurred during the southwest monsoon.

One factor affecting the shrimp yield was the increase in TSS, especially during the southwest monsoon, which caused a seaward distribution of shrimp species.

Bivalves

Study emphasis was put on economically important bivalves, i.e., the short-necked clam *(Paphia* sp.*)* and the cockle *(Anadara* spp.*)*. They were known to spend their early life as planktons drifting along the coastal waters for about 14 days before metamorphosis and settlement. However, various conditions limited the settlement of larvae.

Sediment cores taken during the northeast monsoon showed that the bivalve *(Cuspidaria* sp.*)* of 5 mm inhabited the top sediment surface. It was much disturbed during the southwest monsoon.

Fish larvae

The fish larvae results were based on the analysis of samples taken from January to December 1984 by Janekarn and reported by Janekarn and Natheewathana in 1988 (Fig. 4).

Forty-nine families of fish larvae with 4,122 individuals were identified. Of these, twenty-six families (63.8%) have economic importance. Sciaenidae, Leiognathidae, Engraulidae, Carangidae and Cynoglossidae made up 84.3% of the economically important group. This group was more abundant in the outer bay (15%) than in the inner bay (2%). The highest density was observed in January and the lowest in September.

The distribution dynamics of fish larvae in the bay was in response to the environmental stress due to monsoon variation. The high and low densities were in close correlation with the northeast monsoon where salinity and TSS variations were small but were higher during the southwest monsoon, aside from the residual water circulation resulting from the outer bay.

CONCLUSION AND SUMMARY

The surface residual circulation during the northeast monsoon was counterclockwise. It was accompanied by a subsurface circulation in the same direction. During the southwest monsoon, the surface residual circulation turned clockwise, opposing the subsurface circulation, which caused the resuspension of the bottom sediment. The surface residual circulations can make planktonic larvae drift into the sea within eight days before metamorphosis.

During the southwest monsoon, most of the TSS were derived from the resuspension process at the coasts. Its magnitude was recorded at 96.0 ppm with 615 ppm diurnal variations in the inner bay. Similar patterns were observed during the northeast monsoon but with a smaller magnitude. The TSS contained a relatively low organic fraction from previously discharged mine tailings.

The coastal area was affected by the diurnal salinity variation during the southwest monsoon. The potential variation of 12 ppt affected the coastal areas during prolonged heavy rainfall. On the other hand, less extreme salinity changes were observed during the northeast monsoon. The coastal water was generally saturated with dissolved oxygen. The low DO (<3 ppm) and total alkalinity (<60 ppm $CaCO_3$) were observed in the intensive mariculture sites with corresponding high coliform bacteria (1,700 MPN/100 ml). The pH and temperature values were generally uniform during the northeast monsoon while a small drop in pH and a 3°C increase in temperature were recorded during the southwest monsoon.

High nutrients (NO_3 and PO_4) were generated in the mangrove areas, and these contributed to the high primary productivity (70 mgC/m^3/h) of the coastal water.

The top sediment consisted mainly of silt and clay with relatively low organic content. The deeper sediment contained finer sand and a higher organic fraction with shell fragments. Monsoonal influences altered the depth of the top sediment from around 8 cm during the northeast monsoon to 3 cm with diurnal variations during the southwest monsoon. Relatively high sediment sulfide was recorded during the northeast monsoon. Evidently, low survival of metamorphosed bivalves was attributed to severe sediment conditions such as sediment perturbations.

Finally, the turbid water and low salinity during the southwest monsoon in nearshore areas resulted in the relatively low shrimp yields.

RECOMMENDATIONS

Shellfish larval movement, which is extremely complex and difficult to discern, needs to be further studied before proper management measures can be proposed. The input of sediment to the bay is generally detrimental, thus, it should be decreased. Large ranges of salinity limit the appropriate species to be reared in the bay. Management should be sensitive to the variations that exist in selecting species.

Low dissolved oxygen and high coliform bacteria occur locally near the mariculture sites due to the accumulation of excess feed and waste. Also, water movement is slack because of the cage setup. Thus, proper mariculture management has to consider the density of cages, among other factors.

Abundance of economically important fish larvae in the outer bay depends on water circulation and avoidance of inner bay stresses. However, spatial and temporal information are still lacking to plan for closed seasons for trawling, push-netting and use of other fishing gear responsible for overfishing. Public education will then be necessary to disseminate the importance of controlling overfishing.

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Table 1. Sample variables of units and techniques used in sampling.

Variable	Unit	Technique	Reference
TSS	ppm (mg/l)	GF/C filtration	APHA-AWWA-WPCF (1975)
Organic fraction		H_2SO_4-K_2CrO_4 digestion	HMSO (1981)
Salinity	ppt	Conductivity	APHA-AWWA-WPCF (1975)
Temperature	°C	Thermister YSI	-
DO	ppm (mg/l)	Oxygen meter YSI	-
pH	-		-
Alkalinity	$CaCO_3$		Strickland and Parsons (1972)
Nutrients (NO_3, NO_2, PO_4)	µg-at/l	Spectrophotometry	Strickland and Parsons (1972)
Coliform	MPN/100 ml	Multiple tubes	-
Currents	m/s	Current meter	-
Direction	Degree ref. to north	Current meter	-
H_2S	mg/kg wet wt	Zinc acetate and spectrophotometry	Grasshoff et al. (1983), Jǿrgensen and Fenchel (1974) King and Zarbin (1969)
Fish larvae	Ind./1,000 m^3	Plankton net type WP-3, 1 mm mesh and 4% formalin preservative	UNESCO (1968)

Table 2. General monitoring (January-July 1987).

Parameter	East coast	West coast	Inner bay
TSS, ppm	12.8±3.2	12.8±3.2	18.1±5.0
pH	8.35±0.10	8.35±0.10	8.23±0.09
Salinity, ppt	32.0±0.8	32.0±0.8	31.7±1.3
Temperature, °C	28.6±0.4	28.6±0.4	28.6±0.4
DO	6.5±0.5	6.5±0.5	6.5±0.5
Alkalinity	134.0±32.0	134.0±32.0	134.0±32.0

Table 3. Hydrological conditions.

Parameter	Northeast monsoon (January-February 1988) East coast	West coast	Inner bay	KK site	Southwest monsoon (May-June 1988) East coast	West coast	Inner bay	KK-site
TSS, ppm	10.1±1.3	7.8±1.0	14.0±2.0	5.3-7.3	28.7±5.0	20.8±2.2	96.8±13.2	48.1±55.1
ΔTSS	18.1	18.1	41.0		115.3	48.C	615.0	(75-106)
OF (TSS)	LT 16.4±2.1	31.0±4.6	18.2±6.1	31.96-63.66	18.8±1.4	10.8±2.0	10.8±2.0	
	HT 28.1±4.7							
Salinity, ppt	31.93±0.27	31.93±0.27	31.93±0.27	27.84-30.8	32.28±0.04	32.41±0.02	31.06±0.5	26.9-28.4
ΔSalinity	1.20	1.57	1.56		1.0	1.0	4.3	(14.5-15.6)
DO, ppm	6.84±0.34	6.26±0.31	6.26±0.31	3.80-4.45	Saturated	Saturated	Saturated	
ΔDO	2.05	1.82	2.41		-	-	-	
Alkalinity								
ppm $CaCO_3$	160.0±1.0	160.0±1.0	160.0±1.0	157-158	182.2±2.1	160.0±4.0	160.0±4.0	158.0-160.0
ΔAlkalinity	3.0	3.5	5.0		27.5	5.0	6.0	(59.0-64.0)
pH	8.27±0.02	0.12±0.04	8.12±0.04	7.53-7.78	8.08±0.03	8.18±0.01	7.97±0.04	7.49-7.72
ΔpH	0.08	0.16	0.36		0.57	0.09	0.62	(7.35-7.41)
Temperature, °C	28.62±0.40	28.62±0.40	28.62±0.40	29.6-29.9	32.6±0.5	32.7±0.5	31.6±0.5	2.95-29.6
ΔTemperature	2	2	3		2	1.2	1.8	-
Coliform bacteria,								
MPN/100 ml	-	-	23-260	34-2,400	4-350	-	9-170	33-1,400

Notes: KK = *Kokekrai* cage mariculture; Δ = variation.
Data enclosed in parentheses were collected in August 1987.

Table 4. Upstream-offshore stretch salinity variation.

Location		Northeast monsoon	Southwest monsoon	Potential variation
East coast	**Salinity**	**1.20 ppt**	**3.5 ppt**	**11.90 ppt**
	Offshore	**2 km**	**5 km**	**8 km**
Inner bay	**Salinity**	**1 ppt**	**2.5 ppt**	**3.0 ppt**
	Offshore	**3 km**	**6 km**	**10 km**
West coast	**Salinity**	**1 ppt**	**1 ppt**	-
	Offshore	**2 km**	**2 km**	

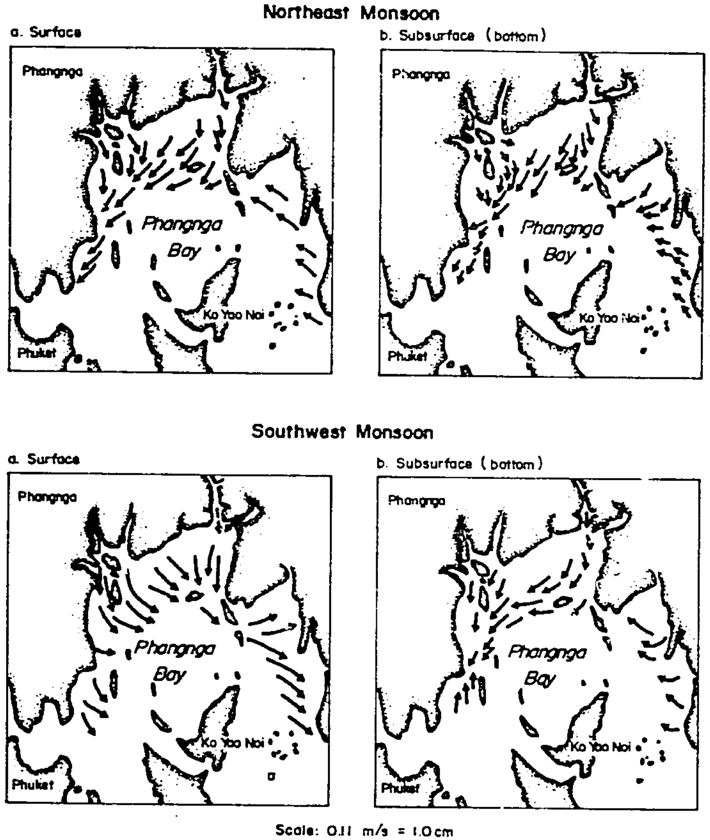

Fig. 1. The coastal residual circulation patterns of Phangnga Bay in the Andaman Sea coast of Southern Thailand. The hydrographic data were collected during spring tides in January 1988 of the northeast monsoon and in June 1988 of the southwest monsoon. Surface patterns (A) represent 1 m below surface circulation. Subsurface patterns (B) represent 0.5 m above the bottom of the 5 m depth mean tidal level.

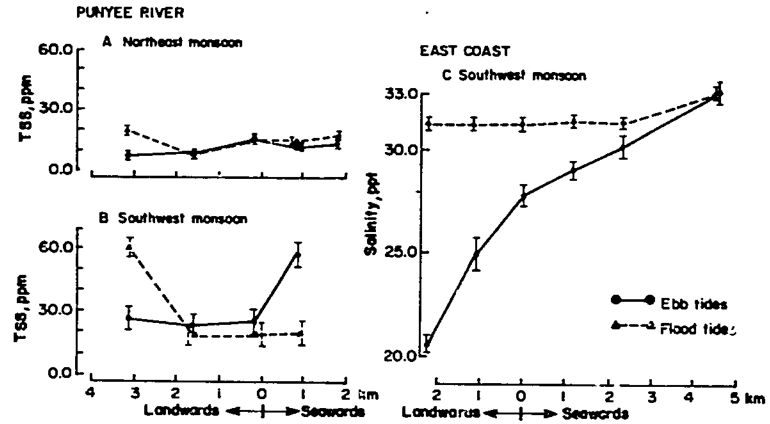

Fig. 2. Typical variation in TSS. Northeast monsoonal-uniform variation (A). Southwest monsoonal-high TSS (B) in upstream and offshore during flood and ebb tides, respectively. Typical salinity variation of 12 ppt (C) located upstream. It can be much larger under heavy rainfall.

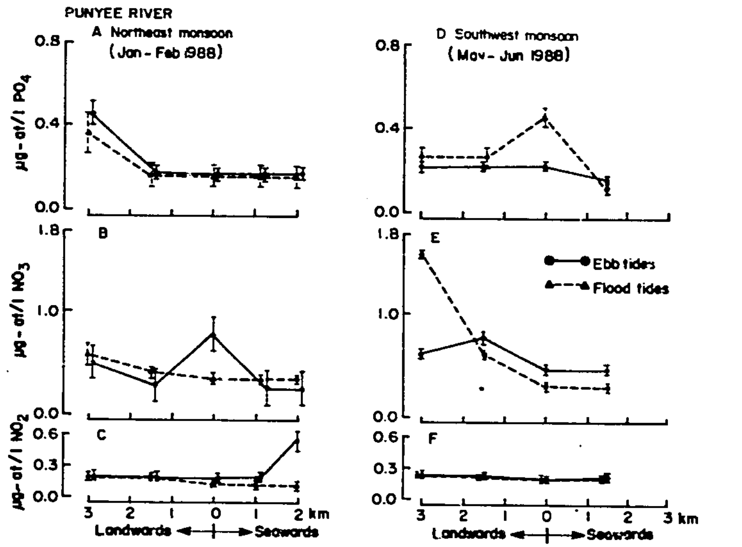

Fig. 3. Nutrients input (A, B, D and E) during the northeast and southwest monsoons, seawards at ebb tides and seawater flushes upstream during flood tides. High nitrite was generated in the coastal waters (C), otherwise, it was uniform (C and F).

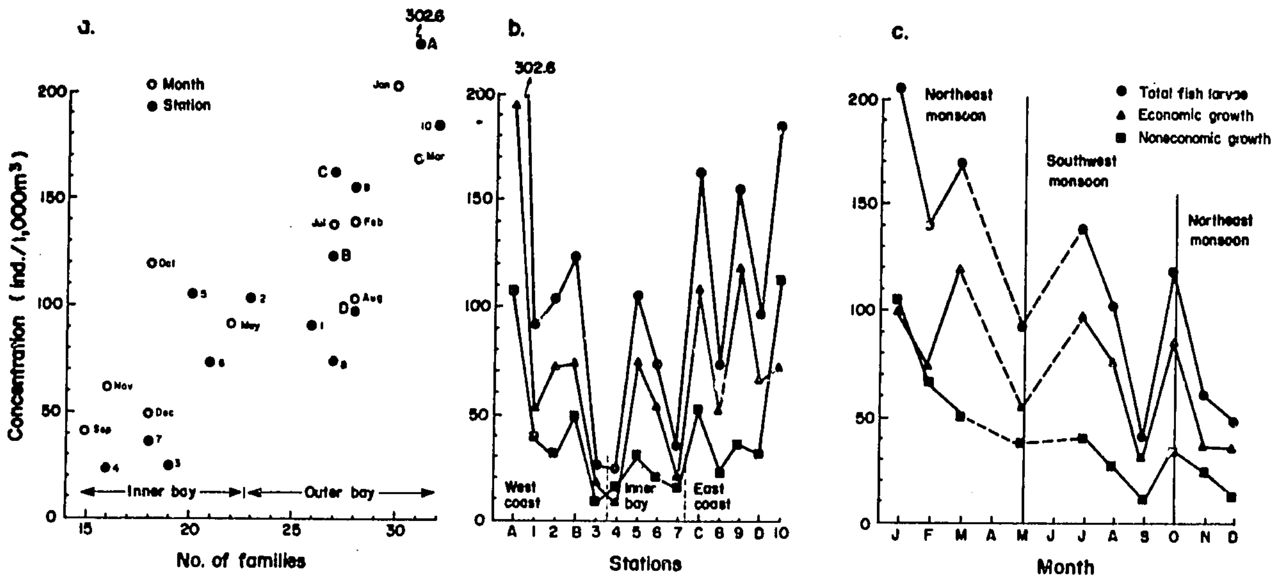

Fig. 4. The fish larvae were based on samples taken from 14 stations around the bay from January to December 1984. There were many families and high density in the outer bay but relatively few families and low density in the inner bay: (a) the abundance and distribution according to site; (b) the seasonal abundance and distribution; and (c) high and low densities in the northeast and southwest monsoons, respectively (Janekarn and Natheewathana 1988).

A review of the stock assessment of fish resources in Brunei Darussalam

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ABSTRACT

Fisheries, while a small contributor in terms of national gross domestic product (GDP), is important to Brunei Darussalam. There is a high per capita consumption of fish, and many people are engaged in fishing, especially on a part-time basis.

This paper reviews the surveys and studies that have been carried out to assess the fish stocks in the country. Surveys have been conducted since the late 1940s; the early ones were incomplete. The demersal trawl survey conducted in 1979-1980 with *K/P Lumba-lumba* was more comprehensive, the results of which were used to develop the fisheries. Subsequent monitoring of the fish stocks has included regular trawling stations at selected grid squares and the collection of catch statistics from fishermen.

INTRODUCTION

Fishing has traditionally been an important occupation in Brunei Darussalam (Fig. 1). Lately, however, there has been a shift from the sea to more secure and comfortable land-based vocations. Despite this trend, there are still part-time fishermen who fish during the holidays or non-working hours. They outnumber full-time fishermen (i.e., in 1987, there were 1,948 and 523 part- and full-time fishermen, respectively).

In spite of the low contribution of fishing to the country's GDP (see Table 1) in comparison to the oil and gas industry, the former is still important given the national policy of diversifying the economy.

Fish stock assessment began in the late 1940s and has continued until the present, with various periods of inactivity in between. The gear and fishing methods have become more sophisticated over the years. The results of the latter surveys, especially those by *K/P Lumba-lumba*, have been used to expand and develop the fisheries in contrast to the earlier surveys, which remained in the form of unpublished catch records. Beales (1982) has dealt extensively with the surveys by vessels in Brunei Darussalam up to that conducted by *K/P Lumba-lumba* in 1979-1980. This paper reviews these surveys and other subsequent works on the stock assessment of fish resources in the country.

MV Saripah/MFV Tinggiri

The first survey was by *MV Saripah* which lasted from June 1949 to January 1950 when another vessel, *MFV Tinggiri*, continued the survey until September 1950. *MFV Tinggiri* was a 75-foot long vessel of 160 hp. The gear used included a demersal trawl Danish seine, fish pots *(bubu)* and long lines. Very little information was given on the vessels, gear used, survey areas, species composition or weight of the catches.

The reports also gave a very pessimistic view of the fisheries resources with statements like, "A four-hour trawl over 30 mls (miles) of sea bottom produced practically nothing" (Beales 1982). These first attempts at surveying seemed to lack scientific methodology; thus, the results retarded, instead of advanced, the development of the fisheries.

R/V Manihine

In 1955, *R/V Manihine*, as part of the fisheries investigation of the waters of Malaysia and Borneo, carried out eight demersal trawl hauls off the coast of Brunei Darussalam from November to December 1955. A "Peter Carey-type" commercial otter trawl with a headrope of 22 m, a footrope of 28 m and an 89-mm stretched mesh cod-end was used. The hauls were made at water depths greater than 36 m because the inshore subsistence fisheries were believed to be fully exploited. This belief may have been based on the *MV Saripah/MFV Tinggiri* results. The catch rate from these hauls did not exceed 100 kg/hour, and the reports concluded that commercial trawling was not economically viable. The hauls were done in areas that presently have low fish biomass. The operating cost used for assessing the viability of a commercial trawl operation was based on large European-type trawlers. Alfred (1980) gives a list of the fish species collected by *R/V Manihine* off Brunei Darussalam.

MFV Arapan Tei and *MFV Berjaya*

In 1968, further surveys were carried out over four periods using small prawn trawlers, namely, *MFV Arapan Tei* and *MFV Berjaya*, which were chartered from the Government of Sabah, Malaysia (Table 2). These vessels were about 13 m in length with 60 hp in each engine. The trawl had a headrope of 17.8 m and a footrope of 21.3 m with a cod-end mesh size of 38 mm.

Trawling was carried out between 3 and 30 nm (nautical miles) from the coast at depths of 11 to 46 m, where tows of 1 to 1.5 hours were made (Fig. 2). The mean catch rate was 59 kg/hour for the entire survey area. A predominance of low market value fish was found, especially of the family Leiognathidae, particularly *Leiognathus splendens* and *L. equulus*. Even though the trawl used was actually designed for catching prawn, its composition in the catch was only 1.3% of the total catch.

R/V Penyelidek I and *II*

The Malaysian research vessels *R/V Penyelidek I* and *II* conducted surveys northwest of the Borneo coast between 29 March and 1 May 1972. Brunei Darussalam was included in the surveys due to the continuity of the Sabah and Sarawak sectors, but there was insufficient coverage of the inshore waters of the Brunei Darussalam sector (Beales 1982).

The two vessels were 23 m in length and were powered by engines between 320 and 365 brake horsepower (bhp). They were equipped with "Engel" German otter trawls with 40 mm cod-end mesh size and 20 m wide at the mouth of the nets. The vessels made 24 valid hauls for the 1-hour duration, mostly at depths of greater than 37 m for each. The survey area was in a region subsequently called Stratum 2 in the following survey by *K/P Lumba-lumba* in 1979-1980 (Fig. 3). The mean catch rates and densities observed are given in Table 3.

As the survey covered only the month of April, the results should not be directly extrapolated throughout the year; subsequent studies showed that seasonal fluctuations of biomass do occur. However, the densities obtained compared well with those of a survey conducted by *K/P Lumba-lumba*.

K/P Lumba-lumba

In September 1978, the Fisheries Department of Brunei Darussalam purchased a 15.2-m steel stern trawler for use as a research and training vessel. Named *K/P Lumba-lumba*, it was used for the demersal resource surveys conducted in the country's waters in 1979 and 1980 and for other stock monitoring work. The vessel could also be used for various fishing operations including pelagic trawling, long lining, potting and gill netting, although it was primarily designed as a stern trawler.

Previous surveys did not comprehensively cover the country's demersal stocks and generated only patchy information. The surveys conducted by *K/P Lumba-lumba* were different--they were well planned and comprehensive, i.e., the report gave not only stock size and yield but also guidelines on the development of trawl fishery. Beales (1982) has dealt extensively with the *K/P Lumba-lumba* surveys. The following summary is based on his report.

The demersal trawl used during the 1979 and 1980 surveys was a Boris "Goshawk" 57-foot headline box trawl. In calculating the swept area, a figure of 30 ft for the mouth opening was used. The area surveyed was generally in the waters between 6 and 100-fathom isobaths (Fig. 4). It was divided into two strata based on depth. Stratum 1, from the coast to the 25-fathom isobath, has an area of 3,533 km^2, of which 1,466.0 km^2 or 41.5%

was taken to be accessible to trawling. Stratum 2 stretched from Stratum 1 seawards, approximately up to the 100-fathom isobath. It has an area of 5,848.0 km^2, of which 4,905 km^2 or 83.9% was considered to be accessible to trawling. The area was then divided into grid squares of 64.75 km^2.

The mean catch rates were from 205 valid hauls of the 1979-1980 survey. The composition of the marketable catch was: 55.4% Leiognathidae, 6.3% Mullidae, 5.2% Carangidae, 4.8% Ariidae, 3.9% Scianidae and 3.4% Nemipteridae. The remaining 21% consisted of trash fish.

The estimated standing stock and potential yield are given in Table 4. The potential yield was estimated using Gulland's equation:

$$Py = M \, 0.5 \, Bo$$

where,

Py = potential yield;
M = coefficient of natural mortality set at unity; and
Bo = unexploited stock size.

CATCH RATE MONITORING IN SELECTED GRID SQUARES

Following the 1979 and 1980 surveys, *K/P Lumba-lumba* was used to monitor stock sizes in three selected grid squares monthly. This monitoring was very important in gauging the state of the stocks through a standardized catch rate, as trawl fishery was progressively developed and expanded through the increase in the number of trawlers.

Halidi (1987a) analyzed the monitored data up to 1986. He concentrated the analysis on two grid squares, namely, P35, Q35 (Square P38 was ignored as this is located within the 3-mile coastal zone where trawling is prohibited.) (Fig. 5). Squares P35 and Q35 are situated well within the permitted trawling zone and, thus, should give an indication of the exploitation level or any changes in the fish stock abundance for the entire Stratum 1. The 1979-1980 survey results for the two grid squares were also used to observe any differences in the unexploited stocks of Brunei Darussalam's marine fisheries.

For each grid square, three hauls of about a half-hour duration were made, and the total catch per hour and catch per unit effort (CPUE) were computed. From early 1979 to the end of 1986, a total of 163 hauls were conducted.

The preliminary analysis (Fig. 6) suggested that the demersal stocks may be declining at the rate of 7.7% per year. In terms of Fox's model, the maximum sustainable yield (MSY) is reached when the biomass is reduced to 37% of its original value (Fox 1970; Ricker 1975) and, thus, overexploitation of the stocks would begin in mid-1991, if the present depletion rate of 7.7% per year continues.

Because only four trawlers have been licensed to operate in Brunei Darussalam since 1984, Halidi's preliminary analysis (1987a) did appear rather alarming and odd. The possible reasons proposed by Khoo et al. (1987) for the apparent decline were (with our comments added):

1. Catch rate in grid squares sampled may not be representative of the total area. (This would mean that the decline is possibly localized in the particular grid squares and, thus, does not reflect the whole situation.)
2. Illegal fishing activity (There is not much evidence of illegal trawling activities in these areas but a thorough investigation is necessary to eliminate this reason for the apparent decline of the demersal fish stock.)
3. Statistical artifacts (Since the data analyzed were limited to total catches and their distribution was extremely skewed, the result could be a statistical artifact.)
4. The apparent decline in CPUE could be due to the natural, long-term fluctuations of recruitment. (Unlikely.)

Whatever the reasons, the Fisheries Department of Brunei Darussalam is presently engaged in redoing the survey conducted in 1979-1980 to ascertain whether there has been any decline in the stocks and to provide details on the present stock composition.

CATCH STATISTICS FROM FISHERMEN

Inshore fisheries (Figs. 7 and 8) are still the mainstay of the fisheries sector. Various fishing gear are operated (Khoo et al. 1987). Catch and effort statistics from the Brunei Muara District have been recorded from these fisheries since late 1982 from the full-time fishermen (Fig. 6). In 1987 and 1988, data collection has been extended to the full-time fishermen of Tutong and Belait Districts, respectively. Data collection will be expanded to include Temburong District's part-time fishermen. (There were no full-time fishermen in this district in 1987.)

Halidi (1987b), in his preliminary analysis of the Brunei Muara District statistics from 1982 to 1986, notes the seasonal nature of the catches of the ten most abundant species. There were generally peak catches between March and May (postmonsoon) and around September and October (premonsoon) when Brunei Darussalam receives most of its rain from the northeast monsoon (around November to March). Halidi also observed that two groups of fish, *Leiognathus* spp. and *Lutjanus* spp. showed distinct changes in total catches over the years, whereas the other groups did not show any clear trend. The total catches of the *Leiognathus* spp. increased, whereas the *Lutjanus* spp. declined. This was thought to be due to a predator-prey relationship in which the large species such as *Lutjanus* spp. feed on small fishes such as *Leiognathus* spp. The removal of the piscivorous lutjanids (by trap, line and trawler) may have caused the increase of the leiognathids.

Khoo et al. (1987) analyzed the same data and estimated the MSY for inshore fisheries at about 13,300 t. This estimate exceeds prawn catches. It appears then that the fishery could support an increase of fishing effort. These observations, however, are preliminary.

In view of the importance of inshore fisheries, the Fisheries Department initiated plans in late 1988 or early 1989 to conduct an extensive survey of the fish and prawn resources available. With the results so obtained, the Department plans to establish a comprehensive management strategy for inshore fisheries.

A comprehensive statistics collection system for full- and part-time fishermen will also be established. This is important because a substantial amount of the fish being caught off Brunei Darussalam by part-time fishermen is possibly not recorded.

CONCLUSION

Fish stock assessments have been carried out since the late 1940s. The earlier surveys, however, provided little or no direction or guidelines as to the development of fish resources.

The surveys conducted by *K/P Lumba-lumba* proved to be a watershed in this respect; the report provided definite guidelines for the subsequent commercial development of the fisheries. The trawl fisheries in Brunei Darussalam developed largely on the results of these surveys.

The demersal stocks in three selected grid squares have been monitored since 1980. Halidi (1987a) suggested that the stocks declined but this must be read subject to the above-mentioned caveats by Khoo et al. (1987). In any case, the Fisheries Department is conducting another demersal resource survey that will answer some of the questions raised by Halidi's investigations.

The assessments of inshore fisheries were based on catch and effort data obtained from full-time fishermen. The data are not comprehensive as they do not cover the whole country or include a very substantial number of part-time fishermen.

Thus, the MSY estimates obtained by Khoo et al. (1987) should be considered preliminary. Here again, a future survey on fish and prawn resources in inshore waters will be instrumental in preparing development and management strategies.

Length-frequency data have been collected on an ad hoc basis in the past. But due to the poor sampling design devised in gathering them, they could be of little use in deriving the population parameters (e.g., growth mortality) of fish. Obtaining reliable length-frequency data must be emphasized because they can be used to expand and develop the fisheries.

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Table 1. Estimates of GDP by kind of economic activity at 1988 value (million dollars).

Economic activity	1988
Forestry and logging	14.8
Fishing	14.9
Electricity, gas and water	17.7
Agriculture and hunting	78.0
Banking and finance	180.1
Construction	233.5
Mining, quarrying and manufacturing	2,920.2
Others (e.g., trade, restaurants, insurance)	2,185.2
Total	5,644.4

Source: Economic Planning Unit.

Table 2. Survey data and number of hauls made by *MFV Arapan Tei* and *MFV Berjaya* in 1968 (from Beales 1982).

Survey	Date	No. of hauls
1	14-16 March 1968	29
2	1-13 July 1968	31
3	14-27 September 1968	24
4	9-23 November 1968	31

Table 3. Mean catch per unit effort and estimated fish density of surveys by *R/V Penyelidek I* and *II* in Brunei Darussalam waters.

Category	Catch/effort (kg/h)	Density[b] +/nm²	t/nm²
Commercial fish	144	1.4	4.8
Trash fish[a]	114	1.1	3.8
Total	258	2.5	8.6

[a]Including all members of the family Leiognathidae, except *Leiognathus splendens*.

[b]The trawlable areas cover 1,400 nm^2 and exclude reefs.

Table 4. Unexploited standing stock size (Bo) and potential yield (Py) in tons in areas accessible to trawling (Beales 1982).

Stratum	1		2	
Area accessible to trawling (km²)	[illegible],466.0 (41.5%)		4,905.0 (83.9%)	
	Bo	Py	Bo	Py
Trash fish	3,461.6	1,730.8	3,142.8	1,571.4
Marketable	15,388.4	7,694.2	5,515.4	2,757.7
Total	18,850.0	9,425.0	8,658.2	4,329.1
Leiognathidae	9,245.0	4,622.5	790.4	395.2
Marketable excluding Leiognathidae	6,143.4	3,071.7	4,725.0	2,362.5

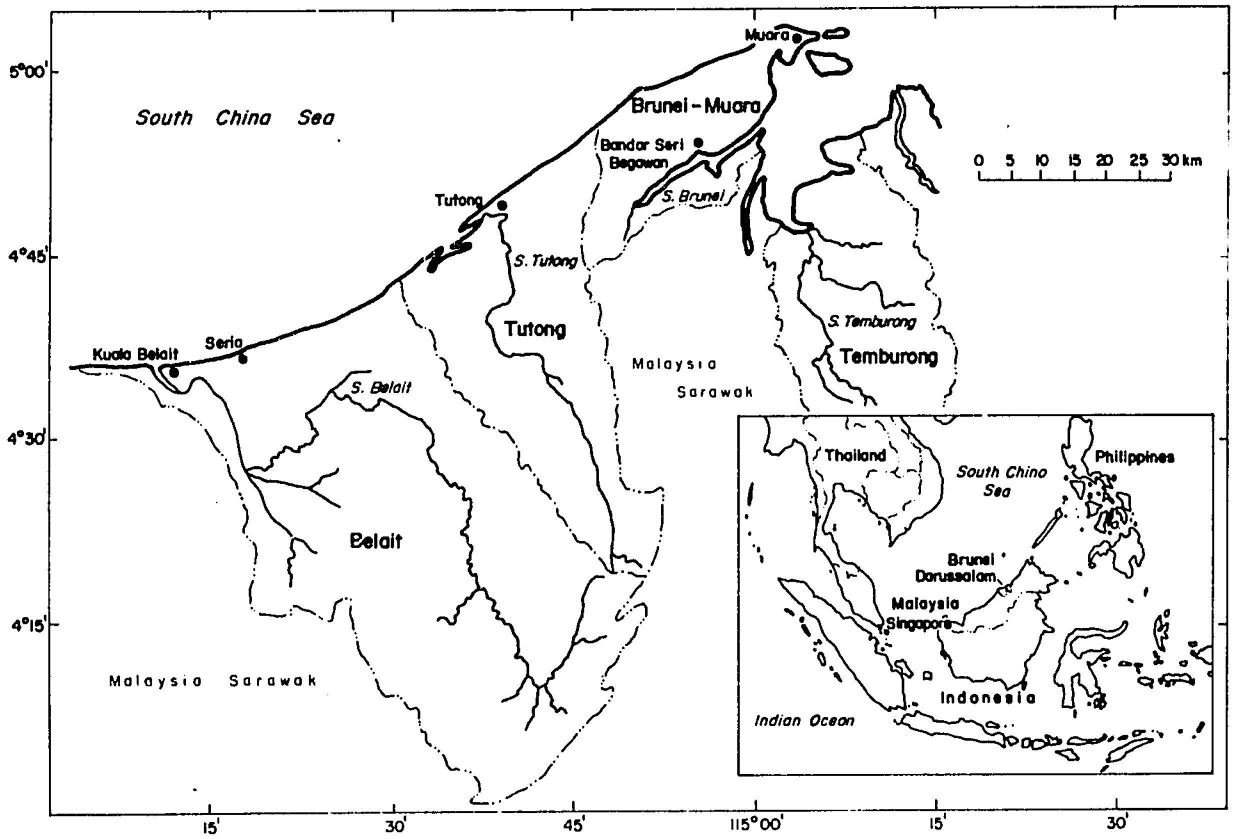

Fig. 1. Brunei Darussalam and its districts (adapted from Chua et al. 1987).

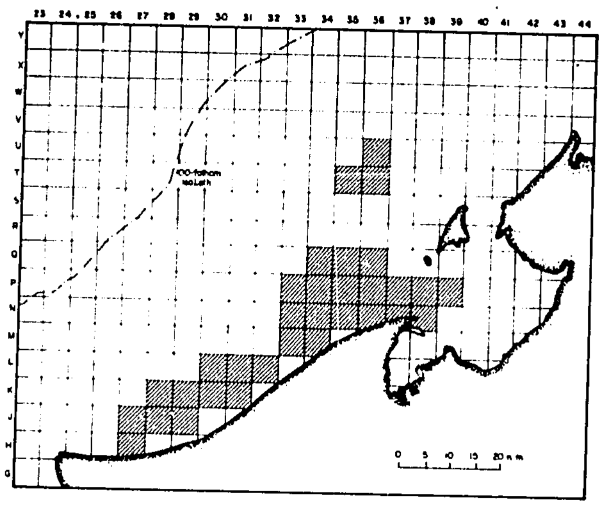

Fig. 2. Areas surveyed by *MFV Arapan Tei* and *MVP Berjaya* in 1968 (adapted from Beales 1982).

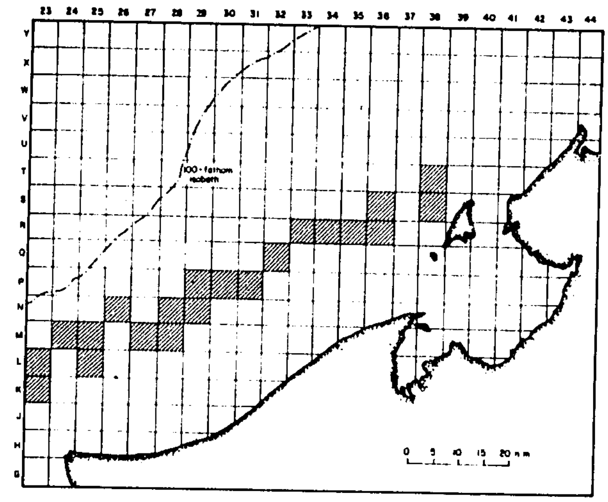

Fig. 3. Areas surveyed by *MFV Penyelidek I* and *II* in 1972 (adapted from Beales 1982).

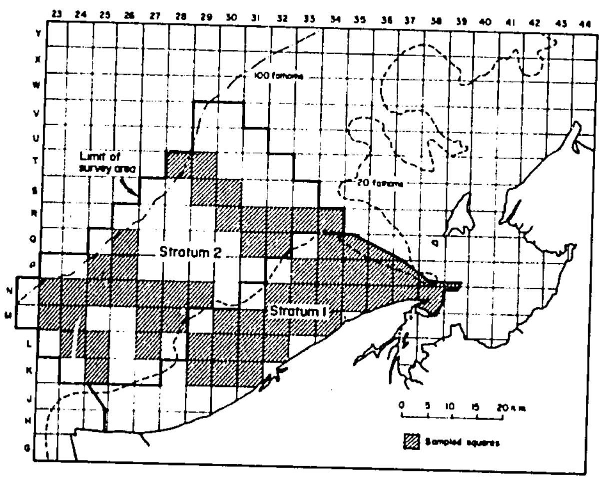

Fig. 4. *K/P Lumba-lumba's* study area and stratum boundaries (adapted from Beales 1982).

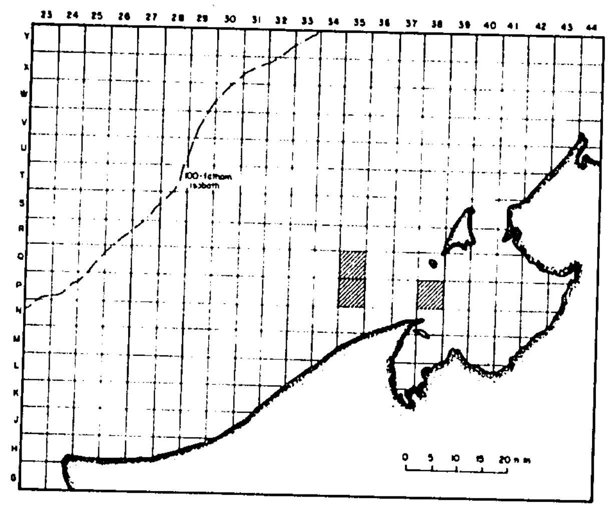

Fig. 5. Position of the three squares monitored from 1978 to 1986.

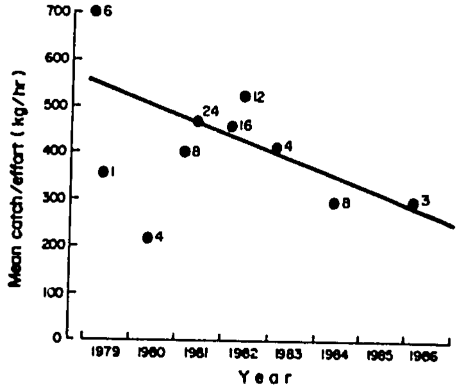

Fig. 6. Trend in catch/effort of demersal fish off Brunei Darussalam, grid squares 1 (Q35) and 2 (P35), 1979-1986. Trend line has a slope significantly different from zero (95% level of confidence) when fitted with a number of hauls used for computing means (black dots) as *rantau* (weighting factors from Chua and Pauly 1989).

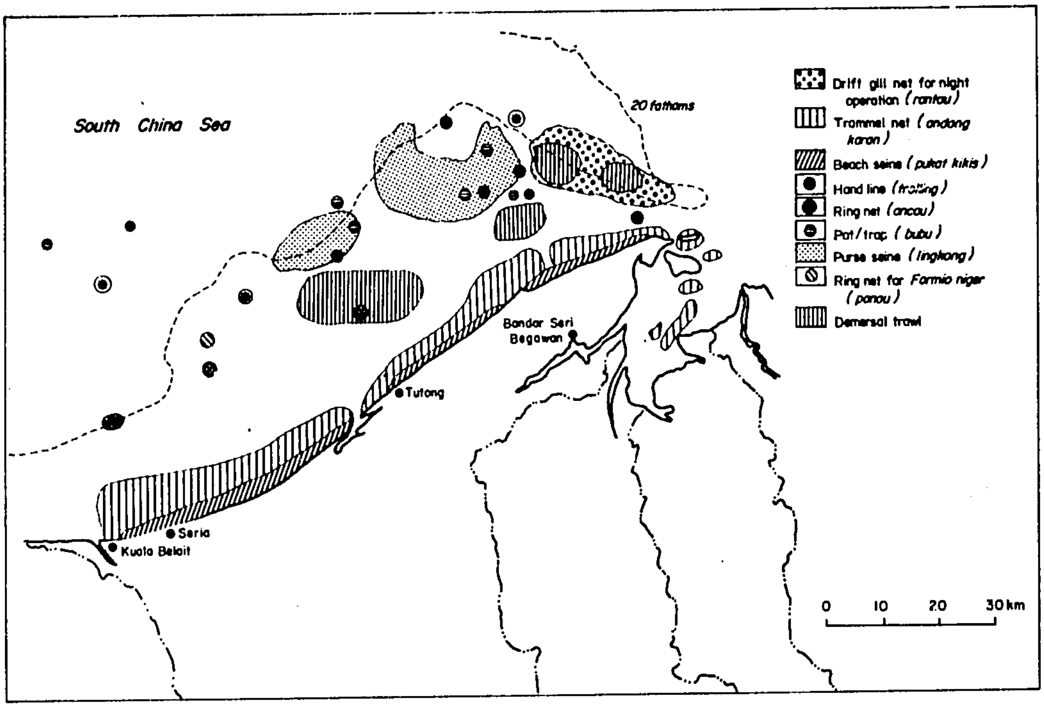

Fig. 7. Brunei Darussalam's coastal fishing grounds classified according to gear (adapted from Chua et al. 1987).

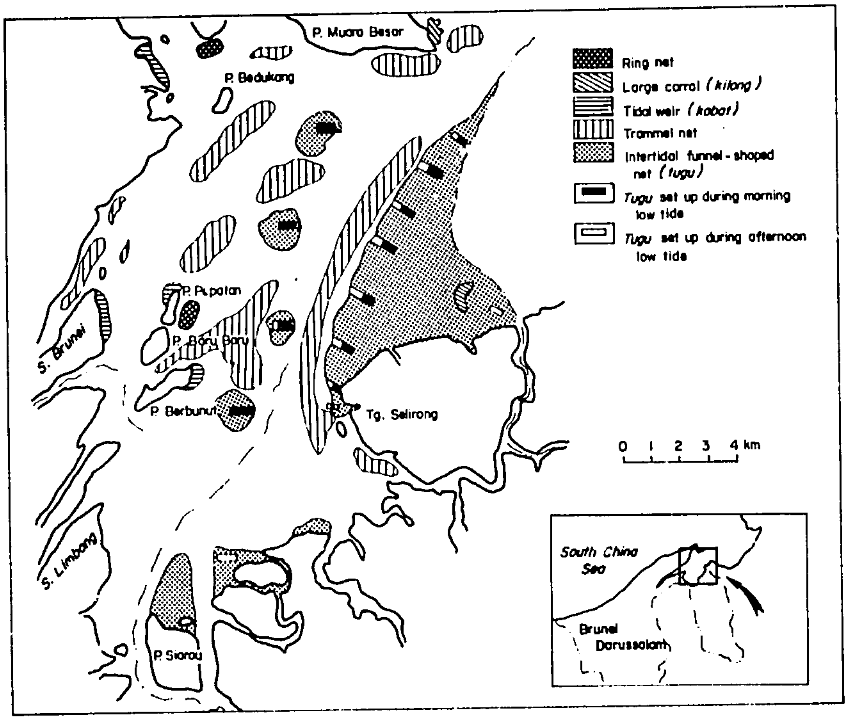

Fig. 8. Brunei Darussalam's estuary fishing grounds classified according to gear (adapted from Chua et al. 1987).

Catch rates and composition of push-net boats in Ban Don Bay, Thailand

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ABSTRACT

A study of push-net boats operating in Ban Don Bay was conducted between March 1987 and May 1988 in response to increased concern for the destructive effect of such operations. A total of 47 push-net boat-trips was sampled in the course of the study. Mean catch per unit effort (CPUE) was about 316 kg/boat/day with a "commercial" to "trash fish" catch ratio of 4:6. The "commercial" component is composed largely of penaeid shrimp (65%) and swimming crab (15%), while the "trash fish" component is composed of more than 60% "true trash fish" (i.e., species groups not preferred for human consumption) and less than 40% undersized individuals of commercially important resource organisms. This implies that approximately a quarter of push-net CPUE--and hence, landings--is composed of undersized individuals, thus hinting at tremendous growth overfishing. Such growth overfishing is a direct result of the mesh size used (1.5 cm) and the concentration of activities by push-net boats in nearshore and shallow areas. Push-net operations compete with the important artisanal gill net/trammel net sector for similar target species (i.e., shrimp and crab). A ban on push-net operations within 3 km from the shore is proposed so as to reduce immediately their damage to the fisheries. The phase-out of push-net boats over the medium-term is likewise recommended.

INTRODUCTION

Ban Don Bay is a shallow, soft-bottom area off Surat Thani Province in the Upper South region of Thailand (Fig. 1). Fishing in the bay is largely small-scale in nature and is an important source of income for coastal residents. The main types of fishing gear employed are gill net (drift gill net for catching crab and threadfins and trammel net for catching shrimp), push-net and otter trawl (NSO 1987). Penaeid shrimp (largely *Penaeus merguiensis*) and swimming crab (Portunidae) dominate the landings in terms of value and account for about 150 and 30 million baht per year, respectively (Lohsawatdikul 1988).

As described in the coastal environmental profile of Ban Don Bay, Paw et al. (1988) point to the excessive fishing effort and the capture of undersized fish as pressing issues for the capture fisheries in the area. The bay is a spawning and nursery ground for various marine organisms, and particular concern has been raised about the destructive nature of push-net operations in the shallow areas. The push-net, an adaptation from the scoop net used in catching *Acetes*, consists of two poles arranged in a cross to spread the net attached to it (SEAFDEC 1986). It is widely used in Thai coastal waters (DOF 1987a; 1987b) and varies in size from the simple, manually operated version to those involving the use of converted trawlers.

Eiamsaard et al. (1985) conducted a preliminary study of the push-net boats in Tha Chang and reported a catch rate of 187 kg/boat/day of which 57% were "trash fish." Of the "trash fish" component, 47% were juveniles (2-6 cm) of commercially important resource organisms. This implies that over a quarter (27%) of push-net landings consists of undersized fish of commercial importance. Under the auspices of the ASEAN/US Coastal Resources Management Project (CRMP), a more comprehensive study of the push-net fisheries of Ban Don Bay was conducted to follow-up the efforts of Eiamsaard et al. (1985) and elaborate on the extent of growth overfishing. This paper presents the initial results of the study covering catch rates and composition of push-net landings between March 1987 and May 1988.

MATERIALS AND METHODS

Data for this study were collected from landings of push-net boats in Don Sak, Kanchanadit and Tha Chang (Fig. 1). Four sampling trips to these landing sites were made between March 1987 and May 1988 to correspond to the monsoons (i.e., one each in March, August and November 1987 and in May 1988, corresponding to the late northeast, late southwest, early northeast and early southwest monsoon periods, respectively). During each sampling trip, information on the magnitude of landings and general area of operation was obtained for each boat that left port that day. Catches are usually sorted into market categories by the time they are landed (i.e., into "commercial" and "trash fish" catch). The "commercial" category is further sorted into grades consisting of "large" shrimp, "small" shrimp, crab, squid and fish. These components of the landings were sampled and further sorted into species whenever possible in the course of the study.

The catch rate of a push-net boat depends on the length of the pole or pushing beam used in gear construction. The greater the length of the pole, the bigger the spread of the net and thus, the volume filtered. For purposes of this study, data generated were grouped according to the length of the push-net pole, as follows: small push-net (<18 m pole length), medium push-net (18-26 m pole length) and large push-net (>26 m pole length). Treatment of the data was done separately for the three push-net types, and for the weighted mean of all push-net boats combined (weighted by the number of boats sampled per push-net type).

RESULTS

The push-net boats in Ban Don Bay make daily trips and land their catches in Don Sak, Kanchanadit and Tha Chang. Most of the boats used are converted "baby" and otter trawlers, while the push-nets used have 1.5 cm stretched mesh codends. Fig. 1 gives the operational range of boats with small, medium and large push-nets in the bay in the course of the study between March 1987 and May 1988. The push-net boats operate in the shallow areas of the bay, the depth of operations increasing sequentially from small, medium to large push-nets.

A total of 47 push-net boat-trips were sampled during the study--8 from small, 18 from medium, and 21 from large push-nets. Table 1 gives the mean CPUE (kg/boat/day) for the three types of push-nets. The CPUE varied from 233 to 367 kg/boat/day, increasing progressively from small to large push-nets. For all push-nets combined, CPUE was about 316 kg/boat/day of which only 38% is of "commercial" importance; the rest is composed of "trash fish." No marked difference exists in the "commercial" to "trash fish" ratio in the catch of the three push-net types.

The "commercial" component of the catch is mostly supplied to the fresh fish market while the "trash fish" is used for duck/fish meal. The "commercial" catch is dominated by "small" and "large" shrimp (which accounted for nearly a quarter of combined push-net catches and the bulk of its value) followed by swimming crab or portunids (6%). The fish and squid components of the "commercial" catch are largely treated as by-catch and seldom marketed, as their quantity is sufficient only for crew consumption. Thus, the push-net fishery in Ban Don Bay is primarily a shrimp fishery. The activities of the push-net boats pose serious competition for similar resources exploited by the artisanal gill net sector.

Table 2 gives the relative abundance (%) of species comprising the "large" and "small" shrimp components of "commercial" catches. The "large" shrimp category is dominated by *Penaeus merguiensis* and *Metapenaeus brevicornis* which together make up around 70% of the catch. Small push-nets deviate from this overall trend, showing a greater dominance of *P. merguiensis* (60%) and a higher contribution of *P. semisulcatus* (15%) in the catch.

The "small" shrimp category is composed primarily of *Metapenaeopsis lysianassa* (35%), *Parapenaeopsis* spp. (23%) and *M. stridulans* (18%). Some variations in relative abundance among the three push-net types are evident, with small push-net catches dominated by *M. lysianassa* (88%) and medium push-net catches showing a relatively even distribution among the five species listed in Table 2. The variations in the catch composition among the three push-net types suggest that some of the species may be abundant in specific areas of the bay.

The "trash fish" catch is composed of the "true trash fish" (i.e., species groups not preferred for human consumption and with very low market value) and undersized individuals or juveniles (2-6 cm) of commercially important components of the catch. Of the "trash fish" CPUE of about 196 kg/boat/day, around 36% (114 kg/boat/day) is "true trash fish," while the rest is composed of undersized demersals (8%), pelagics (12%) and invertebrates (6%). Overall, undersized individuals of commercially important species groups comprise 26% (82 kg/boat/day) of the catch for the combined push-net fleet (i.e., except for the "large" shrimp and squid).

Table 3 gives the relative abundance of families/groups comprising the various "trash fish" landings for the three push-net types. The "true trash fish" group is composed primarily of slipmouths (Leiognathidae) and nonswimming crab (i.e., other brachyurans excluding portunids), which collectively account for over 60%. The demersals are primarily fish of the family Sciaenidae and Cynoglossidae (56%), the pelagics, chiefly Engraulidae and Clupeidae (81%), and invertebrates, mostly shrimp (54%).

DISCUSSION

Results of the present study indicate that the mean catch rate for push-net boats in Ban Don Bay was about 316 kg/boat/day with a "commercial" to "trash fish" ratio of 4:6. The "commercial" component of catches is composed largely of shrimp and swimming crab, while the "trash fish" component is composed of more than 60% "true trash fish" and less than 40% undersized individuals of commercially important resource organisms. This implies that about a quarter of total landings is composed of undersized fish, thus indicating a tremendous rate of overfishing. Such overfishing may be a direct consequence of the mesh size used by push-nets (commonly 1.5 cm in stretched length) and the concentration of the fleet in the shallow areas of the bay. Push-nets compete for similar target species exploited by artisanal drift gill nets for crab and trammel nets for shrimp. The results herein obtained largely agree with those given by Eiamsaard et al. (1985), with the exception of the higher catch rate currently obtained. The higher catch rate is reflective of the trend in the push-net fishery from small to larger-sized push-net gear.

In view of these findings, a licensing scheme should be implemented to prevent the increase of push-net units in the area. Efforts to reduce the number of push-net boats in Ban Don Bay, via accretion of older vessels and/or conversion to drift nets for pelagics or crab, should be given priority. Over the short-term, push-net operations can be banned within 3 km of the shore to minimize their damage to the fisheries. An increase in mesh size may be desirable (and requires further investigation), although mesh size regulation may be impractical since shrimp are the main target species.

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Table 1. Mean catch per unit effort, CPUE (kg/boat/day), of various push-net types operating in Ban Don Bay, Thailand for the period March 1987-May 1988.

Resource/group	Small CPUE	Small %	Medium CPUE	Medium %	Large CPUE	Large %	Weighted mean CPUE	Weighted mean %
"Commercial" catch	79.7	34.2	106.3	36.3	147.2	40.1	120.1	38.0
"Large" shrimp	25.0	10.7	18.0	6.2	30.6	8.3	24.5	7.9
"Small" shrimp	20.4	8.8	39.2	13.4	76.2	20.8	52.5	16.6
Squid	11.3	4.8	11.7	4.0	15.6	4.2	13.9	4.2
Swimming crab	19.7	8.4	21.4	7.3	17.6	4.8	19.4	6.2
Fish	3.2	1.4	3.1	1.0	3.8	1.1	3.4	1.1
Others	0.1	<0.1	12.9	4.4	3.4	0.9	6.4	2.0
"Trash fish" catch	153.4	65.8	186.6	63.7	219.8	59.9	195.8	62.0
"True trash fish"	76.6	32.9	109.2	37.3	132.6	36.1	114.2	36.2
Demersal fish	23.9	10.2	19.9	6.8	29.6	8.1	24.9	7.9
Pelagic fish	42.5	18.2	38.1	13.0	35.3	9.6	37.6	11.9
Invertebrates	10.4	4.5	19.4	6.6	22.2	6.1	19.1	6.0
Total catch	233.1	100.0	292.9	100.0	367.0	100.0	315.9	100.0

Table 2. Relative abundance (%) of species comprising shrimp landings of various push-net types in Ban Don Bay, Thailand. (See Table 1 for catch rates of "large" and "small" shrimp by the three push-net types.)

Group/species	Small	Medium	Large	Weighted mean
"Large" shrimp	100.0	100.0	100.0	100.0
Metapenaeus affinis	4.9	10.0	9.5	8.8
M. brevicornis	4.3	25.6	27.4	22.9
M. ensis	5.0	4.4	14.5	10.0
M. moyebi	6.9	3.3	5.9	5.4
Penaeus merguiensis	60.6	49.4	41.5	47.0
P. semisulcatus	15.0	5.5	1.0	4.7
Others	3.3	1.8	0.2	1.2
"Small" shrimp	100.0	100.0	100.0	100.0
Metapenaeopsis barbata	0	17.2	5.3	8.4
M. fulcus	0	21.8	8.3	11.6
M. lysianassa	88.3	17.7	37.6	35.3
M. stridulans	0.5	19.3	19.2	18.0
Parapenaeopsis spp.	9.0	21.9	24.9	23.0
Others	2.2	2.1	4.7	3.7

Table 3. Relative abundance (%) of families/groups comprising "trash fish" landings of various push-net types in Ban Don Bay, Thailand. (See Table 1 for catch rates of "trash fish" by the three push-net types.)

Family/group	Small	Medium	Large	Weighted mean
"True trash fish"	100.0	100.0	100.0	100.0
Apogonidae	8.6	4.8	3.3	4.4
Bothidae	0	0.1	1.6	0.9
Bregmacerotidae	0.4	5.8	2.0	3.2
Callionymidae	2.2	3.4	1.4	2.2
Gobiidae	2.2	0.8	1.2	1.2
Leiognathidae	34.6	28.1	44.9	37.5
Other crab groups	15.5	20.8	25.5	22.7
Others	36.5	36.2	20.1	27.9
Demersal fish	100.0	100.0	100.0	100.0
Cynoglossidae	24.2	15.0	28.7	23.8
Platycephalidae	10.7	0	2.7	3.2
Sciaenidae	8.5	66.0	19.9	32.2
Sillaginidae	18.2	2.2	1.2	4.3
Others	38.4	16.8	47.5	36.5
Pelagic fish	100.0	100.0	100.0	100.0
Carangidae	7.8	9.2	8.0	8.4
Clupeidae	7.0	23.1	21.6	19.3
Engraulidae	71.3	57.8	60.3	61.4
Others	13.9	9.9	10.1	10.9
Invertebrates	100.0	100.0	100.0	100.0
"Large shrimp"	0	29.2	25.4	24.6
"Small shrimp"	47.2	33.6	23.7	29.7
Squid	2.6	7.5	9.0	7.8
Swimming crab	18.4	13.1	5.8	9.8
Others	31.8	16.6	36.1	28.1

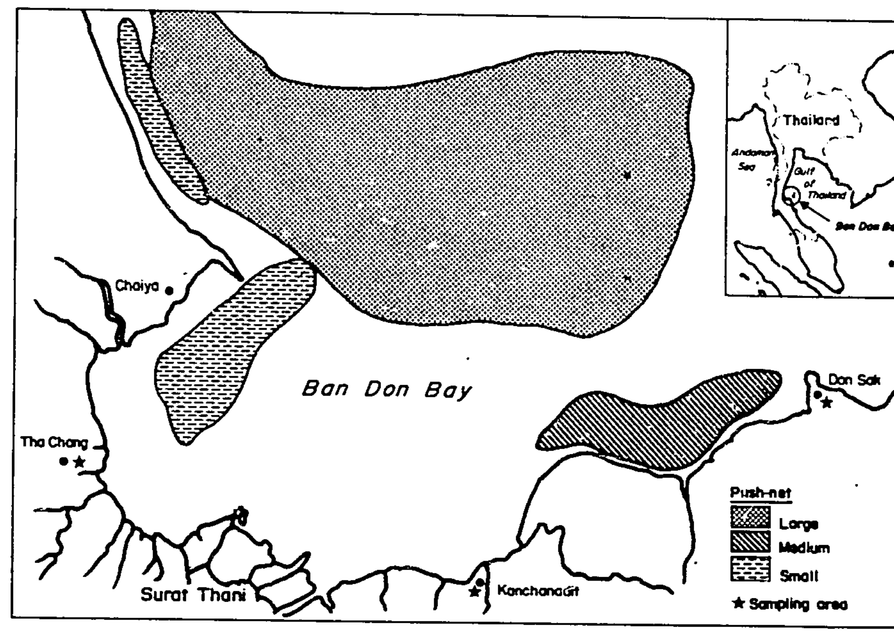

Fig. 1. Operational range of boats using push-net in Ban Don Bay, Thailand.

Assessment of the capture fisheries of Lingayen Gulf, Philippines

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ABSTRACT

This paper presents an overview of the capture fisheries of Lingayen Gulf (covering landings, exploited resources and capture methods) and summarizes the major findings from assessment studies in the area relevant to the status of prevailing exploitation of the fisheries resources. The available information indicates, among others, that: (1) excessive fishing effort on the fisheries resources results in total yield to biomass ratio of about 5.2 and reduction of demersal biomass to about 18-35% of its original levels in the late 1940s; (2) growth overfishing due to the use of small-mesh (2 cm) nets results in losses of about 20% and 40% relative to maxima in yield and value, respectively; and (3) species composition changes reflect overfishing. Rents from municipal and commercial fishing operations, when evaluated, indicate that these are negative or negligible, and show signs (albeit preliminary) of overfishing. The high population density, low income and poverty of fishermen, the intense competition for fishing grounds and resources, the rampant use of explosives in fishing, and the high level of malnutrition in the coastal areas do not represent optimally sustainable conditions. The paper recommends more efficient management, in general, and reduction of fishing effort, in particular.

INTRODUCTION

Assessment of the status of exploitation of Philippine fisheries resources shows that the country's capture fisheries suffers from considerable biological and economic overfishing. The Natural Resources Management Center-Fishery Industry Development Council (NRMC-FIDC) (1980) and Smith et al. (1980) provide a review of studies conducted up to the late 1970s. Assessment during this period principally relied on nonconventional or indirect methods (e.g., yield is compared with productivity per unit area) to infer the status of exploitation. While these do not allow for strong and solid inferences, they point to an increasing trend of overexploitation in various fishing areas, especially in the nearshore, traditional fishing grounds. Studies based on conventional surplus production and analytic modeling confirm overexploitation and the serious biological overfishing problem (e.g., White and Yesaki 1982; Silvestre and Pauly 1986; Silvestre et al. 1986; Dalzell et al. 1987; Ganaden and Stequert 1987; and Silvestre and Pauly 1989). In the case of the neritic pelagic and demersal fish stocks alone, the magnitude of rent dissipation due to overfishing is about US$400 million per year. Moreover, area-specific studies (e.g., Pauly and Mines 1982; Silvestre 1986; and Silvestre et al. 1987) reaffirm that overexploitation is more serious in nearshore fishing grounds and semi-enclosed seas such as shallow bays and gulfs. Thus, a shift in government concern from resources development to resources management is becoming apparent.

Lingayen Gulf (Fig. 1), the site of intensive studies under the ASEAN/US Coastal Resources Management Project (CRMP) in the Philippines, is an important traditional fishing ground in northwestern Luzon. With an area of slightly over

2,000 km², the gulf produced landings of about 11,800 t/year of fisheries products worth approximately ₱150 million in the first half of the 1980s (Mines 1986). These landings met the demand for cheap fish protein in Pangasinan and La Union, and the neighboring landlocked provinces (Aprieto and Villoso 1982). As early as 1976, however, Lingayen Gulf was assessed by the Bureau of Fisheries and Aquatic Resources (BFAR) as "either fully exploited or overfished" together with 13 other traditional Philippine fishing grounds. Despite the significance of the capture fisheries in the gulf and the apparent resource-related problems, the quantitative information necessary to assess and manage these fisheries properly has remained scattered and patchy. In this context, the Resource Assessment component of the ASEAN/US CRMP in the Philippines was formulated and tasked with two objectives: (1) describe the nature (i.e., magnitude of landings, exploited resources, capture methods) of the capture fisheries; and (2) assess the status of exploitation of the fisheries resources. To fulfill these objectives, secondary data--both published and unpublished--were collated and analyzed to infer and identify important data gaps (McManus and Chua 1990). Subsequently, catch and fishing effort information from the commercial and municipal fisheries were monitored from April 1987 to October 1988. Detailed treatments of the research methodology and preliminary results from the original data are given in Calud et al. (1989) and Ochavillo et al. (1989). This paper summarizes the major findings relevant to the two objectives mentioned above, based on a synthesis of the secondary and original data.

The Lingayen Gulf capture fisheries: an overview

Philippine capture fisheries has been traditionally subdivided into the "commercial" and "municipal" fisheries sectors on the basis of vessel gross tonnage. Presidential Decree No. 704--commonly known as the Philippine Fisheries Decree of 1975--defines commercial fisheries as those fishing operations involving the use of vessels of over 3 GT. Municipal fisheries, on the other hand, include fishing activities using vessels 3 GT or less, including operations that do not involve the use of a watercraft. Based on this definition, the municipal sector roughly translates into small-scale, artisanal or traditional fisheries. Similarly, the commercial sector is roughly equivalent to large-scale or industrial fisheries.

The capture fisheries of Lingayen Gulf is characterized by a multiplicity of gear used to harvest the exploited multispecies mix. Twenty-eight different types of fishing gear are used by municipal or artisanal fishermen, while only one type of gear--the trawl--is used by commercial fishermen. Monitoring of landings during the one-year period between May 1987 and April 1988 indicates that landings from the gulf total about 13,900 t of fish and invertebrates worth approximately ₱200 million. About 75% of the total landings were accounted for by the municipal sector, the remainder coming from commercial trawling activities. Table 1 gives the relative contribution of the commercial trawl and major municipal gear/methods to marine fisheries production in the gulf during the period.

Trawling represented the only form of commercial fishing activity in Lingayen Gulf at the start of monitoring activities in May 1987. The rest of the commercial catch reported for the gulf in the BFAR statistics was taken outside the geographical limits of the gulf. These came primarily from purse seine operations with the aid of fish aggregating devices *(payao)* off Lingayen Gulf. These operations are a relatively recent development. As late as 1979, all commercial landings reported by BFAR came solely from trawl operations inside the gulf. However, three commercial vessels based in Dagupan City and using Danish seines, began operating in the gulf in April 1988. Initial findings indicate that these vessels came from the Samar Sea area, attracted by more favorable fish prices in the Pangasinan-La Union region.

Lingayen Gulf is a traditional fishing ground for trawlers. Before the outbreak of World War II, 15 beam trawlers were already operating in the area. After the lull in fishing activities brought about by the war, trawling operations resumed. In 1949, seven otter trawlers (10-30 GT) using reconditioned diesel engines (50-225 HP) were fishing in the gulf (Warfel and Manacop 1950). However, subsequent information on trawl effort was unavailable until 1976 because of the lack of quantitative studies in the intervening years and the aggregate nature (on a countrywide basis) of statistics on trawler size and number. BFAR statistics for the period 1976-1984 indicate that the number of trawlers in Lingayen Gulf varied between 20 and 36 units, with aggregate tonnage varying from 365 GT to 910 GT. Trawler landings for the same period ranged from 1,185 t to 2,110 t.

Mines (1986) reports that the trawl fleet in 1983 was composed of 40% medium (10-20 GT) and 60% large (over 20 GT) trawlers, and that only 23 of the 34 units registered by BFAR were actually operating. Signey (1987) reports that about 345 fishermen were employed directly in trawl operations in the gulf at the time. The 12-month monitoring of trawlers in the gulf between May 1987 and April 1988 has clarified the composition and operational details of the trawl fishery. The trawl fleet in 1987 is composed of 24 medium and 2 large trawlers (20-30 GT). There are 17 (i.e., 16 medium and 1 large) and 8 (i.e., 7 medium and 1 large) trawlers that are based (and land their catches) in Damortis and Dagupan City, respectively. One medium trawler is based in Sual, Pangasinan. Large trawlers make trips lasting 10 days and land their catches with the help of carrier vessels. Medium trawlers, on the other hand, operate at sea for two days and are back in port for a day before the next trip. Vessel and gear dimensions of typical medium trawlers operating in Lingayen Gulf are given in Fig. 2 and 3, respectively. Generally 13 m long and 3 m wide, medium trawlers use two-seam bottom trawls with headrope and groundrope lengths of 40 m and 45 m, respectively. Cod-end mesh sizes vary between 1.5 cm and 2.5 cm with a cover of about 3 cm to 4 cm. The length of towing warps is usually 275 m and adjusted with depth. Trawling activities in Lingayen Gulf are limited to the nearshore soft-bottom areas between Lucap and San Fernando from about right under the shoreline to a depth of 50 m (Fig. 1).

About 220 fishermen were directly employed in commercial trawl fishing operations in Lingayen Gulf in 1987. Landings by the trawl fleet totaled about 3,300 t at the time, approximately 80% of which were accounted for by medium trawlers. Mean catch rate during the period monitored (May 1987 to April 1988) was 32 kg/hr, being highest in June 1987 (51 kg/hr) and lowest in January 1988 (22 kg/hr). The catch during the period consisted of 158 species/groups distributed among 58 families. Table 2 gives the relative abundance of the ten most important families/groups making up the catch of trawlers. In the late 1980s, leiognathids made up almost one-third of trawl catches (i.e., 31.4%) and, together with carangids, hairtails, scombrids and lizardfish, made up 67% of the catch (Ochavillo et al. 1989). Table 3 gives the ten most important species/groups among trawl landings during the same period. The orange-fin ponyfish, *Leiognathus bindus*, made up 18% of the catch, followed by *Trichiurus haumela* (9.0%), *Gazza minuta* (7.1%), *Saurida tumbil* (5.6%) and *Atule mate* (5.5%). These five species made up almost 45% of the trawl catches.

Sixteen towns and one city border Lingayen Gulf from Cape Bolinao to Poro Point. In 1985, BFAR reported the existence of 12,500 municipal fishermen in these places (Calud et al. 1989). About 46% of these fishermen are in Sector I (see Fig. 1), while 36% and 18% are in Sectors II and III, respectively. A total of about 7,050 *banca* (60% of which are motorized) was reported from the area, giving a *banca*-to-fisherman ratio of 0.56. Mean municipal landings in 1983 were 8,700 t (Mines 1986) and this figure implies that each municipal fisherman lands about 0.70 t/year on the average, or about 58 kg/month.

The municipal fisheries in the gulf are complex as can be seen from the various methods/gear used by the small-scale fishermen (McManus and Chua 1990). The variety and seasonality of fishing gear used are influenced by the bottom topography and substrate of the fishing ground, the fauna or target species in the area of operation and the level of capital input and returns that the gear/method entails. Table 4 gives the frequency of use of the different municipal gear in the various municipalities bordering the gulf based on an inventory by Mines (1986). Note the preponderance of simple and inexpensive fishing gear. Surface gill nets, spear guns and pots or traps are preferred by fishermen in Sector I, which is characterized by coralline growth and uneven topography. Meanwhile, baby trawls and beach seines together with gill nets and crab pots are common in Sector II, which has mostly soft and muddy substrate with a few patches of hard/rocky bottom close to the shore. Bottom gill net, line gear and round haul seine operations in the deeper parts are preferred in Sector III, which is characterized by a sandy bottom with a scattered rocky substrate. The shallow areas in this sector are limited.

The original data gathered by the Resource Assessment team have allowed a characterization of the typical design specifications, operations, and catch rate and species composition of the various municipal fishing gear used in the gulf. Detailed discussions covering these topics are given in Calud et al. (1989). Table 1 shows the relative contribution of the various artisanal gear to municipal fisheries production in the gulf. Gill nets contributed 46% of the municipal landings between May 1987 and April 1988, and despite being illegal, blast fishing accounted for 10%. These two methods/gear together with the hook and line contributed about 65% of the total municipal fisheries production during the period. The typical design for bottom gill nets, the most predominant gear in the gulf, is given in Fig. 4, while the ten most important species composing bottom gill net catches are given in Table 3.

Historical information on the level of municipal fishing effort in the gulf is limited. This may be inferred only from the number of fishermen. Since the 1930s, the number of small-scale fishermen in Lingayen Gulf has declined due to World War II but it has tremendously increased in the 1980s (Fig. 5).

Overlaps in area of operations (see Calud et al., this volume) and exploited resources (see Table 3) characterize municipal and commercial fishing operations in Lingayen Gulf. Conflicts between and among municipal and commercial fishermen occur and have intensified in recent years. Because of intense competition, some municipal fishermen use explosives. These activities are illegal and punishable by stiff prison terms but they persist and are rampant. Between August 1987 and April 1988, the mean catch rate was about 13.0 kg per blast, varying between 1.2 kg per blast and 75.5 kg per blast in the same period. Carangids, mugilids and siganids made up 86% of the catch (Table 5). Fig. 6 gives the relative frequency of the number of blasts per 10-16 HP boat (per day) involved in blast fishing in the gulf.

Assessment of exploitation status

The assessment of the status of fisheries resources exploitation in Lingayen Gulf is limited by the nature of the existing database. Previous assessments in the literature, therefore, have resorted to indirect or nonconventional methods (e.g., comparison of estimated productivity per unit area with current landings or harvest) to infer the status of prevailing exploitation. Based on such an assessment, BFAR declared Lingayen Gulf, together with 13 other traditional fishing grounds in the Philippines, as overfished in 1976 (Smith et al. 1980). Using the same approach, NRMC-FIDC (1980) concluded that the fisheries resources of Lingayen Gulf are either heavily exploited or overfished. Fox (1986) inferred that Lingayen Gulf is heavily fished based on the density of fishermen in the area--there are more than 70 fishermen per kilometer of coastline--and their projected per capita extraction rate. The fisheries resources are subjected to heavy fishing pressure and competition is quite intense, especially in the nearshore areas (Mines 1986). Available assessments, therefore, indicate that the gulf's resources are heavily exploited, if not overfished.

The term "overexploited" or "overfished" refers to the unsatisfactory use by a fishery of a given stock or resource. The perception of what constitutes an overfished stock has evolved with the "ideal" management goal from: (1) maximum sustainable yield (MSY) in the 1950s; to (2) maximum economic yield (MEY) in the 1960s; to (3) optimum sustainable yield (OSY) in the 1970s. Correspondingly, three forms of overfishing are recognized, namely: (1) biological overfishing, associated with nonattainment of MSY; (2) economic overfishing, associated with nonattainment of MEY; and (3) "system" overfishing, associated with nonattainment of OSY. Biological overfishing results from excessive fishing effort and/or low length-at-first-capture leading to: (1) yields that are lower than what the stock can maximally sustain; (2) impairment of the reproductive capacity or sustainability of the stock; and/or (3) undesirable species composition changes. These types of biological overfishing are classified into growth, recruitment and ecosystem overfishing (Pauly 1980). Economic overfishing occurs when fishing effort exceeds the level which will maximize rent from the resources (i.e., marginal cost of fishing exceeds marginal revenue). "System" overfishing implies that the "optimum" societal benefits from the resources, given the biological, economic, social and political realities of the overall system affecting fisheries exploitation, were not achieved.

The secondary and original data reinforce the previous assessments of Lingayen Gulf. While some still argue that the information at hand does not convincingly demonstrate overexploitation, the authors maintain that the collective evidence does indicate heavy fishing pressure and overfishing. Evidences are described below.

High Fisherman and Boat Density. Fishermen and *banca* in the coastal municipalities adjoining the gulf (i.e., 12,500 municipal fishermen and 7,050 *banca*) mean that there are: (1) 78 fishermen per km of coastline; (2) 47 boats per km of shoreline; (3) 12.5 fishermen per km^2 of municipal fishing ground (defined as the area enclosed by the coastline and the 7-fathom, 7-km ban); and (4) 7 boats per km^2 of municipal fishing ground. The number of fishermen in (1) and the number of boats in (2) are among the highest in the country; it implies that the municipal fishermen and boats would be, on the average, 13 m and 38 m apart, respectively, when spread evenly along the coastline. Combined with fishing effort from the 26 commercial trawlers in the gulf, the figures support previous observations of heavy fishing pressure on the fisheries resources.

Low and Declining Catch Rates. Annual municipal fisheries production in Lingayen Gulf (i.e., 10,500 t/year) in 1987 implies a catch rate of about 0.84 t/fisherman/year or 70 kg/fisherman/month, which is very low (in fact, one of the lowest in the country). For the commercial fisheries sector, the catch rate during the late 1940s approximates that which would be obtained at near virgin biomass levels due to the lull in fishing activities brought about by World War II. The catch rates in the late 1980s have declined to about 18-35% of their original levels in the 1940s (Fig. 7). Surplus production models indicate that a stock is overfished when catch rates have declined below 40-50% of their value in the unexploited stock.

High Extraction Rates. The harvest levels given in the previous section (see Table 1) show that (1) the extraction rate is at least 10.5 t per km^2 of municipal fishing ground and (2) the yield is 6.9 t per km^2 of the total area in Lingayen Gulf (i.e., about 2,000 km^2). Moreover, Calud et al. (1989) estimate the total yield-to-biomass ratio in Lingayen Gulf to be about 5.2 at current production levels, and trawl yield-to-demersal biomass ratio to be about 2.8. These are quite high compared with the productivity of similar tropical fishing grounds (see Armada et al. 1983).

Growth Overfishing. Fig. 8 illustrates, for the trawl fisheries of the Philippines, the range of eumetric lines that maximize yield from the faunal assemblage in the mesh size (Ms), and fishing mortality (F), plane (Silvestre et al., in press). The figure in essence delineates the optimum operational range for the fisheries given the two factors (Ms and F) that are frequently the object of management intervention. Note that the 2.0-cm mesh size commonly used in Lingayen Gulf is appropriate only for very low F levels. The prevailing Ms and F (= 2.8 per year) on the trawlable biomass lead to considerable growth overfishing, resulting in losses of up to 20% and 40% relative to maxima in yield and value, respectively. In addition, Ochavillo et al. (this volume) show high exploitation rates (0.23-0.72) for most species making up the catch of trawlers in Lingayen Gulf.

Recruitment and Ecosystem Overfishing. Table 2 shows that the changes in family/group composition of the demersal biomass in Lingayen Gulf reflect recruitment and ecosystem overfishing. Such changes were brought about by, among others, the increasing level of fishing effort (see Fig. 5 and the previous section) that caused the decline of demersal biomass in the gulf (see Fig. 7). The observed changes in the faunal composition, which is similar to those noted in other fisheries of the Southeast Asian region, include: (1) increased squid abundance; (2) disappearance of rays (i.e., large, long-lived species); (3) disappearance of formerly abundant lactarids; (4) increased abundance of triggerfish; and (5) above-average decline of large, high-valued species (e.g., lutjanids and flatfish).

These changes illustrate the existence of heavy fishing pressure on the fisheries resources of Lingayen Gulf and show symptoms of the three forms of biological overfishing. While economic analyses of the Lingayen Gulf fisheries are quite limited in scope to establish the elements of economic overfishing, some indications are given by the works of Signey (1987) and Añonuevo (1989). These works estimate pure profit or resource rent in commercial and municipal fishing operations in the gulf to be negative or negligible. They also argue that the low profitability of fishing operations has resulted in very low repayment rates for fisheries credit programs in the gulf area (e.g., zero repayment rate for the Kilusang Kabuhayan at Kaunlaran (National Livelihood Program) credit scheme between 1981 and 1986).

The occurrence of "system" overfishing is difficult to illustrate because available information is inadequate, objectives for "optimization" of benefits are unclear, and such evaluations are subjective. This paper, however, argues that the following do not constitute optimally sustainable conditions: high density, low income and extreme poverty of the fishermen; the increased competition for fisheries resources and fishing ground and conflict among them; the high incidence of malnutrition; and the rampant use of explosives in fishing.

CONCLUSION

There is an excessively high fishing pressure on the fisheries resources of Lingayen Gulf. The immediate issue confronting the capture fisheries in the area is biological overfishing. Estimates of prevailing extraction rates (i.e., F = Y/B = 5.2) point to the need for reducing fishing effort and for improving management. As an initial step to reduce the magnitude of fishing effort, strict enforcement of existing fisheries laws/regulations is in order. Such laws include the 7-km, 7-fathom ban on commercial vessels, the ban on the use of explosives and poisons in fishing, and the 3-cm minimum mesh size regulation. This would effectively reduce the extraction rates by trawlers (currently F = 1.26 overall) and perhaps those by blast fishing activities (presently at F = 0.40). Licensing or entry of new commercial trawlers and other commercial boats such as Danish seiners should be stopped as these will put additional pressure on the stocks. Trawl mesh size should be increased to about 3.5 cm. Moreover, it would be advisable to reduce the number of commercial trawlers by accretion of the older vessels, given the high municipal fishing pressure (which may persist given the prevailing economic situation) and the considerable dependence of the coastal population on fishing. Note, however, that the remaining municipal extraction (F = 3.57) would still be very high even without the fishing pressure from trawling and blast fishing activities. Thus, municipal fishing effort would ultimately have to be reduced by about half to ease fishing pressure on the resources and thus assure their sustainability.

Over the medium-term, improved management of the fisheries would have to be effected. Measures toward this end include, among others, the following: (1) creation of a fisheries management council (with representatives from the various sectors) under the Regional Development Council to oversee and/or address resource allocation and management of the resources; (2) creation of alternative employment opportunities to draw effort away from capture fisheries; (3) identification and/or clarification of management goals and objectives for resource utilization; and (4) identification and operationalization of supplemental strategies of viably enforcing laws and regulations apart from the penal provisions of the law. The latter can include information dissemination or education campaigns, extension activities to strengthen existing or traditional institutional structures, and organization of resource-users to manage the gulf's resources.

Over the long-term, the ultimate solution to most of the problems confronting the capture fisheries of Lingayen Gulf (and, for that matter, Philippine fisheries) cannot be found within the fishing sector itself. Macrolevel programs that address the problems of socioeconomic inequality and foster genuine (albeit initially labor-intensive) industrialization are essential to increase opportunities outside the fisheries sector.

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Table 1. Relative contribution of the municipal and commercial sectors to annual marine landings in Lingayen Gulf for the period May 1987 to April 1988.

Sector/gear type	Landings (t)	% of total landings	% of sector landings
Municipal	10,524	75.8	100.0
Gill net	4,795	34.6	45.6
Blast fishing	1,054	7.6	10.0
Hook and line	948	6.8	9.0
Lift net	885	6.4	8.4
Shrimp trawl	826	6.0	7.8
Danish seine	446	3.2	4.2
Beam trawl	443	3.2	4.2
Others	1,127	8.0	10.8
Commercial	3,351	24.2	100.0
Large trawl	606	4.4	18.1
Medium trawl	2,745	19.8	81.9
Total	13,875	100.0	-

Sources: Calud et al. (1989) and Ochavillo et al. (1989).

Table 2. Relative abundance of important families/groups in the catch of trawlers operating in Lingayen Gulf, from the late 1940s to the late 1980s.

	Period							
	Late 1940s[a]		Late 1970s[b]		Early 1980s[c]		Late 1980s[d]	
Rank	Family/group	Relative abundance (%)	Family/group	Relative abundance (%)	Family/group	Relative abundance (%)	Family/group	Relative abundance (%)
1	Leiognathidae	63.0	Leiognathidae	52.4	Leiognathidae	33.6	Leiognathidae	31.4
2	Synodontidae	7.4	Carangidae	8.2	Carangidae	12.0	Carangidae	12.9
3	Pomadasyidae	6.7	Balistidae	6.8	Trichiuridae	8.4	Trichiuridae	9.3
4	Nemipteridae	6.6	Trash fish	5.1	Apogonidae	7.0	Scombridae	6.9
5	Lutjanidae	3.1	Scombridae	3.2	Nemipteridae	6.9	Synodontidae	6.1
6	Psettodidae	2.5	Meneidae	3.0	Synodontidae	5.8	Mullidae	3.6
7	Dasyatidae	1.9	Serranidae	3.0	Clupeidae	5.4	Cephalopods	3.5
8	Lactariidae	1.8	Synodontidae	2.8	Balistidae	5.1	Nemipteridae	3.4
9	Carangidae	1.4	Cephalopods	2.5	Scombridae	4.4	Engraulidae	2.6
10	Serranidae	0.9	Mullidae	2.3	Mullidae	4.4	Apogonidae	2.4
	Total	95.3	Total	89.3	Total	93.0	Total	82.1
Catch rate (kg/hr)		92.1		63.7		40.5		31.8

[a]Based on data from Warfel and Manacop (1950), covering the period February to April 1949.
[b]Based on data from Aprieto and Villoso (1982), covering the period February 1978 to January 1979.
[c]Based on data from Mines (1986), covering the period April 1983 to April 1984.
[d]Based on data from Ochavillo et al. (1989), covering the period June 1987 to April 1988.

Table 3. Relative abundance of the ten most important species/groups making up the catch of trawls and bottom gill nets in Lingayen Gulf, Philippines.

Gear type	Species/Group	Relative abundance (%)
Trawl	**Leiognathus bindus*	18.0
	**Trichiurus haumela*	9.0
	**Gazza minuta*	7.1
	Saurida tumbil	5.6
	**Atule mate*	5.5
	**Rastrelliger brachysoma*	4.6
	Loligo spp.	3.3
	**Upeneus sulphureus*	3.1
	Apogon spp.	2.4
	Priacanthus tayenus	2.2
	Total	60.8
	Rastrelliger kanagurta	14.2
	**Gazza minuta*	12.7
	Leiognathus splendens	9.7
	**Trichiurus haumela*	6.0
	**Upeneus sulphureus*	5.8
	**Rastrelliger brachysoma*	5.8
	Alepes djedaba	4.7
	**Atule mate*	4.1
	Leiognathus brevirostris	4.1
	**Leiognathus bindus*	3.9
	Total	71.0

*Species common to the two gear/methods.
Sources: Calud et al. (1989), Ochavillo et al. (1989).

Table 4. Frequency of use of the more important municipal fishing gear in Lingayen Gulf.

Type	Sector of operation I	II	III
Bottom set gill net	X	XX	XX
Drift/surface gill net	XX	XX	X
Round haul seine	-	X	XX
Beach seine	-	XX	XX
Baby trawl	-	XX	X
Bag net	X	-	-
Spear gun	XX	-	-
Fish pot	XX	X	X
Crab pot	XX	XX	X
Fish corral	XX	X	XX
Hook and line	XX	X	XX
Multiple hook and line	X	X	XX
Long line	XX	X	XX
Lift net	-	X	-

Notes:
-- not used in the sector
X - less common
XX - very common
Source: Mines (1986).

Table 5. Relative abundance of the ten most important families caught by blast fishermen in Lingayen Gulf.

Rank	Family	Relative abundance (%)
1	Carangidae	66.2
2	Mugilidae	10.8
3	Siganidae	9.1
4	Engraulidae	2.6
5	Lutjanidae	2.1
6	Leiognathidae	2.0
7	Scombridae	1.6
8	Sphyraenidae	1.3
9	Lethrinidae	1.1
10	Serranidae	1.1
	Total	97.9

Source: Calud et al. (1989).

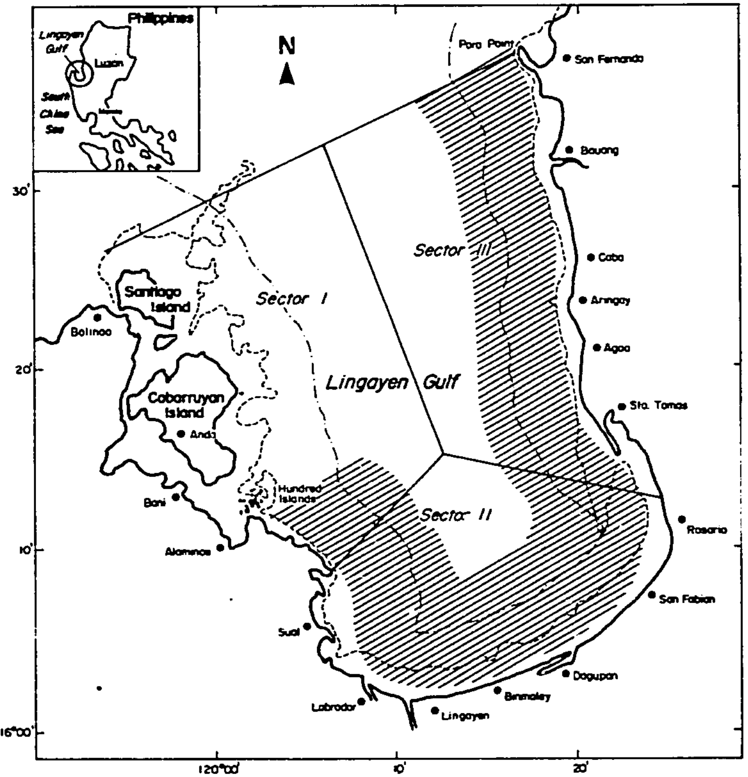


Fig. 1. Lingayen Gulf showing sectoral delineation of its coastal area, the 7-kilometer (-·-) distance from the shoreline and the 7-fathom (--) depth isoline. The hatched area represents the operational range of trawlers.

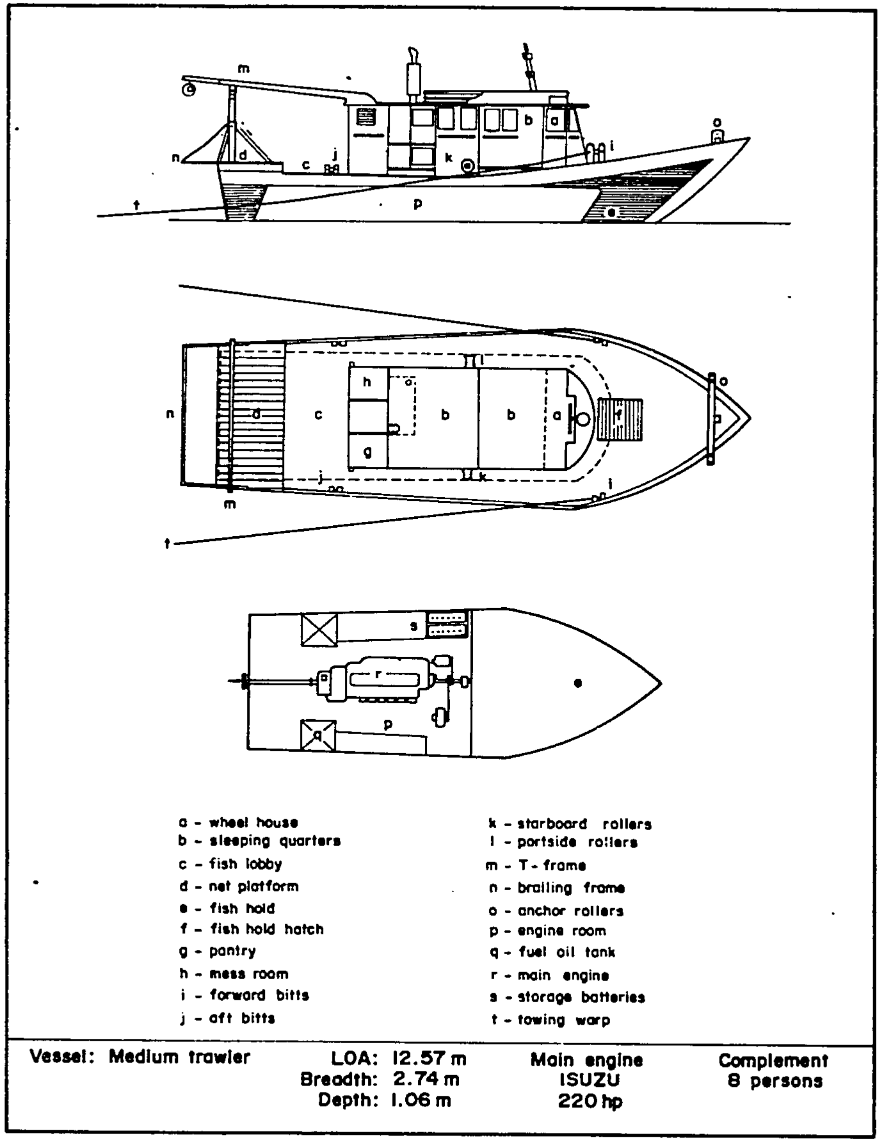
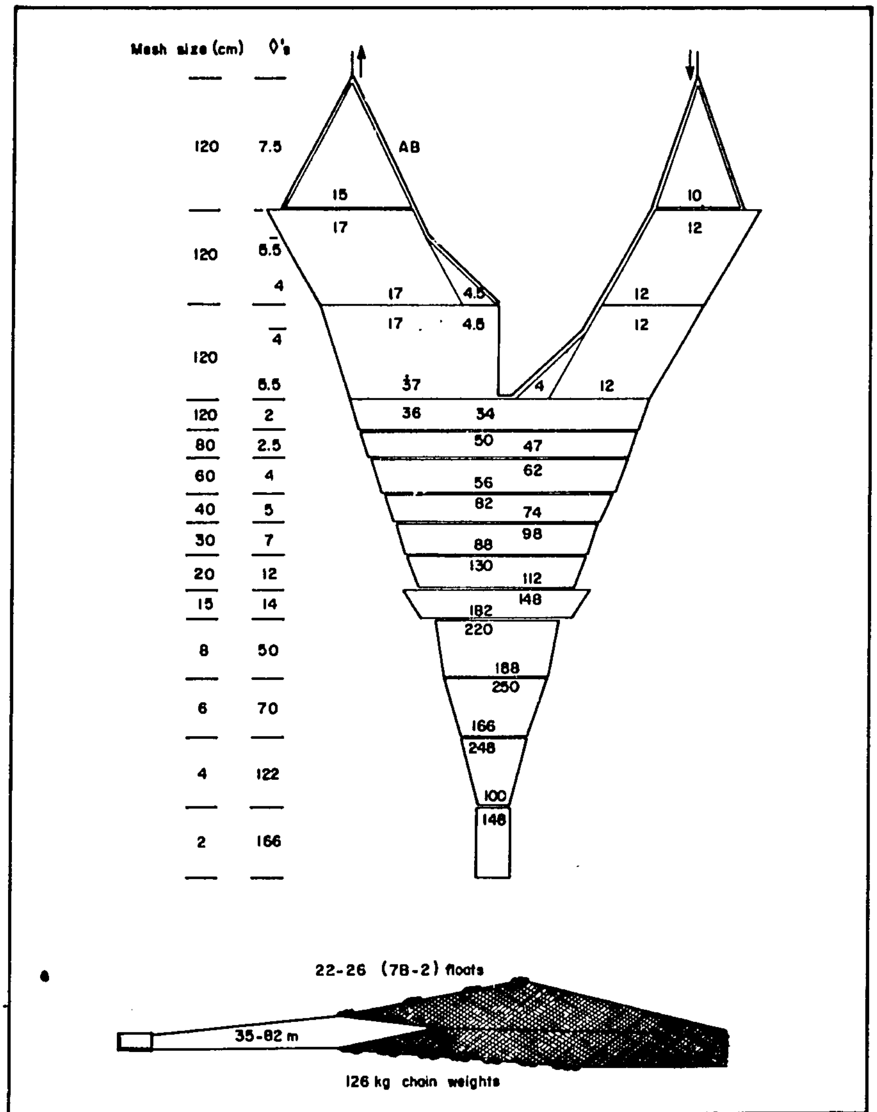


Fig. 2. Diagram of a typical medium trawler operating in Lingayen Gulf, Philippines (Ochavillo et al. 1989).



Gear	Otterboards	Vessel
Two-seam bottom trawl	flat 1.8x0.8m	200-250hp

Fig. 3. Typical design of bottom trawl used by medium trawlers in Lingayen Gulf, Philippines (Ochavillo et al. 1989).

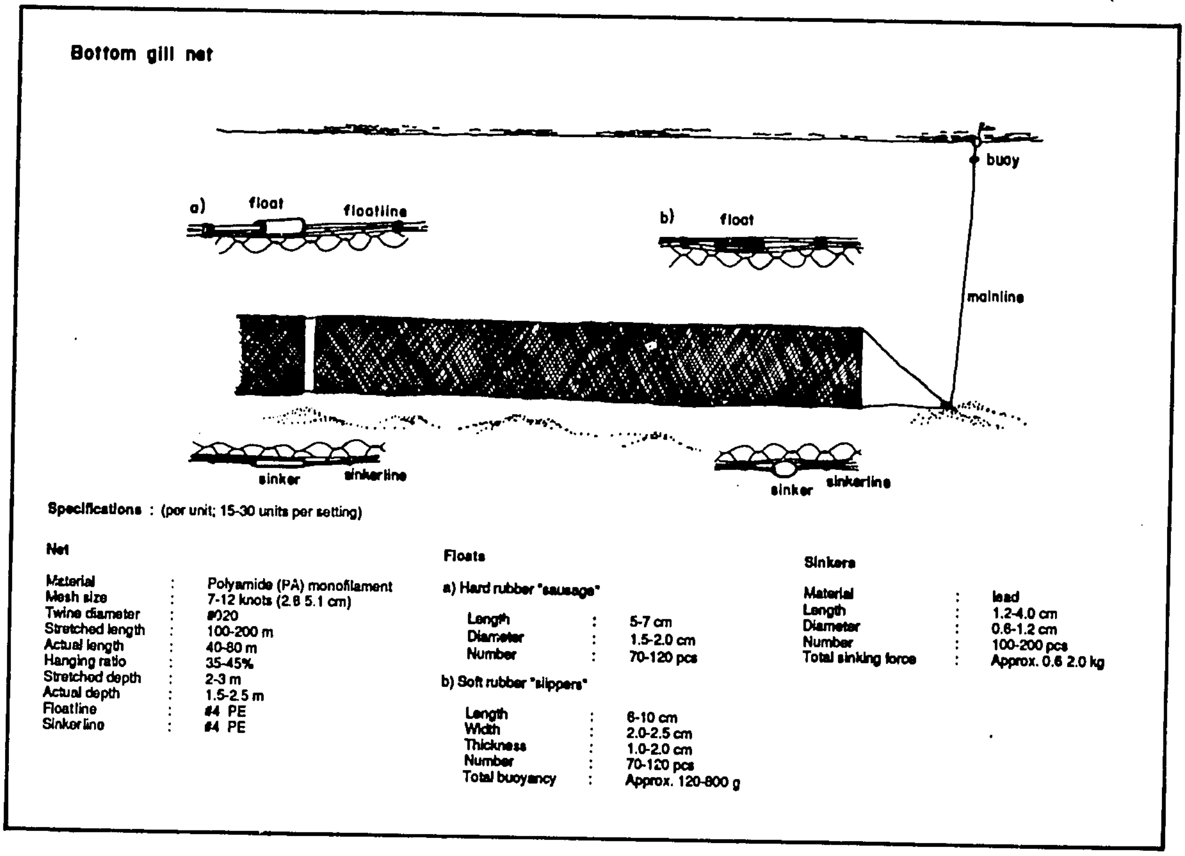


Fig. 4. Typical bottom set gill net design and specifications in the Lingayen Gulf (Calud et al. 1989).

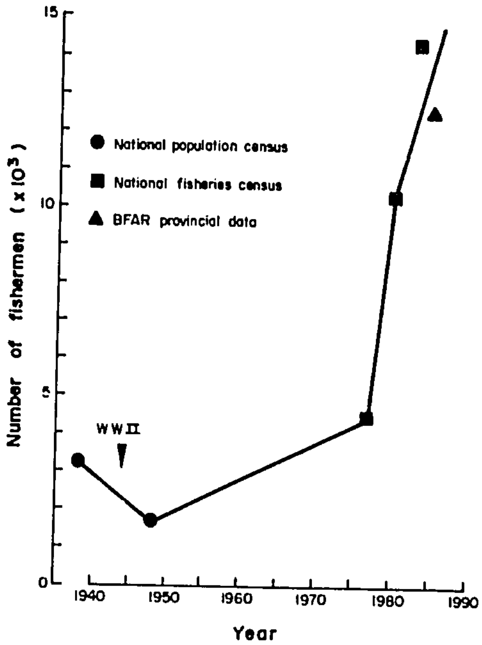


Fig. 5. Changes of the number of small-scale fishermen in the Lingayen Gulf area from the 1930s to the early 1980s. Note dip due to WW II and the tremendous increase in the 1980s. (The last point does not reflect a decrease but is the result of a different sampling methodology.)

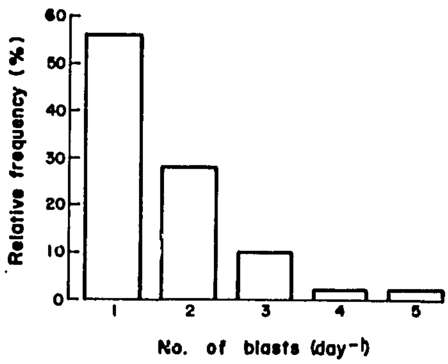


Fig. 6. Relative frequency in Lingayen Gulf, Philippines, of the number of blasts per 10-16 hp boat involved in dynamite fishing (Calud et al. 1989).

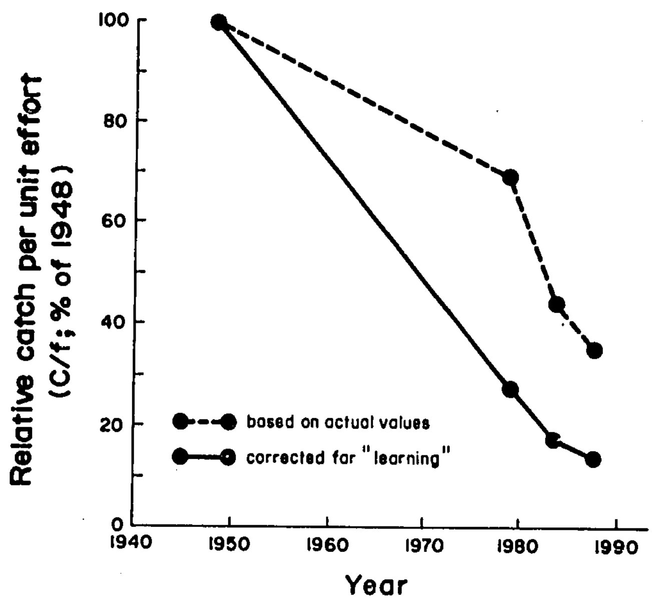


Fig. 7. Relative catch/effort of trawlers in Lingayen Gulf, Philippines (From data in Warfel and Manacop 1950; Aprieto and Villoso 1982; Mines 1986 and Silvestre et al. 1986). Note that surplus production models assume a stock to be overfished when c/f <40-50% of its value in unexploited stock.

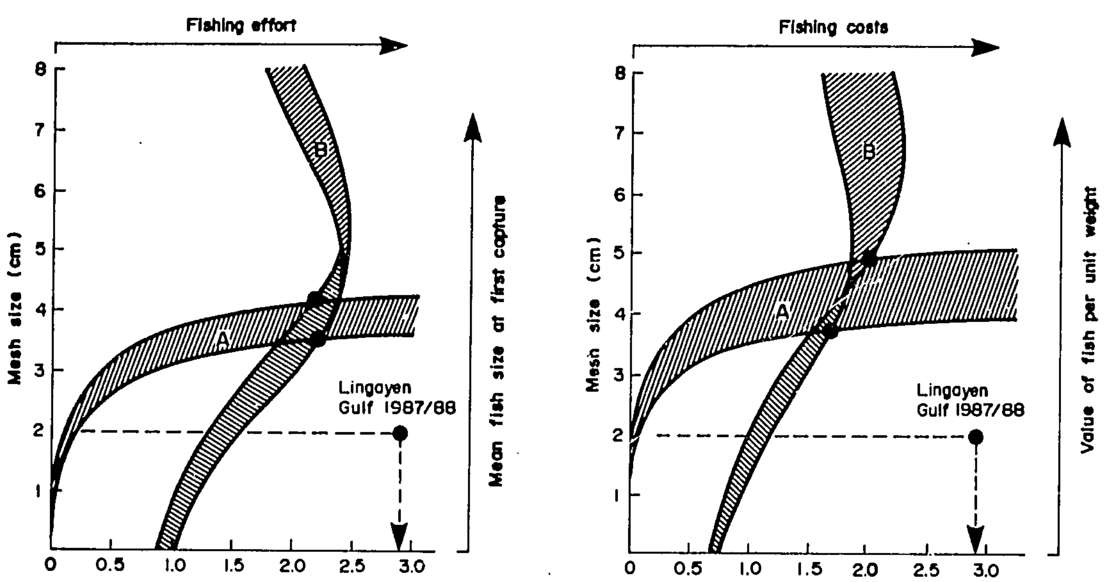


Fig. 8. Multispecies yield-per-recruit (*left*) and value-per-recruit (*right*) assessment of the demersal trawl fisheries of the Philippines (based on vital statistics, relative recruitment rate and per kg prices of 28 representative groups of fish and invertebrates from three major fishing areas, i.e., West Sulu Sea, Lamon Bay and Visayan Sea). The method used, which relies on logistic selection ogives rather than the assumption of knife-edge selection, is detailed in Silvestre and Soriano (1988). Dots on intersections of lines A (= "eumetric fishing") and B (= "cacometric fishing") show the range of optimum mesh size and fishing mortality combinations. Note excessively high effort and low mesh sizes in Lingayen Gulf, leading to losses of up to 20% and 40% relative to maxima in yield and value, respectively.

Population parameters and exploitation rates of trawl-caught fish species in Lingayen Gulf, Philippines

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ABSTRACT

Growth parameters (L_∞ and K) of the von Bertalanffy equation and mortality coefficients (M, F and Z) of the exponential decay model (estimated via ELEFAN I and II) are presented for the more abundant species comprising the catch of trawlers in Lingayen Gulf. The recruitment patterns and exploitation ratios (E = F/Z), using these parameters are also given. The results indicate high growth rates (K = 0.38-1.32) and mortality coefficients (Z = 2.59-6.87) for the species analyzed. These imply high turnover rates for most species composing the bulk of the trawlable biomass. Recruitment patterns obtained indicate that the event is bimodal for most of the species. The exploitation levels computed, at least for the length ranges examined, are relatively high (i.e., 0.23-0.72) and confirm previous assessments (based on yield-to-biomass ratios) of high extraction rates.

INTRODUCTION

Lingayen Gulf is an important fishing ground for pelagic and demersal fishes in the Philippines. During the first half of the 1980s, landings in the area ranged from 7,500 to 11,800 t of fisheries products valued at ₱110-150 million (McManus and Chua 1990). Fishing provided a major source of livelihood for over 12,000 fishermen and cheap protein for the people of the neighboring landlocked provinces.

Based on the multispecies resources, the gulf's fisheries are characterized by a multiplicity of gear, most of which are simple and inexpensive. Twenty-eight artisanal gear have been identified, which contribute 75% to 80% of the landings. Although purse seines are also present, they operate outside the geographical limits of the gulf, making trawling the only form of commercial fishing activity. Trawlers contribute about 95% of the commercial fisheries production (Aprieto and Villoso 1982).

Lingayen Gulf is a traditional trawl fishing ground. At the outbreak of World War II, 15 to 25 medium trawlers were operating in the area. The war reduced the fisheries to seven otter trawlers (10-30 GT), which used reconditioned diesel engines of 50 to 225 hp (Warfel and Manacop 1950). At present, the gulf is the most productive trawl fishing ground in Northern Luzon. There are about 26 trawlers in the gulf, 23 of which are medium (10-20 GT) and 3 are large (>20 GT). Operations are limited to the nearshore areas (0-50 m) in Sectors II and III where the substrate is generally muddy (see Silvestre et al., this vol.).

Due to their efficiency, the trawlers are being blamed for the dwindling catch of the other fishing gear. Municipal fishermen are vocal against the unrestricted operations of these vessels. The competition for the resources is further aggravated by the rampant use of dynamite and cyanide. These illegal forms of fishing indiscriminately destroy marine life upon which a burgeoning coastal population is dependent.

While previous studies indicate that the fishing ground is heavily exploited, conclusions are often based on inferences or nonconventional methods. This paper represents an attempt to provide information toward validation and/or further refinement of previous assessment studies. Population parameters (growth, mortality and number of recruitment peaks) and exploitation ratios of species comprising the bulk of trawl catches are presented.

MATERIALS AND METHODS

The data used in this study were collected during the commercial trawl fisheries survey conducted under the Resource Assessment subtask of the ASEAN/US Coastal Resources Management Project in Lingayen Gulf from April 1987 to June 1988. The survey covered the area of medium trawl operations (0-50 m) in Sectors II and III (see Silvestre et al., this vol.). The researchers boarded an average of 2.1 commercial trawl trips and sampled an average of 8.8 day-hauls per month for an aggregate of 106 day-hauls from 25 trawl trips during the course of the survey.

A typical trawl trip lasted about two days and each drag, an average of 3 hours. From each haul, samples were taken. Sorting was to species level whenever possible. The length distribution (measured from the tip of the snout to the shortest median caudal ray, i.e., fork length) of the species with a high occurrence was taken.

The growth parameters (L_∞ and K) of the von Bertalanffy equation were estimated via ELEFAN I (Gayanilo et al. 1988) using the length distribution data generated for each species.

ELEFAN II was used in estimating total (Z), natural (M), and fishing (F) mortalities and exploitation ratios (E = F/Z), as well as in deriving seasonal oscillations in recruitment, expressed as "recruitment pattern." These patterns are obtained by back-projecting length-frequency data on a time axis of one year, using the growth parameters estimated via ELEFAN I. The peaks of such patterns reflect the seasonality of recruitment in relative terms.

RESULTS AND DISCUSSION

Fig. 1 shows the results obtained via ELEFAN I and II for the most abundant species, *Leiognathus bindus* (orange-fin ponyfish). Estimates of the growth parameters (L_∞ and K) are summarized in Table 1 for the 15 most abundant species of commercial interest making up the catch of trawlers. Relatively high K and low L_∞ values were obtained, which are typical for small and fast-growing tropical species. Growth coefficients (K) ranged from 0.38 to 1.52. The yellow-striped trevally *(Selaroides leptolepis)* had the highest K. The ponyfishes *(Gazza minuta, G. acclamys* and *L. bindus)*, which are the most abundant species group in the catch of trawlers, exhibited the highest K values as a group. The hairtail *(Trichiurus haumela)*, on the other hand, had the lowest K while the threadfin breams *(Nemipterus japonicus* and *N. nematophorus)* exhibited the lowest growth coefficients as a group. These estimates are within the range of the values in other fishing grounds in the Philippines (see Corpuz et al. 1986; Silvestre 1986; Silvestre et al., in press, and references therein).

All the species investigated showed two recruitment peaks, except for the yellow-striped trevally *(S. leptolepis)* and the hairtail *(T. haumela)*.

The mortality parameters estimated are also given in Table 1. All the investigated species showed high total mortality rates (i.e., more than 2.5). Such high Z values entail very low annual survival rates. The high Z and F values obtained for the yellow-striped trevally *(S. leptolepis)*, the yellow goatfish *(Upeneus sulphureus)*, the double-whip threadfin bream *(N. nematophorus)* and the rainbow sardine *(Dussumieria acuta)* may not reflect the true mortality rates of the species in question. Apparently, the trawlers did not properly sample the large individuals of the population. The splendid ponyfish *(L. splendens)* had the lowest Z value.

All the species investigated showed high exploitation rates (E = 0.23-0.72). Conventional theory suggests that E values between 0.20 and 0.50 are optimal in maximizing biological yield (Gulland 1971; Beddington and Cooke 1983; Pauly 1984). For short-lived species such as the ones considered here, the E values computed are too high, given that most exceeded the E = 0.50 level with the exception only of the slipmouths *L. splendens, L. equulus* and *G. minuta.*

Overall, the results indicate relatively high growth rates and low L_∞ values which are typical of fast-growing but short-lived tropical species. Mortality rates, likewise, are high, which imply low survival rates and high turnover rates for the species investigated. The findings also indicate high extraction rates (i.e., more than 0.20) and confirm previous assessments based on yield-to-biomass ratios of heavy fishing pressure (see Calud et al. 1989; Ochavillo et al. 1989).

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Table 1. Summary of relative abundance growth (K) and mortality parameters (Z), exploitation ratios (E) and number of recruitment peaks (NRP) for 15 trawl-caught fish species in Lingayen Gulf, Philippines, obtained via ELEFAN I and II.

No.	Species	Relative abundance (%)	K (yr^{-1})	L_∞ (cm)	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E (yr^{-1})	NRP
1	*Leiognathus bindus*	17.64	1.05	12.3	6.87	2.37	4.50	0.66	2
2	*Trichiurus haumela*	8.84	0.38	68.1	2.62	0.75	1.86	0.71	1
3	*Gazza minuta*	6.74	1.17	11.8	3.64	2.57	1.07	0.30	2
4	*Saurida tumbil*	5.37	0.52	39.0	3.33	1.08	2.25	0.68	2
5	*Atule mate*	5.22	0.81	24.9	4.59	1.63	2.95	0.64	2
6	*Rastrelliger brachysoma*	4.37	1.00	25.0	5.23	1.88	3.35	0.64	2
7	*Upeneus sulphureus*	3.00	1.32	19.9	8.72[a]	2.40	6.32[a]	0.72[a]	2
8	*Gazza acclamys*	2.01	1.17	12.8	5.91	2.51	3.40	0.58	2
9	*Selaroides leptolepis*	1.74	1.52	18.5	15.11[a]	2.69	12.42[a]	0.82[a]	1
10	*Nemipterus nematophorus*	1.48	0.62	27.0	7.15[a]	1.35	5.80[a]	0.81[a]	2
11	*Leiognathus equulus*	1.44	1.30	19.0	4.05	2.41	1.64	0.41	2
12	*Pentaprion longimanus*	1.12	1.05	13.7	5.34	2.29	3.05	0.57	2
13	*Nemipterus japonicus*	1.08	0.46	26.7	3.99	1.11	2.88	0.72	2
14	*Dussumieria acuta*	0.98	1.30	18.0	6.72[a]	2.44	4.28[a]	0.64[a]	2
15	*Leiognathus splendens*	0.85	0.79	11.6	2.59	2.00	0.59	0.23	2

[a]Possibly includes emigration or loss of vulnerability to sampling gear with increasing length.

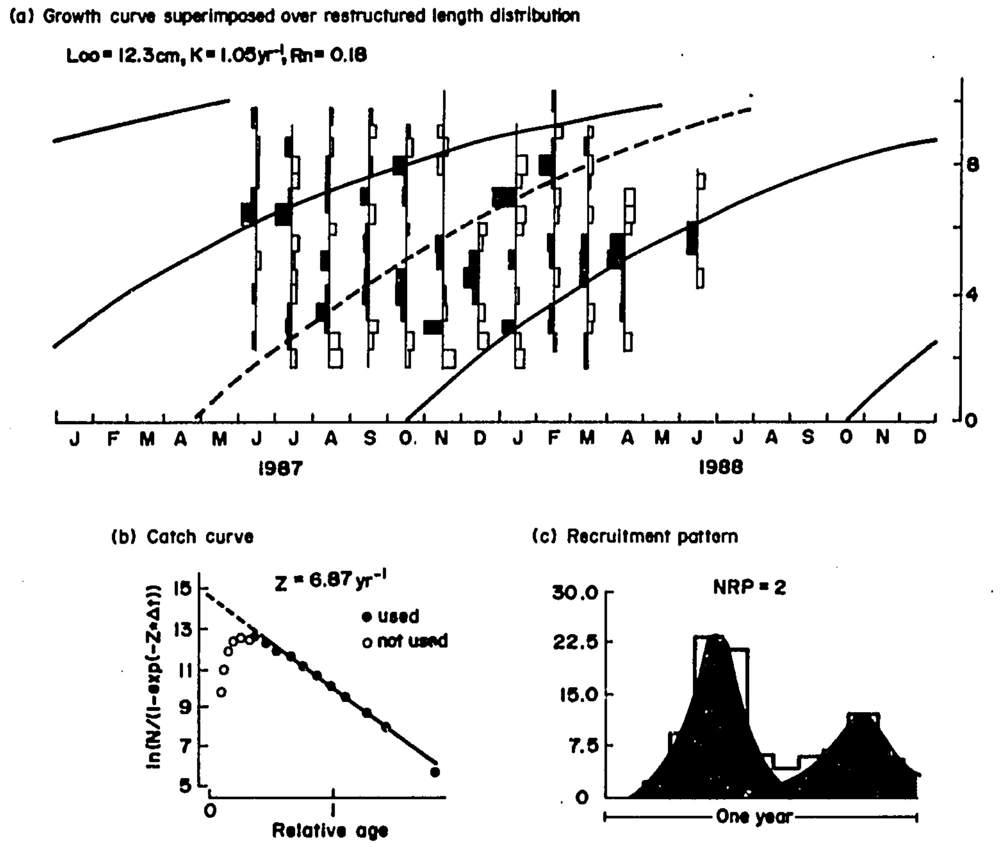

Fig. 1. Summary of results obtained via ELEFAN I and II for the orange-fin ponyfish, *Leiognathus bindus*, in Lingayen Gulf, Philippines.

Optimum mesh size for the trawl fisheries of Lingayen Gulf, Philippines

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ABSTRACT

This contribution examines the issue of growth overfishing in the Lingayen Gulf trawl fisheries. Growth (L_∞, W_∞, K), mortality (Z, M) and selection (SF, L50, L75) parameters of the more abundant species in the catch of the trawlers are presented, as compiled from studies conducted in the area and the existing literature. These parameters, combined with indices of relative recruitment and prices, were used for aggregate yield per recruit (Y/R) analysis to determine the optimum mesh size for the exploited multispecies mix. A mesh size of about 4 cm was found to be most appropriate for optimizing yield from the species included in the analysis. The 2-cm mesh size common among trawlers in the area is inappropriate and leads to considerable economic losses.

INTRODUCTION

Lingayen Gulf is an important traditional fishing ground in northern Luzon, Philippines. In 1987, annual landings from the area are about 15,000 t of fish and invertebrates worth approximately ₱200 million (US$10 million). About 80% of the landings come from municipal or small-scale fishing activities. The municipal sector includes 12,500 fishermen using 7,000 *banca* (small dugout boats with outriggers) and relatively simple and inexpensive fishing gear. Twenty-eight types of artisanal gears are used in the gulf, with gill net (bottom set and surface drift varieties) being the most common. The commercial sector comprises 24 medium (10-20 GT) and two large (over 20 GT) trawlers employing about 220 fishermen on a full-time basis. Detailed treatments covering the historical landings, capture methods, exploited resources and status of prevailing exploitation are given in Calud et al. (1989), Ochavillo et al. (1989) and McManus and Chua (1990).

The prevailing consensus is that the Lingayen Gulf fisheries resources are overfished (NRMC-FIDC 1980; Mines 1986). Silvestre et al. (this vol.) give a summary of initial findings of assessment work conducted under the auspices of the ASEAN/US Coastal Resources Management Project (CRMP). This paper refines previous assessments in that it evaluates the extent of growth overfishing by determining the optimum mesh size appropriate for the multispecies stocks of Lingayen Gulf.

MATERIALS AND METHODS

The data used in this study were culled from various existing literature sources. The investigated species represent the top 24 species from the mean trawl landings in the Lingayen Gulf Statistical Area for 1980-1984. The asymptotic weight (W_∞) values, the natural mortality estimates (M) and the recruitment indices were taken from Silvestre et al. (1988) and references therein. The fish prices were obtained from Signey (1987) while the L50 and L75 values were taken from Silvestre et al. (1988); Pauly (1980); Pauly (1985); Pauly et al. (1984) and Jones (1976).

The analysis involved the aggregation of individual Y/R response surfaces as described in Silvestre and Soriano (1988). This is done through a standardization along the three axes of the Y/R response surface, namely: (1) the fishing mortality axis, which entails the determination of the relative catchabilities of the mix of species; (2) the age/length at first capture or mesh-size axis; and (3) the Y/R axis, which entails the determination of absolute or relative recruitment. In this study, the catchability coefficients of the various species/groups were taken as equal and constant through the range of F. The fish prices of the investigated species were later incorporated in a separate attempt to translate the aggregate yield index into a gross value index. The price indices were taken as constant through the range of lengths for the various species/groups and therefore accounted only for value difference between species/groups.

RESULTS AND RECOMMENDATIONS

Table 1 shows the parameter values used in the study. The estimates of the growth coefficient (K) ranged from 0.14 to 1.61 per year while the L_∞ values ranged from 5 to 140 cm. These imply high turnover rates. The natural mortality estimates were also high, which imply low survival rates. The fish prices show the varying preference for the investigated species.

Fig. 1 shows the aggregate yield per recruit through a range of mesh sizes from 1 to 7 cm. For the multispecies stocks of Lingayen Gulf, a mesh size of about 4 cm appears to be appropriate. Mesh sizes smaller and bigger than 4 cm decrease the aggregate yield, with the loss increasing with increasing or decreasing mesh size. Fig. 2 shows the aggregate value per recruit through a range of mesh sizes from 1 to 7 cm. Aggregate gross value appears to be maximized at a mesh size of 3.5 cm.

Fig. 3 shows the extent of loss relative to the optimum mesh size for the aggregate Y/R and aggregate value per recruit. Smaller mesh sizes are shown to be appropriate at low F values. However, given the high fishing mortality presently prevailing in the gulf (F = 2.8 per year), mesh sizes smaller than 4 cm appear to be unreasonable. About 20% of the Y/R is apparently lost because of the 2-cm mesh size used by trawlers in Lingayen Gulf. Value per recruit decreases similarly with departure from the 3.5-cm mesh size (i.e., mesh sizes smaller than 3.5 cm are permissible only at low fishing mortalities).

The above results illustrate the growth overfishing occurring in the gulf, confirming the findings of the previous fish stock assessments.

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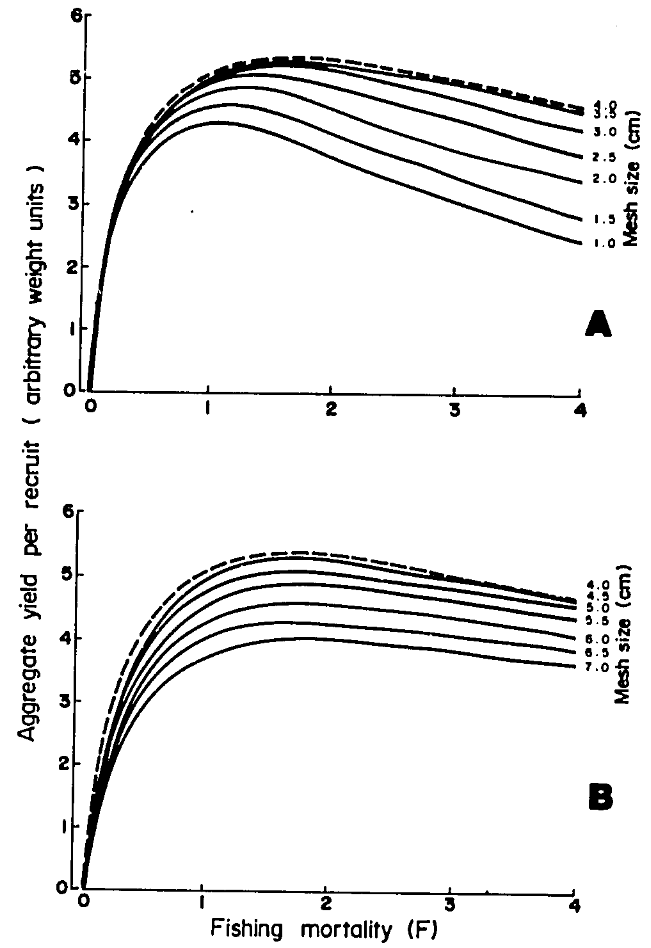

Fig. 1. Aggregate Y/R for the Lingayen Gulf multispecies trawl fisheries as inferred from mean landings for 1980-1984 given in BFAR statistics and parameters in Table 1. A: mesh sizes from 1 to 4 cm; B: mesh sizes from 4 to 7 cm. Note that Y/R is maximized when mesh size is near 4 cm.

Table 1. Abundant species/groups comprising the landings of trawlers in Lingayen Gulf for 1980-1984 as shown in BFAR statistics and their corresponding parameter values as used to estimate aggregate yield. Parameter estimates are from Silvestre et al. (1988). (See text.)

Species/groups	W_∞ (g)	L_∞ (cm)	K (yr^{-1})	M (yr^{-1})	R' (yr^{-1})	P'	L50 (cm)	L75 (cm)
1. *Leiognathus bindus*	44	12.1	0.98	2.21	993,082	12.8	6.3	6.7
2. *Nemipterus japonicus*	340	26.6	0.45	1.08	108,306	12.6	9.1	10.0
3. *Trichiurus haumela*	247	65.2	0.44	0.83	91,554	10.5	15.3	16.7
4. *Saurida tumbil*	966	43.0	0.64	1.18	21,976	6.3	7.4	8.9
5. *Upeneus sulphureus*	146	18.8	0.55	1.33	173,504	10.3	9.4	10.3
6. *Mene maculata*	115	22.5	1.22	2.20	129,461	9.7	6.3[a]	6.7[a]
7. *Rastrelliger brachysoma*	257	25.5	1.45	2.32	40,166	11.9	9.1	9.9
8. *Stolephorus indicus*	30	14.5	1.30	2.55	385,412	7.0	10.3	11.5
9. *Alepes djedaba*	317	24.5	1.00	1.86	33.678	11.4	8.8	9.3
10. *Selar crumenopthalmus*	419	25.9	1.25	2.17	21,496	10.3	8.8[b]	9.3[b]
11. *Caranx armatus*	228	21.5	0.82	1.69	44,321	12.6	8.2	8.9
12. *Rastrelliger kanagurta*	366	28.5	1.31	2.13	16,083	11 [illegible]	9.4	10.0
13. *Sphyraena barracuda*	23,021	140.0	0.14	0.31	444	10.1	14.2	15.6
14. *Loligo* sp.	150	20.7	1.00	1.18	19,906	14.0	5.2	5.8
15. *Decapterus macrosoma*	116	23.0	1.25	2.19	35,874	8.9	10.9	11.5
16. *Scomberomorus commersonii*	707	49.0	0.70	1.23	6,492	14.4	10.8	12.3
17. *Dussumieri acuta*	66	21.0	1.05	1.97	34,953	7.1	10.6	11.0
18. *Sardinella fimbriata*	58	18.0	0.70	1.63	44,501	7.9	9.7	10.0
19. *Formio niger*	643	29.5	0.68	1.40	4,162	15.2	6.4	6.8
20. *Priacanthus tayenus*	293	29.0	0.68	1.40	4,162	15.2	6.4	6.8
21. *Epinephelus sexfasciatus*	7,120	78.0	0.14	0.66	1,474	20.2	8.9	10.4
22. *Penaeus merguiensis*	125	5.0	1.61	2.01	3,421	23.7	2.5	2.7
23. *Lutjanus vitta*	446	38.5	0.70	1.28	2,077	13.5	7.1	9.1
24. *Chirocentrus dorab*	3,703	38.0	0.90	0.30	[illegible]	8.8	13.4	14.7

[a]Selection parameter of *L. bindus*.
[b]Same as *S. mate*.

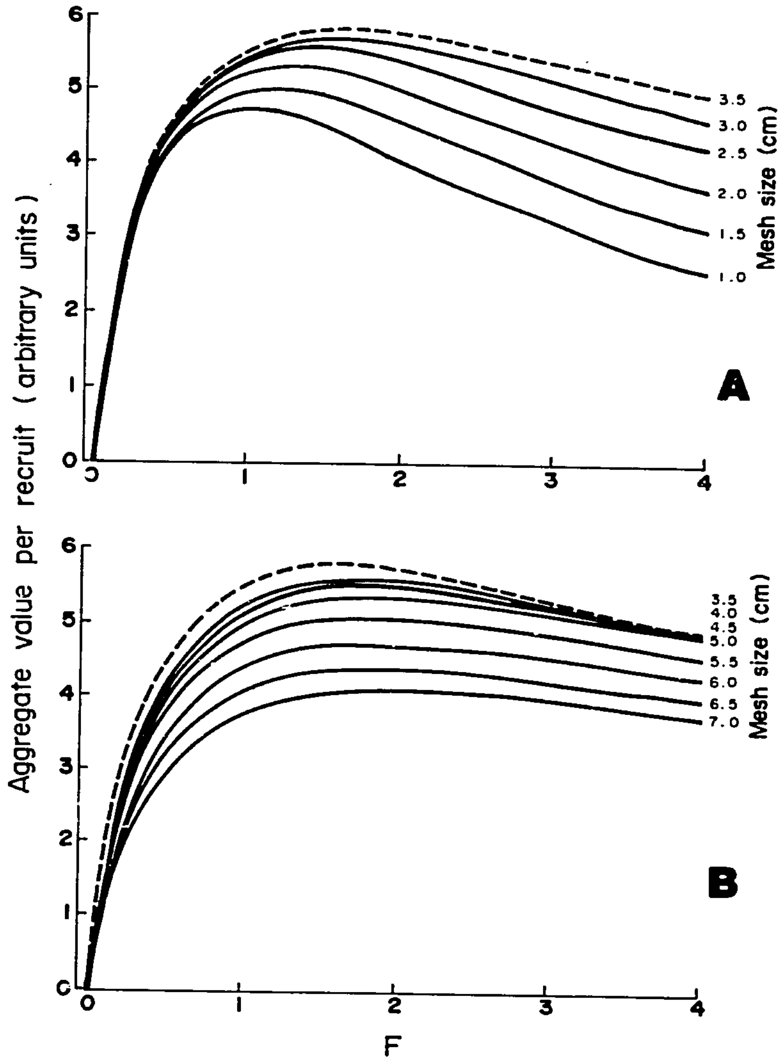

Fig. 2. Aggregate value per recruit for the Lingayen Gulf multispecies trawl fisheries as inferred from mean landings for 1980-1984 given in BFAR statistics. A: mesh sizes from 1 to 3.5 cm; B: mesh sizes from 3.5 to 7 cm.

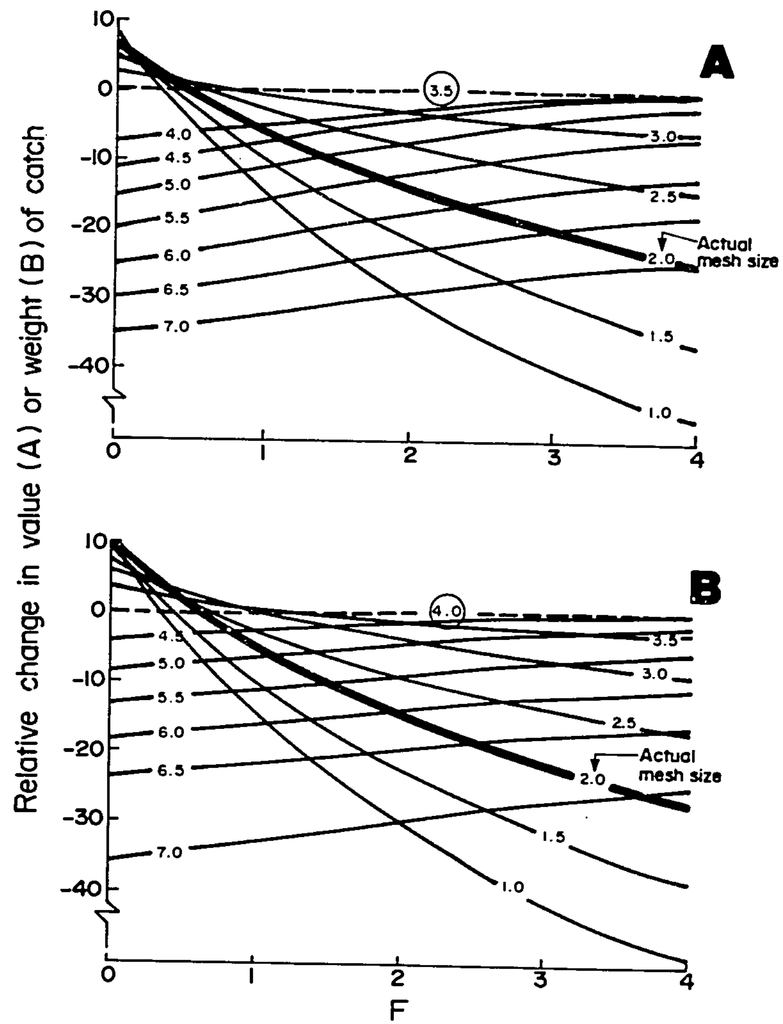

Fig. 3. Losses in value (A) or weight (B) of multispecies Y/R through a range of mesh sizes relative to the optimum mesh sizes in centimeter. Note that for a mesh size of 2 cm prevalent in Lingayen Gulf and current fishing pressure, there is a 20% loss in both weight and value.

The gill net fishery of Lingayen Gulf, Philippines

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ABSTRACT

The gill net is the predominant fishing gear used by municipal fishermen in Lingayen Gulf, Philippines, and accounts for about 50% of the municipal landings in the area. Thus, the municipal sector is primarily a gill net fishery. This paper describes the fishery with emphasis on catch rates, species and length composition of landings and areas of operation. The results are compared with information pertaining to the commercial trawl fishery as an initial step in qualifying the extent of its competition (for fishing ground and fisheries resources) with this sector. The results indicate, among others, that: (1) nonenforcement of the 7-km ban on commercial fishing results in tremendous overlap between trawl and gill net grounds, and (2) the species and length compositions of trawl and gill net catches illustrate severe competition for similar target species and length groups.

INTRODUCTION

Lingayen Gulf (Fig. 1), an important traditional fishing ground off northwestern Luzon, is one of the most heavily fished areas in the Philippines. At present, about 12,500 municipal fishermen reside in the 16 towns and lone city bordering the gulf, using 28 varieties of relatively simple, inexpensive gear. Moreover, 26 trawlers operate in the gulf on a regular basis, directly employing about 220 fishermen. Combined landings from these fishing activities is currently 13,900 t/year, about a quarter of which comes from trawl operations and the rest from municipal fishing activities (Calud et al. 1989; Ochavillo et al. 1989). Of the 10,500 t/year of municipal landings, about half (46%) is accounted for by the mix of gill net gear used in the gulf (see Silvestre et al., this vol.). The municipal sector of the capture fisheries in the area is, therefore, largely a gill net fishery.

McManus and Chua (1990) give a coastal environmental profile of Lingayen Gulf and point to excessive effort, growth overfishing and increased competition and conflict between the municipal and commercial sectors as issues requiring attention with respect to the capture fisheries in the area. Under the auspices of the ASEAN/US Coastal Resources Management Project (CRMP), a study of the municipal and commercial fisheries sector in the gulf was conducted to elaborate on the nature and extent of these issues and explore plausible management strategies. Initial results of the study are given in Calud et al. (1989) for the municipal fisheries and Ochavillo et al. (1989) for the trawl fisheries, while Silvestre et al. (this vol.) give a summary of the implications of the assessment work conducted thus far.

The present contribution is a follow-up to the report of Calud et al. (1989), which elaborates on the characteristics of the municipal fisheries with emphasis on the design, operation and catch of the various types of municipal fishing gear. This paper describes the gill net fishery with emphasis on catch rates, species and length composition of landings and areas of operation, based on more complete data collected in three coastal towns over a one-year period. An initial attempt to elaborate on the extent of the gill net fishery's competition with the commercial trawl fishing is also incorporated.

MATERIALS AND METHODS

Data on gill net landings were collected between May 1987 and April 1988 in three coastal towns adjoining Lingayen Gulf, namely: Dulao and Bani in La Union Province and Tobuan in Pangasinan Province (Fig. 1). The three sites were selected from considerations of the level of municipal landings, number of municipal fishermen, variety of gear types employed and accessibility. Details of the sampling design and research methodology are given in Calud et al. (1989). Briefly, monitoring of gill net catches was conducted every other day in Dulao and Bani, and once every week in Tobuan during the course of the study. During each monitoring day, a sample of the boats that went fishing was taken. The catch (kg/boat-trip) of each of these boats was noted together with the relative abundance of the species/groups comprising it. The length composition of the more abundant species was subsequently taken. Information pertaining to the area of operation for the day's trip and gear specifications were also obtained for each boat sampled.

Data on the trawl fisheries in Lingayen Gulf used herein for comparison purposes were obtained during the commercial fisheries survey in the area running concurrently with the gill net survey. Ochavillo et al. (1989) describe the sampling procedure employed. Briefly, about two trawl trips per month were monitored by the research team. During each trip, the magnitude of the catch for each three-hour haul was recorded. Each haul was sorted to species level whenever possible and the length composition of the more abundant species comprising the catch was taken.

RESULTS AND DISCUSSION

Several types of gill net are used by municipal fishermen in Lingayen Gulf. Depending on where they are deployed in the water column, these can be classified into bottom and surface gill nets. The latter group includes two common varieties, namely: tuna gill net and drift gill net (for catching other pelagics). Calud et al. (1989) give the design, specifications, mode of operation and relative contribution to municipal fisheries production of the various types of gill net observed during the course of the study. Bottom gill nets were the most popularly used in the gulf, accounting for 83% of gill net landings in the area. The tuna and drift gill nets made up 17%. Fig. 2 gives the typical design and specifications of the bottom gill net used in the area.

Motorized and nonmotorized *banca* are used by municipal fishermen in gill net operations (Fig. 3). The craft is a keeled dugout with a marine plywood siding powered by a 10-16 hp gasoline engine. Nonmotorized craft are essentially identical in design except that they are smaller in length or size. Gill net operations usually involve the use of motorized *banca*, except those bottom gill net activities closer to the shore. Gill net fishermen make daily trips usually lasting about four to six hours. Catches are landed in the morning, normally several hours after sunrise. An average gill net unit operates 27 days of every month during the fishing season.

Fig. 4 shows the mean monthly catch per unit effort (CPUE) (kg/boat-trip) of bottom and surface gill nets in the three study sites. Bottom gill nets were used all-year-round, with mean catch rates of 2.9 and 1.6 kg/boat-trip for motorized and nonmotorized units, respectively. Motorized units consistently had higher catch rates compared to nonmotorized ones. This is similar to trends noted in other Philippine fishing grounds. However, this does not necessarily indicate increased productivity--as motorized units made less profit in real terms on the average due to greater fixed and variable costs--but merely implies that motorization enables fishermen to exploit farther, less crowded grounds. The data herein further show that there is no pronounced seasonality in catch rates for bottom gill net operations. Comparatively, surface gill nets showed a high seasonality in operation and catch rate levels. Surface drift gill net fishermen increasingly shifted to tuna gill net operations during the peak months of abundance of tuna-like species from November to February. Mean catch rates for tuna and drift gill nets, exclusive of the lean months when such gear were not used, were 24.3 and 15.8 kg/boat-trip, respectively.

The operational range of gill net boats based on data from the three study sites is given in Table 1 and Fig. 1. Areas of operation of nonmotorized bottom gill net, motorized bottom gill net and surface drift/tuna gill net units were distributed sequentially with increasing depth and distance from the shoreline. Nonmotorized bottom gill nets were deployed fairly close to the shore (2.5-6.0 km) in depths ranging from 15 to 25 m. Motorized gill net units, on the other hand, went farther offshore (at least 4.5 km), operating in depths of more than 25 m. No tuna gill net units operated from Tobuan because this side of the gulf is exposed to the effects of the northeast monsoon at the time of peak abundance of tuna-like species.

Table 2 gives the relative abundance (%) of the various species comprising the combined catch of the different gill net types in the three study sites monitored. The catch of gill nets consisted of 118 species/groups belonging to 49 families. The 25 most abundant species/groups alone constituted about 90% of landings, the remainder of the catch distributed among 93 species/groups caught incidentally in small quantities. The top ten species accounted for over half (55%) of gill net catches, most of which are pelagic or semipelagic species. Table 3 gives the length range and mean length of selected fish species comprising the catch of gill net in the three study sites. The gill net, as expected, was quite selective, with sizes caught by species falling within fairly narrow ranges. Moreover, the mean lengths of the catches were considerably large, given the average maximum lengths that these selected species could attain.

As an initial step in quantifying the extent of competition between gill net and trawler in the area, selected information pertaining to the trawl fishery was obtained and compared with that pertaining to gill net. Fig. 1 and Table 1 illustrate the considerable overlap between trawl and gill net fishing areas in Lingayen Gulf. Noncompliance with the existing 7-km, 7-fathom ban in commercial fishing operations by the trawl fleet has exacerbated the competition for fishing grounds. Instances of destruction of gill net gear and conflict between gill net and trawl fishermen were observed during the period of study. Trawlers preferred the shallower areas because of the higher catch rates obtained there. However, even if the 7-km, 7-fathom ban was observed by trawlers, considerable overlap still existed between the fishing areas of the two sectors. It is conceivable, nevertheless, that gear conflicts would be minimized in such a case inasmuch as the overlap will be with surface gill nets, which would be much easier to avoid physically by the trawlers.

Table 2 gives a comparison of the species composition of gill net and trawl catches, indicating great overlap in resources exploited. Of the 25 most abundant species/groups exploited by gill net, only two were not caught by trawl. Moreover, 15 of the 25 were also in the list of the top 25 species comprising trawl catches. Overall, about 85% of the 118 species/groups caught by gill net was also exploited by trawl.

Table 3 comparatively shows the length range, mean length and length-at-first-capture (in this context, referring to length at 100% probability of capture) of ten selected species exploited by both gill net and trawl. Fig. 5 illustrates the method used in computing the mean length and length-at-first-capture of each species in the catch of gill net and trawl, respectively, using data for *Leiognathus equulus*. Considerable overlap existed in the sizes of fish exploited by both gear. Moreover, trawlers were more likely to cause growth overfishing because of their gear's lower length range and the onset of full exploitation that their gear entailed.

CONCLUSION

Gill nets, the predominant gear used by municipal fishermen in Lingayen Gulf, account for about 50% of the 10,500 t/year of municipal landings in the area. The municipal sector, therefore, is primarily a gill net fishery. Mean catch rates for boats using various types of gill net were relatively low, varying between 1.6 kg/boat-trip for nonmotorized bottom gill net units and 24.3 kg/boat-trip for motorized surface tuna gill net. Bottom gill net operations proceeded all-year-round while those for surface gill net were highly seasonal, with a pronounced shift from drift to tuna gill nets around November to February. Combined gill net landings were made up primarily of pelagics, the size composition of which is composed of fish in the larger length groups. Comparison of fishing area and exploited resources of gill net and trawl indicated, among others, that: (1) noncompliance of the trawlers with the 7-km, 7-fathom ban on their operations leads to tremendous overlap between trawl and gill net grounds, resulting in conflicts between the two fisheries sectors and (2) severe competition for similar resources/species and length groups. Silvestre et al. (this vol.) present recommendations relevant to these findings and the results of other assessment work conducted thus far.

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Table 1. Operational range of gill net and trawl in Lingayen Gulf, Philippines, based on data for the period May 1987 to April 1988. (See also Fig. 1.)

Fishing gear	Depth range (m)	Distance from shoreline (km)
Bottom gill net		
Motorized	25-40	7.0-10.0
Nonmotorized	15-25	2.5- 6.0
Surface gill net		
Tuna gill net	over 30	over 4.5
Drift gill net	over 30	over 5.0
Bottom trawl	8-75	over 0.5

Table 2. Comparison of the species composition of gill net and trawl catches in Lingayen Gulf from May 1987 to April 1988. Gill net data reflect relative number of units of the various types in the three study sites while the trawl data are for the entire trawl fleet.

Species/group	Gill net		Trawl	
	Rank	Relative abundance (%)	Rank	Relative abundance (%)
Megalaspis cordyla	1	8.27	27	0.81
Rastrelliger brachysoma	2	7.93	6	4.57
Saurida tumbil	3	5.21	4	5.57
Gazza minuta	4	4.86	3	7.12
R. kanagurta	5	4.83	23	1.02
Selar cromenophthalmus	6	4.80	22	1.03
Euthynnus affinis	7	4.74	-	0
R. faughni	8	4.71	19	1.11
Rays	9	4.29	-	<0.50
Alepes djedaba	10	4.29	-	<0.50
Leiognathus splendens	11	4.01	26	0.85
Upeneus sulphureus	12	3.75	8	3.08
Xiphias gladius	13	3.68	-	0
Atule mate	14	3.47	5	5.52
Gerres filamentosus	15	2.42	-	<0.50
Trichiurus haumela	16	2.19	2	8.87
Scomberomorus commersonianus	17	2.14	-	<0.50
Selar boops	18	2.04	25	0.93
Nemipterus japonicus	19	2.02	21	1.08
Anodontostoma chacunda	20	1.93	-	<0.50
L. bindus	21	1.91	1	17.97
Chirocentrus dorab	22	1.63	28	0.74
Priacanthus tayenus	23	1.29	10	2.18
L. equulus	24	1.28	15	1.44
Selaroides leptolepis	25	1.18	13	1.74
Others	-	11.13[a]	-	32.28[b]

[a]Consists of 93 species/groups, 82% of which are also caught by trawlers.
[b]Consists of 128 species/groups.

Table 3. Length range (cm), mean length (cm) and length-at-first-capture (cm) of some fish caught by gill net and trawl in Lingayen Gulf. (See also Fig. 5.)

Species	Gill net		Trawl	
	Length range	Mean length[a]	Length range	Length-at-first capture[b]
Atule mate	14.5-20.5	15.4	5.0-19.0	11.6
Chirocentrus dorab	26.0-35.0	26.2	7.5-33.0	11.5
Gazza acclamys	7.5-9.5	8.2	3.0-11.0	6.7
G. minuta	6.5-9.0	7.0	3.0-11.5	8.3
Leiognathus equulus	8.5-19.5	10.8	6.0-19.0	7.8
L. leuciscus	6.5-7.5	6.7	4.0-11.0	6.0
Rastrelliger brachysoma	16.0-22.5	17.2	8.5-25.0	14.4
R. kanagurta	10.0-17.5	14.6	5.5-20.0	11.9
Sardinella fimbriata	9.5-18.5	10.2	6.0-12.0	10.1
Selar boops	15.5-20.0	16.4	6.5-22.5	12.8

[a]Lengths deviating from the normal were excluded in the computation of mean length (see Fig. 5).
[b]Lengths at full exploitation were estimated using catch curves generated via ELEFAN II.

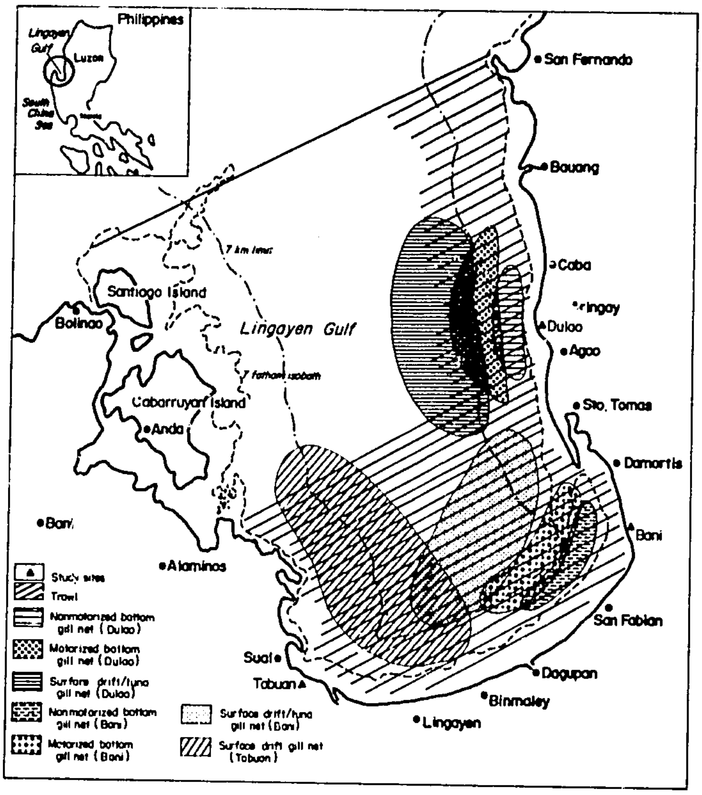
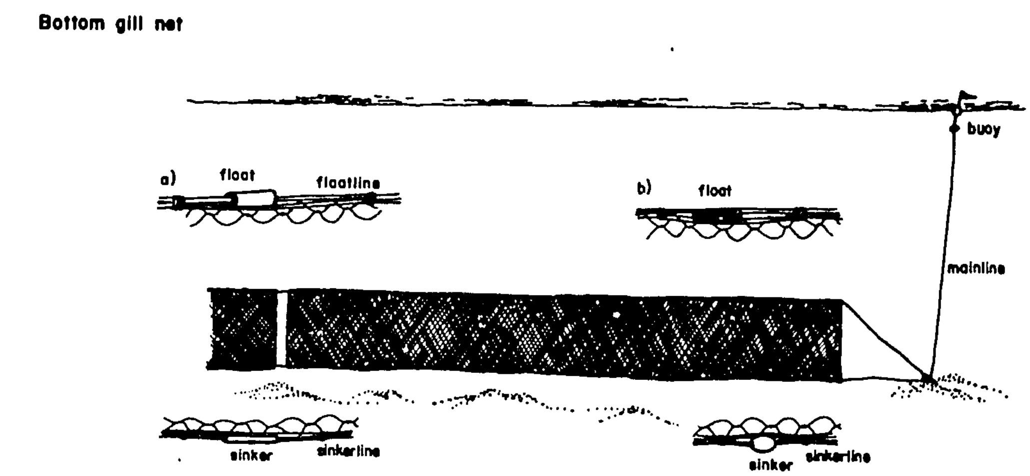


Fig. 1. Lingayen Gulf showing the operational range of gill net and trawl fisheries (see legend) together with the 7-km (--·) distance from the shoreline and the 7-fathom (---) isobath.



Specifications : (per unit; 15-30 units per setting)

Net

Material	:	Polyamide (PA) monofilament
Mesh size	:	7-12 knots (2.8-5.1 cm)
Twine diameter	:	#020
Stretched length	:	100-200 m
Actual length	:	40-80 m
Hanging ratio	:	35-45%
Stretched depth	:	2-3 m
Actual depth	:	1.5-2.5 m
Floatline	:	#4 PE
Sinkerline	:	#4 PE

Floats

a) Hard rubber "sausage"

Length	:	5-7 cm
Diameter	:	1.5-2.0 cm
Number	:	70-120 pcs

b) Soft rubber "slippers"

Length	:	6-10 cm
Width	:	2.0-2.5 cm
Thickness	:	1.0-2.0 cm
Number	:	70-120 pcs
Total buoyancy	:	Approx. 120-800 g

Sinkers

Material	:	lead
Length	:	1.2-4.0 cm
Diameter	:	0.8-1.2 cm
Number	:	100-200 pcs
Total sinking force	:	Approx. 0.8-2.0 kg

Fig. 2. Typical bottom gill net design and specifications in Lingayen Gulf (Calud et al. 1989).

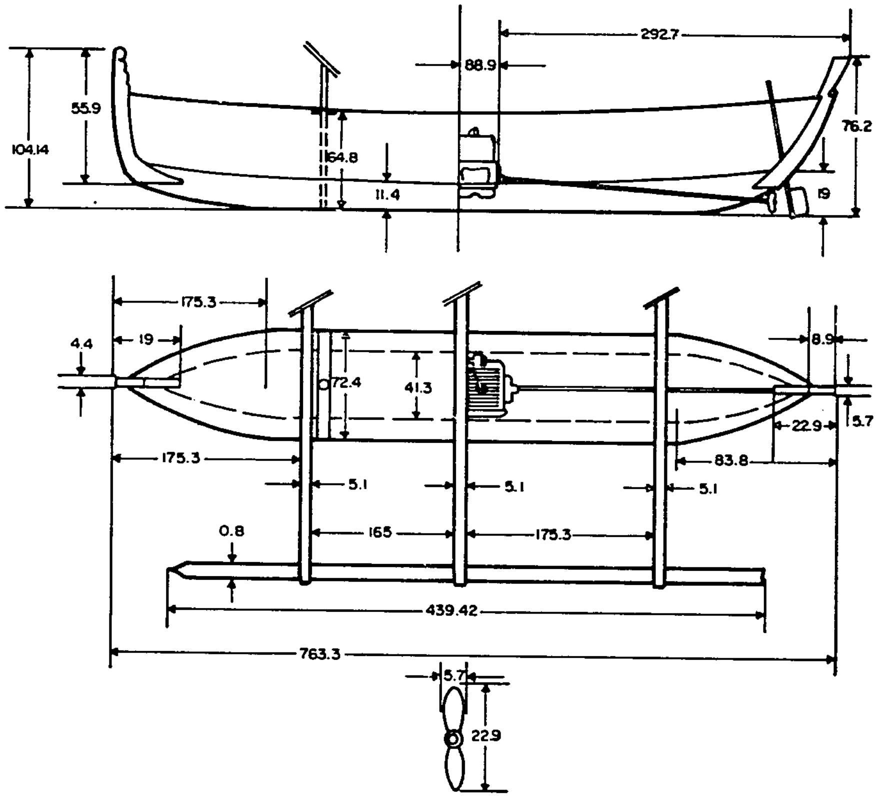


Fig. 3. Design and specifications of a typical motorized *banca* used by municipal fishermen in Lingayen Gulf. Dimensions are in centimeters.

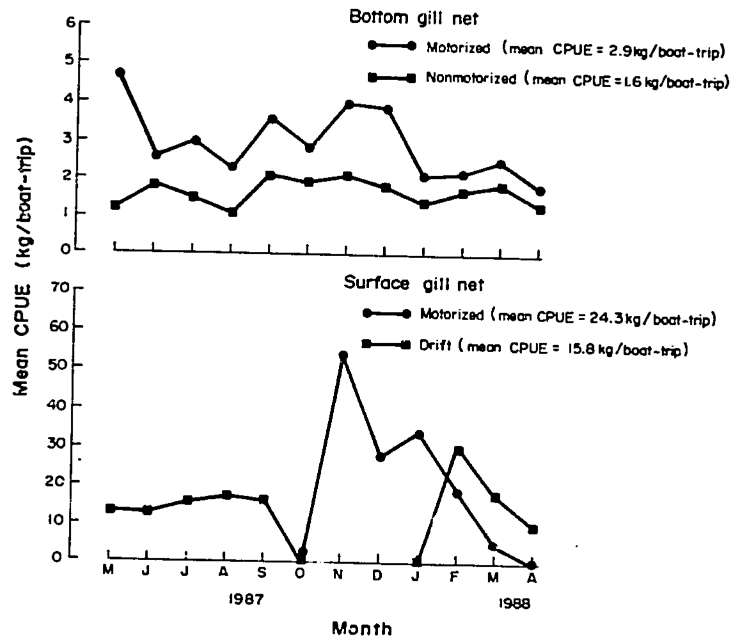


Fig. 4. Mean CPUE (kg/boat-trip) for the various types of gill net used in Lingayen Gulf between May 1987 and April 1988. The zero catch rate levels indicate nonfishing or lean months. See text.

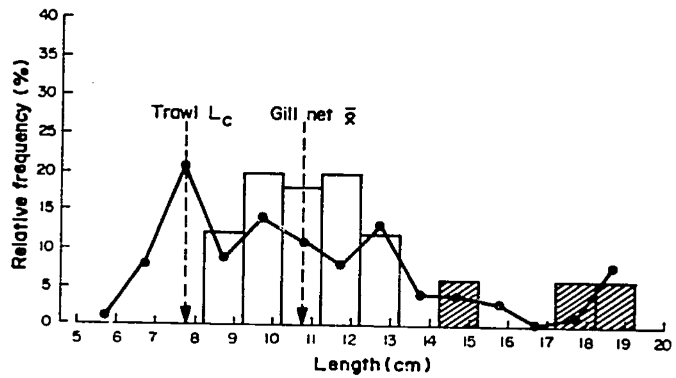


Fig. 5. Length distribution of *Leiognathus equulus* in the catch of trawl superimposed over the length frequency histogram of the same species in the catch of bottom gill net in Lingayen Gulf. The hatched portion of the frequency histogram was excluded in the computation of mean length (l) in gill net catches. See text and Table 3.

The capture fisheries of Segara Anakan, Indonesia

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ABSTRACT

Segara Anakan, a mangrove-fringed lagoon in the southern coast of central Java, is a rich nursery ground for shrimp and fish that are the bases of sequential exploitation by artisanal lagoon fisheries and coastal fisheries in the adjacent Cilacap area. Man-induced stresses on the ecology of the lagoon (e.g., high sedimentation rates, mangrove denudation, intense fishing and the use of small-meshed nets) have caused concern for the sustainability of fisheries. As part of the efforts under the auspices of the ASEAN/US Coastal Resources Management Project (CRMP) to formulate and implement sustainable resource use in the area, a fisheries survey was conducted in Segara Anakan between July 1987 and June 1988. This paper presents the initial results of the survey and describes the existing lagoon fisheries with emphasis on the types of fishing gear, their operational ranges, catch rates and catch composition.

Fishing activities in Segara Anakan are wholly artisanal in nature. The survey showed that fishing intensity was high and annual production was about 1,600 t valued at Rp840 million.[a] Catch rates of the various gear were low, varying between 4 and 15 kg/boat-trip. Shrimp were the most important components of the landings. However, there is a need to reduce fishing effort and prohibit the use of destructive fishing methods to assure sustainability of the fisheries.

INTRODUCTION

Segara Anakan, the site of intensive studies under the Indonesian component of the ASEAN/US CRMP, is a mangrove-fringed lagoon in the southern coast of central Java (Fig. 1). The area is a rich nursery ground for fish and shrimp, which are the bases of artisanal fisheries in the lagoon and coastal fisheries in the adjacent Cilacap area (Martosubroto and Sudradjat 1973). Napitupulu and Ramu (1981) and Ludwig (1985) documented the decrease in the surface area of the lagoon while Wahyuni et al. (1987) noted a trend of declining catch rates in the lagoon fisheries; all attributed these to the high sedimentation rates. Guarin and White (1988) pointed out that the loss of mangroves and tidal swamplands together with high fishing rates and the use of destructive fishing methods were the factors contributing to the decline of the lagoon fisheries.

Fishing in Segara Anakan is a traditional source of livelihood for residents. Stresses on the ecology of the lagoon have posed threats to fishing and have resulted in the decline of the coastal fisheries off Cilacap. As part of the efforts to rationalize conflicting and competing resources use in the Segara Anakan-Cilacap area and to formulate implementable management plans, a fisheries survey in Segara Anakan was conducted between July 1987 and June 1988. The survey aimed at establishing the status of existing fisheries in the lagoon. Ten trips were made to the area to examine the following: (1) the type of fishing gear and number of units of each gear used in the lagoon; (2) the number of fishermen and frequency of their operations; and (3) the catch rates (kg/trip) and their species and length compositions. This paper attempts to characterize the nature of existing fisheries in the lagoon based on the initial results of the survey.

FISHING METHODS AND GEAR

During the period of study, a total of 964 full-time fishermen operated in Segara Anakan, using

[a]April 1990: Rp1,811 = US$1.00

relatively simple gear and small dugout boats. The gear were trammel net (*jaring kantong*) and gill net (*ciker*), tidal trap made primarily of nettings (*apong*) or bamboo slats (*wide tadahan*); push-net (*waring surungan*); and trap made of bamboo (*wadong*) or nettings (*pintur*). The typical designs of these fishing gear are shown in Fig. 2.

The trammel net and gill net are set in surface waters to drift with the currents. The nettings are made of hung polyamide (PA) materials (usually 1.75 in. stretched mesh size) using polyethylene (PE) selvages and float/sinker lines. The outer nettings for the three-walled trammel net are 4 in. in stretched mesh length.

The tidal traps are stationary gear set in areas of relatively strong tidal currents. The push-nets are made of polypropylene (PP) netting (3 mm stretched mesh length) mounted on wooden frames. These are operated in the tidal and/or mangrove swamps. The traps made of bamboo or nettings are commonly 30 cm in diameter by 60 cm in length and are used specifically for catching crabs (*Scylla* spp.).

The operational ranges of the various fishing gear in Segara Anakan are given in Fig. 3. The trammel net and gill net were operated in the deeper and more open parts of the lagoon near the Majingklak and Karang Anyar areas and on the eastern side of the lagoon. The *apong* tidal traps were used in the shallow areas of Cibeureum River, off the Kayu Mati River and around Karang Anyar in the western part of the lagoon, and from around Klaces to the Kembang Kuning River in the southern part of the lagoon. The *wide tadahan* tidal traps were found in the shallow areas in the northern and central parts of the lagoon. The push-nets were operated near Bugel in the north, Karang Anyar in the west and between Klaces and Motean in the south. The traps were set in the mangrove and tidal swamps in the eastern and southern parts of the lagoon, *wadong* in the shallower areas and *pintur* in the deeper ones.

FISHERIES PRODUCTION AND CATCH COMPOSITION

Table 1 gives the number of units per fishing gear type, fishing effort (boat-trips/month) and catch rates (kg/boat-trip) in Segara Anakan during the period of study. Fishing effort varied between 1,117 and 7,999 boat-trips/month while catch rates were from 4.0 to 15.1 kg/boat-trip for the various fishing gear. Annual production from the mix of fishing gear was estimated at 1,593 t valued at Rp840 million. About 74% of the landings were accounted for by tidal traps, followed by push-nets (8.6%), *wadong* traps (8.1%) and trammel/gill nets (6.6%).

Table 2 gives the catch composition of the various fishing gear, excluding the *wadong* and *pintur* traps, which caught crabs almost exclusively. The tidal traps caught shrimp primarily. These comprised the bulk of the value of landings. The difference in the value of shrimp landings between the two types of tidal traps was because *apong* caught mostly live shrimp that fetch higher market prices. About 75% of the catch of push-nets was composed of shrimp; the rest was small fish with low market value. Trammel net and gill net caught mostly fish (68%), although the bulk of the value of the landings was accounted for by penaeid shrimp, which made up only a quarter of the landings. Overall, penaeid shrimp were the most important components of the Segara Anakan fisheries.

Among the various gear used, the push-nets cause the most damage because of their small meshes. Fig. 4 illustrates this point in the case of *Penaeus merguiensis*, the most abundant among the shrimp in the lagoon, which are fished sequentially at a later stage off Cilacap. However, the push-nets provide a considerable amount of fingerlings to aquaculture activities in the lagoon area. Efforts to evaluate an optimum balance between these competing interests are in progress.

CONCLUSION

The results of the survey emphasize the need to regulate the lagoon fisheries. Efforts to reduce fishing intensity are necessary and the high seasonality of fishing activities indicates that such is plausible. Provision for alternative sources of income through agriculture, aquaculture and animal husbandry, which are the sources of livelihood during nonfishing months (Anon. 1986), should be given priority. This provision should be integrated with overall measures to reduce man-induced stresses on the ecology of the Segara Anakan area resulting from high sedimentation rates, loss of mangroves and tidal swamps and improper use of mangrove forests.

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Table 1. Catch and fishing effort in the Segara Anakan fishery for the period July 1987 to June 1988.

Gear	No. of units	Catch rate (kg/trip)	Fishing effort (trips/mo.)	Monthly catch (t)	Operational months (mo./year)	Annual catch (t)	Annual catch (%)	Annual catch (x 10^6 Rp)
Trammel net/ gill net	195	5.9	2,535	14.9	7	104.6	6.6	92.12
Tidal trap								
apong	320	15.1	5,760	86.8	9	780.8	49.0	350.03
wide tadahan	421	10.0	7,999	80.2	5	401.0	25.2	178.26
Push-net	289	7.1	3,212	22.8	6	137.1	8.6	73.16
Trap								
wadong	6,459	4.4	3,682	16.2	8	129.5	8.1	113.11
pintur	6,649	4.0	1,117	5.0	8	40.0	2.5	34.28
Total	-	-	-	-	-	1,593.0	100.0	840.96

Table 2. Catch composition of selected fishing gear used in Segara Anakan between July 1987 and June 1988.

Resource/ group	Tidal trap (*wide tadahan*) Relative abundance (%)	Tidal trap (*wide tadahan*) Value (x10^6 Rp)	Tidal trap (*apong*) Relative abundance (%)	Tidal trap (*apong*) Value (x10^6 Rp)	Push-net Relative abundance (%)	Push-net Value (x10^6 Rp)	Trammel net/ gill net Relative abundance (%)	Trammel net/ gill net Value (x10^6 Rp)
Shrimp	77.2	166.90	47.5	297.03	73.8	72.53	26.7	76.65
Penaeids	75.6	165.59	42.4	293.99	68.6	66.34	26.7	76.65
Carideans	0.2	1.11	1.0	1.35	0.4	0.27	0	0
Sergestids	1.4	0.20	4.1	1.69	4.8	5.92	0	0
Crab	0	0	4.0	10.06	0	0	2.1	1.71
Fish	21.7	9.75	44.7	28.37	26.2	0.63	68.2	12.81
Mugilidae	1.5	3.30	1.4	2.80	0	0	15.9	8.44
Scatophagidae	0	0	2.2	2.41	0	0	9.7	1.23
Others	20.2	6.45	41.1	23.16	26.2	0.63	42.6	3.14
Eel	1.1	1.61	3.8	14.57	0	0	3.0	0.95
Total	100.0	178.26	100.0	350.03	100.0	73.16	100.0	92.12

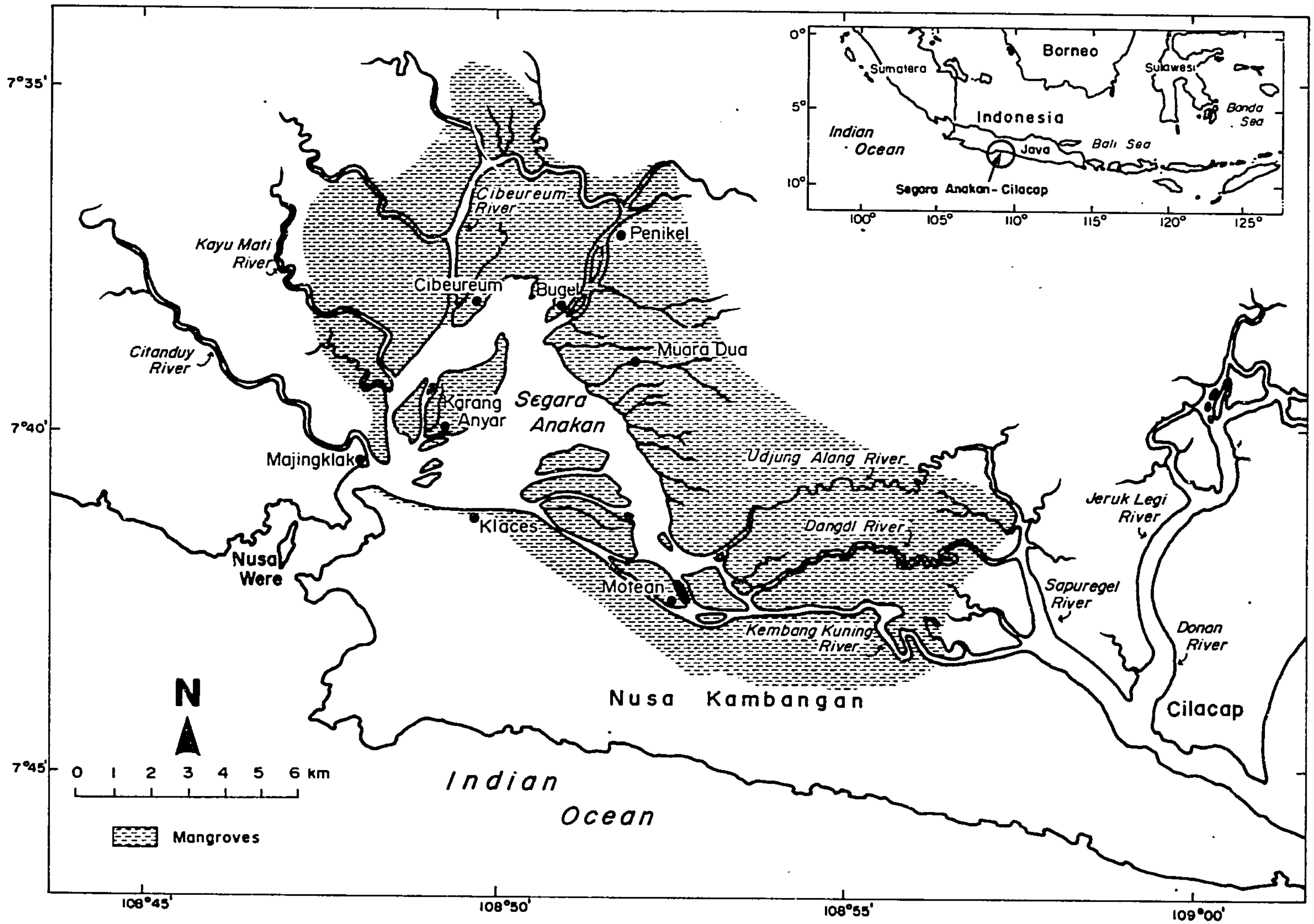

Fig. 1. Segara Anakan, the pilot site of the ASEAN/US CRMP in Indonesia.

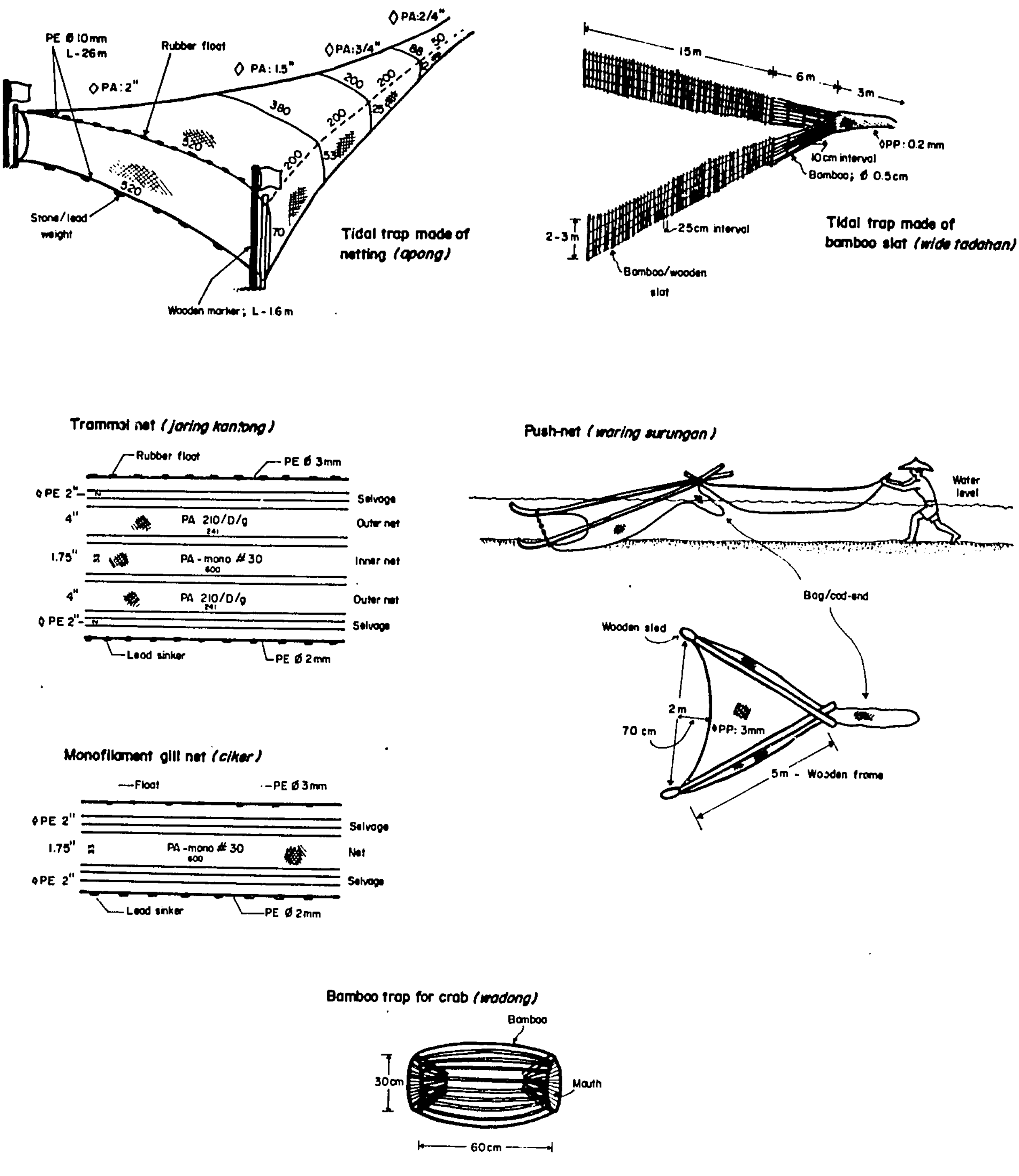

Fig. 2. Typical designs of fishing gear used in Segara Anakan. Numbers without units indicate number of meshes.

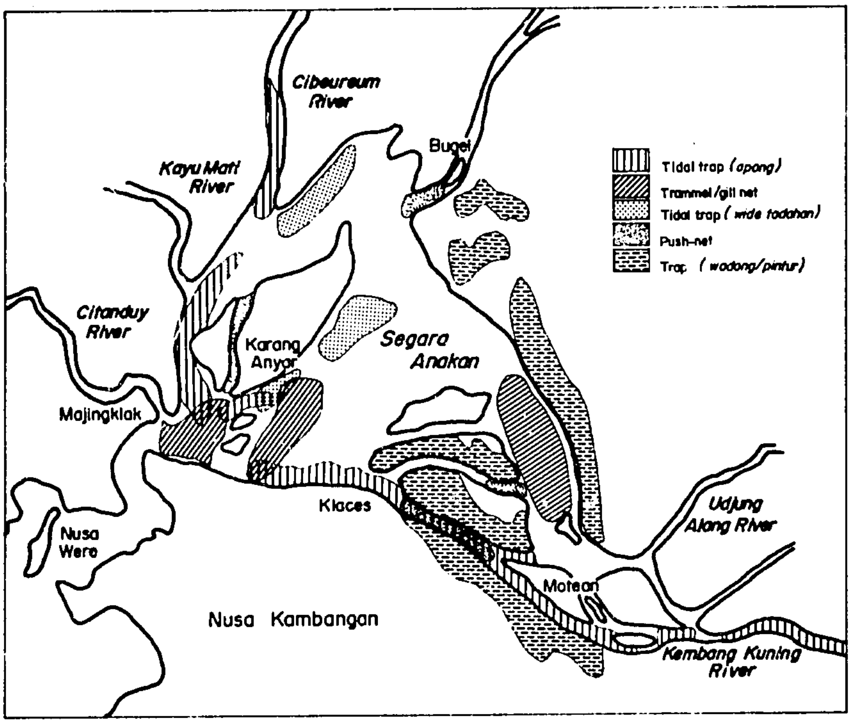

Fig. 3. Operational ranges of the various fishing gear used in Segara Anakan, Indonesia.

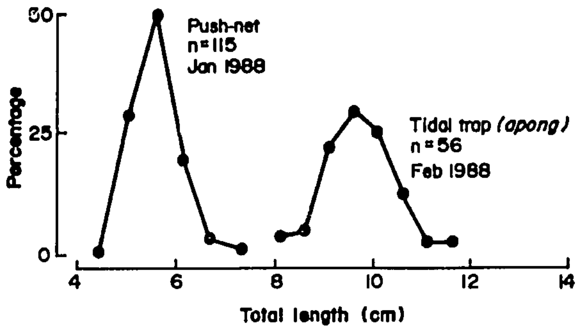

Fig. 4. Length distribution of *Penaeus merguiensis* caught by push-net and tidal trap off Udjung Alang River, Segara Anakan, Indonesia.

The crab fishery around the mangrove areas of Segara Anakan-Cilacap, Java, Indonesia

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SUWARSO and WASILUN. 1991. The crab fishery around the mangrove areas of Segara Anakan-Cilacap, Java, Indonesia, p. 57-64. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

The mud crab, *Scylla serrata* (Forskal), is one of the fisheries resources of the mangrove areas of Segara Anakan-Cilacap. It is mainly caught by trap and lift net. The catch rate for bamboo trap is 4.5 kg/trip/day while for lift net, 3.2 kg/trip/day. In the lagoon, this crab appears to spawn all-year-round. Some biological and socioeconomic aspects of the fishery are also discussed.

INTRODUCTION

The mud crab (*Scylla serrata*) is one of the main fisheries resources in Segara Anakan-Cilacap. So far, there is no report on the crab fishery in this region but some studies on the biological aspects have been conducted (Wahyuni and Sunaryo 1981; Toro 1982; and Hutabarat 1983).

Local fishermen catch the crab using the *wadong* (bamboo trap, fish pot) and *pintur* (lift net). This paper discusses the catch, marketing system, income of fishermen and biology of the crab fishery.

MATERIALS AND METHODS

The *wadong* and *pintur* (Fig. 1) differ in their local effectiveness and use. Table 1 shows that the bamboo trap operation depends on tide conditions while the lift net is operated any time, independent of the tide. The fishing grounds for each gear are shown in Fig. 2.

The most common bait used are obtained from *apong* (tidal trap) catch or other gear such as eels (*Anguillidae* and *Muraenidae*), and scats (*Scatophagidae*), among others.

In Segara Anakan, crab fishery is distributed in five areas: Motean, Karang Anyar, Cibeureum, Muara Dua and Penikel. The number of fishermen according to region is shown in Fig. 3.

Crab catch data were obtained from the fishermen and were distributed in seven categories based on marketable size and sex (Table 2). The size and weight frequency distribution of each category is presented in Fig. 4.

The total production was estimated by calculating the monthly total catch of each fishing gear using the formula:

$$T = h \times n \times CPUE$$

where T: total production
h: average number of fishing days per month
n: estimated number of active fishermen
CPUE: catch per unit effort (kg/trip/day)

The socioeconomic factors such as marketing and income of fishermen were determined by interviewing fishermen and fish sellers.

RESULTS AND DISCUSSION

Catch fluctuation

In Segara Anakan, the mud crab is caught throughout the year: 77% by bamboo traps and 23% by lift net.

The average daily catch rate by bamboo trap was 4.5 kg/trip/day, while for lift net, it was 3.5 kg/trip/day (Table 4). Fluctuation by catch rate is shown in Fig. 5, and by market-size categories in Fig. 6.

The catch peak for bamboo trap occurred in December (west monsoon) whereas for lift net, in June and July (east monsoon) (Fig. 5). In general, all market-size categories appeared in the catch every month (Fig. 6), including the mature female crab. Thus, it can be assumed that the crab in this lagoon spawn all-year-round. In the Philippines, the mud crab spawn all-year-round with a peak season between May and September (Arriola 1940). Whereas in Hawaii, the mud crab spawn between May and late October (Beick 1974).

The mature crabs were in the Ia, Ib, IIa and IIb categories (Tables 2 and 3). In the Karang Anyar area, the carapace length at first maturity was 42.7 mm (Toro 1982); in Motean, 59.3 mm (Hutabarat 1983); and in Malaysia, 66 mm (Ong in Toro 1982). Based on the body condition, the IIIa category was assumed to have already spawned. Generally, this category was the dominant catch (31%), except during the period May to July 1988 for the lift net catch, when the dominant catch was category IV (Fig. 6). The latter category was the smallest-sized crab, the catch peaks of which probably indicate the spawning season. Catch fluctuation by size was probably related to the behavior of the crab such as feeding, molting and reproduction.

Estimation of fishing days and total production

From 69 fishermen using the bamboo trap and 60 fishermen using the lift net, the estimated fishing intensity expressed as monthly fishing days and total number of trips of the fishermen is shown in Table 5. The monthly fishing days of bamboo trap fishermen were less than those of the lift net fishermen. Similarly, the number of active trap fishermen was more than that of net fishermen, as with the total number of trips.

Monthly crab production by fishing gear and region is presented in Tables 6 and 7. Findings indicate that Segara Anakan produced an average of 21.7 t of crab per month, of which 16.7 t were caught by bamboo trap and 5.0 t by lift net. Motean and Karang Anyar regions were the main production areas.

Size measurement

A total of 861 specimens were measured. The carapace length range was from 47.5 to 92.5 mm. The monthly frequency distribution of carapace length is illustrated in Fig. 7, while Fig. 8 shows the monthly movement of modal values of the crab--usually below the mean values--in the lagoon during this period. In the 1981 to 1982 period, Toro (1982) obtained the same result and suggested that the crab fishery in Segara Anakan was overexploited.

Socioeconomic aspects

Generally, the fishermen do not sell their catch to the consumer or exporter directly. Fig. 9 shows the various stages in the marketing system of the crab caught in the lagoon and the trend in crab prices.

Based on the price of each crab category, the income of a crab fisherman and the values of total crab production (Table 8) could be estimated. Based on the average monthly income and number of trips per month, a bamboo trap fisherman earned Rp 3,619* per trip, while a lift net fisherman made Rp 3,294 per trip (Tables 5 and 9). Since the net fishermen had substantially longer fishing days in the first two quarters of 1988, they had a higher total income compared to the trap fishermen.

CONCLUSION

The catch of *Scylla serrata* in the lagoon fluctuated but occurred all-year-round with a total production estimated at 21.7 t per month, which could be a case of overexploitation. It was recommended that the culture of mud crab be instituted in Segara Anakan so that production could be increased while managing the wild population on a sustainable basis.

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*April 1990: Rp1,811 = US$1.00

Table 1. Fishing grounds and methods of bamboo trap and lift net fishing.

Description	Bamboo trap	Lift net
Fishing ground	Mangrove areas, submerged at high water	Channel in mangrove areas, river or lagoon
Fishing method		
a. setting	Placed at low water	Used any time
b. hauling	Taken before the next low water	
Neap tide	Not active	Active

Table 2. Market-size categories of *Scylla serrata* in Segara Anakan.

Description	Size category Ia	Ib	IIa	IIb	IIIa	IIIb	IV
Average carapace length (mm)	76	66	73	64	68	63	56
Average weight (g)	320	192	193	138	195	142	108
Sex	m	m	f	f	m & f	m & f	m & f
Cost (Rp/kg)	1,500	800	3,000	1,500	500	350	300

Note: m = male; f = female

Table 3. Percentage of catch composition of *Scylla serrata* by bamboo trap and lift net.

Kind of gear	Size category Ia	Ib	IIa	IIb	IIIa	IIIb	IV	Total
Bamboo trap	13	17	9	6	7	31	17	100
Lift net	20	8	12	1	10	30	19	100

Table 4. The average daily catch rate of *Scylla serrata* by fishing gear.

Kind of gear	CPUE kg	CPUE Individuals
Bamboo trap	4.5 (0.8)	29 (5)
Lift net	3.5 (1.2)	22 (9)

Note: Numbers in parentheses are standard deviations of CPUE.

Table 5. Estimated number of fishing days, fishermen and trips by gear type.

Month	Fishing days		Fishermen		Fishing trips	
	Bamboo trap	Lift net	Bamboo trap	Lift net	Bamboo trap	Lift net
Sep. 1987	13	-	258	-	3,354	-
Oct.	13	-	258	-	3,354	-
Nov.	12	-	258	-	3,096	-
Dec.	13	10	258	35	3,354	350
Jan. 1988	13	13	258	36	3,354	468
Feb.	16	23	258	38	4,128	874
Mar.	12	30	258	39	3,096	1,170
Apr.	-	30	-	39	-	1,170
May	22	30	258	48	5,676	1,140
June	25	28	258	96	6,450	2,688
July	28	31	103	61	2,890	1,897
Average	17	24	242	49	3,875	1,220

Table 6. Estimated tons of *Scylla serrata*, by area, caught with bamboo trap.

Month	Motean	Karang Anyar	Cibeureum	Penikel	Muara Dua	Total
Sep. 1987	8.38	5.49	0.72	0.87	3.18	18.65
Oct.	6.26	4.10	0.54	0.65	2.37	13.92
Nov.	6.93	4.54	0.60	0.72	2.63	15.42
Dec.	8.48	5.55	0.73	0.88	3.22	18.85
Jan. 1988	6.83	4.48	0.59	0.71	2.59	15.19
Feb.	8.46	5.54	0.73	0.88	3.21	18.82
Mar.	6.42	4.20	0.55	0.66	2.43	14.27
May	7.96	5.22	0.69	0.82	3.02	17.71
June	0.87	7.12	0.94	1.12	4.12	24.19
July	4.7	23.10	0.41	0.52	1.79	10.49
Average	7.53	4.93	0.65	0.78	2.86	16.75

Table 7. Estimated tons of *Scylla serrata*, by area, caught with lift net.

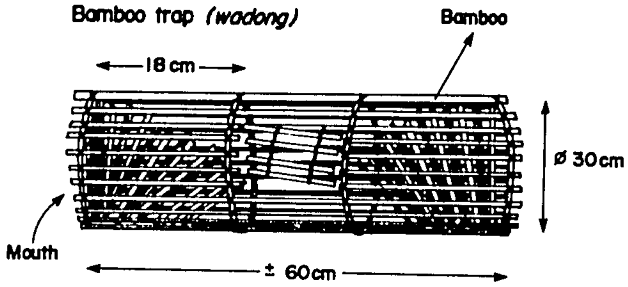
Month	Motean	Karang Anyar	Cibeureum	Penikel	Muara Dua	Total
Dec. 1987	0.09	0.89	0.10	0.04	0.18	1.31
Jan. 1988	0.07	0.72	0.08	0.03	0.14	1.05
Feb.	0.15	1.39	0.16	0.06	0.27	2.02
Mar.	0.23	2.23	0.26	0.10	0.44	3.25
Apr.	0.22	2.13	0.25	0.09	0.42	3.11
May	0.35	3.35	0.39	0.15	0.66	4.89
June	1.02	9.77	1.13	0.43	1.93	14.28
July	0.72	6.87	0.79	0.30	1.36	10.06
Average	0.36	3.42	0.39	0.15	0.68	4.99

Table 8. Estimated value (in million Rp) of crab production by fishing gear.

Month	Bamboo trap	Lift net	Total
Sep. 1987	19.57	-	19.57
Oct.	11.38	-	11.38
Nov.	11.61	-	11.61
Dec.	15.46	1.2	16.66
Jan. 1988	13.85	0.79	14.64
Feb.	17.12	2.03	19.15
Mar.	14.01	3.95	17.96
Apr.	-	3.86	3.86
May	16.73	4.58	21.31
June	19.55	9.96	29.51
July	7.58	7.90	15.48

Table 9. Estimated total monthly catch (kg) and income (Rp) of a crab fisherman by fishing gear.

Month	Bamboo trap		Lift net	
	Catch	Income	Catch	Income
Sep. 1987	72.3	75,855	-	-
Oct.	53.9	44,116	-	-
Nov.	59.6	45,006	-	-
Dec.	72.9	59,904	37.5	34,525
Jan. 1988	58.9	53,690	28.8	22,106
Feb.	72.8	66,584	53.8	53,475
Mar.	55.3	54,294	84.3	101,370
Apr.	-	-	80.1	98,965
May	68.7	64,834	101.1	95,520
June	94.0	75,788	148.8	103,782
July	101.6	75,236	164.2	122,729
Average	71.0	61,531	87.3	79,062



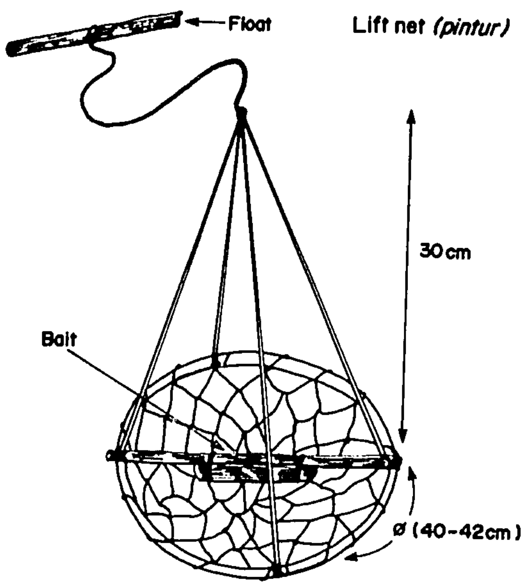


Fig. 1. Fishing gear for *Scylla serrata* in Segara Anakan.

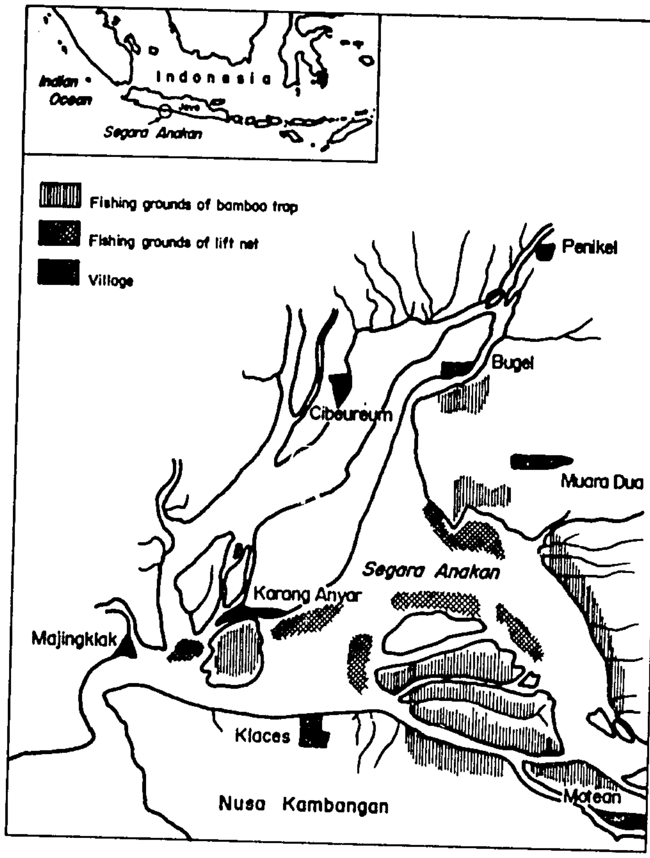


Fig. 2. Distribution of the crab fishery in five areas in Segara Anakan and the location of the fishing grounds of bamboo trap and lift net.

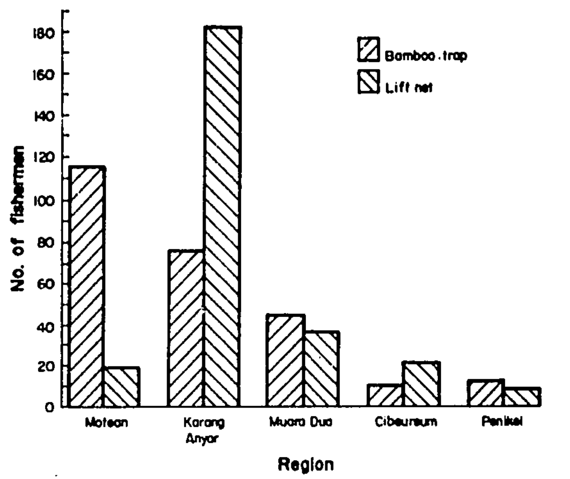


Fig. 3. Number of fishermen according to area in Segara Anakan.

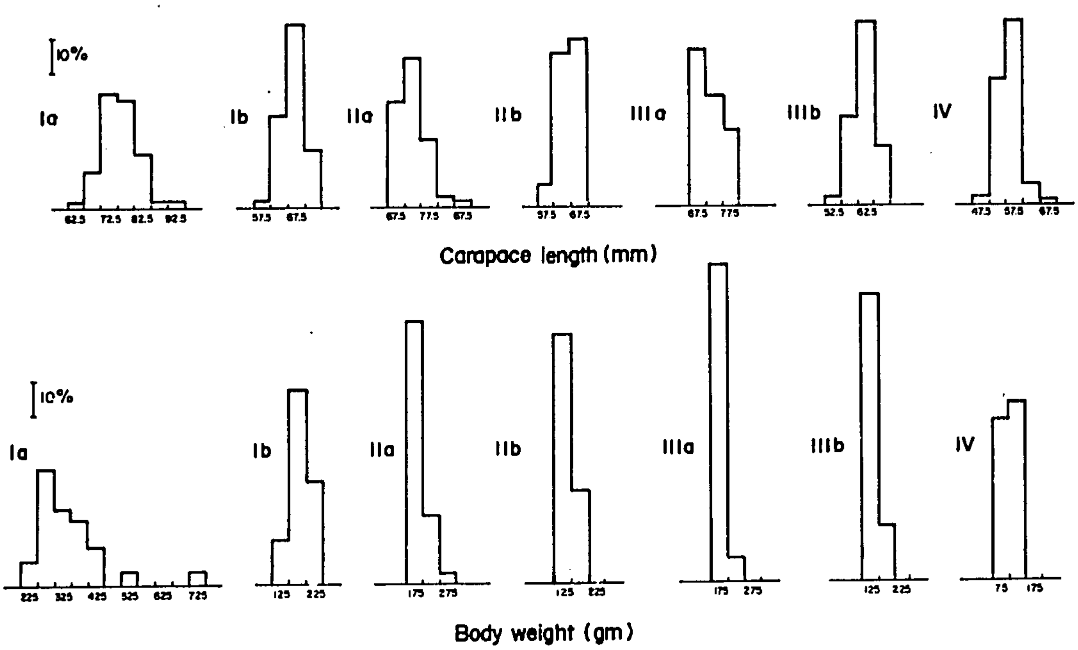


Fig. 4. Carapace length and body weight frequency distribution of *Scylla serrata* in Segara Anakan.

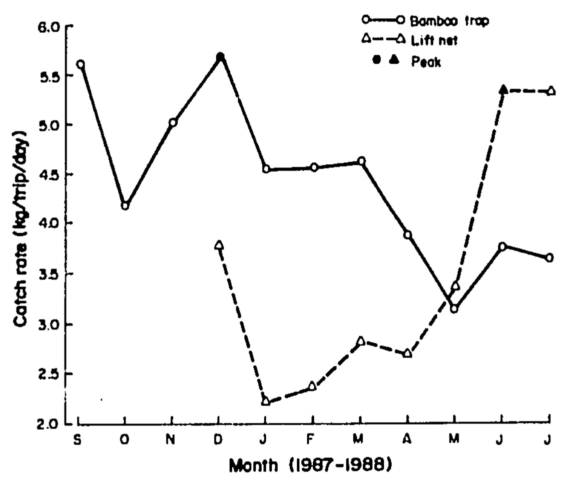


Fig. 5. Fluctuation of catch rate for *Scylla serrata* in Segara Anakan.

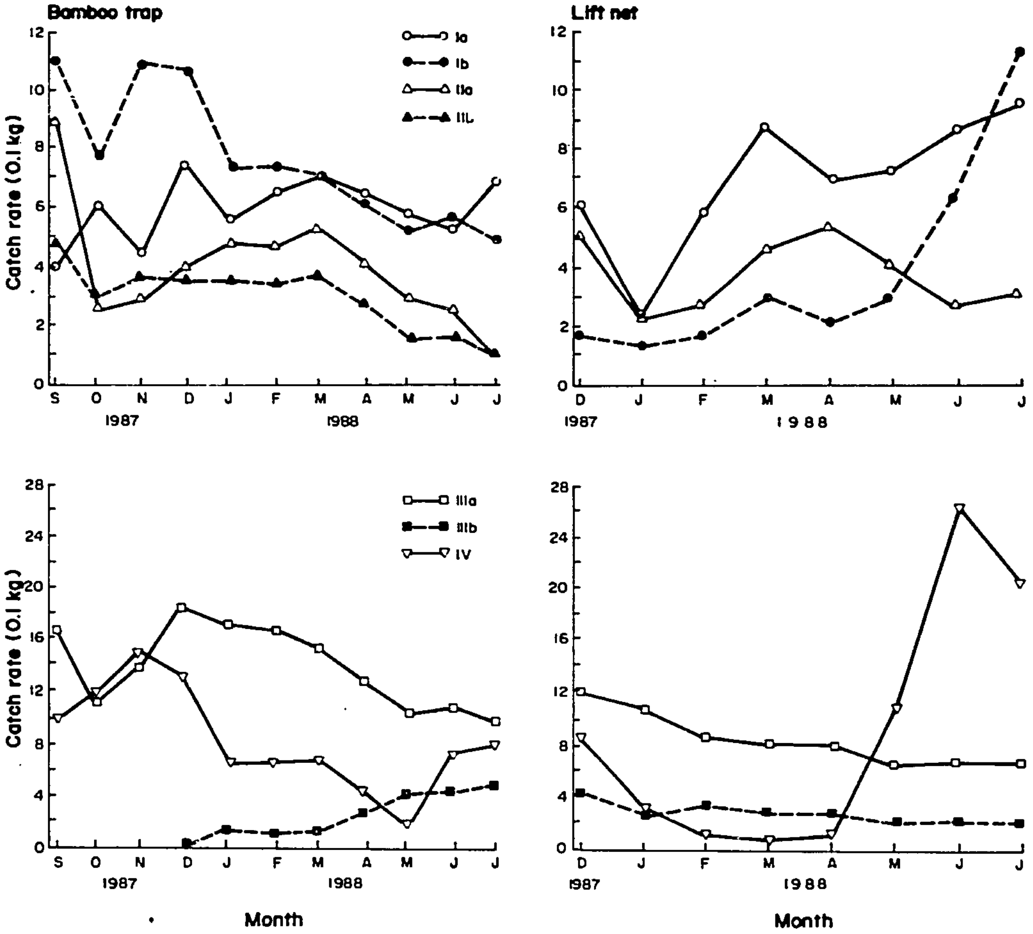


Fig. 6. Catch fluctuation of seven market-size categories of *Scylla serrata* in Segara Anakan.

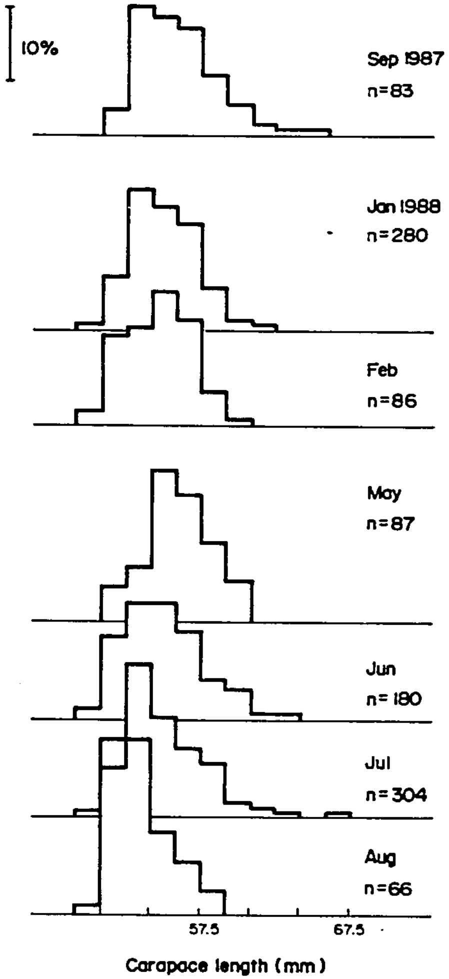


Fig. 7. Monthly frequency distribution of the carapace length of *Scylla serrata* in Segara Anakan.

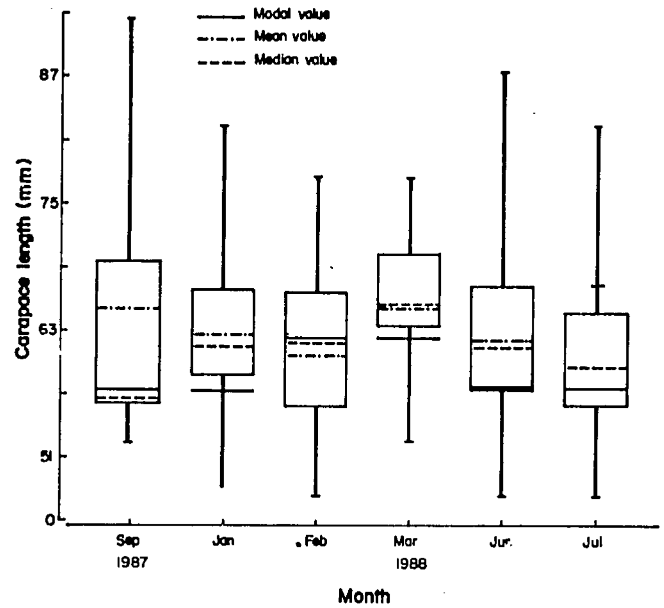


Fig. 8. Box plot of carapace length of *Scylla serrata* in Segara Anakan.

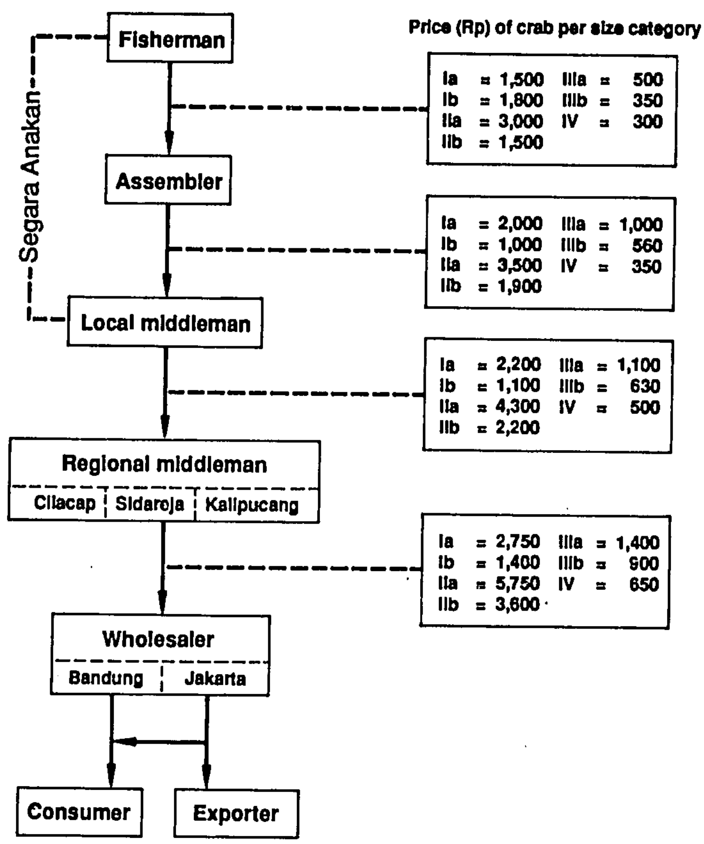


Fig. 9. Marketing system for crab caught in Segara Anakan.

Present status of aquaculture practices and potential areas for their development in South Johore, Malaysia

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ABSTRACT

Coastal aquaculture is becoming an important sector in South Johore in recent years. Aquaculture practices involve pond culture of penaeid shrimp *(Penaeus monodon* and *P. merguiensis)*, cage culture of seabass *(Lates calcarifer)*, groupers *(Epinephelus* sp.) and snapper (*Lutjanus* sp.), and raft culture of mussel *(Perna viridis)* including hatcheries for shrimp and seabass. These aquaculture practices vary in each of the three districts: Pontian, Kota Tinggi and Johore Bahru. Further development of aquaculture in the State of Johore may accelerate in response to the government policy to attract foreign investment in aquaculture.

Potential aquaculture sites have been developed in the Pontian District using the Geographic Information System (GIS). Various criteria and determinants were utilized, generating maps showing that 17,366 ha are suitable for shrimp ponds and 180 ha for mariculture.

INTRODUCTION

Johore was one of the earliest states to start coastal aquaculture in Malaysia. In 1987, about 600 ha of land were developed for shrimp farming; about 3,570 units of finfish cages and about 300 units of rafts for mussel culture were established, the distribution of which is shown in Figs. 1 and 2. Total gross income from coastal aquaculture for Johore in 1987 was estimated at M$16 million with shrimp farming constituting more than 50% of the production (OJP-KPM 1987).

The growth of aquaculture activities is expected to accelerate with present government policy, particularly enticing foreign investors to start large-scale shrimp farming. Very little study has been done to see the environmental impact of various coastal aquaculture activities. Thus, there is a need for proper planning and utilization of coastal resources with respect to aquaculture development in Johore.

A study was conducted under the ASEAN/US Coastal Resources Management Project (CRMP) with these objectives:

1. evaluate the present status of aquaculture practices in the three districts of South Johore: Johore Bahru, Pontian and Kota Tinggi;
2. identify the various types of aquaculture practices that have potential development in the Pontian District and its adjacent areas;
3. identify potential areas for aquaculture development and its possible impact; and
4. generate thematic maps showing the present and potential aquaculture areas in the Pontian District.

The study, carried out using GIS, will enable the formulation of guidelines and strategies for aquaculture industry in Pontian District and to some extent, in the other two districts of South Johore.

GIS is a computer-aided resource assessment and planning tool for the input, storage, retrieval, analysis and display of interpreted geographic data. Data sets, such as water quality parameters, land use patterns, topographic projections and others, are used, analyzed and interpreted according to a set of criteria in determining potential areas for coastal aquaculture development.

Present status of aquaculture practices in South Johore

Coastal aquaculture practices in the three districts of South Johore are shrimp (penaeid) hatchery and pond culture, finfish cage culture and mussel culture (Figs. 1 to 3). The main species for shrimp hatchery and pond culture are *P. monodon* and *P. merguiensis*. For finfish cage culture, the species are seabass *(Lates calcarifer)*, groupers *(Epinephelus* sp.*)* and red snapper *(Lutjanus* sp.*)*, while the mussel *Perna viridis* is cultured in rafts. Marine finfish hatchery is mainly on seabass.

A total of 365 ponds comprising 600 ha were utilized for shrimp culture in the State of Johore as of 1987. In the districts of Pontian, Kota Tinggi and Johore Bahru, shrimp ponds comprised about 17%, 28% and 30%, respectively, of the total shrimp ponds in the state. In terms of areal extent, Kota Tinggi represented 60% of the total land area utilized for shrimp culture. There were 11 shrimp and marine finfish (seabass) hatcheries, with Kota Tinggi having five establishments (Fig.3).

Of the three districts, Pontian had the largest number of cages for finfish culture (76%) operated by 69 farmers. Kota Tinggi and Johore Bahru constituted 24% of the total cage culture ventures in Johore. Mussel culture was rather restricted to Johore Bahru with about 283 rafts operated by 39 farmers.

Although these aquaculture activities have been practised in all three districts since the early 1980s, some of them have ceased to operate for various reasons. For example, Pontian started with mussel culture in 1982 with 20 rafts operated by 9 farmers and reduced to 4 rafts in 1986. Similarly, Johore Bahru had 141 cages in 1980 and increased to 464 cages in 1987, whereas Pontian had 6 cages in 1980 and increased to 2,725 units in 1987. Such a development trend has been attributed to the availability of suitable sites for aquaculture in the respective districts.

Potential areas for aquaculture development in Pontian District

Coastal aquaculture development in South Johore, particularly in Pontian, is relatively new and has good potential for expansion. However, it is necessary to identify suitable areas for aquaculture development, taking into consideration the possible environmental impact, which had been largely ignored in the past. Such process of evaluation using both spatial and attribute information (empirical data sets) can be effectively generated using GIS.

The following are the general criteria in selecting and evaluating the suitability of an area for aquaculture:

Environmental Parameters. Water quality is the most important criterion in site selection. Water quality parameters used to evaluate the suitability of a site include pH, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), temperature, nutrients, heavy metals and microbial count. The choice of parameters will depend on the type of species being cultured.

With respect to water quality, one must also consider other factors such as land use patterns. For instance, upland agriculture and mining activities can cause soil erosion and, consequently, contribute to high turbidity and sedimentation of coastal waters, while agricultural farms generate pesticide and nutrient runoff that eventually goes into the sea. These factors, although quite difficult to control, must be determined to minimize or safeguard their short- or long-term adverse impact on aquaculture establishments.

Other environmental parameters include soil types, hydrographic factors, coastal geomorphology and meteorological characteristics. These parameters must be assessed with respect to other factors such as land use patterns and infrastructure to establish comprehensive suitability indices useful for GIS operations.

Infrastructure. Accessibility to existing infrastructure, such as roads, water and power supplies, communication facilities and others, is also an important criterion in assessing the suitability of an area for aquaculture. Such accessibility partly predetermines the ease and expenditure required for aquaculture operation. The distance of farm sites from existing roads and towns will have an important bearing on the cost of obtaining supplies and the transport of aquaculture products.

Other factors, some environmental in nature, are covered more appropriately below since these are rather system-culture specific. All this information, particularly spatial data such as maps showing roads, settlements and various land uses, has been digitized and georeferenced (conforming to actual projections) for GIS analysis and interpretation.

Potential areas for shrimp pond culture

The other criteria for evaluating or determining the suitability of an area for shrimp culture are:

Salinity Requirements. Suitable salinity levels for shrimp farming are usually those that fall within the combined optimum salinity range of different species. *P. merguiensis* has an optimum salinity range of 25-32 ppt while *P. monodon* has 12-25 ppt. Thus, the optimum salinity range for shrimp farming is 12-32 ppt.

Soil Characteristics. The chemical (pH) and physical (texture) properties of soils are no longer critical as determinants in site selection for pond culture because mitigative measures are available to improve soil quality with less capital expense. However, it is best to consider existing soil characteristics from maps that have been classified according to chemical and physical properties and are obtainable at low cost in determining sites for shrimp ponds. Data for GIS were extracted from existing soil maps of Pontian District and sites were ranked according to their suitability for shrimp pond culture (e.g., excellent, good, fair, poor and unsuitable).

Rainfall Pattern. Rainfall affects shrimp growth and production, water quality and incidence of flooding. Slow growth and possibly high mortalities can be experienced during heavy rainfall due to acidic runoff from the leaching of acid sulfate soils. Damage to aquaculture infrastructure can be exacerbated by flooding coincident with high tides. For South Johore, areas with less than 400 mm monthly rainfall are preferred. Areas experiencing more than 400 mm of rainfall for 3 months or more annually are also classified with respect to the number of culture cycles that can be carried out in one year. A map on the rainfall pattern for the study site based on the above-mentioned classification was generated from rainfall data of Johore from 1950 to 1968 (JK 1971; Rosly and Ti 1987).

Mangrove vs. Nonmangrove Areas (Land Use). Although mangrove areas are ecologically important as nursery and feeding grounds for many aquatic species (see Paw and Chua, this vol.; Naamin, this vol.; and Chan, this vol.), these areas are also suitable for aquaculture. In this study, however, the nonmangrove areas that were given priority for shrimp farm development were the reclaimed coastal lands (located behind the Jabatan Parit dan Taliair or JPT's bunds), secondary forests and marginally productive agricultural lands.

To determine which areas can be developed for shrimp farming--those that are not mangrove reserves and less important to agriculture and other land use schemes--a mangrove forest map obtained from the Department of Forestry, a land use map and the JPT's bunds location map were overlaid. Thus, resultant maps showed areas where shrimp farming could be sited. Several steps utilizing the various maps and attribute information were also made using the GIS (Fig. 4). The areal extent of suitable sites for shrimp pond culture has a total of 17,366 ha within Pontian District (Table 1 and Fig. 5).

Potential areas for shrimp and fish hatcheries

In selecting areas for establishing shrimp and finfish hatcheries, water quality and existing land use patterns were emphasized. Hatchery operation requires large amounts of good quality water. Distance from the water source is also important since it will determine the cost of installing a water supply system for the hatchery.

Geomorphological features like mudflats and sandbars are also important. Areas with sandbars or a rocky coast are more suitable than mudflats, which are generally exposed during low tides and easily induce water turbidity. Installing water supply lines in mudflats would entail a longer distance from the hatchery to a good water source. This could increase installation and maintenance costs compared to a site off the sandbars or along a rocky coast.

Hatchery sites should preferably be sheltered from strong winds as an exposed coastline normally has choppy water and is often turbid, especially along shallow areas. Finally, the sites should be near aquaculture farms to ensure a viable market outlet for the produce. Based on these factors, suitable sites for hatchery have been identified following a series of analytical procedures (Figs. 6 and 7).

Potential areas for finfish cage culture and raft culture of mussel

Other factors that must be considered for the cage culture of finfish and raft culture of mussel are bathymetry, current pattern and coastal features.

Sufficient depth--at least 1 m from the cage bottom to the seabed--is important for floating cages to minimize adverse water conditions that may be due to accumulated waste feeds and feces. Cages with a net depth of 2-3 m require a water depth at lowest tide of at least 3-4 m. Tiensongrusmee (1977) rated depths of 4-10 m as fair to good. At greater depths, however, the anchoring cost increases from 3% in shallow waters to 6% in deeper water (Chua 1978). In the present study, 4-10 m depth was considered good, while >10-20 m was fair for cage and raft culture.

In terms of water current, a speed of 0.2-0.5 m/s was considered optimal for cage culture. Sites that have water current below or above that range were rejected as unsuitable. Bathymetric and current data were obtained from maritime charts and spatially presented as a base map.

Floating cages and rafts require some protection against strong winds and waves. Since wave height is a function of wind speed and depth, normal monsoons in Peninsular Malaysia create a wave height of less than 0.5 m along some coastal waters, which is ideal for siting floating aquafarms. In designating sheltered areas suitable for siting cages or rafts, a line of 0.5 km from riverbanks and shorelines was digitized, generating a map of such areas.

An analysis of the above data with the use of GIS generated a suitability map for siting cage farms and rafts for mussel culture (Figs. 8 and 9). About 180 ha have been identified as potential sites within Pontian District.

CONCLUSION

The study identified potential areas for aquaculture development in the Pontian District using GIS. About 17,366 ha of land have been identified as suitable for shrimp pond culture, with mangroves comprising about 33% or 5,864 ha. If the mangrove areas are protected as reserves, the remaining area for shrimp culture is about 11,500 ha. The potential sites for mussel and finfish cage culture have a total area of 180 ha, with many of these located in sheltered areas along river systems.

The criteria in determining potential sites under various suitability indices for the diverse aquaculture practices within Pontian District are not limited to what have been discussed. The other factors that must be considered are the number of cages and the environmental impact of petrochemical factories or agroindustries. The number of cages per site must be controlled to minimize adverse environmental impact due to overcrowding of cages and wasteload. Agroindustries or chemical factories must be properly built in areas farther from the coast to minimize the negative impact of effluents on the aquaculture activities downstream and along the coast.

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Table 1. GIS results for land use types and areas available for shrimp farms in Pontian District.

Present land use	Soil category (ha) Excellent	Good	Fair
Mangroves	5,800	15	0
Mixed horticulture	510	1,504	0
Coconut	4,997	784	0
Coconut and banana	1,281	24	0
Rubber	617	1,538	0
Oil palm	142	5	0
Pineapple	105	17	0
Newly cleared land	0	27	0
	13,452	3,914	0

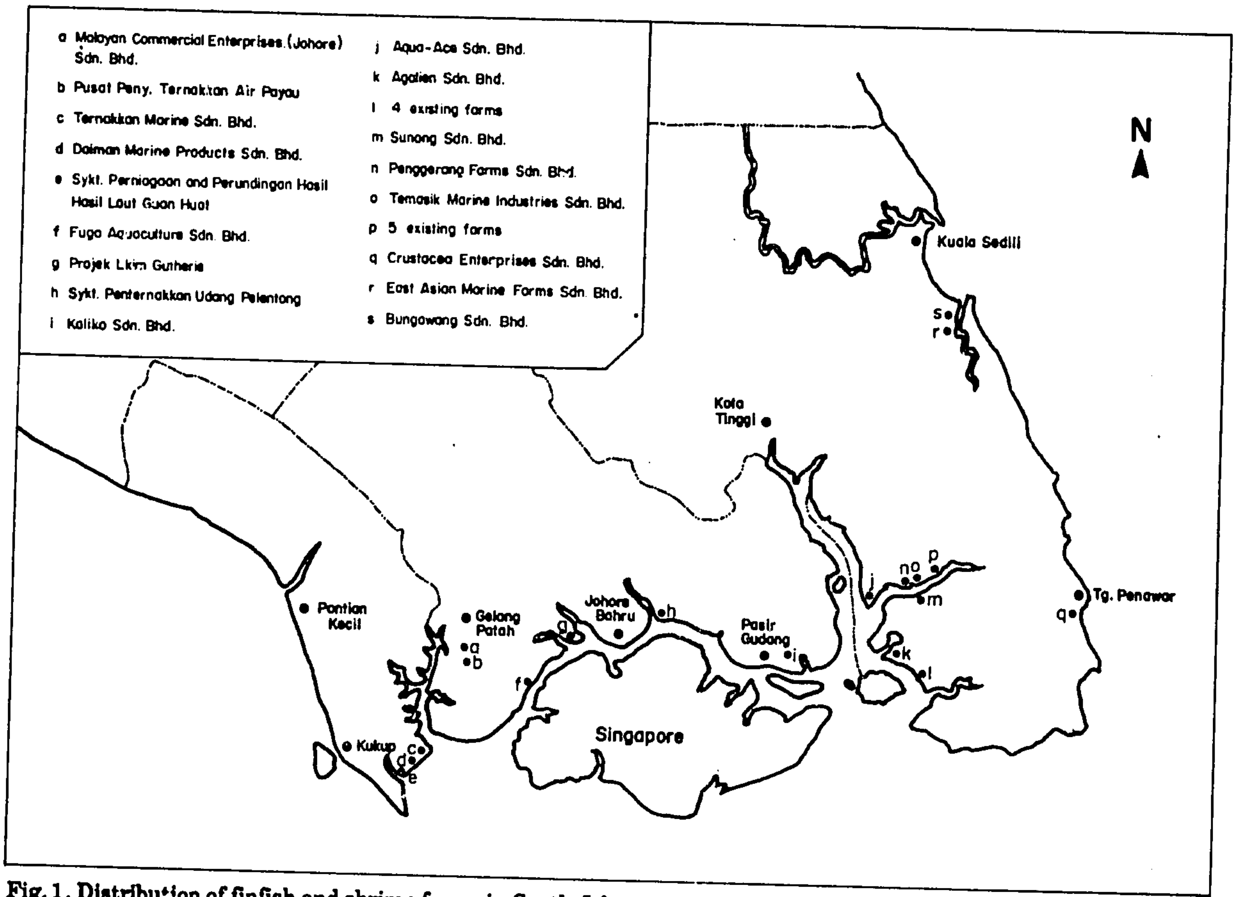

Fig. 1. Distribution of finfish and shrimp farms in South Johore.

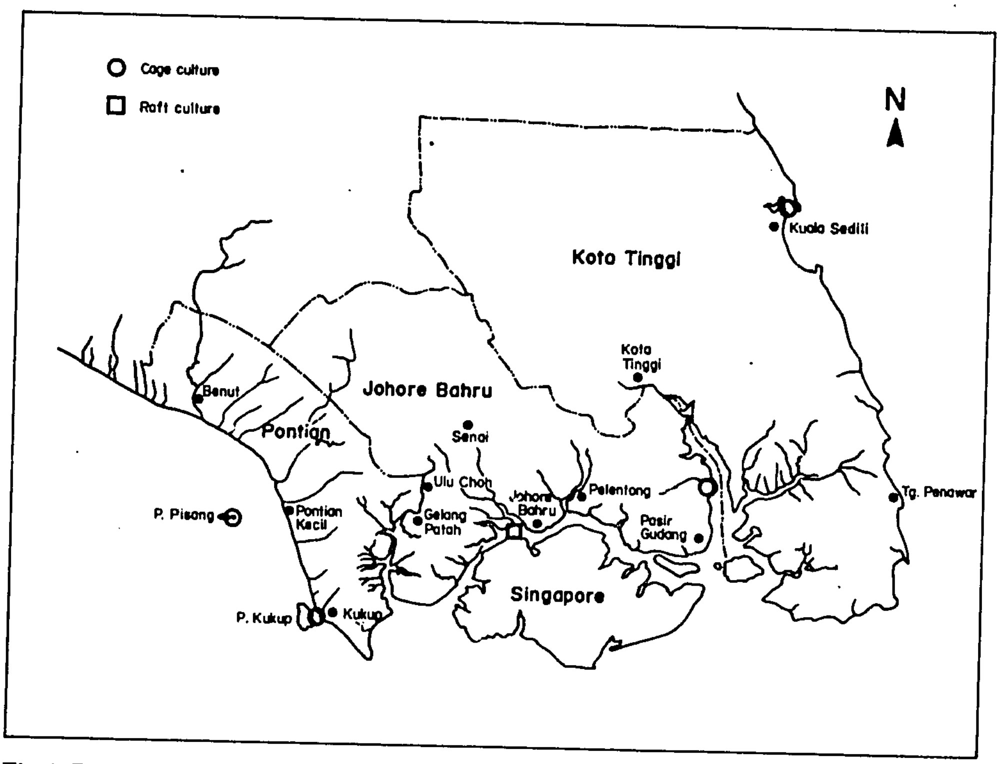

Fig. 2. Distribution of marine cages and raft culture in South Johore.

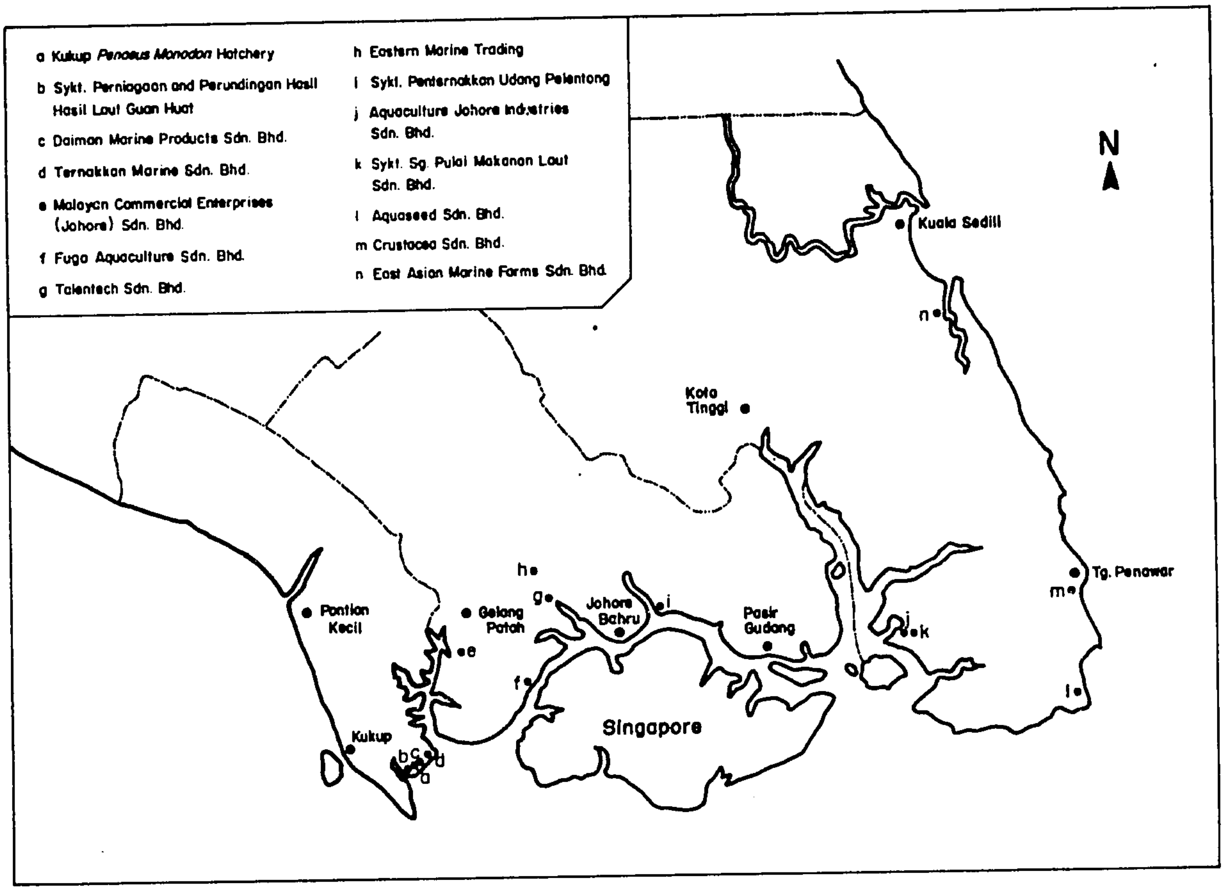

Fig. 3. Distribution of finfish hatcheries in South Johore.

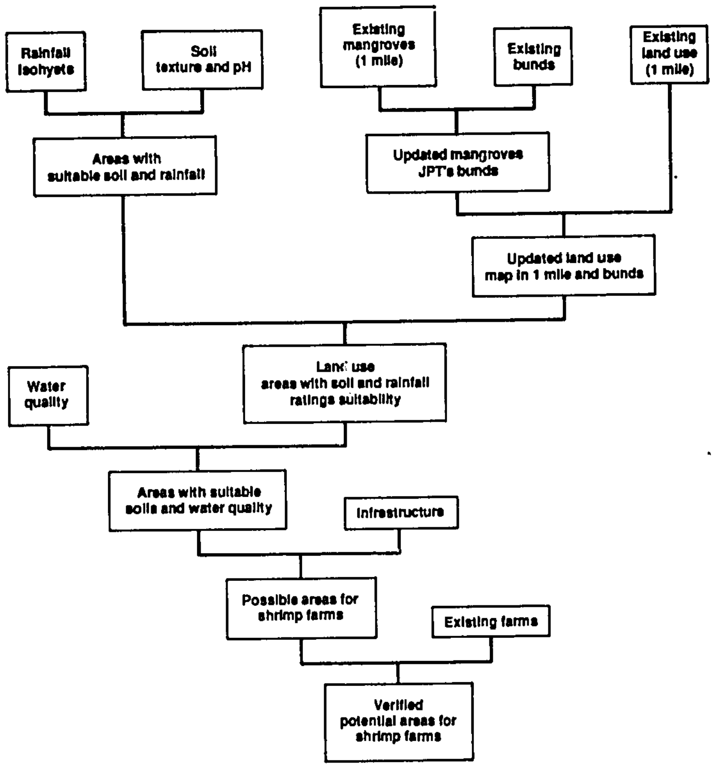

Fig. 4. GIS analysis flowchart for the identification of potential areas for shrimp farms.

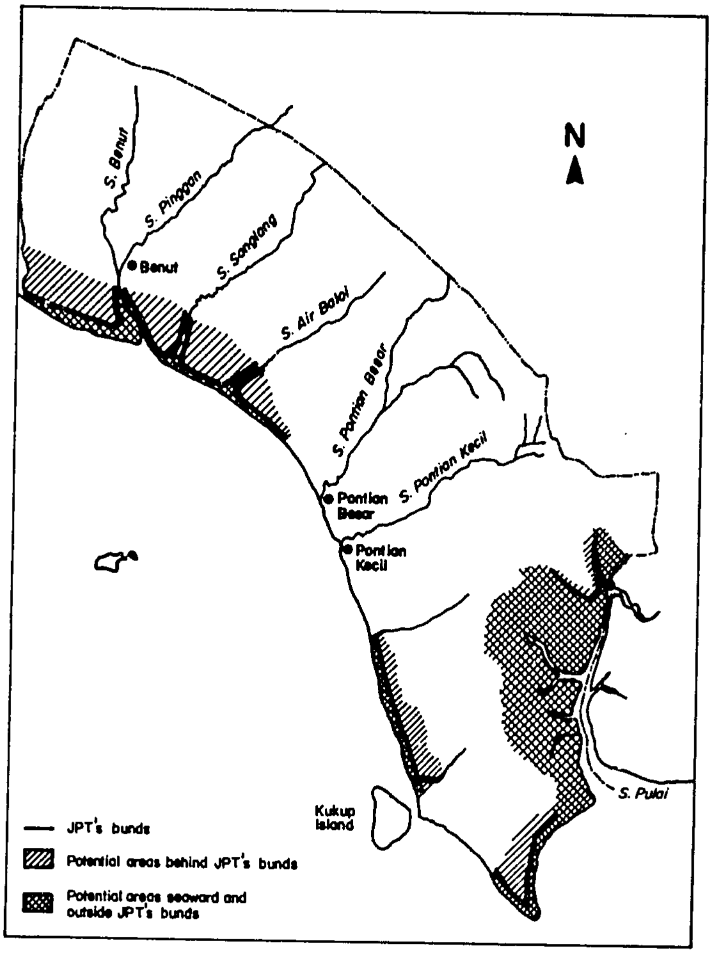

Fig. 5. Potential sites for shrimp pond culture.

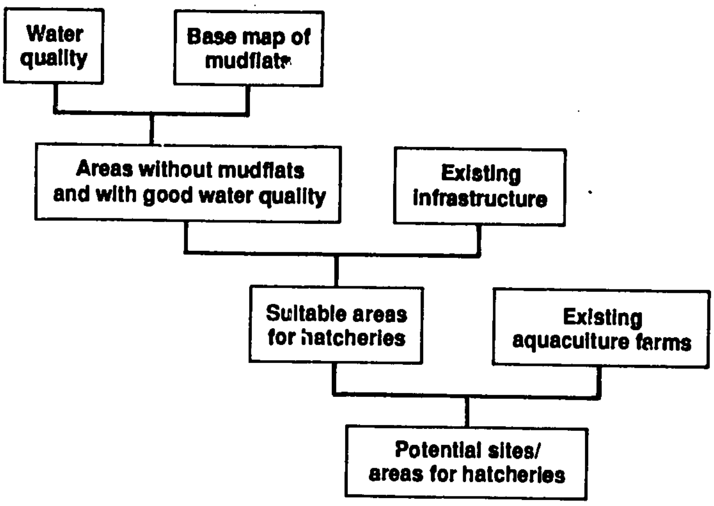

Fig. 6. GIS analysis flowchart for the identification of potential sites for hatcheries.

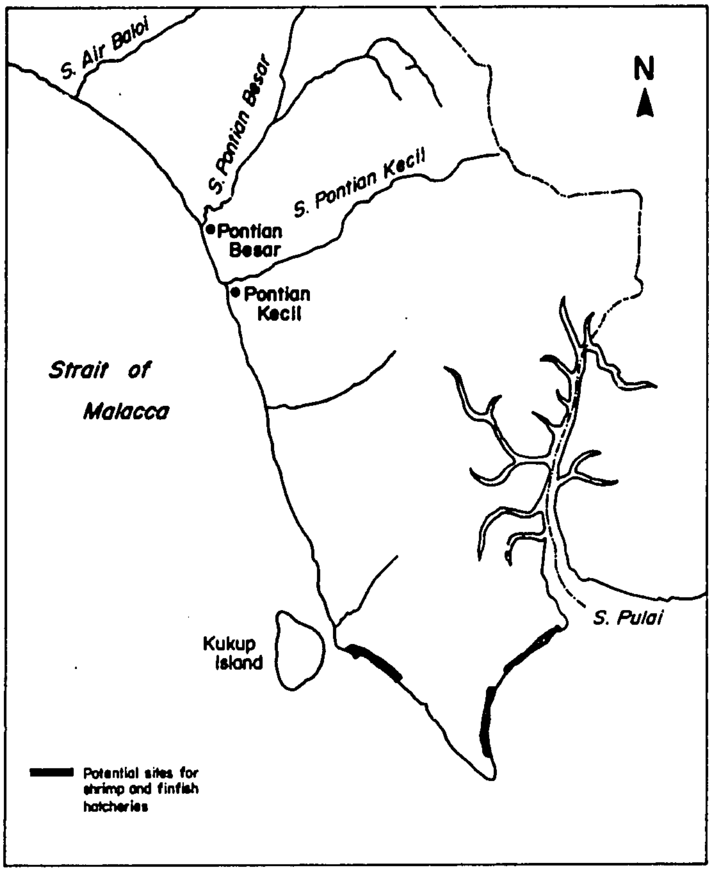

Fig. 7. Potential sites for shrimp and finfish hatcheries.

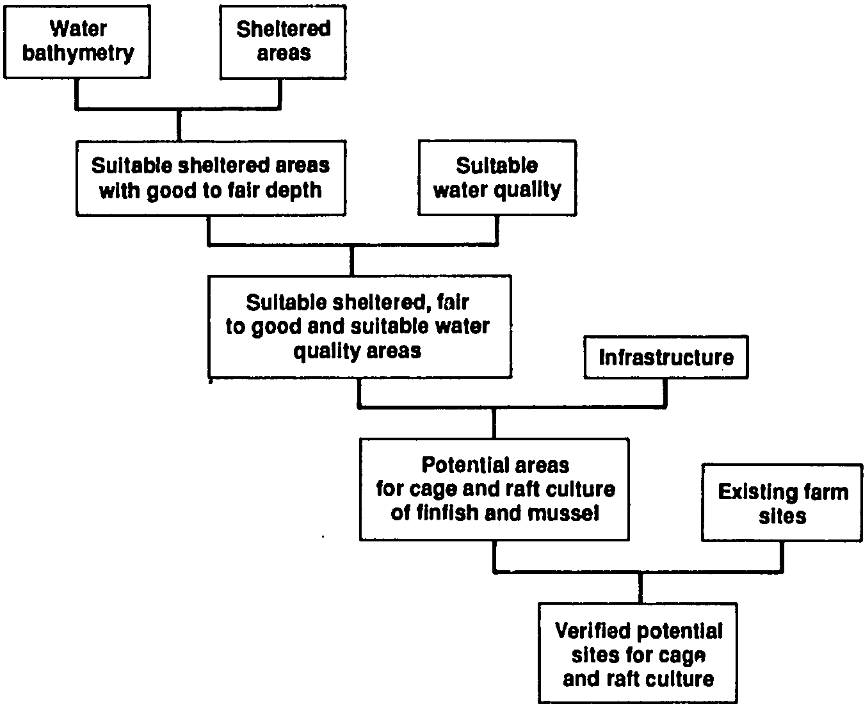

Fig. 8. GIS analysis flowchart for the identification of cage culture of finfish and raft culture of mussels.

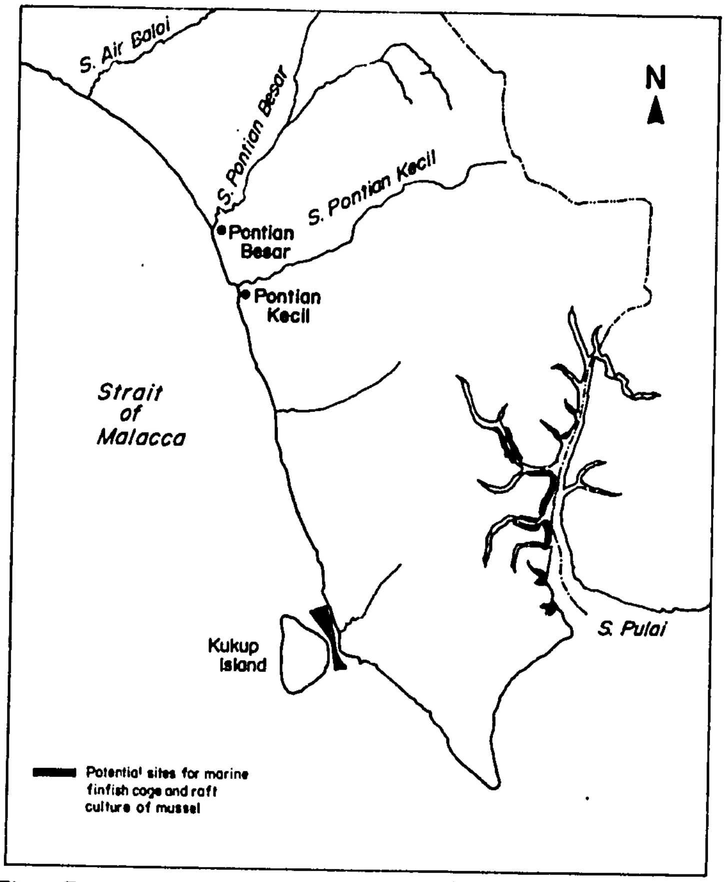

Fig. 9. Potential sites for marine finfish cage and raft culture of mussel.

Present status of aquaculture practices and potential areas for development in Ban Don Bay

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ABSTRACT

Coastal aquaculture plays a significant role in Thailand's Upper South Region, especially in the Bay Don Bay area. Existing aquaculture activities in the area are shrimp pond culture and oyster and cockle culture. This paper summarizes the aquaculture practices in Ban Don Bay and the potential areas for their expansion. Some constraints have been underscored such as pollution from land-based activities that greatly affects mollusk culture. Some strategies are recommended to address the management issues affecting coastal aquaculture in Ban Don Bay.

PRESENT STATUS OF COASTAL AQUACULTURE

Rapid expansion and development of coastal aquaculture in Thailand's Upper South Region have been attributed to declining fish catch due to the overexploitation of marine fisheries resources and the reduction of Thailand's fishing ground resulting from the imposition of the 200-mile Exclusive Economic Zone by its neighboring countries and high oil prices. A study was made under the ASEAN/US Coastal Resources Management Project (CRMP) to assess the status and potential of aquaculture in the Upper South Region, particularly in the Ban Don Bay area. Field surveys were undertaken from December 1986 to January 1988. Field survey includes sampling and analysis of biological parameters (plankton and nekton) and water and soil quality.

In 1985, there were about 3,341 ha of shrimp ponds distributed in the provinces of Surat Thani and Nakhon Si Thammarat. However, as of 1987, the total area for shrimp culture in the two provinces was 11,356 ha, based on interpretations of aerial and satellite photos. Notwithstanding this difference, shrimp pond culture appears to be the dominant aquaculture activity in Ban Don Bay. Other aquaculture activities (in the order of importance) are cockle (*Anadara granosa*) culture and oyster and fish culture. For cockle culture, total culture area in 1985 was 388 ha while that of oyster was 259 ha. Fish culture is of two types: pond culture and cage culture. Pond and cage culture have a total culture area of 13 ha and 33 ha, respectively (Fig. 1).

POTENTIAL FOR AQUACULTURE EXPANSION

Coastal aquaculture in Ban Don Bay has great potential for expansion. Several areas have been assessed for possible development. Potential areas for shrimp pond culture in the two provinces are about 14,242 ha in five districts: Tha Chana, Chaiya, Tha Chang, Kanchanadit and Khanom. Kanchanadit District in Surat Thani has, by far, the largest area at 3,715 ha. For cockle and oyster culture, the study showed that only a number of areas in Surat Thani are suitable for further expansion. In the case of cockle culture, the possible areas are Chaiya and Tha Chang Districts with an aggregate total of 1,790 ha. For oyster culture, mainly in Chaiya, Kanchanadit and Don Sak Districts, potential areas are estimated at 2,458 ha. Mussel (*Perna viridis*) culture is possible in Ban Don Bay. While there is no natural occurrence of spat in the area, the study showed that about 10,315 ha are suitable for mussel culture.

Aside from potential culture areas, a number of areas have been assessed to serve as preservation areas for mollusks, especially as spawning and rearing grounds for *Merethrix merethrix*, *M. lusoria*, *Arcuatula arcuala* and cockle. In Chaiya District, the preservation zone for *Merethrix* is about 700 ha while that for *Arcuatula* in Kanchanadit District is about 300 ha. For cockles, spawning ground is about 800 ha in Tha Chang and Phunphin Districts.

CONSTRAINTS AND STRATEGIES

The use of illegal fishing gear (push-nets) infringes on the preservation zone for mollusks. The discharge of water with high saline and high nutrient content from shrimp ponds and the release of pesticides into coastal waters affect the water quality for mollusk culture. These are the constraints to mollusk culture in Ban Don Bay. On the other hand, the expansion of shrimp culture conflicts with mangrove reforestation activities.

To manage coastal aquaculture in Ban Don Bay, these strategies must be implemented:

1. Protect the seed beds for mollusks from illegal fishing gear and land-based pollution sources.
2. Give alternative livelihood opportunities to fishermen engaged in push-netting.
3. Confront pollution problems by establishing proper procedures and a sewerage system to control indiscriminate effluent discharge into coastal waters.
4. In shrimp culture, demarcate zones for aquaculture activities and for mangrove reserves.

To reach the various sectors of the aquaculture industry, a strong public information program should disseminate an understanding of the interdependence of the coastal resources in Ban Don Bay. This program should advocate pollution management and aquaculture practices that minimize the discharge of pollutants.

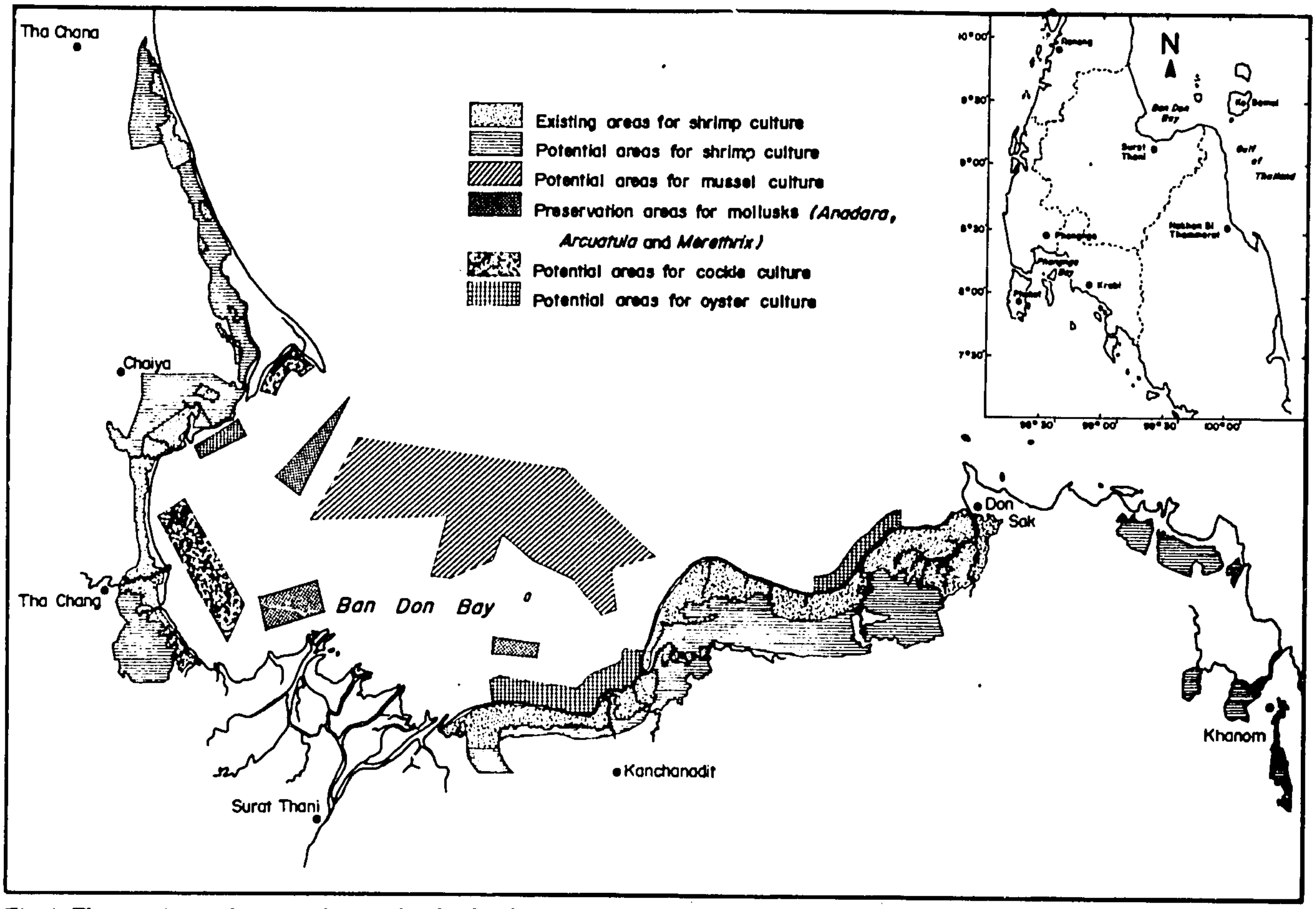

Fig. 1. The existing and potential areas for the development of coastal aquaculture in Ban Don Bay.

Survey of the coral reef resources of Western Lingayen Gulf, Philippines

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ABSTRACT

Thirteen sites along the western coast of Lingayen Gulf were surveyed to assess the general status of coral reef resources in the area. The reefs were found to be in relatively fair condition with living coral cover ranging from 29.5 to 51%. Coral growth was dominated by the low-lying species making up about 40% of the total coral cover. The fish population was dominated by pomacentrids, labrids and scarrids, while only 3.7% was accounted for by the higher-priced target species. Human-made stresses such as enhanced siltation and destructive fishing practices, together with excessive fishing pressure, were the factors behind the classification of reef condition as fair and the relatively low densities of reef fish.

INTRODUCTION

Coral reefs are highly productive communities and serve as a crucial resource base for the coastal fisheries of the Philippines. Murdy and Ferraris (1980) calculated that 9.8% and 8.4% of the total finfish production, in 1976 and 1977, respectively, were derived from coral reefs. Carpenter (1977) gives a higher estimate, 15%, considering the quantity of fish caught directly and consumed by sustenance fishermen, which are not reflected in fisheries statistics.

The reefs of Lingayen Gulf provide a year-round fishing ground not only for the 6,000 fishermen (Ferrer et al. 1985) there but also for the rest of the 14,000 artisanal fishermen of the gulf. A habitat for numerous invertebrates and finfish, these reefs are accessible sources of cheap protein and income.

This paper summarizes the results of surveys conducted along the major reefs of Lingayen Gulf to assess the general status of the coral reef resources in the area. It also identifies the more dominant human-made stresses responsible for reef degeneration.

METHODS

Detailed habitat surveys in selected sites in Santiago and Cabarruyan Islands (Fig. 1) were made to determine the abundance of coral reef fish, percentage cover of hard and soft corals, algae, seagrasses and macroinvertebrates associated with the reefs. Essentially, the conduct of the surveys was based on the ecological concept that habitats with a large number of live organisms are in good condition, and vice versa. The method of underwater survey used was the life-form transect technique adapted from the ASEAN-Australian Coastal Living Resources Project as described in Dartnell and Jones (1986). In each site, three or more 100-m fiberglass transect lines calibrated in centimeters were laid along the same depth using a scuba (self-contained underwater breathing apparatus). One line was placed on the reef flat in 2-3 m of water while two others were set up on the fore reef slope at 6 and 9 m. A pair of divers proceeded along the transect and recorded the abundance of finfish within a 10 x 100 m^2 corridor. Size estimates of commercially important fish, here referred to as target species, and their numbers were obtained. Fish that indicated the relative health of the reefs, called indicator species (e.g., butterflyfish), were also counted. Other fish species were grouped according to families and their numbers estimated.

The fish monitoring team was followed by a second set of three to four divers spaced 20 m apart along the transect, recording the length of each life-form or substrate type (e.g., sand, rubble, rock, etc.) found along the line. Organisms recorded were live hard corals of the *Acropora* and non-*Acropora* types, dead corals, sponges, etc. The reefs were then arbitrarily classified as excellent, with 75-100% live coral cover; good, 50-74.9%; fair, 24-49.9%; and poor, 25% live coral cover (Gomez and Alcala 1979; Gomez et al. 1981).

RESULTS

Benthic life-forms

The coral reef resources of Lingayen Gulf are concentrated on the western coast (Fig. 1) with a few coralline nonreef patches on the northeastern section. An extensive reef complex fringes the islands of Santiago and Cabarruyan, reaching 3 km from shore to crest north of Santiago Island. The reefs have varied topography consisting of broad seagrass beds along the shallower portions, lagoons 3-4 m deep cutting across the generally shallow reef flat, wide sand flats mostly emergent at extremely low water, and an abundance of coral-rock and rubble substrate occurring toward the reef crest.

Assessment of reef condition was made primarily on the fore reef slope at depths of 6 and 9 m. Samplings conducted on the back reefs were not considered in the analysis of reef condition since the areas were predominantly seagrass beds and including them would give a biased estimate toward lower live coral cover percentages. A total of 38 transects were made along 13 study sites from Trinchera, Bolinao to Batiarao, Anda. The percentage composition of the benthic components of the reefs are summarized in Table 1. The percentage of living coral cover (both scleractinian and alcyonarian species combined) ranged from a minimum of 29.5% north of Silaqui Island to a maximum of 51% along Malinap Channel with a mean of 41%. Based on standards established by the Marine Science Institute (Gomez and Alcala 1979; Gomez et al. 1981) for reefs throughout the country, the results indicate a generally fair condition in terms of coral cover. Of the 13 sites visited, only 18% were assessed to be in good condition (51% and 50% for Malinap and Cangaluyan Islands, respectively), with the rest having relatively fair cover. Except for a few sites (e.g., Batiarao, Guyoden and Sablig), the deeper portions (9 m) of the reefs exhibited a relatively higher percentage of live coral cover compared to the upper slopes (6 m).

Dead coral cover, consisting of those considered "recently" killed (coral colony identifiable), those overgrown by algal growth and coral rubble, accounted for the next higher percentage composition with a mean of 26%. This was highest in Dewey Island, where up to 45% of the reefs were dead followed by Cabungan, Tanduyong and Cangaluyan with 38%, 33% and 30%, respectively. The reefs north of Silaqui Island, despite showing low coral cover, had the lowest amount of dead coral (7%). The reef along this area is generally made up of a broad rocky platform covered with dense algal assemblages with up to 41% cover.

The general growth forms of corals in the area show a dominance of low-lying forms consisting of encrusting, submassive and mushroom species with an average of 16% cover or 40% of the total coral cover in the area (Table 2). The branching species (both *Acropora* and non-*Acropora*) and soft corals are the next dominant group followed by the massive and foliose types, the latter mostly encountered on the deeper slopes. A higher percentage of dead corals consisted of the branching species and in several instances, these were overgrown by algae or were recolonized by encrusting and submassive species (Dewey, Cangaluyan and Cabungan Islands).

Present in relatively lesser quantities along the fore reef slopes were other invertebrates such as sponges, zoanthids, echinoderms, gorgonians and hydroids.

Reef fish population

Fish population densities computed per 1,000 m^2 are given in Table 3. Reef fish were classified according to target species, which include the commercially important (relatively higher-priced) serranids, lutjanids, lethrinids and haemulids, the indicator species (butterflyfish), and all other major fish families visually dominant in the area.

Overall, the highest density was observed along Trinchera with 576 per 1,000 m^2 followed by Sablig and Silaqui, with 552 and 512, respectively. Lowest density was observed at Tanduyong (186) and Caniogan (114).

A total of 40 families of reef fish was recorded. Pomacentrid and labrid fishes dominated, with densities reaching up to 289 and 191 individuals, respectively, per 1,000 m^2. Those belonging to families Scaridae, Acanthuridae and Siganidae were less common. The rest of the families were rarely represented.

The higher-priced species made up only 3.7% of the total population with an average of 4 individuals per 1,000 m^2 and a density range of 0 to 18. Of the four families of target species mentioned earlier, serranids were the more dominant followed by haemulids. These were found to be relatively small with a total length from 5 to 30 cm. It was likewise observed that more individuals were confined to the lower slopes (9 m). Indicator species constituted up to 8% of the total number of species with an average density of 15 individuals.

DISCUSSION

The general health of coral reefs has always been associated with the amount of living coral (both hard and soft coral species) present. This is due to the basic role these organisms play in the construction and maintenance of the reef ecosystem (Endean 1976). The reef, where food and shelter are always available, serves as a refuge for numerous organisms. The alteration of the basic structure such as the removal of the corals or forms of perturbation would result in the deterioration of this highly productive environment.

The condition of coral reefs in Western Lingayen Gulf reflects the present state of reefs throughout the Philippines. Studies made by the Marine Science Institute (MSI) from 1978 to 1980 (Gomez and Alcala 1979; Gomez et al. 1981), covering most of the major reefs throughout the country, indicate that as many as 70% of the reefs sampled had less than 50% living coral cover. Similar observations were made by the UNEP-Natural Resources Management Center Coral Reef Monitoring Project of Silliman University (1984) and the ASEAN-Australia Coastal Living Resources Project of MSI in more recent surveys which included areas declared as marine reserves (Table 4).

Although natural stresses are responsible for the destruction of large portions of reefs, these are exacerbated by human activities ranging from poor land management to pollution and the use of destructive fishing techniques.

Common to fringing reefs is the perennial problem of siltation, which is one of the major causes of reef degradation in the area. Being adjacent to land, these reefs are affected by sediment runoffs particularly during a heavy downpour. Increased sediment production is the result of a number of development activities not only along the shore but also as much as several kilometers upland. Farming, building, road construction and deforestation all increase the rate of soil erosion and sediment input into rivers and streams (Hodgson and Dixon 1988), which eventually empty into the gulf. Those reefs along the passageways connecting Tambac Bay (an inner bay where most of the rivers of northwestern Pangasinan empty--see Fig. 1) to Lingayen Gulf have been found to be silted, with turbidity increasing during tidal ebb. Although coral cover is comparatively high (Cangaluyan and Batiarao), continued siltation of these reefs would result in either a shift in the general growth form (if it has not yet occurred) or species composition toward more silt-adapted types or outright decimation of the reef.

Destructive fishing methods such as the use of dynamite and sodium cyanide have likewise caused significant damage to reefs. Both methods are illegal but continue to be used not only in Lingayen Gulf but also all over the country. There is a high incidence of blast fishing operations around Santiago and Cabarruyan Islands, with an average of six explosions per hour recorded during the months of July, September and November 1987 and April 1988 (this study). The relatively high percentage of dead corals along the reefs fronting Dewey Island is also largely due to blasting. Although some fishermen use sodium cyanide in gathering food fish, it is primarily utilized for catching aquarium fish. Studies conducted by the Bureau of Fisheries and Aquatic Resources of the Philippines indicate that the repeated exposure of corals to this chemical eventually kills them. Damage to the reefs along Tanduyong and Caniogan has been attributed by the fishermen of Tondol in Cabarruyan Island to the use of sodium cyanide. According to them, reefs treated with sodium cyanide become unsuitable fish habitats, and they take several months to repopulate.

The relatively low density of reef fish, particularly the commercially important species, is an indication that the area is heavily fished. The decrease in average mean length and declining catch per unit effort (CPUE), both of which have been observed in the area, are likewise signs of an overexploited fishery. In an area where a large portion of the fishing population is below the poverty threshold (Yazon and McManus 1987) and where no other jobs are available, fishing effort to sustain or maintain income is greatly increased. This results in further depletion of the fish stocks, thus reducing the adult/spawning population and consequently decreasing the number of young fish that would eventually repopulate the area. Increased effort often leads to the use of more efficient but more ecologically destructive tools such as dynamite and sodium cyanide, which are primary causes of reef degradation.

In general, fish are sensitive to habitat degradation like massive coral mortalities (Buchon-Navaro et al. 1985). Once the coral cover has been reduced to rubble, the area becomes unsuitable for successful recruitment and growth of most reef-associated species (Pfeffer and Tribble 1985).

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Table 1. Average percentage composition of the benthic components of reefs surveyed and general condition of the area.

Site	No. of transects	Live coral (%)	Dead coral (%)	Algae (%)	Other benthic organisms (%)	Nonliving (%)	Reef condition
Santiago Island, Bolinao							
Trinchera	2	43.8	29.1	3.5	7.6	14.5	Fair
Lucero	2	40.3	15.2	7.1	8.2	7.0	Fair
Silaqui	4	29.5	6.6	46.6	1.8	4.2	Fair
Malinap	4	51.0	26.7	7.4	2.2	10.2	Good
Guyoden	4	49.6	18.3	18.4	1.1	6.3	Fair
Dewey	4	34.2	45.2	2.3	2.8	10.0	Fair
Cabarruyan Island, Anda							
Cangaluyan	4	50.4	29.9	4.9	3.5	5.2	Good
Cabungan	4	42.0	37.6	9.0	1.8	6.5	Fair
Tanduyong	4	32.9	33.3	18.5	1.2	3.2	Fair
Caniogan	2	27.8	24.1	5.8	3.0	8.3	Fair
Sablig	2	43.4	22.8	13.4	2.4	4.9	Fair
Macaleeng	2	47.2	21.1	21.5	2.2	6.8	Fair
Batiarao	2	44.1	25.1	19.5	1.5	10.8	Fair

Note: The above percentages represent the averages of results obtained from several transects.

Table 2. Percentage composition of coral growth forms.

Site	Hard coral				Soft coral
	Branching	Low-lying	Massive	Foliose	
Santiago Island, Bolinao					
Trinchera	4.9	8.1	5.2	2.9	22.7
Lucero	8.2	15.8	6.0	6.0	4.4
Silaqui	14.7	7.1	3.7	0.1	3.9
Malinap	20.5	8.9	6.1	3.1	12.4
Guyoden	11.1	18.3	5.1	1.9	13.2
Dewey	13.6	8.5	4.2	3.2	4.7
Cabarruyan Island, Anda					
Cangaluyan	8.4	22.6	3.9	3.4	12.2
Cabungan	8.5	20.4	4.0	2.8	6.3
Tanduyong	3.3	18.9	6.2	0.7	3.7
Caniogan	3.7	7.8	7.9	0.3	8.1
Sablig	7.9	17.2	8.4	2.2	10.8
Macaleeng	4.5	31.6	5.7	0.7	4.7
Batiarao	4.5	26.8	3.8	5.1	1.6
Average	9.7 (21%)	16.3 (40%)	5.4 (13%)	2.5 (0.1%)	8.4 (20%)

Table 3. Population densities of reef fish in study sites (individuals/1,000m²).

Site	Total density	Target species	Indicator species	Pomacentridae	Labridae	Acanthuridae	Scarridae	Siganidae	Others
Santiago Island, Bolinao									
Trinchera	576	0	18	158	28	20	12	0	340
Lucero	445	6	6	194	95	24	18	7	95
Silaqui	512	5	4	41	150	52	34	11	215
Malinap	333	4	15	85	74	27	20	12	96
Guyoden	324	2	8	114	47	28	23	6	96
Dewey	304	4	2	40	114	26	20	8	90
Cabarruyan Island, Anda									
Cangaluyan	250	3	16	97	52	5	25	4	48
Cabungan	277	3	12	105	59	3	35	0	60
Tanduyong	186	2	16	64	54	4	12	4	50
Caniogan	114	18	5	22	26	1	8	0	34
Sablig	552	6	33	96	68	2	86	5	256
Macaleeng	346	2	26	84	60	3	24	10	137
Batiarao	295	2	34	30	46	0	2	0	181

Table 4. Comparison of coral cover and reef fish density from various localities.

	Sumilon, Cebu[a]	Apo, Negros[a]	Balicasag, Bohol[a]	Bantayan, Negros[a]	Pamilacan, Bohol[b]	El Nido, Palawan[c]	Puerto Galera, Mindoro[c]	Western Pangasinan[d]
% Living coral cover								
Soft	9	22.8	12.3	1.3	4.8	32.6	14.5	8.4
Hard	26	29.8	23.1	17.6	12.1	41.3	28.1	3.9
Total	35	52.6	35.4	18.9	16.9	73.9	42.6	12.3
Density of target species (individuals/1,000²)								
Serranidae	7	0	7	1	0	15	5	2
Lutjanidae	9	1	8	0	6	0	2	1
Lethrinidae	4	0	2	0	1	32	4	0
Haemulidae	0	2	0	0	1	0	3	1
Total	20	3	17	1	8	47	14	4

[a]UNEP-NRMC (1984).
[b]Savina and White (1986).
[c]MSI, University of the Philippines.
[d]This study.

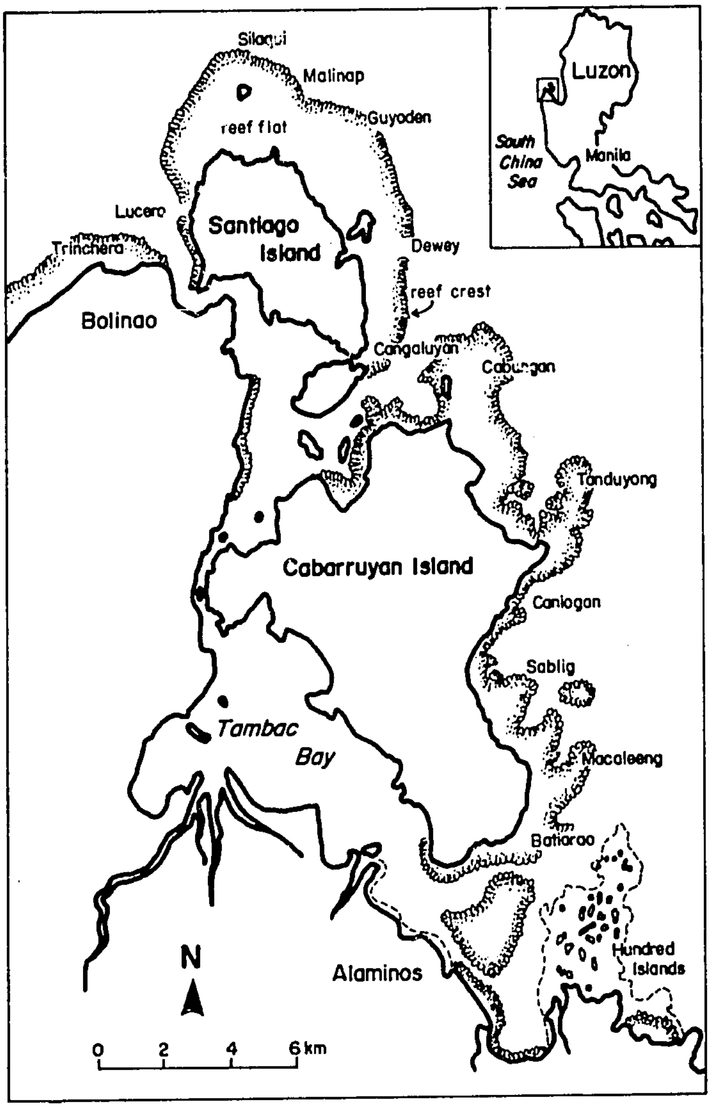

Fig. 1. Reefs fringe the islands of Santiago and Cabarruyan, located at the northwestern section of Lingayen Gulf.

The ecological history of Negombo Lagoon: an example of the rapid assessment of management issues

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ABSTRACT

The Coastal Zone Management Plan (CZMP) for Sri Lanka includes estuaries as a class of coastal habitats requiring management. The national objective for estuaries is to manage them to ensure sustainable development of these resources for multiple uses. Broad national objectives have to be translated into implementable activities for particular estuaries to achieve the desired results. A special area management plan (SAMP) provides such a plan of action. The first SAMP for an estuary under the Coast Conservation Department/USAID/University of Rhode Island Coastal Resources Management Project in Sri Lanka was prepared for Negombo Lagoon. A SAMP, however, must be responsive to the needs of the actual resource users, their conflicts and concerns; it must take into account the etiology of these issues to ensure their participation in the plan's implementation. Therefore, management issues must be identified, assessed and prioritized before a SAMP is drafted. The ecological history for a special area provides the mechanism to meet this requirement.

INTRODUCTION

The national plan and estuaries

The CZMP for Sri Lanka was prepared by the Coast Conservation Department in accordance with the Coast Conservation Act No. 5 of 1981. The general objective of the plan for estuaries is to ensure the sustainable development of these resources for multiple uses. Its specific objective is to maintain these brackishwater bodies as fisheries habitats while accommodating other uses. As long as the ecosystems of these estuaries are not impaired, they will remain available for other uses. Anent to this concept, sewage can be seen as a source of nutrients that could enhance fisheries productivity if contained within desirable levels.

Recognizing the need to manage estuaries as fisheries habitats has an important socioeconomic implication. At the broad economic level, estuarine fisheries yield, although marginal, contributes to the gross national product and is thus included in local and national planning. At the social level, the traditional practices and lifestyles of the estuarine fisherfolk identify them as a community and have a role in the framework of modern approaches to natural resources management. This recognition is significant today precisely because of its absence in the planning framework of post-independent Sri Lanka and its declared commitment to modernization (Myrdal 1972). Left out from the planning process, estuarine fisherfolk eventually became impoverished and had to resort to destructive fishing for their subsistence. Thus, the broad objectives of a national plan, however inspirational, have to be translated into clear and implementable activities to let the plan acquire value as a seminal document. A special area management plan performs this task.

Special area management plan

A SAMP responds to the particular needs of diverse users of a defined unit of water and land space. In this instance, the unit of management is the estuary and a contiguous belt of land. Estuary users in Sri Lanka do not have any experience with SAMP. Therefore, the first SAMP to be chosen for the estuary had to have users who could clearly recognize the benefits of adhering to a set of rules and guidelines that are not necessarily confluent with their traditional worldview. It had to possess attributes that would make benefits readily apparent. Negombo Lagoon was selected for this pioneering exercise.

The next logical step to make the SAMP more responsive to the needs of estuary users was to prepare an ecological history that will identify and evaluate these needs in a management context.

Ecological history

An ecological history documents the functional status of a natural ecosystem (e.g., an estuary) by analyzing the relationship between its resource users and the productive processes it undergoes, and by identifying the relevant management issues it affects. Its important feature concerns the etiology of resources use conflicts that it traces and finds to have an adverse impact say, on the Negombo Lagoon as fisheries habitats. An ecological history is expected to yield valuable information in a year's time.

METHODS

The preparation of an ecological history is a multidisciplinary exercise. In this case, it involved a fisheries biologist, an estuarine ecologist, a social anthropologist, an urban planner/ geographer and a demographer/geographer. Three of the investigators were already working on an ongoing research project at Negombo Lagoon when the others arrived. Three important considerations guided the assembly of the investigative team: familiarity with the lagoon and some of its resource users, knowledge of the relevant literature and a strong constitution.

Published and unpublished literature constituted the major source of data. Fresh ecological data collection was kept to a minimum. A questionnaire was designed to yield data that could be adopted for use in the most important management issues. The main aspects of the questionnaire pertained to:

- the household, family size, occupations of income-earning members, ownership of land and house, pattern of inheritance and kinship ties;
- income and expenses;
- community relations, participation in community activities, leadership roles, social identity and political relationships; and
- dependence on fishing in the lagoon, gear and methods, changes in catches, characteristics of superior fisherfolk and market relationships.

During the interviews, the respondents were also indirectly asked about:

- state authority over and control of lagoon use;
- the possibilities of lagoon management by the resource users without the intervention of the state;
- the expectations of present resource users with respect to the achievements of their children;
- any relationships arising from changes in the lagoon's fisheries productivity and in their methods of fishing;
- the impact of local and national politics on the relationships among lagoon users; and
- the acceptable role of the state in the management of the estuary.

The ecological history of the lagoon was intended to serve as: (1) the basis for the working documents to be used in the workshops that would precede the SAMP's formulation; (2) an educational material for participants at the workshop and generally for persons associated with the estuary as a resource system; and (3) an educational material for the secondary schools in the Grama Sevaka Divisions, areas associated with the Negombo Lagoon.

The resource users were mostly artisanal fishermen and mechanized fishing fleet owners who used the estuary as a fishing harbor, children of lagoon fishermen and politicians who regarded the lagoon fishermen mainly as a source of votes during elections. Consequently, data interpretation had to take into account the differences in the interests of the various sources so that the analytical framework would be relevant to the needs of the preparatory workshops.

The analytical framework consisted of the following major elements: (1) the management objectives of the CZMP for estuaries; (2) the ecological interaction between the estuary and its resource users; and (3) the sociopolitical factors at the local and national levels that shape estuary use. These elements were chosen for the following reasons: (1) the resource users had to be oriented on the purpose and intent of the CZMP and the possible regulatory activities of the Coast Conservation Department; (2) the estuary's ecosystem is inseparable from its resource users--they are, therefore, taken as interacting elements between which there are material connections such that the sustainability of the estuary's yields is seen as part of the result of the actions of its resource users; and (3) the resource users should be helped to recognize the various sociopolitical influences that may have determined their actions and focus their attention on the political representation required to safeguard their interests. The unifying assumption underlying the analytical framework was that the planners and resource users were committed to the sustainable use of the estuary.

RESULTS AND DISCUSSION

Some important issues identified in the process of preparing the lagoon's ecological history pertained to land encroachment, intercaste suspicion, fragmentation of the stake net fishery and mismatch between traditional perceptions and the actual functioning of the ecosystem. The complexity of the issues involved and the need to study carefully the management issues before proceeding with the plan preparation were some of the lessons learned.

Encroachment and landownership

The fastest rate of encroachment into estuarine waters is that of landfill for low-cost housing. Landfill consists of transporting earth from elsewhere, placing coconut trunks on the periphery of an intended housing plot and filling the area with material excavated from the estuary bed. A slower type of encroachment is done by planting mangroves on the border of an intended plot and allowing natural sedimentation to proceed for months or years before finally filling it with imported earth. Landfill generally occurs on state-owned intertidal land.

The predictable impact of land encroachment on the sustainability of the yields from Negombo Lagoon is best illustrated by events at Munnakkare, an island at the northern end of the lagoon (Fig. 1). The island has been occupied for more than 300 years. The earliest settlements predated Portuguese rule in Sri Lanka (Pieris 1949). This small island is linked by bridges to the town of Negombo on the north and to Duwa-Pitipana on the west (Fig. 2).

Munnakkare has a total area of about 37 ha where about 1,400 dwellings stood in 1985. These consisted of a mixture of colonial-type brick- and-mortar houses, other permanent residences and semipermanent and temporary dwellings. The temporary houses are constructed of packed mud and *cadjan* (woven coconut fronds). The floor area varies between 12 and 30 m². They are simple rectangular structures without any amenities. At least 50 more houses of this type have been constructed since January 1988 on the intertidal area at the southern end of the island. The number of dwellings at Munnakkare is expected to increase further to about 500 within the next decade (den Boer et al. 1986). If the present trend continues, house construction will further expand into the state-owned intertidal areas since those who will be putting up these houses evidently can not afford to purchase land (Figs. 3 and 4).

The population of Munnakkare exceeds 9,000 and comprises a relatively uniform social group (Table 1). They are predominantly Roman Catholic, belong to the Kurukulasuriya subcaste of the Karawe caste, and earn their livelihood mainly by fishing in the sea and estuary. A special feature of this community is that 90% of the residents have been there since birth; 82% of the children who became independent of the parental household at marriage chose to build their houses also on the same island. Thus, the population of Munnakkare is expected to increase to 12,000 within the next decade. Moreover, it is likely that the majority of this population will continue to reside there.

The main source of income of Munnakkare residents, as mentioned above, is fishing. A household's average monthly income varies, but it is around Rs1,000[a] (US$30). The minimum monthly income required by a household is twice this amount. Thus, this category of residents, the squatters on state-owned intertidal land, use whatever fishing method is available to generate income. The push-net is the most recent (1988) addition to their list of destructive fishing methods.

Low-cost housing construction at Munnakkare and elsewhere in Sri Lanka has been directly linked to the Hundred Thousand Houses Programme (HTHP) initiated in 1978 and the One Million Houses Programme (OMHP) which followed in 1984. These programs of the Ministry of Local Government and Housing were implemented through an organizational structure (Fig. 5) that was linked to the house owner by way of nongovernmental organizations (NGOs). Housing construction under this program rapidly became a house-count exercise in which semipermanent and improvised housing contributed about 50% to the target. Legalizing the ownership of housing plots under these programs was greatly facilitated by

[a]March 1990: Rs = US$1.00.

group application. Thus, housing in the intertidal areas of Munnakkare benefited from this scheme since ownership of a house was given high priority at the national level.

CZMP objective: habitat functioning

The management of the Negombo Lagoon for sustainable fisheries yield depends on maintaining: (1) functional water space; (2) recruitment of planktonic larvae of commercially important fish and crustaceans from the sea during high tide; and (3) retention of seagrass beds in the shallow intertidal and subtidal areas that have critical functions as nursery and breeding areas. About 70% of fish and crustacean larvae that support commercial and subsistence fisheries are carried into the estuary during tidal inflow (Pillai 1965). In the absence of such recruitment, fisheries yield declines drastically. Thus, the sandbars that block the mouths of lagoons along the southwestern and southern coasts of Sri Lanka already inhibit recruitment. Following recruitment, the early benthic stages of penaeid shrimp utilize seagrass beds in the estuary as a nursery area (Samarakoon and Raphael 1972). These seagrass beds are also used as a breeding site by the indigenous estuarine cichlid fish (*Etroplus* spp.), which contribute substantially to fisheries yield (Ward and Samarakoon 1981). Therefore, to maintain the fisheries, the encroachment into estuarine water space must be prevented.

The socioeconomic status of the residents of Munnakkare who are most inclined to squatting on intertidal state land continues to decline. These residents are trapped in a spiral of activities that degrade the estuary as fisheries habitats. However, they may be motivated to adopt a realistic approach in exploiting the estuarine habitat on a sustainable basis if: (1) economic activities not dependent on the estuary are promoted and/or (2) the estuary's productivity is substantially increased by way of novel technology. While these approaches are meant to stabilize the present incomes of the residents of Munnakkare, they can become ineffective in the face of inflation, rapid population increase and emotive politics.

Moreover, the political objectives of the national housing programs do not accommodate the environmental stability of an estuary or the sustainable use of its natural resources. Furthermore, the publicity and effective campaigning that characterize the programs override such concerns.

CONCLUSION

This paper discussed the effectiveness of preparing an ecological history for the rapid assessment of management issues. The achievement of the desired results, however, rests on the selection of a special target area and the well-screened assembly of an investigative team. For the Negombo Lagoon and the squatter area on the intertidal land at Munnakkare, the ecological history has brought to light the complexity of the issues they face. Without this ecological history, a simplistic and self-destructive management approach may have been thought of instead.

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Table 1. A general socioeconomic profile of the Munnakkare residents (den Boer et al. 1986).

Social feature	Distribution (%)
Religion	
Roman Catholicism	95
Buddhism	3
Others	2
Total	100
Caste	
Karae	
Kurukulasuriya subcaste	82
Durawe	15
Others	3
Total	100
Occupation	
Fishing	60
Trading (mainly on Munnakkare)	10
Local crafts and industries	10
Well-paying job outside Munnakkarre	10
Unemployed/occasionally employed	10
Total	100

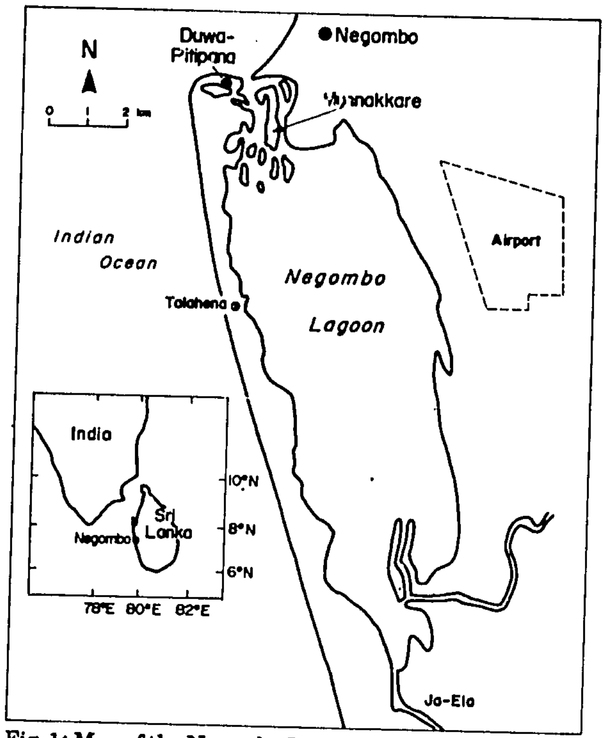

Fig. 1: Map of the Negombo Lagoon.

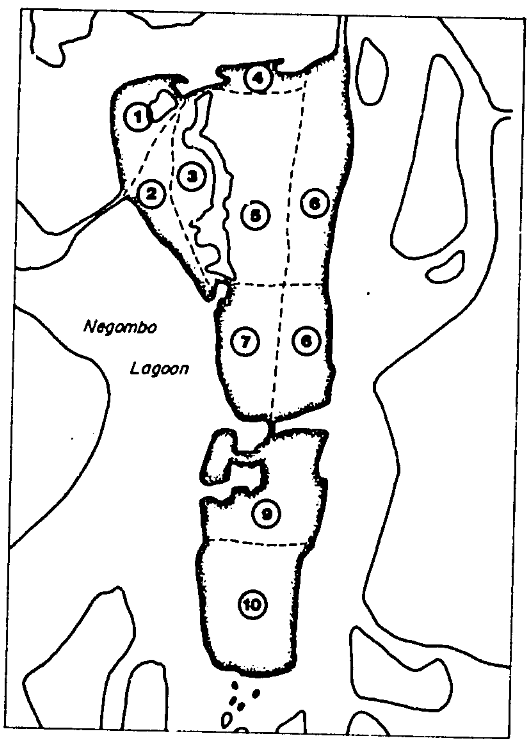

Fig. 2. Map of Munnakkare. The encircled numbers indicate the constituent areas: Mankuliya, 1-3; St. Nicholativu, 4-8; Sir Sirikurusawatte, 9-10. The most intensive colonization of the intertidal areas is occurring at Sirikurusawatte (den Boer et al. 1986).

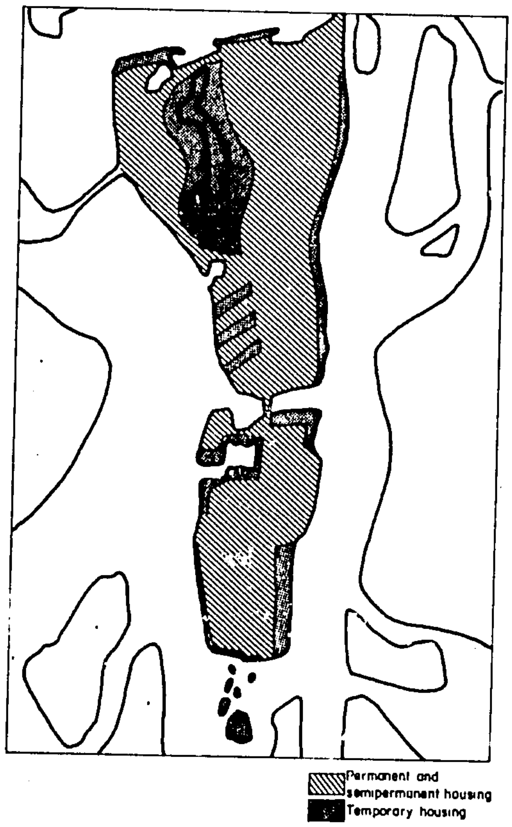

Fig. 3. The pattern of housing expansion at Munnakkare. Squatting occurs on the intertidal areas (note patches at the southern tip of Sirikurusawatte).

Fig. 4. The predictable pattern of housing expansion in the Negombo Lagoon (den Boer et al. 1986). Over the long term, the existing channels may close or become severely constricted. These channels are already getting narrower.

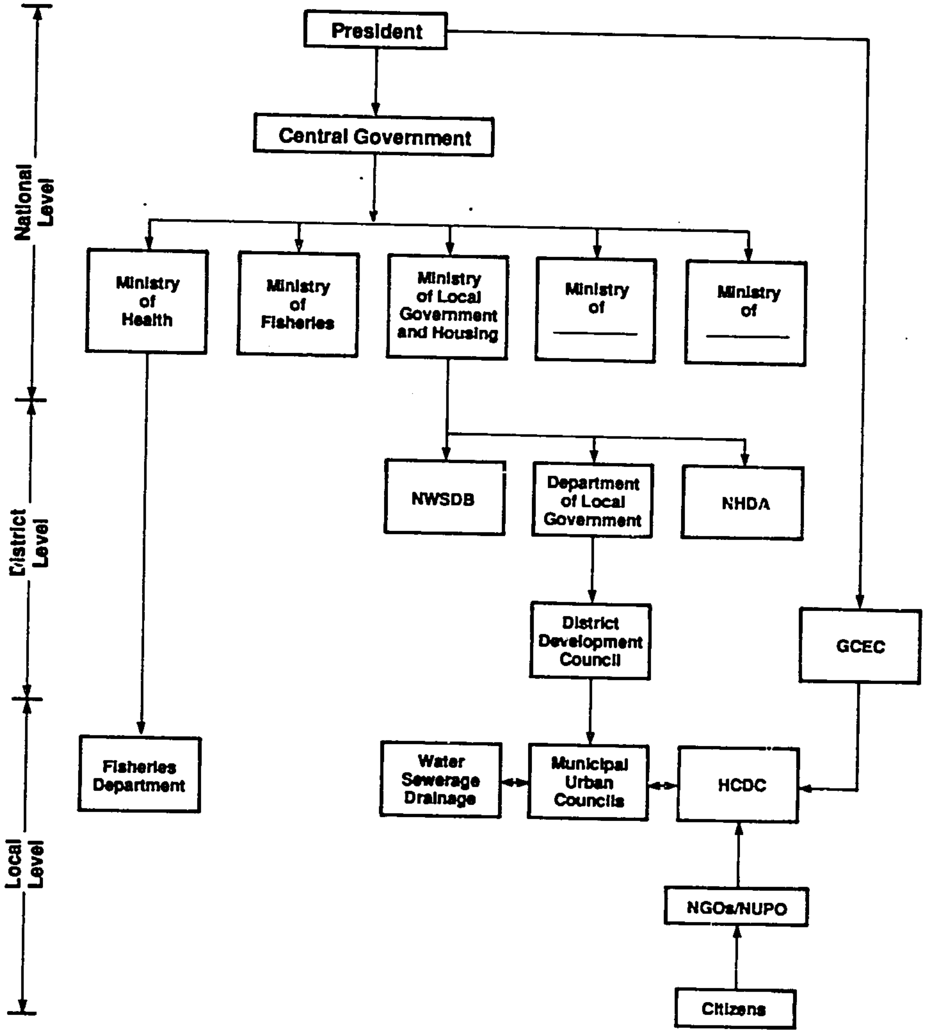

Fig. 5. The organizational structure linking the squatters on intertidal land at Munnakkare with the Offices of the President and the Minister of Local Government and Housing. (NWSDB: National Water Supply and Drainage Board; NHDA: National Housing Development Authority; GCEC: Greater Colombo Economic Commission; HCDC: Housing Community Development Committee; NUPO: Negombo United People's Organization; and NGOs: Nongovernmental organizations.)

Session IIA
Environmental Degradation

Environmental impact due to pollutant discharge in Johore Strait

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ABSTRACT

Rapid development and industrialization in Southern Johore are likely to cause significant environmental degradation in Johore Strait due to the large quantity of pollutants being discharged into it. An assessment of these possible environmental impacts is needed to provide crucial planning parameters to preserve and enhance environmental quality consistent with the needs for development. This paper presents such an assessment using simulation models.

INTRODUCTION

Johore Strait (Fig. 1) receives domestic and industrial waste discharges from Johore Bahru and Pasir Gudang and from a number of rivers. The two major rivers which discharge into the straits are Skudai and Tebrau between the estuaries of which lies Johore Bahru. Other rivers draining into the straits are much smaller and not of much consequence in terms of pollution load, except Segget River, which is grossly polluted by domestic sewage. The fecal coliform (FC) level was estimated to be about 10^7 MPN/100 ml (Envilab 1985) near the mouth of the river.

The causeway effectively divides Johore Strait into the eastern and western portions. This results in stagnant bodies of water on both sides of the causeway extending to the Skudai and Tebrau estuaries. Since Segget River discharges into the western portion of the strait close to the causeway, and the seafront of Johore Bahru west of the causeway possesses a high amenity value, there is an increasing concern about the capability of the western portion of the strait to dilute and disperse the urban waste effectively.

This paper presents an assessment of the impact of urban waste discharge on Johore Strait (western portion) close to the causeway using simulation models.

SIMULATION MODELS

The transport, dispersion and eventual degradation of pollutants in Johore Strait depend on the strength and direction of the tidal current, the dispersion coefficients and the FC decay rate, respectively. Simulation of this phenomenon subject to various operating conditions can be achieved by computer models (i.e., hydrodynamic and advection-diffusion models). This section describes the advection-diffusion model that uses the tidal flow regimes generated from the hydrodynamic model and other inputs to simulate the transport and decay of pollutants. It is assumed that the water column is shallow and vertically well mixed.

The advection-diffusion model consists of the following vertically integrated two-dimensional equation, which is solved by the finite element method:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} - \frac{1}{H}\frac{\partial}{\partial x}\left(H.k_x\frac{\partial c}{\partial x}\right) - \frac{1}{H}\frac{\partial}{\partial y}\left(H.k_y\frac{\partial c}{\partial y}\right) + \alpha c - R = 0$$

where k_x, k_y are the dispersion coefficients in x, y directions, respectively; c, the vertically averaged concentration of a single neutrally buoyant pollutant; α, the decay constant; H, the total depth of the water column; and R, the source-sink term.

RESULTS AND DISCUSSION

Fecal coliform (FC) was chosen as the pollutant model since the proposed water quality criterion for bathing waters is based on the FC level. The most frequently quoted criterion of 200 MPN/100 ml was recommended by the United States Environmental Protection Agency (USEPA 1976), which is also the proposed criterion for bathing waters in Malaysia (DOE-UM 1986).

Since dye tracer studies have not yet been conducted to determine the dispersion coefficients in Johore Strait, it was decided that the results obtained from a similar study conducted at the Western Channel of Penang (Koh et al. 1987) be used. This study site shares similar hydrographic and meteorological conditions as Johore Strait. The Western Channel study estimated the following values for the input parameters required in the simulation model:

$$k_c = 1\ m^2\ s^{-1},$$
$$k_a = 30\ m^2\ s^{-1} \text{ and}$$
$$T_{90} = 3 \text{ hours}$$

where k_c and k_a are the cross-flow and along-flow dispersion coefficients, respectively; and T_{90}, the time needed for a 90% reduction to take place in the FC density.

The discharge rate of Segget River into the strait is taken to be $5.3 \times 10^3\ m^3\ day^{-1}$ with a mean FC density of 1×10^7 MPN per 100 ml based on the findings of Envilab (1985).

Fig. 2 shows the simulated tidally averaged FC concentration contours. The FC level is in the region of 4,000 MPN/100 ml at the river mouth and decreases rather drastically to less than 50 MPN/100 ml near the Lido Beach area. This indicates a highly localized polluted area due to a practically zero flow near the causeway.

The mean FC levels determined at the Department of Environment's (DOE) marine monitoring stations located at the western portion of Johore Strait for 1985-1987 are shown in Table 1. It was observed that the FC levels measured off the Lido Beach and the surrounding areas were very much higher than the simulated results. This indicates that the microbial pollution at the beach area was most likely contributed by other nearby sources such as Skudai River, which has a mean discharge rate of $2.0 \times 10^5\ m^3\ day^{-1}$ (JICA 1985) with a mean FC density of 6.3×10^3 MPN per 100 ml at station 1536610 (DOE-UM 1986 data).

The simulated FC level at Segget River is about one order of magnitude lower than the measured value (at about 1×10^4 MPN/100 ml). This indicates that there are other significant sources nearby contributing to the microbial pollution.

Even at the present input of pollution load, close to the causeway Johore Strait is found to be incapable of providing adequate dilution and dispersion to reduce the pollutant (FC) level to satisfy the water quality criteria for recreational waters. If no physical modifications to the causeway are anticipated to enable better tidal flushing of the strait, the only effective measure that can be adopted to preserve the amenity value of the area is to reduce the microbial load of the discharges from Segget, Skudai and other major sources to an acceptable level. This would entail the implementation of a comprehensive water quality management scheme at both regional and local levels.

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Table 1. Mean FC levels in the western portion of Johore Strait for 1985-1987. (See Fig. 2).

Section name	FC (MPN/100 ml) 1985	1986	1987
Melayu River	1.5×10^2	4.7×10^1	4.3×10^1
Skudai River	4.0×10^3	3.2×10^3	6.9×10^2
Lido Beach	2.2×10^4	9.8×10^2	6.5×10^2
Hospital	7.3×10^3	6.9×10^3	1.3×10^3
Segget River	1.2×10^4	1.5×10^4	1.3×10^4

Source: DOE-UM 1986.

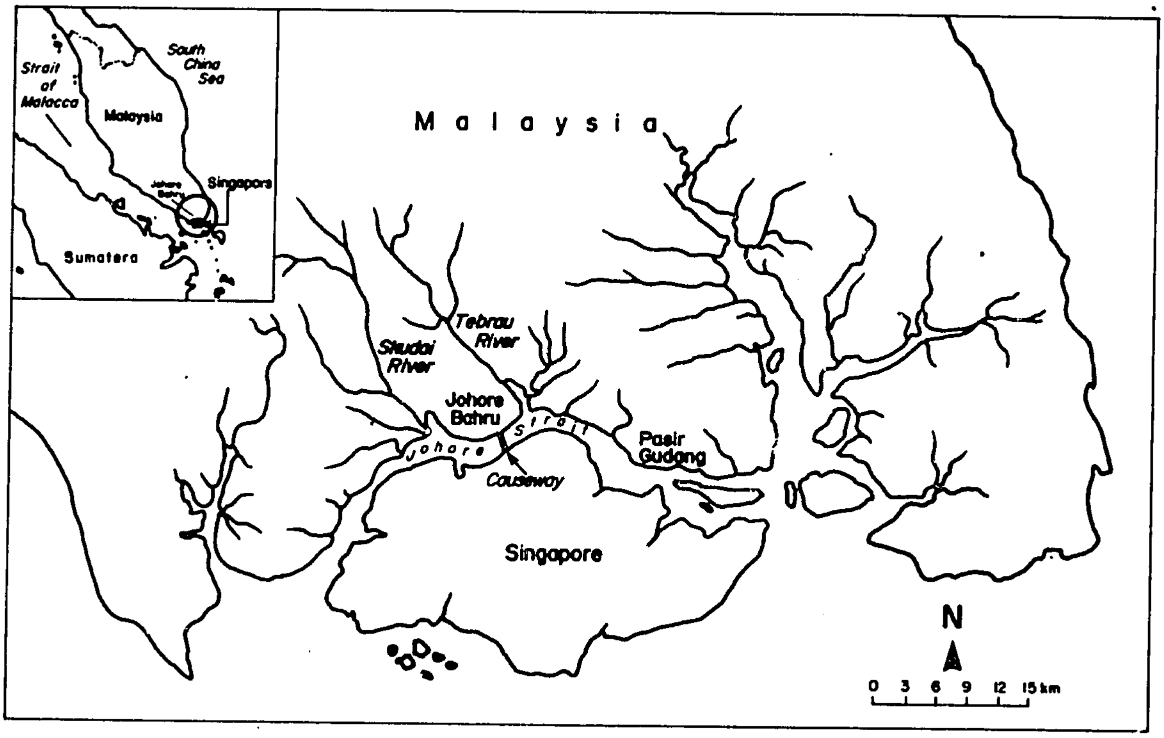

Fig. 1. Location map of Johore Strait.

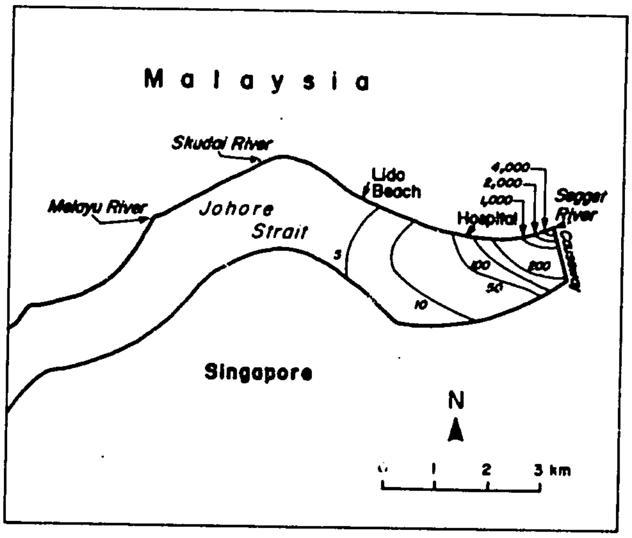

Fig. 2. Tidally averaged FC densities (MPN/100 ml) in the western portion of Johore Strait.

Water quality status and management of South Johore, Malaysia

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ABSTRACT

The inland and coastal waters of South Johore are subject to various types of pollution arising from human activities. Aside from domestic sewage, other materials discharged into the receiving waters include organic waste from agro-based industries such as palm oil mills and rubber processing factories and industrial waste from factories. If left unchecked, pollution would result in the degradation of the water quality and ultimately limit the beneficial uses of inland and coastal waters.

This paper presents an assessment of the status of the water quality of rivers and coastal waters in South Johore and analyzes the water quality trend over the past 10 years. Management strategies to mitigate water quality degradation are also discussed.

INTRODUCTION

South Johore is among the fastest growing regions in Malaysia in terms of population and economy. Within Johore Bahru, there has been a great increase in industrial activities, with the setting up of various industrial estates and the concomitant increase in population. The increase of sewage and industrial waste discharges into the waterways has resulted in the gross pollution of some rivers and surrounding coastal waters.

North of Johore Bahru, in the hinterland of Johore, there have also been rapid land use changes in which vast tracts of forests have been converted into tree crop plantations, notably rubber and oil palm. The processing of these agricultural crops has generated a large amount of waste, which is eventually discharged into the rivers and thus greatly increases the organic load of the water.

Besides these pollution sources, livestock industries found in various parts of South Johore also generate considerable waste.

In view of such rapid changes and, consequently, pressure on the waterways, there is an urgent need to manage the water quality of South Johore to minimize the pollution problems and optimize the beneficial uses of inland and coastal waters.

THE RIVER SYSTEMS OF SOUTH JOHORE

The Department of Environment (DOE) has placed water quality monitoring stations in nine major rivers. The total catchment area is about 6,000 km^2. The rivers in the Pontian District are Benut, Air Baloi, Pontian Kecil and Pontian Besar, which drain toward Malacca Strait. In Johore Bahru, the rivers are Skudai, Tebrau and Johore, which discharge into Johore Strait. In Kota Tinggi, the major rivers are the Sedili Besar and Sedili Kecil, which drain into the South China Sea. The general location of these rivers is shown in Fig. 1.

Water quality status

DOE has been monitoring water quality of rivers and coastal waters since 1978. Over the years, the number of water quality parameters used for monitoring rivers has increased to over 20 variables in 1987. However, it is difficult to assess the water quality status based on so many parameters as some may be able to meet prescribed standards while others may not. Thus, the use of an appropriate water quality index (WQI) (i.e., a set of parameters considered important in characterizing water quality that are related to a common scale) would be more beneficial for administrative and management purposes and for meaningful communication with the public.

The computation of the general WQI of the rivers was based on the procedure adopted by the United States National Sanitation Foundation (USNSF) WQI (Brown et al. 1970). A total of seven parameters--biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, suspended solids (SS), ammonia-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N), were selected with the weighted factors to compute the mean WQI at each water quality monitoring station. The index values were then related to five descriptor words on water quality as suggested by McClelland et al. (1976). These were:

WQI	Descriptor Words
0 - 25	Very bad
26 - 50	Bad
51 - 70	Medium
71 - 90	Good
91 - 100	Excellent

Finally, the water quality data of the nine major rivers collected over the years were converted to their WQI. Lim and Leong (1988) presented the current water quality status of the rivers using different colors to indicate the existing water quality at various stretches of the rivers.

To compare the water quality status of the rivers and their changes over the past three years, the maximum, minimum and average values of the annual mean WQI for each river in 1985, 1986 and 1987 are plotted in Fig. 2. The water qualities of the Tebrau and Sedili Besar Rivers are consistently better than those of Benut, Pontian Besar, Pontian Kecil and Skudai for the past three years, based on their general WQI. There is a noticeable decline in the overall water quality of the rivers in 1987 compared to earlier years. Nevertheless, most of the rivers are still categorized as "medium" or "good" except for certain stretches of Air Baloi and Skudai, which have been categorized as "bad".

Fig. 3 displays the water quality trend at each monitoring station for the period that the monitoring program was implemented. The rivers' water quality generally deteriorated toward the estuaries, indicating multiple inputs of pollutants along the river systems. Fig. 3 also indicates that the water quality of Benut, Skudai and Sedili Besar declined significantly from the late 1970s to 1983. But this downward trend was arrested and, in fact, there was a marked improvement in the water quality in subsequent years until 1986. With regard to the water quality classification, only two monitoring stations consistently belong to the "bad" category. These are Station No. 1632601 and Station No. 1633602, which are found at Benut and Air Baloi Rivers, respectively. Both stations are located relatively downstream of these rivers.

Pollution sources

The main pollution sources in the region are: (1) domestic waste from cities and towns; (2) agro-based waste from palm oil mills, rubber and pineapple-processing factories; (3) waste from factories in industrial estates and (4) animal wastes from stock farms.

Organic wastes from these identified sources constitute the most significant form of pollutants adversely affecting the water quality of inland and coastal waters.

According to DOE (1988), the percentage of the BOD load being discharged into the rivers by various pollution sources in 1987 was estimated as follows: domestic sewage (54%); animal waste (26%); industrial waste (17%) and agro-based waste (3%). These show that domestic sewage demands attention as a pollution source and has a bearing on the type of management strategies to be adopted in mitigating water quality degradation in South Johore.

COASTAL WATERS

Coastal waters receive pollutants either through direct discharges from coastal activities or indirectly through rivers which may be polluted from inland activities. Special attention has been given to Johore Strait, in particular, since it receives waste discharges from human activities in South Johore and Singapore. On the Johore side, the strait receives water discharges from Johore Bahru, Pasir Gudang and also river discharges from Skudai and Tebrau, which flow past the most populated areas in South Johore. Thus, out of the 13 DOE marine water quality monitoring stations, nine are located in Johore Strait (Fig. 1). Over 20 water quality parameters of coastal waters, including physicochemical and microbial parameters and heavy metals, were monitored at these stations.

Water quality status

Unlike rivers, there is as yet no single value index that can be employed to characterize seawater quality. Consequently, the water quality status is assessed using the proposed criteria for the specific beneficial uses of the coastal waters of South Johore, primarily recreational, aquaculture and navigational uses.

Recreational use

To protect human health, the need for water quality criteria for coastal waters used for primary contact recreational purposes, such as bathing and swimming, has long been recognized. In response to this need, various criteria and guidelines have been established based on microbial indicator systems. Among others, the US Environmental Protection Agency (USEPA) (1976) recommended that the fecal coliform (FC) bacterial level should not exceed a log mean of 200 MPN/100 ml, based on a minimum of five samples over a 30-day period, for bathing waters. This is also the proposed criterion for bathing waters in Malaysia (DOE-UM 1986).

The mean FC levels determined at the 13 DOE monitoring stations from 1985 to 1987 are shown in Table 1. Based on the proposed Malaysian criterion for bathing waters, this table shows that only two sites in the strait, which are located at the estuaries of the Melayu and Masai Rivers, satisfied the criterion. The four other monitoring sites outside the strait also met the criterion.

The FC data also indicate that the western portion of the strait close to the causeway is consistently more polluted than the eastern portion in terms of microbial pollution as most of the urban wastes from Johore Bahru are being discharged there. Although there is some noticeable reduction in the FC levels detected at Pantai Lido and Kuala Sungai Skudai in the past two years, the overall microbial pollution remains high and has certainly decreased the recreational potential of the western portion of the strait.

Aquaculture use

The setting of water quality criteria for aquaculture use of coastal waters is necessary for the protection of human health as well as for the propagation of aquatic species. However, water quality criteria for human health protection should be of paramount importance. Among the aquatic species cultured for human consumption, shellfish, being filter feeders, require water of high quality to be microbiologically safe for eating. One of the most widely quoted criterion for shellfish-harvesting waters is that of the USEPA (1976), which recommended that the medium FC bacterial concentration should not exceed 14 MPN/100 ml for harvesting shellfish.

Based on the USEPA criterion for shellfish-harvesting waters, only one site--Luar Pantai Kukup (1334925)--was found to be satisfactory for all three years of data.

The microbial criterion for harvesting shellfish, however, is considered to be too stringent for other marine species that are not filter feeders. Thus, other less polluted sites such as Kuala Sungai Melayu and Kuala Sungai Masai may be suitable for finfish and prawn cultures from the human health protection standpoint.

At this stage, it is still not yet possible to grade the suitability of the coastal waters for the propagation of aquatic species due to the lack of field data and the absence of published criteria.

WATER QUALITY MANAGEMENT

As can be seen in the preceding sections, the water pollution problems of rivers and coastal waters, especially at the strait, are serious and are expected to increase given the projected rate of economic development and population growth.

A number of different approaches have been taken for the control and management of the water quality. One approach was the adoption of various legal measures that would specify the permissible levels of pollution of the different sources. This was seen in the enactment of the Environmental Quality Act of 1974 and the subsequent enforcement of various regulations under the provisions of the act.

In the enforcement of regulations, the underlying principle is that of pragmatism. This means that the effluent standards are set, taking into consideration the practical situation. For instance, the effluent standards for agro-based industries were progressively tightened over the years to allow the industries time for compliance and to ensure that enforcement is not economically disruptive.

Nonetheless, there are still shortcomings in the act's regulations as they are not comprehensive enough. There are various types of discharges that are not covered such as those of hazardous and piggery wastes. It is hoped that, eventually, such shortcomings will be redressed and standards set for these wastes. Another problem is the weakness inherent in the establishment of effluent standards as a means of environmental protection. While it is possible for all the factories to comply with the standards, the total levels in the environment would still be unacceptable when all the discharges are added (Lim 1983).

The other approach was through some form of environmental planning that would seek to prevent or at least minimize environmental problems in the planning stage. At the project level, this can be seen in the introduction of the requirements of an Environmental Impact Assessment (EIA) for various projects, which came into effect on 1 April 1988 in Malaysia. At the level of program or policy, environmental considerations have not been legally mandatory. For example, in the planning of land development schemes, implementation of industrialization policies and regional development plans, environmental considerations are taken into account only occasionally.

At present, the EIA requirement is still in its early stages of implementation, thus how effective it will be in minimizing the adverse environmental impacts of development projects remains to be seen. However, it is a tangible indication of the intention of the government to improve environmental quality.

Since EIA deals with environmental issues at the project level, it is possible that environmental conflicts would still occur even if EIAs were conducted for projects, when incompatible forms of coastal zone uses have already been established such as the siting of industries next to aquaculture areas. This can, and should be, avoided at the regional plan level.

ENVIRONMENTAL MANAGEMENT ISSUES

Incompatibility of coastal zone uses

The coastal zone can be regarded as an ecosystem in which different components are linked together by the various ecological processes. The modification of one part of the ecosystem can have adverse impacts on its other parts. For example, the destruction of mangroves affects the productivity of the surrounding coastal waters because the mangroves are the feeding and breeding grounds of many commercially important species of prawns and other finfishes. These impacts are well documented in scientific literature.

Because the various components of the ecosystem are linked together in many ways, some activities in one part of the coastal zone may also be incompatible with another. An example would be the siting of aquaculture areas close to industrial estates or urban centers in South Johore. The industrial wastes and sewage discharged into the waterways would result in the contamination of the sediments and coastal waters, rendering aquaculture activities, such as shellfish culture or fish cage culture, unsuitable. Given that industrial activities, urban centers, aquaculture, agriculture and recreation will increase in the future, one of the key requirements in avoiding conflicting coastal zone use would be to ensure compatibility by some form of coastal use zoning. The planning of a coastal zone's use would need to consider all competing uses of the area.

Poor coordination of pollution control

Some of the water pollution problems of South Johore do not fall under the jurisdiction of any of the government departments and agencies that normally deal with water pollution problems. A case in point is that of piggery waste and that of the livestock industry's. Despite the attention to this problem over the years, there is no one department or agency that has direct jurisdiction in managing and controlling this problem. As yet, the DOE does not have any effluent standards for such a type of waste, unlike the case of palm oil mill effluents or industrial discharges. The jurisdiction of the Department of Agriculture does not extend to discharges into waterways, while that of the Fisheries Department covers the situation only when fisheries are affected.

Therefore, there is a need for better coordination to deal with all the various forms of water pollution and to strive for an improvement in water quality.

There is also a need for better coordination of water quality management across the national boundary. In view of its proximity to Singapore and the significant contribution of pollution to the coastal waters, particularly Johore Strait, water pollution control will have to be coordinated with Singapore if it is to be effective.

Absence of certain environmental information

One of the requirements for an effective water quality management program is the availability of systematic and current environmental information. While there exists a considerable amount of data on the source strengths of palm oil mills and rubber processing factories, the information on other sources of pollution, notably industrial sources and other diffused sources, is often inadequate and incomplete. While this is due to insufficient resources and manpower, this situation will hopefully improve in the future.

With regard to environmental quality, a comprehensive monitoring network has already been established nationwide to provide valuable base line information. However, data gaps pertaining to certain important pollutants such as pesticides still exist. Again, the collection of such information requires more allocation of financial resources and manpower.

Inadequacy of sewage treatment systems

One of the most important sources of organic pollution in the waterways is the discharge of untreated or partially treated sewage and sullage water. With the population of South Johore expected to grow about 5% a year, this means that the population would double approximately every 15 years. This would place great stress on the existing treatment systems that are already inadequate (Bumi-Watson 1982). Thus, sewage and sullage water pollution are anticipated to become the two major problems in the water quality management of South Johore.

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Table 1. Mean fecal coliform (FC) levels of coastal waters in South Johore for 1985-1987.

WQMS Name	WQMS No.	FC (MPN/100 ml) 1985	1986	1987
(L) Luar Pantai Kukup	1334925	3.0×10^0	3.8×10^1	3.0×10^0
(A) Kuala Sungai Melayu	1437940	1.5×10^2	4.7×10^1	4.3×10^1
(B) Kuala Sungai Skudai	1437922	4.0×10^3	3.2×10^3	6.9×10^2
(C) Pantai Lido	1437921	2.2×10^4	9.8×10^2	6.5×10^2
(D) Hospital	1437920	7.3×10^3	6.9×10^3	6.6×10^3
(E) Kuala Sungai Segget	1437919	1.2×10^4	1.5×10^4	1.3×10^4
(F) Tunku Ismail Power Station	1437951	6.8×10^2	5.5×10^2	3.5×10^2
(G) Kuala Sungai Tebrau	1438943	2.9×10^2	3.4×10^3	8.4×10^2
(H) Kuala Sungai Masai	1438918	2.8×10^1	3.4×10^4	7.0×10^1
(I) Pasir Gudang	1436939	1.6×10^2	1.1×10^3	7.4×10^2
(J) Kuala Sungai Johor	1440916	5.0×10^0	7.0×10^0	4.0×10^0
(P) Pantai Desaru	1542914	1.7×10^1	1.4×10^2	ND
(T) Teluk Mahkota	1841911	-	2.5×10^1	1.0×10^2

Source: DOE 1988.
ND-Not detected.

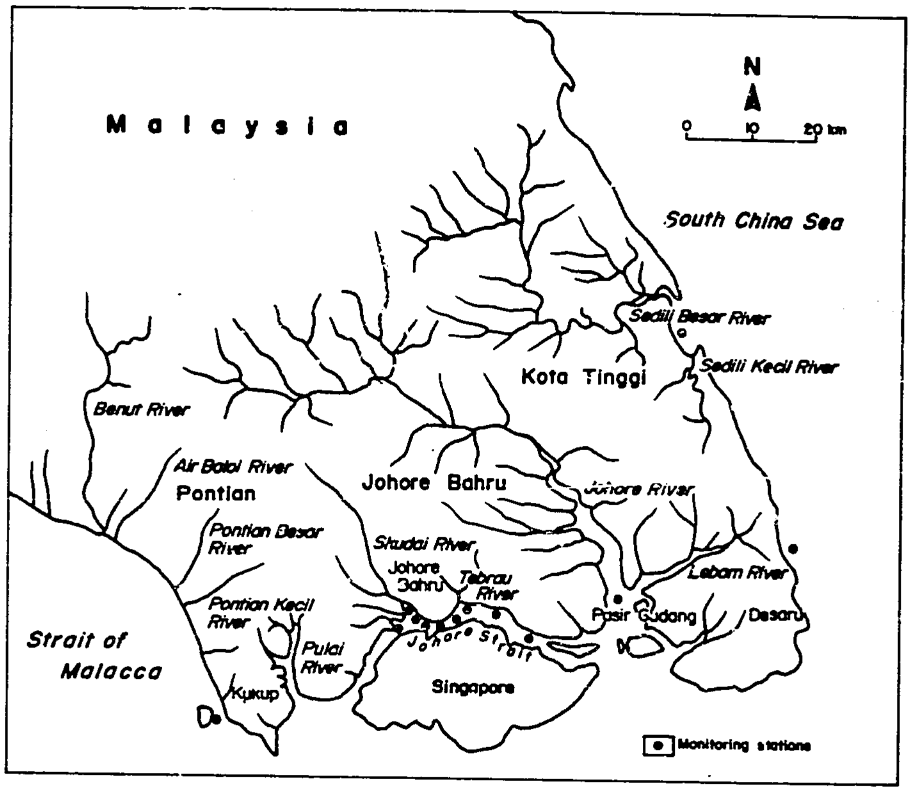

Fig. 1. Major rivers and marine water quality monitoring stations in South Johore.

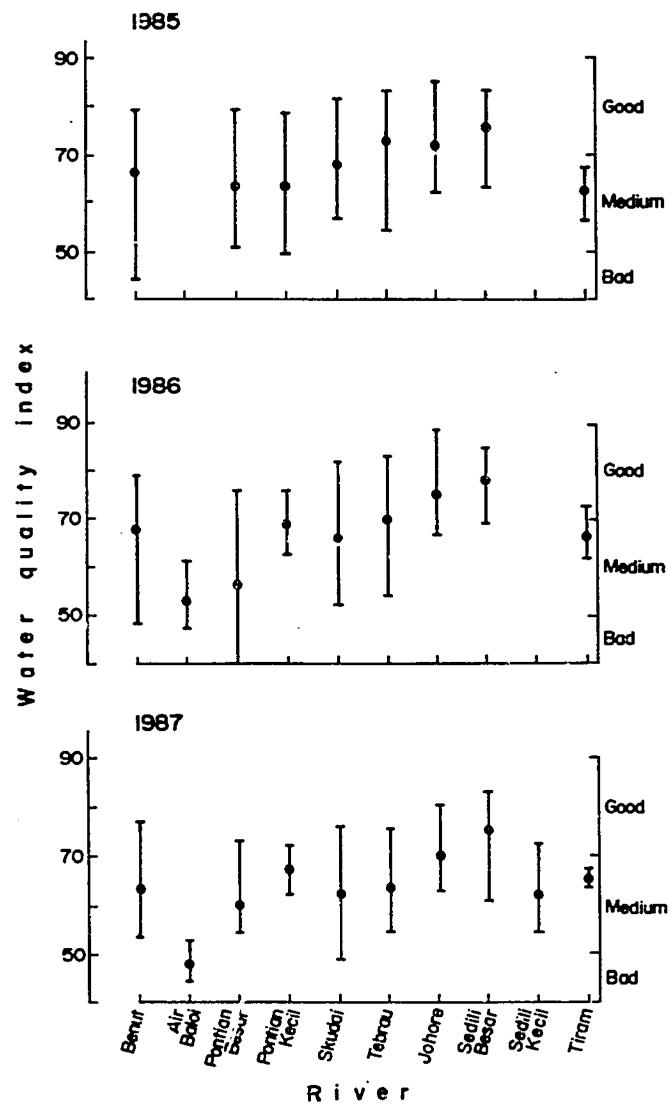

Fig. 2. Ranges of water quality index for selected rivers in South Johore.

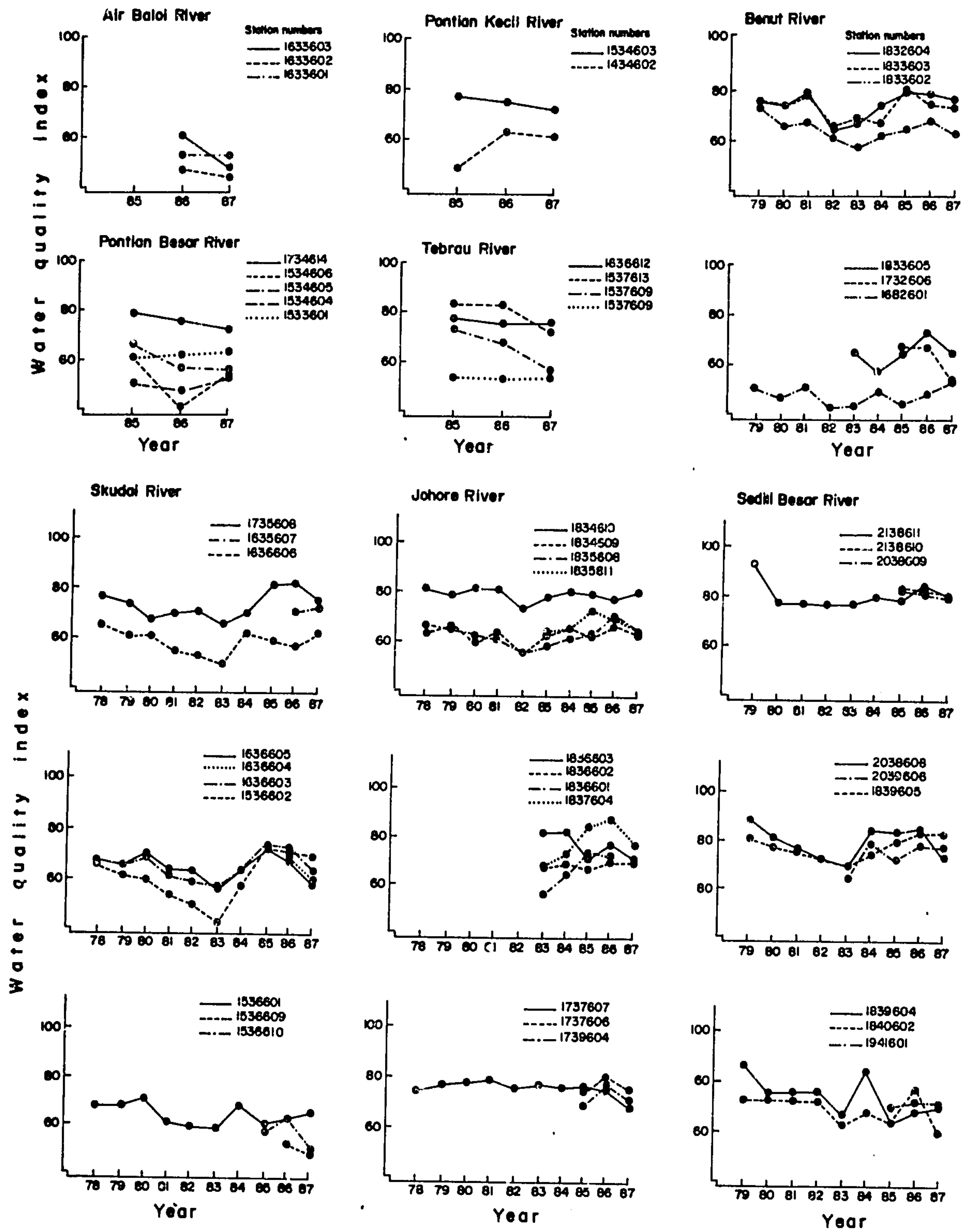

Fig. 3. Water quality trends at DOE monitoring stations.

Simulation of hydrodynamic regimes in Johore Strait, Malaysia

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ABSTRACT

Johore Strait (Selat Johor) separates the island of Singapore from Peninsular Malaysia over a distance of about 50 km between the estuaries of Sungai (Sg. throughout this text; it means "river") Pulai to the west and Sg. Johore to the east. The strait is divided by the causeway linking Singapore to mainland Malaysia.

The primary hydrodynamic force acting on this semi-enclosed body of water is tidal. The current is driven primarily by the astronomical tide entering at the end near Tanjung (Tg. throughout this text; it means "cape") Changi in the east and Tg. Merawang (Singapore) in the west. Since the end of the causeway is closed due to the shutting of the balancing culverts across the causeway, the normal flow at the causeway's end is essentially zero, thus resulting in a standing wave propagation.

The characteristics of these tidal movements will significantly influence the transport characteristics of the strait and the dispersion of pollutants into the causeway. This paper presents a finite element analysis and simulation of the tidal movements.

INTRODUCTION

Johore Strait separates the island of Singapore from Peninsular Malaysia over a distance of about 50 km between the estuaries of Sg. Pulai to the west and Sg. Johore to the east. The strait is divided into two by the causeway linking Singapore to the mainland. Fig. 1 shows the location of Johore Strait while Figs. 2a and 2b show some salient features in the eastern and western portions of the strait, respectively.

Located around latitude 1°26'N and from longitude 103°35'E to longitude 104°E, the eastern portion of Johore Strait is about 26 km long and varies in width from 1 km at the causeway to about 3 km at the eastern end near Tg. Changi (Singapore). The western portion is roughly similar to the eastern portion in length and shape.

The primary hydrodynamic force acting on this semi-enclosed body of water is tidal. The current is driven primarily by the astronomical tide entering at the end near Tg. Changi in the east and Tg. Merawang (Singapore) in the west. Since the end of the causeway is closed due to the shutting of the balancing culverts across the causeway, the normal flow at the causeway's end is essentially zero, thus resulting in a standing wave propagation.

Urban centers, industrial estates and a wide spectrum of developments exist on both sides of the strait. Since the strait is at the receiving end of the sewage systems on both of its sides, it is essential to study its hydrodynamic regime for this has a significant influence on its transport characteristics and the dispersion of pollutants into it. This paper presents the results of a finite element analysis and simulation of the tidal movement in the eastern portion of the strait. An attempt is also made to simulate the tidal movement in the western portion by using similar input conditions as those for the eastern portion.

HYDRODYNAMIC MODEL

Since the entrance to the strait is quite wide, a two-dimensional horizontal model is required to simulate the hydrodynamic regime in this area. No data on the degree of mixing in this area are available. However, in this model, the strait is assumed to be well-mixed--the variation of water density over depth is negligible and the driving force is the horizontal variation of pressure caused by the surface slope of the water. This assumption is plausible since there is no major river with a large upland catchment in the area. A vertically well-mixed condition was also observed in the western and southern channels of Penang by Koh and Zubir (1987). Since the climatic and meteorological conditions and the physical configurations of the western and southern channels are similar, the same holds true for Johore Strait as far as the mixing regime is concerned.

Based on the equations of fluid motion and continuity, the depth-integrated, two-dimensional models used by Koh (1986 and 1988) are:

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}(uH) + \frac{\partial}{\partial y}(vH) = 0 \; . \qquad \text{(i)}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu + g\frac{\partial \eta}{\partial y} + K\frac{v\sqrt{u^2+v^2}}{H} - \frac{\tau^y}{H} = 0 \; , \qquad \text{(ii)}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - fv + g\frac{\partial \eta}{\partial x} + K\frac{u\sqrt{u^2+v^2}}{H} - \frac{\tau^x}{H} = 0 \; , \qquad \text{(iii)}$$

In the above formulation, u and v refer to the current velocities in the x and y directions, respectively; g, the gravity; H, the depth below mean sea level; η, the water elevation above mean sea level; and K, the bottom friction coefficient.

In the tropics, the Coriolis term f may be set to zero. The second to the last term in equations (ii) and (iii) above accounts for the frictional losses at the bottom of the channel, with the friction coefficient taken as K = 0.0025. The last term in the same set of equations refers to the wind stress, which is conceived to act as a body force throughout the water column.

The complete set of equations is solved numerically. Although various numerical approaches are available to solve problems involving tidal phenomena, a finite element method is used in the study. General implementation of the hydrodynamic model by the finite element method has been discussed by many researchers such as Kawahara et al. (1983) and Koh (1986 and 1988).

Boundary conditions

There are two standard ports in the area (i.e., Pasir Gudang and Sembawang Shipyards on the Malaysian and Singapore sides, respectively). After analyzing the spring tidal heights at Pasir Gudang for the period of 1-8 January, the following major tidal components were found:

1. semidiurnal tide: amplitude 0.94 m, accounts for 66% of the variation;
2. diurnal tide: amplitude 0.64 m, accounts for 31% of the variation; and
3. mixed tide: amplitude 1.25 m, accounts for 97% of the variation.

In the study, the effect of diurnal tide was ignored and an equivalent semidiurnal tide of amplitude 1.25 m during mean spring tide, which appears to be consistent with the value for mean spring tide given in the Admiralty Chart 2586 (1983), was assumed. A similar conclusion was arrived at for the neap tide, which has an average amplitude of 0.65 m. The tidal period used was 12 hours 25 minutes.

The geometry of the strait is schematized to the shape shown in Figs. 2a and 2b.

Model calibration

At present, there is no systematic measurement of current carried out in the area to calibrate the model. The nearest area where some information on tidal current is available is at Malang Beldaun (Singapore) and Sg. Belungkor, located at the seaward extremity of the eastern portion of the strait. However, the information available is incomplete, so only a partial calibration of the model has been done at this stage.

RESULTS AND DISCUSSION

Figs. 3a to 3h show the tidal stream plots for the eastern portion of Johore Strait for an average tide of amplitude 1.20 m at Tg. Punggul, with a time difference between two successive plots of 1.5 hours or one-eighth of a semidiurnal tide. The results show that the tidal currents near Tg. Punggul are about 0.25 m/s, 0.37 m/s and 0.25 m/s for 1.5, 3 and 4.5 hours before a high water slack, respectively. Compared to the tidal currents measured at a depth of 4.5 m below the water surface from 13 December 1985 to 14 January 1986 at Sg. Belungkor and Malang Beldaun (KEJORA 1986), these computed velocities appear to agree reasonably well with the measured values. For example, the tidal velocities measured at the Malang Beldaun station on 30 December 1985 were 0.24 m/s, 0.52 m/s and 0.34 m/s for 1.5, 3 and 4 5 hours before a high water slack, respectively. This measurement was done at 4.5 m below the water level during spring tide. Assuming that the water depth is 10 m, then the point measurement gives approximately the mean velocity at that particular depth.

Figs. 4a to 4h show the tidal stream plots in the western portion of Johore Strait, which employed the same input conditions in the simulation model as those in the eastern portion. The western portion of the strait exhibits a similar flow behavior.

In both portions of the strait, a standing wave with no normal flow is formed at the causeway. The flows in this area are practically zero during both the ebb and flood tides. This standing wave tidal propagation has a significant influence on the dispersion of pollutants in the strait and on the transport characteristics of Johore Strait.

CONCLUSION

An attempt was made to simulate the hydrodynamic regime of Johore Strait by using a two-dimensional depth integrated model. However, the model could not be calibrated and refined at this stage because reliable, measured field data were unavailable. The results clearly show that a standing wave with an almost zero horizontal tidal velocity occurs on both sides of the causeway. This is expected to influence significantly the dispersion of pollutants in the strait and the transport characteristics of the strait, which is at the receiving end of the sewage systems of the Johore Bahru township and the northern part of Singapore.

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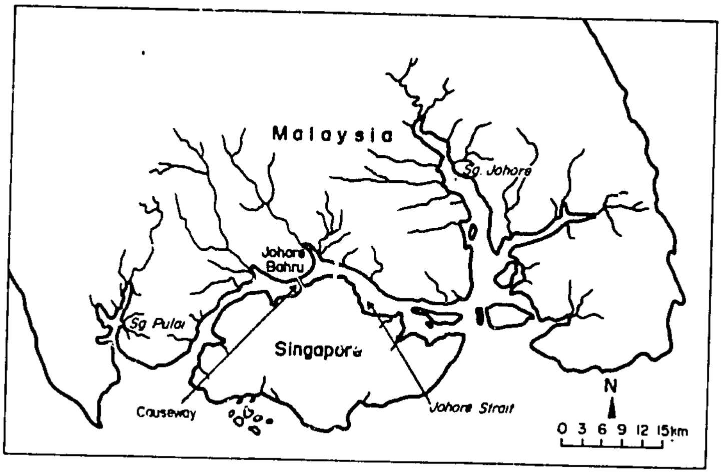

Fig. 1. Location map of Johore Strait.

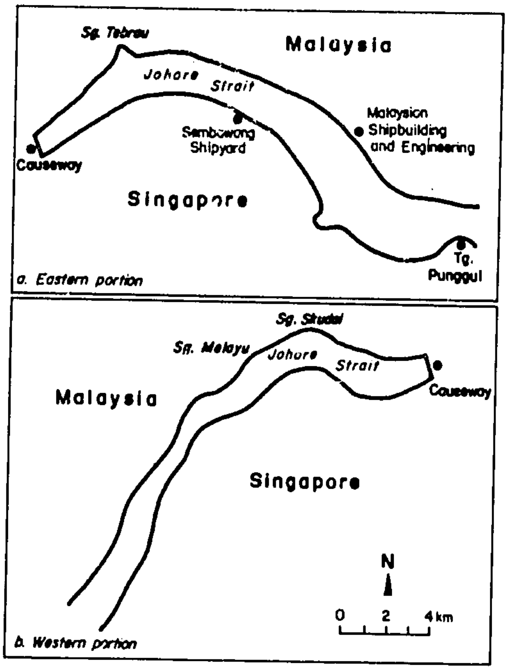

Fig. 2. Johore Strait.

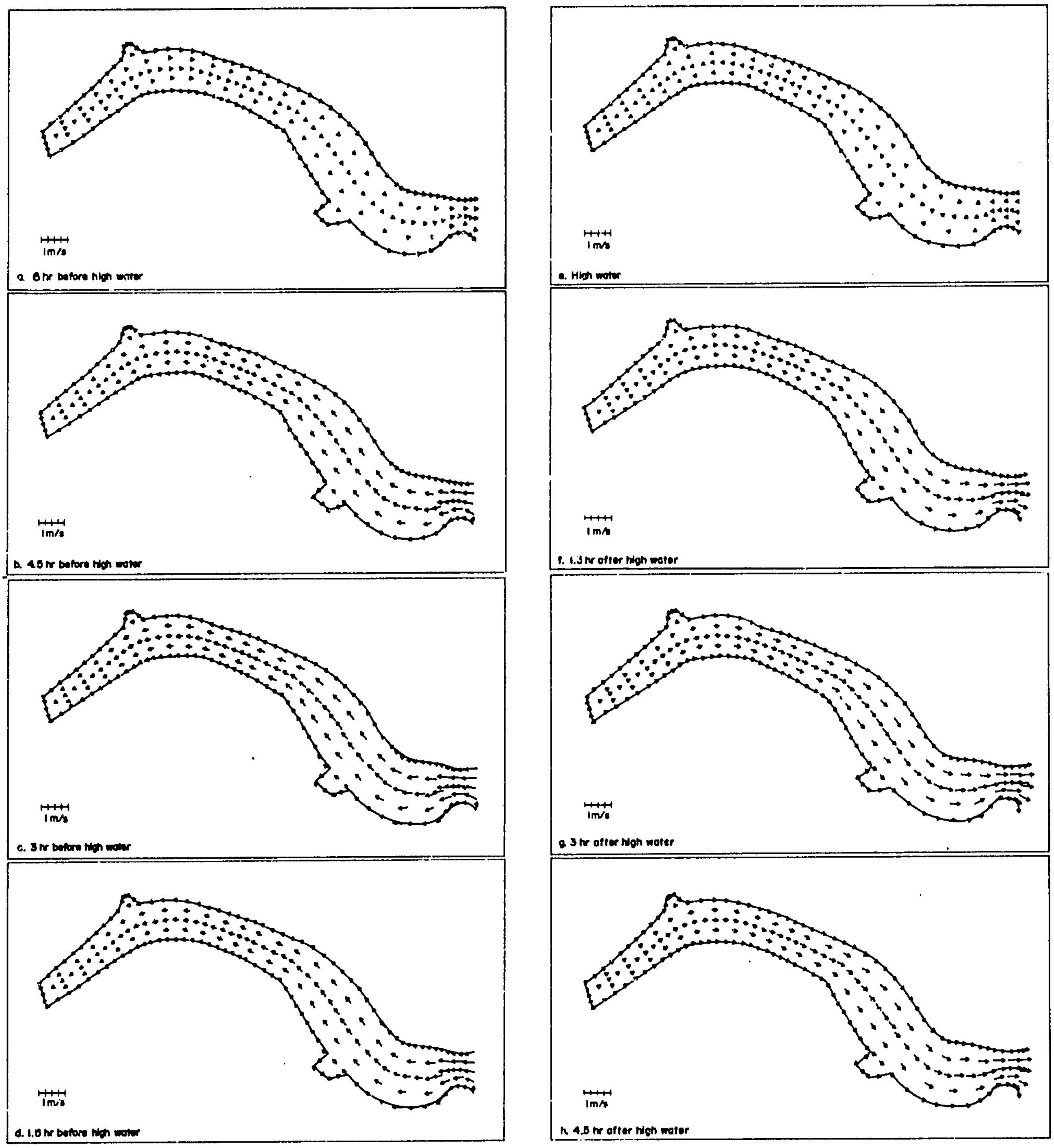

Fig. 3. Current velocity plots for the eastern portion of Johore Strait.

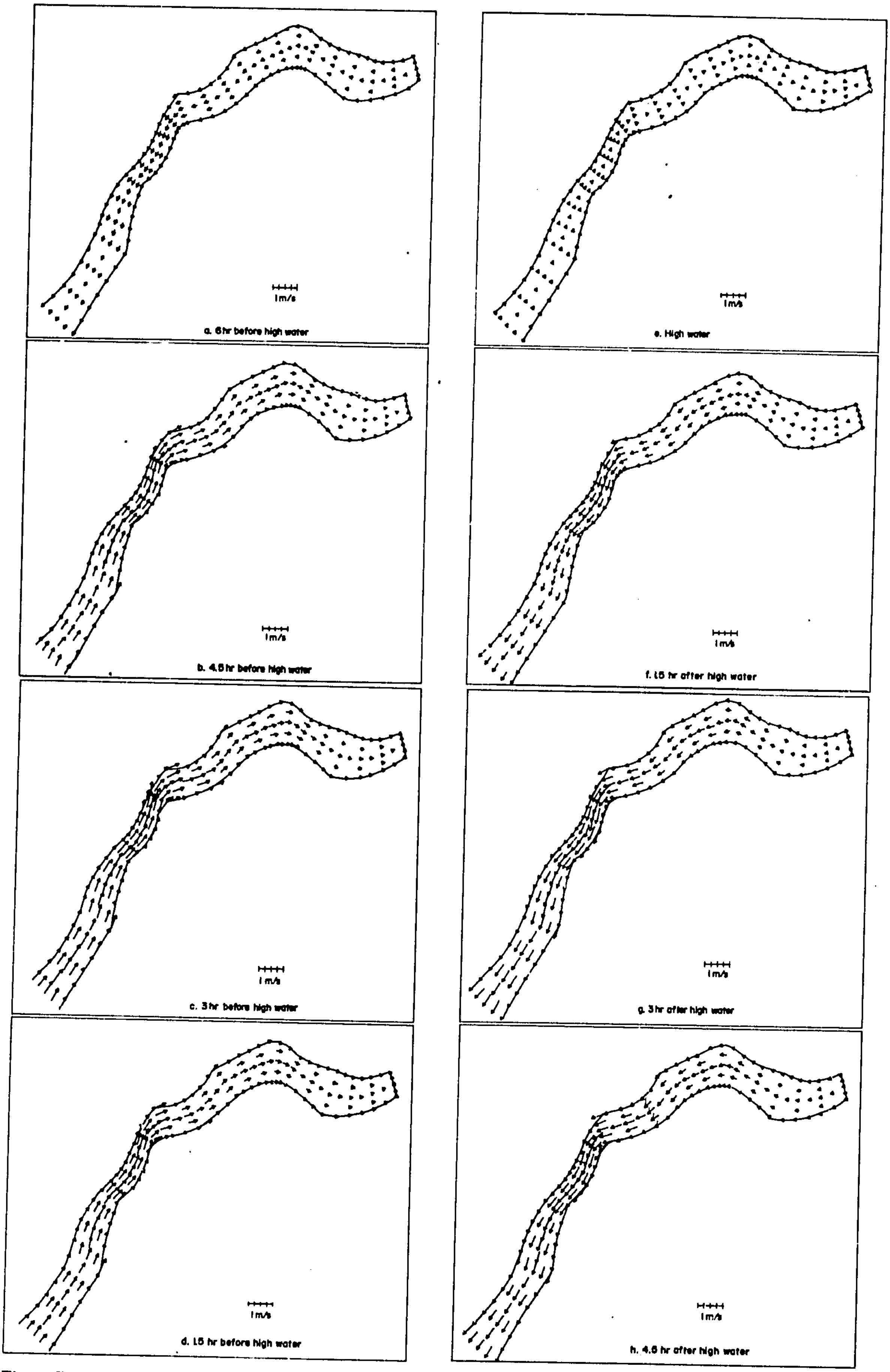

Fig. 4. Current velocity plots for the western portion of Johore Strait.

Analysis of coastal protection work along the southwestern coast of Johore, Malaysia

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ABSTRACT

In 1974, the Malaysian government obtained a World Bank loan to develop agricultural land in the Southwest Johore Agricultural Development Project area (Johor Barat). The project entailed the construction of 198 km of river improvements, 1,041 km of drains, 1,486 km of farm and secondary roads, 942 structures, 66 km of coastal earth work (bunds), a dam and the necessary extension facilities.

The coastal bund, which excludes seawater from the agricultural area, was previously built inland with a belt of mangroves protecting it against direct wave action. However, mangroves along the coast have vanished, thus exposing the bund to direct wave action. Protecting the threatened coastal bund has now become a necessity. To date, a total of 4.8 km of bund revetment has been built at a cost of M$2.5 million. This measure protects thousands of hectares of coconut and cocoa plantations from seawater inundation.

This paper discusses the causes of erosion in the area, the economic analysis of coastal protection work and the recommended solutions for the protection of a highly developed coastal plain.

INTRODUCTION

The Western Johore Agricultural Development Project area is essentially agricultural, covering some 148,517 ha of Johore's western coast. Flooding, water logging and saline intrusion into the coastal area and the valley plains commonly occurred before the project's implementation. To alleviate these problems and to increase the area's economic potential, the government implemented an integrated agricultural development project in 1974. The project primarily involved the construction of coastal embankments, canalization and diversion of rivers, improvement of drainage networks, construction of control structures such as dams, barrages and tidal control gates, road communication, bridges and crossings, and the provision of important agricultural extension services. This paper does not deal with the project in its entirety; it focuses only on one aspect of its engineering work (i.e., coastal bunding).

Tidal flooding, an intrusion into the project area, is alleviated by an embankment (a coastal bund or dike) built along the coast and estuaries. Drainage of the hinterland is regulated through a series of tidal control gates. The coastal bund, constructed from earth, is 3.3 m (10 ft) wide at the top with a side slope of 3 (horizontal) to 1 (vertical). Its crest elevation is about +3.0 m LSD (Land Survey Datum). The spoil for the bund construction was obtained from the excavation of a borrow pit landward of the bund. This bund is constructed at least 400 m (20 chains) from the seaward edge of the mangrove area so that it is adequately protected against waves by the mangrove buffer. Quite often, however, the protection afforded by the mangrove vanishes due to erosion. Consequently, the waves will break directly on the bund slope and the wave run-up generated goes over the bund. The resulting bund breach and seawater intrusion will then damage the crops. Therefore, in this project, bund protection work has to be carried out along the major part of the 66-km project coastline. This paper evaluates the technical aspects of the coastal protection work in the project area (Fig. 1) and suggests the necessary improvements and economic viability of such a work and its impact on the environment.

CAUSES OF EROSION

The consequences of erosion worldwide have been most severe in recreational and urban areas, often situated on sandy beaches. While there is more information available on coastal engineering in sandy shores, the theory regarding the erosion and suspension of cleave material under waves and current action is not well developed. Various researchers have given different explanations on the erosion process on mud coasts.

Ueda (1980, 1982) distinguishes between erosion and scouring, which he says are the mechanisms by which shore retreat occurs on Johore's western coast. This distinction is based on the results of many case studies carried out in Malaysia over a long period of time. He believes that when a cohesive material is immersed under tidal water, its properties are changed and it becomes erodible. The scouring is caused by wave impact and proceeds shoreward by keeping a constant critical land elevation. The situation is accentuated by the abrasive action of driftwood, which further contributes to the disappearance of coastal lands.

Chan (1984), who did a study along the Kedah coast (northwestern coast of Peninsular Malaysia), cites the abrasive action of littoral shell fragments and the conditions that cause stress and unsuitable growth by the barraging and diversion of upstream freshwater supply. Such factors are responsible for the coastal erosion there. The loss of mangroves deprives the mud of their stabilizing effect and the seaward barrier afforded by the mangrove belt.

Freshwater supply is important to sustain the mangrove ecosystem. An alternative hypothesis explains the episodes of coastal erosion thus: When the freshwater supply, usually silt-laden, is not diverted, it brings with it a substantial amount of detrital materials. These materials get trapped in the mangroves' root system, accumulate and consolidate to form a relatively dense stratum. These materials replenish those that are brought into suspension by wave agitation and subsequently transported away by coastal currents. When the freshwater streams are diverted and discharged into the sea at discrete points through the tidal control gates, the affected stretch of mangroves suffers because it has difficult access to the detritus supply.

Another hypothesis, based on field observations, concerns the underwater migration of huge mud waves. Moni (1970) and Allersma (1980) reported the longshore propagation of a mud belt off the coasts of southwest India and Surinam, respectively. The transitory mounds and troughs of the mud belt correspond to the sites of accretion and recession along the coast, which alternate in a temporal cycle. This cyclic trend is also observed in Malaysia.

Since there was no long-term monitoring of data, no conclusion can be drawn on the causes of erosion in southwestern Johore. Nevertheless, any or all of the hypotheses described above need to be considered. Aerial photographs have revealed that in the Benut Forest Reserve area--the northern boundary of the South Johore Coastal Resources Management Project--a vast generation of new mangroves has grown over the last 20 years. The total area of new mangroves is 524 ha, of which 389 ha are in the Benut area. Concurrently, a total of 164 ha of mangrove forests was lost in the Buntu, Kukup, Piai and Chokoh areas.

No mangrove loss was observed by Chan (1984) in the Rambah Rimba Terjun area since the mangrove forest there has completely vanished with most of the coastal bunds provided with rock revetment on their seaward slope. The contiguous accretion and erosion of a mangrove-fringed shoreline in this area seems to be consistent with the above-mentioned causes of erosion.

With the exception of Kukup Island and Piai, erosion was reported in the areas where the upland has been bunded either for agriculture or aquaculture. In areas where the river systems retain their unaltered passage to the sea, a new generation of mangroves flourishes. Fig. 2 shows that even if the hinterland area of the Benut Forest Reserve is bunded and the local drainage is regulated by tidal gates to flow into the river, the Benut River still functions as a main drainage outlet for the large upland catchment. Thus, the river still brings sufficient sediment and freshwater to nourish the adjacent coast continuously. In other areas, small rivers and creeks have been closed and tidal gates constructed in their places to regulate the flow. This eventually deprives the coastal area of sediment and freshwater supply, thereby contributing to mangrove loss.

Regardless of the underlying mechanism of mud coast erosion, man's action in the coastal zone serves to either initiate or accelerate further erosion. Bund revetment only protects the properties behind it against erosion. Along the protected area at both ends, erosion continues and, most likely, becomes more severe because of the effects of wave diffraction. This phenomenon can be seen in the Buntu and Rimba Terjun areas, where the erosion down-coast of the completed revetment became more severe after the completion of the revetment in 1985-86.

TECHNICAL EVALUATION: THE PRESENT PROTECTION WORK

Traditionally, a coastal bund is built from earth (Fig. 3). The practice of the Drainage and Irrigation Department is to construct this earth bund about 400 m landward from the outer edge of the mangrove. A total length of 66 km of earth bund has been completed to protect the project area from tidal flooding and seawater intrusion at a cost of M$50/m run. However, along some parts of the coast, the removal of mangroves due to coastal erosion has exposed the earth bund to direct wave action. In these places, bund protection work has been carried out.

Fig. 4 shows a typical cross-section of the bund protected with rock revetment. Typically, the system comprises two layers of armor rocks, with the weight of each ranging from 200 kg to 300 kg so that they remain stable under the breaking wave and secondary layers made of smaller rocks and geotextile materials. The side slope of the revetment is 3 (horizontal) to 1 (vertical). The armor rock was designed to withstand waves of up to 1.05 m high and the crest to withstand waves of up to 1.05 m high. The crest level is sufficiently high to prevent overtopping by the associated wave run-up. The toe of the structure is located at R.L. -1.42 m LSD, which is about 1 m below the present seabed elevation. With the MHWS (mean high water spring) level of +1.32 m LSD and an average seabed level of 0.4 m LSD, the maximum water depth in front of the structure is 1.7 m.

Analysis of the structure's cross-section design reveals that it can withstand the significant wave heights normally encountered in the Strait of Malacca under present seabed conditions. Wave reflection results in scouring in front of the structure. When the water depth fronting the structure becomes deeper, bigger waves can reach the shore and break directly on the structure's slope. Unfortunately, no monitoring data are available to check the occurrence of the scouring phenomenon that may have occurred. However, monitoring data collected from 1979 to 1986 in Sg. Lurus, which is about 50 km north of this area, indicate that scouring occurs at an average rate of 0.23 m/year (C.H. Lim, pers. comm.).

The long-term scouring at the toe of a structure is not directly related to the extent of the future scouring that is likely to occur. As a rule, the maximum local scouring depth in front of the structure is about 1.5 times the wave height. The projected water depth in front of the structure is then the sum of the existing depth, the local scour depth, known erosion rate and the foreshore slope. This analysis leads to a maximum 2.8-m water depth in front of the structure during the 25 years of the project's life. The maximum unbroken waves that can be sustained in this water depth is 2.2 m or 0.78 times the water depth. However, the probability of the occurrence of a wave of such magnitude is very small. Therefore, the cost-benefit of this extreme wave height or the significant wave height using either design should be evaluated.

PROPOSED UPGRADING OF THE PROTECTION WORK

Assuming that this area is highly sensitive and can not afford any damage from erosion, then the design for protection work has to be based on the 2.2 m wave height. This will result in the use of 1.2 t of rocks if the side slope is kept at 3:1. This is still considered low when the effect of the impact by drifting logs and debris is taken into account (Ueda 1980). However, using heavier armor rocks may lead to foundation problems because quite often, the bund is built on very soft ground. Fig. 5 shows the typical surface spill profile along the western coast of Peninsular Malaysia (DID 1985). Typically, layers of soft to very soft coastal clay can be found from 20 to 30 m deep.

The sheer strength of this marine clay obtained from the drained striaxial compression stress ranges from 3 to 45 m^2 to 230 m^2. The bearing pressure of a revetment using 1.2 t of rock according to a profile of the soils of the type shown in Fig. 5 is 90 KN/m^2. Thus, when the structure is located on softer soil, the soil is unable to sustain the imposed pressure of the structure. Excessive settlement and slip failure may then ensue.

The various ways to overcome this geotechnical problem are:

a. the use of a flatter slope, hence a wider base;
b. soil improvement or replacement; and
c. the use of articulated concrete units that are lighter.

By flattening the slope, the revetment base becomes wider, which results in lower bearing pressure. However, the flatter section usually requires more materials. Soil improvement or replacement is also expensive and may not be justified unless the value of the properties protected is exceptionally high since articulated concrete units derive their stability from their interlocking system. Also, normally, under the same wave conditions, the weight required is only about a quarter of the weight of a rock. However, this system is a civil engineering innovation, and field experience and knowledge about its behavior is rather limited when compared to a rock environment. Moreover, its cost is normally less competitive than the rock's. Therefore, the use of such a system should be closely monitored.

Fig. 6 shows the general sequence of erosion in a mangrove-fringed coast. Erosion normally starts with the lowering of the mudflats in front of the foreshore scarp. This is followed by the erosion of the scarp, thereby stripping off the mangroves. This leads to the concept of scarp protection. By protecting the scarp instead of the bund, the rock size can be reduced and, at the same time, two defense lines are created. Bigger waves break offshore as they pass through the scarp revetment and the smaller regenerated waves are filtered by the mangroves. Replanting of mangroves can be done between the scarp and the bund, if site conditions permit. The possibility of using this method of protection depends on the foreshore bathymetry of the area and the availability of sufficient mangroves.

The foreshore bathymetry of the southwestern coast of Johore does not indicate the existence of a foreshore scarp, which could imply that this has already been eroded. This precludes the possibility of implementing the scarp protection scheme. Therefore, the most feasible method of improving the revetment is by adopting a flatter slope for the structure. This can be easily incorporated in the course of the maintenance work.

ECONOMIC EVALUATION: PROJECT BENEFITS

It is very difficult to separate the benefits of coastal protection work from the total benefits we can get from the project itself. The benefits derived from the implementation of the project (Nesadurai et al. 1970) are:

a. increased productivity of existing agricultural crops through drainage improvement;
b. increased availability of land suitable for cultivation; and
c. justification of the change of the existing cropping pattern to maximize returns from lands due to improved soil and drainage conditions of existing arable land.

All these benefits are the results of the overall drainage and flood mitigation improvement in the project area and are not exclusively due to coastal bunding alone, although bunding forms are major components of drainage improvement. Therefore, in the economic evaluation of coastal bunding and the required protection work, the above will be considered indirect benefits only. The direct benefit of coastal bunding is then the value of agricultural production from the crops planted on new cultivable lands, which were previously abandoned because of tidal flooding but are now made available through seawater exclusion measures.

To arrive at the benefit and cost analysis, the following assumptions are made:

a. an average continuous erosion rate of 4 m per year, without the project; and
b. land values of M$20,000/ha for first-grade agricultural land and M$12,500/ha for marginal land (MOF 1985).

Fig. 7 shows the area subject to tidal flooding before the implementation of the agricultural development project. The total affected area is about 7,260 ha. These marginal lands were either undeveloped or of a very low yield because of their susceptibility to tidal flooding. Construction of the 77-km earth bund has transformed these lands into first-grade agricultural lands. The area is now planted with coconut and cocoa. Therefore, the direct benefits derived from the bund construction are as follows:

a. Land value has increased from M$12,500/ha to M$20,000/ha. With a total improved area of 7,260 ha, the gain in land value is M$54.45 million; and
b. Increase in income of the farmers working on 2.2 ha of coconut land intercropped with cocoa is from M$819.5/year to M$2,463.18/year (MOA 1981); the net increase is M$5,424/year.

The National Coastal Erosion Study noted a total length of 13.7 km of eroding coastline in this area where protective measures are required to prevent the further loss of properties. If nothing is done in the next 25 years, erosion will lead to the loss of agricultural and village (*kampong*) lands and damage to commercial buildings, private and public houses and other amenities such as fish farms. The direct benefit of coastal protection work is then the stability of these properties (DID 1985), which are valued at about M$39 million. For example, in the event of bund breach due to erosion, about 1,050 ha of farmland will be inundated by seawater during high tide. Yields from these periodically submerged lands for the current crop will definitely plummet, with lower yields to be expected for the subsequent crops. This gradual loss of yield over the years has not been included in the benefit qualification.

Project cost

The total length of the coastline that requires protection is 13.7 km, out of which a total length of 4.8 km has been completed at a cost of about M$2.5 million. However, as mentioned earlier, upgrading these rock bunds along this stretch may be required as part of the maintenance program.

The proposed revetment with a typical cross-section (Fig. 8) costs about M$1,600/m. Hence, the total cost required for the balance of 8.9 km of eroding coast is M$14.24 million and the construction period may spread over a period of five years. Based on the scouring rate at a nearby site, the existing revetment may need to be upgraded in ten years' time, the cost of which is assumed to be M$1,000/m. The total revetment cost thus covers the cost in constructing the existing and new revetments and in upgrading the existing revetment.

Benefit-cost analysis

The benefit accrued from protecting 13.7 km of coastline is M$17.84 million in five years (DID 1985). This gives a present value of M$17.75 million at a discount rate of 8%. The capital cost to protect 8.9 km of coastline is about M$14.24 million spread over the first five years, plus the upgrading cost for the existing revetment will require a total of M$4.8 million after 10 years. In addition, M$2.5 million has been spent for 4.8 km of coastline, making the total cost of M$14.42 million at the same discount rate of 8%. Therefore, the benefit-cost ratio of the project is 1.23 at the discount rate of 8%.

ENVIRONMENTAL IMPACT OF COASTAL PROTECTION WORK

The effects of the development of coastal farmland for agriculture, in relation to the coastal ecosystem and the planning procedure for their preservation, is discussed by Ueda (1988). However, the Western Johore Project was planned and implemented since the early 1970s when environmental quality was not yet an issue. Therefore, it is very unlikely that this aspect of the project was considered adequately during the planning stage. Also, there is still no study on the impact of the project on the physical and biological environments, except for a casual remark that bunding has caused erosion in the mangrove area.

The present physical, biological and socioeconomic environments of South Johore, which includes the southwestern coast of Johore, have been discussed in detail (Kadri 1987). However, this study was prepared after the completion of the Western Johore Project and it did not include a comparison of the preproject condition. Therefore, the impact of the project on the environment is still unknown.

As for coastal protection work using rock armoring, the effect of the construction on the environment stems from the fact that rock layers replace the mud strata in the inner-tidal zone. Therefore, changes in the marine species composition in this zone can be expected. Invertebrates and shellfish, which attach themselves to rock surfaces, will most likely replace the mud-dwelling invertebrates in this zone. However, no change is expected in the subtidal and the terrestrial habitats since the physical environment in these zones remains the same. The revetment will prevent further losses to the land behind the bund, and the erosion of the mudflats and remaining mangroves seaward of the bund will continue until a stable offshore profile is reached. Changes, however, can be expected in the area both up- and down-coast of the protected area. In these areas, erosion will accelerate and more damage can be expected as a result of the end-scouring effects. This can be alleviated if the ends of the revetment are tied to natural formations such as hills, rocks or rivers.

CONCLUSION

Although there have been numerous speculations on the likely cause and effect relationship between coastal bunding and coastal erosion along a mangrove-fringed coast, no concrete conclusions can be derived since there has been no thorough study on this subject. However, on-site observation has indicated some correlation between the alteration of the natural drainage pattern and the demise of mangroves.

The existing revetment should be upgraded in some way to protect the area from projected long-term wave-induced erosion. This can be done by flattening the seaward slope of the rock revetment in the course of carrying out maintenance work. Protecting the entire 13.7 km of currently eroding coastline is economically viable, even without considering the various intangible benefits and their general contribution to the overall success of agricultural projects. Further study should determine the revetment's impact on the physical, biological and socioeconomic environments.

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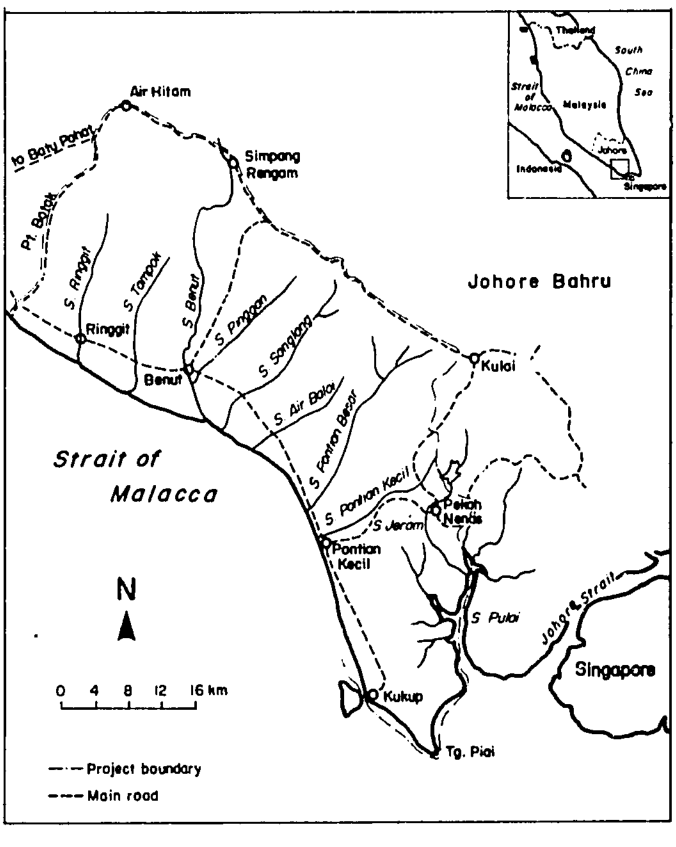

Fig. 1. Project location.

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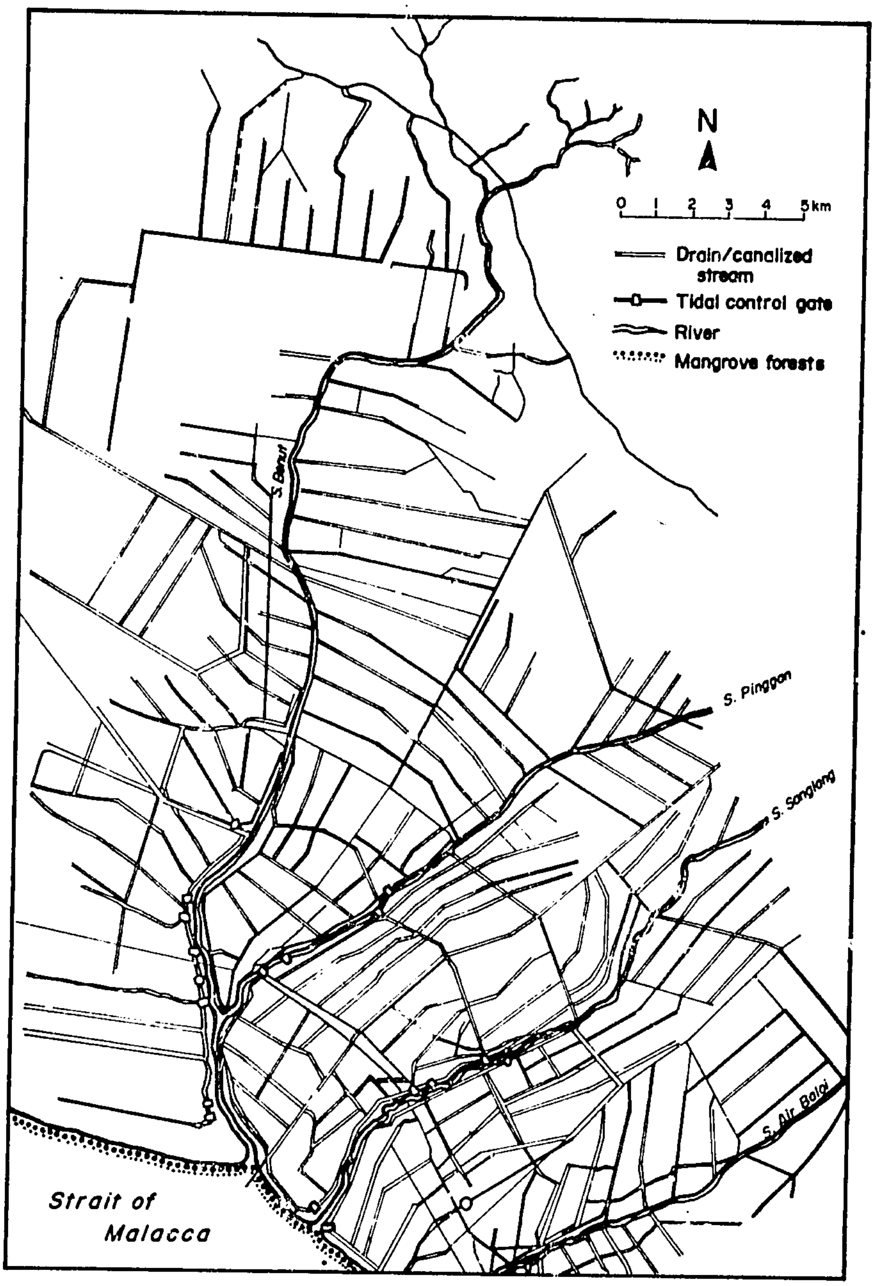

Fig. 2. Drainage controls in Sg. Benut catchment.

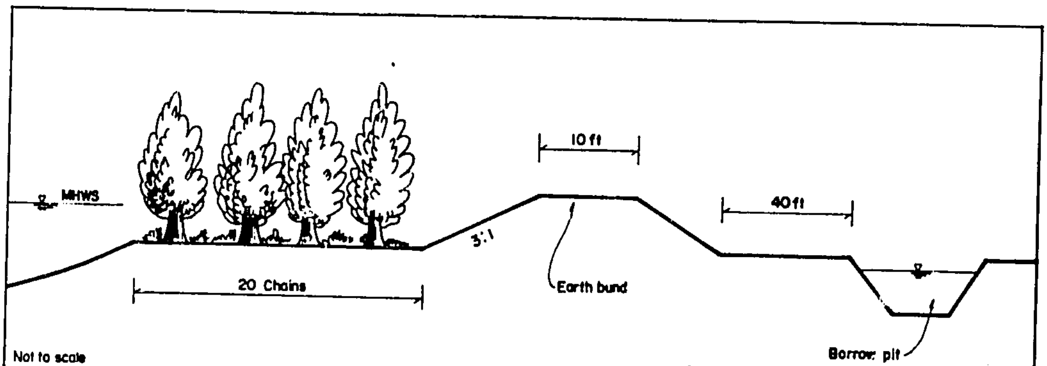

Fig. 3. A typical cross-section of a traditional earth bund.

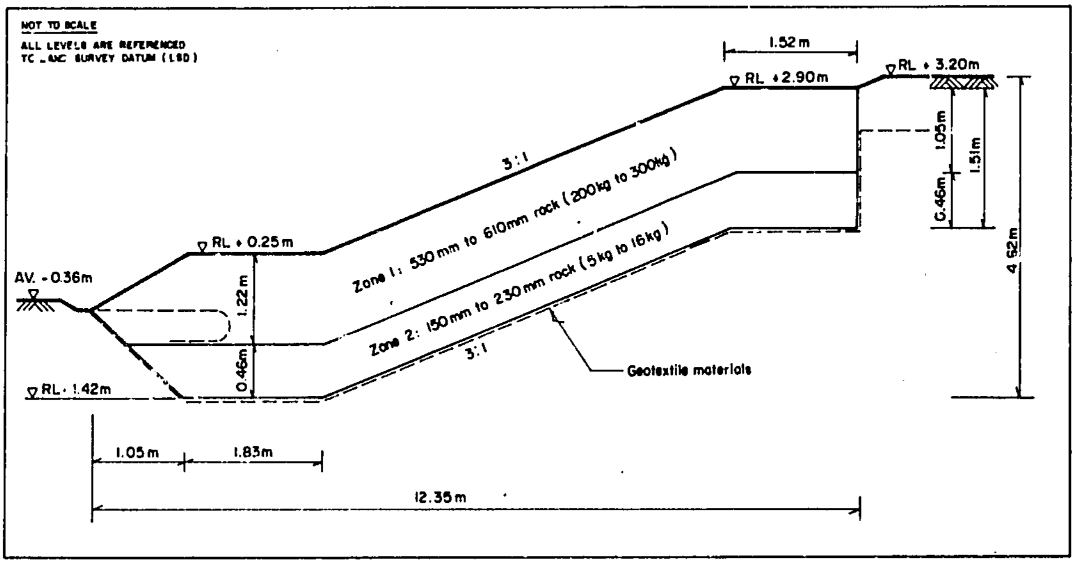

Fig. 4. A typical cross-section of the bund protected with rock revetment.

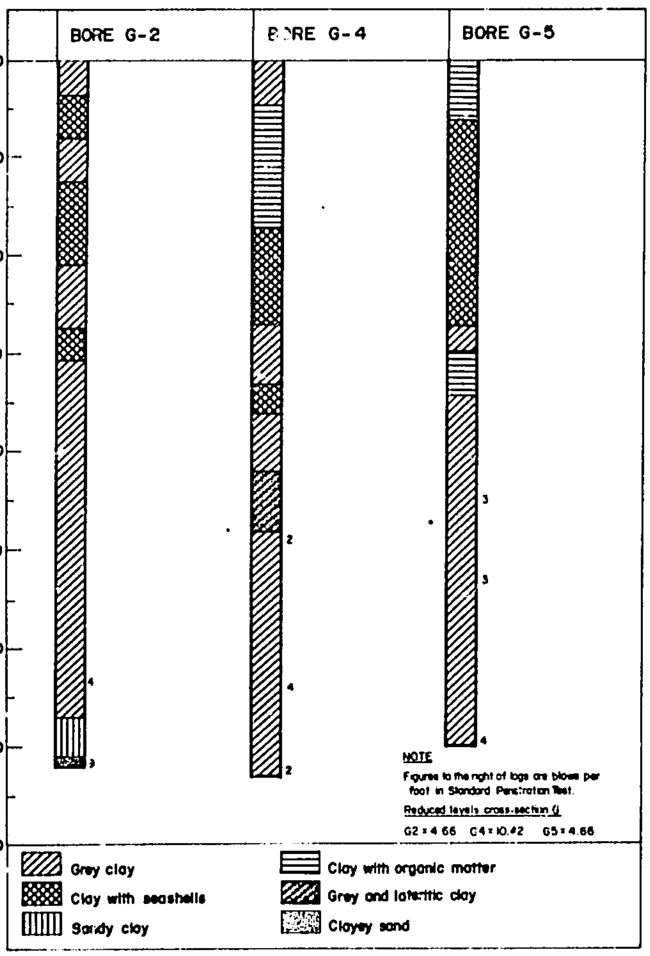

Fig. 5. Typical surface spill profile along the western coast of Peninsular Malaysia.

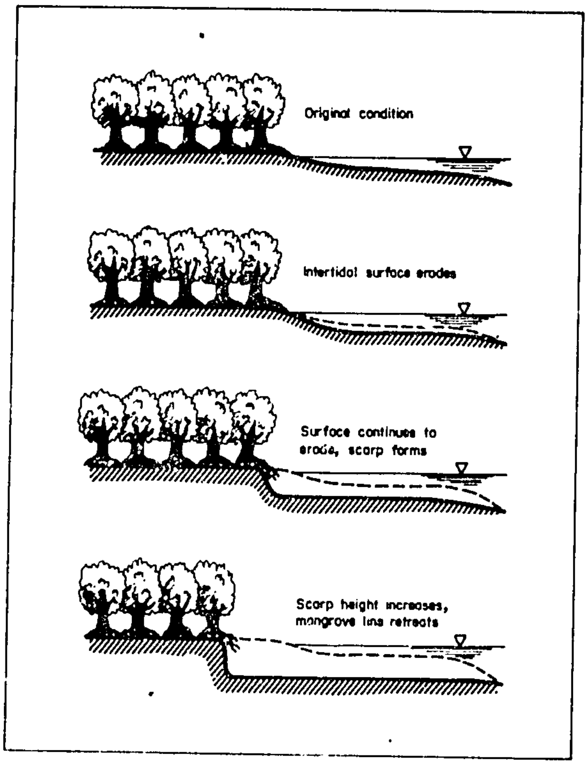

Fig. 6. Sequence of erosion in a mangrove-fringed coast. Source: Stanley Consultants, Inc. 1985.

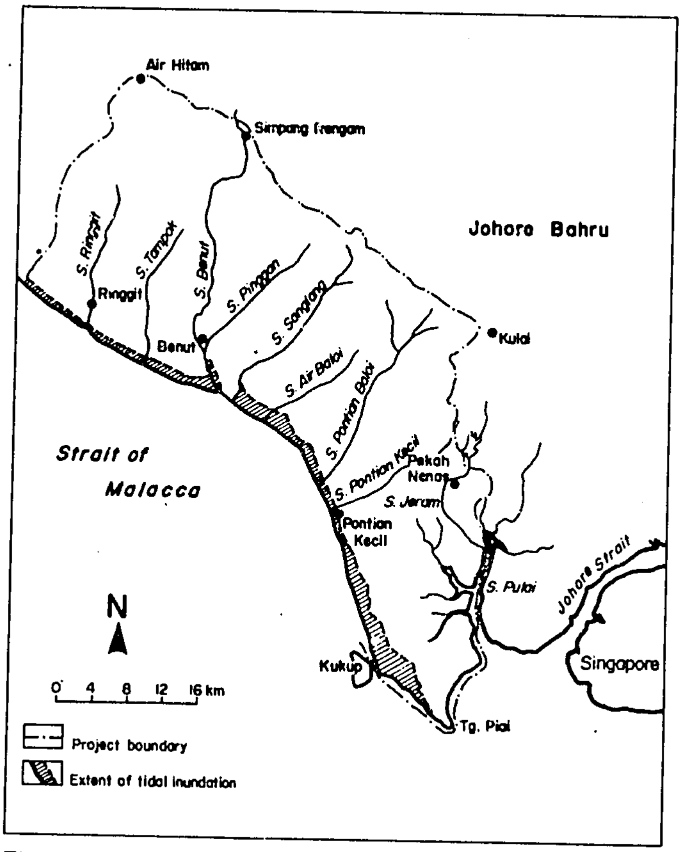

Fig. 7. Tidal inundation.

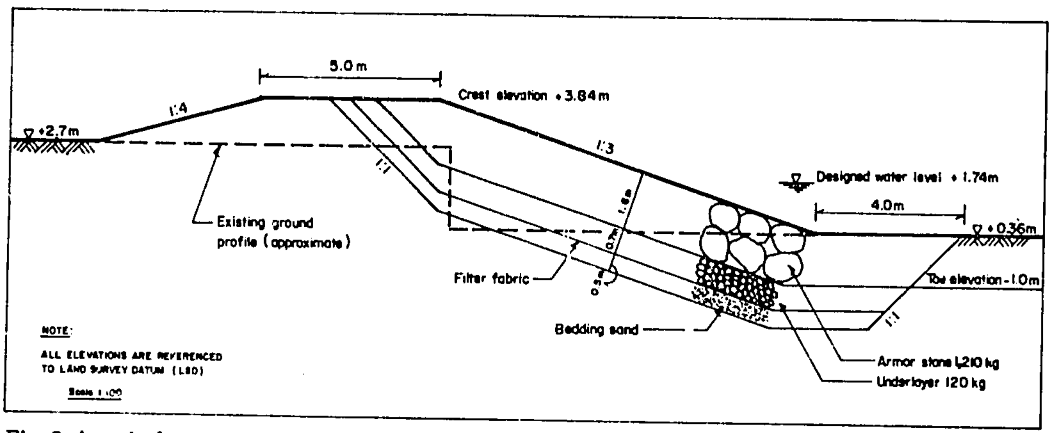

Fig. 8. A typical cross-section of the proposed rock revetment.

The ecological and economic roles of Segara Anakan, Indonesia, as a nursery ground of shrimp

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NAAMIN, N. 1991. The ecological and economic roles of Segara Anakan, Indonesia, as a nursery ground of shrimp, p. 119-130. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

Segara Anakan, a brackishwater lagoon located in the west side of Cilacap on the south coast of Java, is becoming shallower and smaller yearly due to siltation. The two distinct shrimp fisheries in the Cilacap areas are the lagoon and the offshore fisheries.

Several problems have been hindering the ecological role of Segara Anakan and the surrounding mangroves as a nursery ground for penaeid shrimp: the decreasing water volume due to rapid siltation; the shrinking mangrove areas; the excessive fishing effort and the use of nets with very fine mesh size; and the deteriorating water quality. Thus, there was a need for the research.

As observed, one possible consequence of the siltation of the lagoon is the reduction of the size of the nursery ground. Such a condition of the nursery ground will influence the recruitment of adult shrimp from the offshore area and then affect its population size and the magnitude of the catch.

INTRODUCTION

Background of Segara Anakan

Segara Anakan ("the child of the sea") is a brackishwater lagoon of approximately 4,000 ha in the west side of Cilacap on the south coast of Java. It has two connections to the sea, one in the eastern and the other in the western part of the lagoon (Fig. 1).

The lagoon is surrounded by about 14,000 ha of mangrove forests, the largest single mangrove area in Java. Several rivers flow into Segara Anakan; the most important ones are the Sapuregel, Cibereum, Cikujang and Citanduy Rivers. Due to upland deforestation, these rivers bring much sediment, thus causing siltation especially during the rainy season.

Since it has become shallower and smaller yearly, the lagoon has a maximum depth of only 2 m during ebb tide (tidal amplitude ranges from 50 to 150 cm).

Occurrence of species

Catches from the lagoon most often comprise common fish such as: anchovy (*Stolephorus* spp.), sardine (*Sardinella fimbriata),* ponyfish (*Leiognathus* spp.), mullet (*Mugil* spp.) and squid (*Loligo* spp.), and these shrimp: *Metapenaeus ensis, M. elegans* and *Penaeus merguiensis.* These are the species that migrate to the lagoon. Meanwhile, the sedentary, macrobenthic mud crab *(Scylla serrata)* and cockles *(Anadara granosa* and *A. antiquata)* naturally occur in the lagoon and its surrounding mangroves.

In certain seasons, jellyfish in their blastula stage form the bulk of the catch of plankton nets. During flood tide, the rest of the catch consists of copepods, mysids and sergestids. Table 1 lists the fish, crustacean and mollusk species that occur in Segara Anakan and the offshore area of Cilacap. On the other hand, Table 2 lists the larvae and postlarvae stages of fish, shrimp, crab and mollusk species as well as zooplankton samples from the east and west entrances of Segara Anakan.

Lagoon and offshore shrimp fisheries

There are two distinct shrimp fisheries in the Cilacap areas: the lagoon and the offshore fisheries. The former is characterized by the use of tidal traps *(jaring apong, wide* and *sero),* gill nets and cast nets, which mostly catch juveniles. In the latter, trammel nets and beach seines *(arad)* are used, thus yielding larger shrimp for export.

The main shrimp species caught in the lagoon are *M. ensis, M. elegans, M. dobsoni* and *P. merguiensis.* All four species can also be caught in the offshore area, including *P. monodon, P. chinensis, Parapenaeopsis coromandelica, Trachypenaeus asper* and *Metapenaeopsis stridulans.*

Much of the lagoon's fish landings consisted of shrimp juveniles. In certain months, shrimp catch exceeded those of fish although the former were decreasing yearly prior to 1980 (Table 4). However, from 1981 onwards, shrimp fisheries yield began to increase again. Crustaceans like the penaeid shrimp, caridean shrimp, mysid and crab constituted from 60 to 75% of the total catch, while finfish made up the rest (25-40%).

Offshore shrimp resource exploitation can be divided into three periods, with the trawl ban as the point of reference. Before the trawl era (before 1972), bottom gill net, Danish seine and beach seine were used as gear for catching shrimp. During the trawl period (1972-1980), trawl was the main gear employed, making up about 95% of the total shrimp catch. After the trawl ban (from 1981 onwards), the trammel net has been used in the offshore area and the beach seine in the shallow-water portions along the beach or the inshore area.

Before the trawl era, the shrimp catch amounted to 195 t/year, while during the trawl era the shrimp catch ranged from 1,614 to 5,242 t/year (Table 3). In the period between the trawl era and after the trawl ban, there were some changes in shrimp catch composition. During the trawl era the small-type shirmp, ***krosok***, were the dominant catch (about 53% of the total). However, after the trawl ban, the trammel net, a more selective fishing gear, has been catching mostly shrimp belonging to the *dogol* and *jerbung* groups.

Moreover, during the trawl era, the level of exploitation exceeded that needed to generate the maximum sustainable yield (MSY). The MSY of the offshore fishery is estimated at 5,800 t/year (Naamin 1980). Effort was excessive and the very fine trawl cod-end mesh size was used. Fortunately, it seems that the shrimp stock has recovered since 1983. This stock has not been fully exploited by the present fishing effort such that the shrimp catch is at present much less than that of the trawl era. However, the value of the present catch is higher because the price of shrimp has been increasing in the last few years.

The problems

A number of problems have been hindering the ecological role of Segara Anakan and the surrounding mangroves as nursery grounds of penaeid shrimp: (1) the decreasing water volume due to rapid siltation; (2) the shrinking mangrove areas; (3) the excessive fishing effort and the use of nets with very fine mesh; and (4) the deteriorating water quality.

Objectives of the research

This research was conducted for the following reasons: (1) to identify the ecological and economic functions of Segara Anakan as nursery ground of penaeid shrimp and (2) to assess the impact of changes in environmental conditions (i.e., mangrove degradation, water pollution and size reduction of the lagoon's nursery ground due to sedimentation) on the lagoon and the offshore fisheries.

MATERIALS AND METHODS

Selection of species for study

P. merguiensis, M. ensis and *M. elegans* were chosen for study because they are the dominant species in the yields of the lagoon and the offshore fisheries.

Selection of stations

The lagoon's shape, with two connections to the sea, dictated the choice of two stations at the east and west entrances for immigrating larvae and postlarvae to the lagoon.

Four sampling stations were selected for studying the emigration of juveniles from the lagoon and the surrounding mangrove ecosystem. Stations were located close to the east and west entrances and the two other stations were located in the middle of the lagoon (Fig. 1). The selection was based on the presence of the tidal traps fixed by the fishermen in these areas. It was assumed that the existence of these traps indicated where the shrimp and fish juveniles are abundant during ebb tide.

Sampling methods

Immigration. Immigrating larval and postlarval shrimp and fish were sampled by setting a plankton net suspended from a buoy moored near each entrance to the lagoon. The plankton net measured 113 cm in mouth diameter and 350 cm in length (from the mouth to the cod-end). It had a stainless steel frame and nylon netting with a mesh size of 170 µ. This large net, when used with a 60 kg weight, could be handled by two people from an open boat and hence used in shallow waters (Fig. 2). The net was set at 0.5 m from the surface fortnightly during both flood and ebb tides to monitor lunar periodicity and seasonal changes in the number of immigrating larvae. Additional nets moored in the middle of the river, about 0.5 m from the bottom, provided information on the depth distribution of migrating shrimp and fish. The samples were identified and the numbers of all fish, penaeid shrimp and other crustacean species were then recorded. The postlarvae of each species were identified from the description of Hall (1962), Poernomo (1968) and Kirkegaard (1975).

Emigration. Emigrating juvenile shrimp, other crustaceans and fish were sampled with set nets (*jaring apong*) from buoys moored near the river's mouth at both entrances to the lagoon, at the tidal creeks in the mangrove area and in that portion of the lagoon perpendicular to the outflow (at ebb tide). A trawl-type set net with an 18-m headrope and with a 20-mm cod-end mesh size was set at the bottom during ebb tide once in a fortnight. All species of penaeid shrimp, fish and other aquatic animals were identified in the field or the laboratory and recorded. Juveniles of each species were identified from the description of Kubo (1949), Dall (1957), Racek and Dall (1965) and Kirkegaard et al. (1970).

Spawning Season. The spawning season, spawning ground and other population parameters such as recruitment patterns of offshore shrimp and fish were identified by taking samples regularly (i.e., every fortnight) from the commercial catches at the landing places. Spawning seasons were identified by observing the gonadal maturity stage: stage I-quiescent/undeveloped, stage II-developing, stage III-early maturity/ nearly ripe, stage IV-ripe and stage V-spent (Fig. 3). Those in stages I and II were classified as immature shrimp and those in stages III, IV and V as mature shrimp. A higher percentage of mature shrimp was considered a sign of the spawning season.

Fishing season and fishing ground were identified and offshore shrimp and fish stock were estimated from catch-and-effort data collected at the landing places of the commercial fisheries. The abundance of the stock was estimated from catch per unit effort (CPUE) and the relative stock size was estimated using Surplus Production Models (Schaefer 1957; Fox 1970). The data collected were analyzed monthly to check the seasonality of shrimp occurrence according to its life stages. Time-series data, which were available for several years, were treated as the monthly average.

Shrimp larvae and postlarvae coming into Segara Anakan and its surrounding mangrove ecosystem were sampled during flood tide, as described above. To check whether these also emigrate to the sea from the lagoon during ebb tide, the plankton net was also set several times in previous trips. Since approximately 90% of the larvae and postlarvae were taken during the incoming flood tide, sampling during ebb tide was terminated in August 1987.

RESULTS

Taxa immigrating into the lagoon

Immigrating larvae and postlarvae consisted of penaeid shrimp (*Penaeus merguiensis, P. monodon, P. chinesis, Metapenaeus ensis, M. elegans, M. dobsoni* and *Metapenaeus* spp.) in the mysis and postlarval stages; *udang rebon* (Sergestidae and *Acetes* spp.); zooplankton [*Lucifer*, amphipods, copepods (*Cyclops* spp.); *Nauplius* spp., *Calanus* spp.]; mesogastropods; bivalve larvae; annelids; rotifers; *Sagitta* spp.; fish larvae and postlarvae; squids; cuttlefish, jellyfish and crabs. Sampling results showed that the catch was usually dominated by *Cyclops* spp. and at certain times, by jellyfish (in blastula stage).

P. merguiensis, M. ensis and *M. elegans* were the penaeid species of shrimp larvae that consistently occurred in the samples. Their seasonal patterns show that they occur throughout the year, with peaks in February and June (Table 5 and Fig. 4).

Seasonal distribution of juveniles

Emigration of juveniles occurred all-year-round, with peaks in February, August and November-December (Table 6, Fig. 4). Based on the monthly number of trips for the set net and its CPUE, it was estimated that the catches of juvenile penaeid shrimp were high (more than 40 t/month) during May and December-February.

Juveniles caught by set net consisted of penaeid shrimp (*P. merguiensis*, *P. chinensis*, *P. monodon*, *M. ensis*, *M. dobsoni*, *M. elegans*, *Metapenaeus* spp.); other crustaceans (crab, Sergestidae, *Acetes* spp., *Palaemon* spp.); fish (*Leognathus* spp., *Johnius* spp., *Pseudociena* spp., *Engraulis* spp., Bothidae, Gerridae, *Mugil* spp., *Trichiurus* spp., *Cynoglosus* spp., *Stolephorus* spp., *Saurida* spp., *Sardinella* spp., *Apogon* spp., *Chirocentrus* spp., *Harpodon* spp., *Muraenesox* spp., *Therapon* spp., *Scomberemorus* spp., Scatophagadidae), mollusks (*Loligo* spp., *Sepia* spp.) and jellyfish.

Toward the west entrance, *M. ensis* was the dominant shrimp species caught, followed by *M. elegans*, *P. merguiensis*, *M. dobsoni*, *P. chinensis* and *P. monodon*. At the east entrance, the catch was also dominated by *M. ensis*, but in February 1988 it was dominated by *P. merguiensis* (24% of the total in terms of volume and 80% in terms of number). Juvenile fish belonging to the Clupeidae, Cynoglossidae, Engraulidae, Gobiidae, Carapidae, Scianidae and Scatophagadidae genera were abundant in the catch. Sergestids were also abundant.

Yields

Maximum sustainable yield (MSY) of the lagoon shrimp was about 605 t/year. The population consisted of juveniles with a size range of 3-12 mm carapace length or 0.10-2.0 g total weight.

The shrimp resources (mainly juveniles) in the lagoon and the adjacent mangroves are exploited by artisanal fishermen living in the nearby village. About 74% of the population of Kampung Laut depends on fisheries for its livelihood.

The tidal traps commonly used by these fishermen have very fine mesh (about 4 mm) and depend on the strength of the ebb-tide current. When the current is not so strong (described in the vernacular as *ngember*), there is very little catch, or sometimes none at all, and fishing activities using tidal traps are terminated. (Shrimp yields are listed in Table 4.)

Seasonal distribution of offshore catch

The growth parameters of *P. merguiensis* were estimated by Sumiono (1987) based on length-frequency data from the offshore area of Cilacap from 1977 to 1984 (Table 7).

The spawning season of *P. merguiensis* in the offshore area of Cilacap can be determined from the monthly average of maturity stages (in percentage) (Table 8). Spawning occurs all-year-round with peaks in March-April, August and November (Fig. 4). Schaefer's linear model and Fox's exponential model suggest that, based on the data in Table 3, MSY ranged from 5,000 to 5,800 t/year.

Both monthly catch and CPUE were high from September to December. This seasonality was similar to the trend during the trawl and trammel net era (after the trawl ban).

The catch consisted of all the 12 species of shrimp covered by three resale categories: *jerbung* (*P. merguiensis*, *P. monodon*, *P. chinensis*); *dogol* (*M. ensis*, *M. elegans*, *M. dobsoni*); and *krosok* (*Parapenaeopsis coromandelica*, *P. maxillipedo*, *P. probata*, *Trachypenaeus asper*, *Metapenaeopsis stridulans*, *Solenocera subnuda*). *Krosok* includes the small types of shrimp and this group made up about 53% of the catch. *Dogol* (endeavor group, *Metapenaeus* spp.) accounted for 31% and *jerbung*, 16% of the total catch.

Ecological parameters of the lagoon and offshore waters

The shelf portion along the south coast of Java is relatively narrow and of this entire portion, the Cilacap area is the widest. Segara Anakan lies in the west side.

Nusa (it means "island") Kambangan protects Teluk (it means "bay") Penyu in the east, Pangandaran Bay in the west and Segara Anakan against the waves and currents of the Indian Ocean. Many rivers flow into the waters of Cilacap and Segara Anakan (Fig. 1).

The hydrology of the region is dominated by a seasonal alternation of the east and west monsoons. There is a coastal current that flows east along south Java during the months of November to June and flows west from July to October (Soeriaatmadja 1957). The high tide current ranges from 7 to 462 cm/minute at the east entrance and from 5 to 110 cm/minute at the west entrance. The ebb-tide current ranges from 4 to 113 cm/minute at the east entrance and from 3 to 142 cm/minute at the west entrance. These very strong tidal currents considerably influence the recruitment of shrimp from the offshore waters to the lagoon and vice versa.

The planktonic larvae and postlarvae are transported from the spawning ground to the lagoon by drifting with the flood tide current, while the juveniles are transported from the lagoon to the offshore area by following the ebb tide current. During the flood tide, the juveniles have a resistant mechanism against the flood tide current called reotaxis.

According to Wyrtki (1962), upwelling in south Java occurred during the southeast monsoon. This was confirmed by the results of the *R.V. Oh Dae San* (1972) survey, which showed high plankton concentrations of 350 mg/m^3 in the south Java coastal area, 660 mg/m^3 in the Cilacap waters and 50 mg/m^3 in the north Java area in November 1972.

Salinity is influenced by the flow of water from the rivers. The effect of this is significant during the rainy season (September-December). During low tide in the rainy season, the salinity ranges from 2 to 18 ppt. During low tide in other seasons, the salinity ranges from 23 to 30 ppt and during high tide, from 25 to 32 ppt. The surface temperature of the Cilacap and Segara Anakan waters ranges from 28.30 to 30.30°C.

Rainfall in the Cilacap-Segara Anakan area is given in Table 9, and as shown, 1987 was a relatively dry year, compared to the previous years (1984-1986).

The fishing ground of the offshore fisheries can be divided into the Pangandaran waters in the west, and the waters of Teluk Penyu-Gombong and the waters south of Yogyakarta in the east. These three divisions have approximately 1,300 km^2, 3,100 km^2 and 800 km^2 of demersal ground area, respectively, at a depth of 100 m. The traditionally exploited pelagic ground runs up to some 10 km off the coastline. Cilacap is the main fish landing place on the south coast of Java.

Outside of the shelf area, upwelling occurs, during the southeast monsoon in an area between 16 and 36 km off the coast, while during the northwest monsoon, upwelling occurs about 100 km off the coast. These areas are expected to become pelagic fishing grounds in the future.

DISCUSSION AND CONCLUSION

Shrimp population and distribution

A strong correlation was found between the lagoon population and the offshore population. The species composition of the larvae and postlarvae samples collected at the lagoon's entrances during flood tide were similar to that of the juveniles caught during ebb tide in the lagoon and offshore area. Among the commonly occurring species were *P. merguiensis, P. chinensis, P. monodon, M. ensis, M. elegans* and *M. dobsoni.*

There were no larvae and postlarvae of *P. semisulcatus, Solenocera* spp., *Parapenaeopsis* spp. and *Metapenaeopsis* spp. immigrating to Segara Anakan and the surrounding mangrove areas, and there were no emigrating juveniles of these species either. The absence of these species could imply that they do not need the lagoon and mangrove areas as nursery grounds.

Most of the commercially important species of penaeid shrimp found in the Cilacap waters have a very similar overall pattern of life cycle. The cycle involves marine and estuarine or lagoon phases with a shoreward migration of the larvae and seaward migration of the juveniles, adolescents and adults.

Based on the high percentage of gonadal maturity in the offshore samples, spawning strongly appears to occur in the offshore area at depths ranging from 20 to 30 m. Monthly samples of gonadal maturity showed that spawning occurred throughout the year with peaks in March-April, August and November.

Samples of immigrating larvae and postlarvae from both entrances to the lagoon also showed that they occurred throughout the year with peaks in May-August and December. Emigrating juveniles from the lagoon and the surrounding mangroves also occurred throughout the year with peaks in February, August and November. The fishing season in the offshore area occurred from August to January with peaks in September to November.

By correlating the peaks of each life phase (Fig. 4) to subsequent life phases through the progression method, it can be seen that the peak of spawning in the offshore area (indicated by the maturity stage) occurred in March-April and that the peak of subsequent life phases--larvae and postlarvae--at the lagoon's entrances occurred in May and June. The cycle progressed with the peaking of the juvenile phase at the lagoon in July-August, and then the peaking of fishing in the offshore area from September to November. The second peak of spawning was in August, followed by a peak in the occurrence of juveniles in November, and then a peak in fishing in January.

The above observations imply that:

1. There is a strong correlation between the lagoon and offshore populations of commercially important shrimp species, *Penaeus* spp. and *Metapenaeus* spp.
2. The catch of larvae/postlarvae, juveniles and adults, as well as the spawning

season (the maturing stage) of the above species in the lagoon and offshore areas of Cilacap seem to show a seasonal pattern, although factors governing this pattern have not yet been determined.

3. There is a time lapse of six to seven months between the spawning season (maturing stage) and the fishing season. (Most of the shrimp caught in the offshore area were from six to seven months old and most of the juvenile shrimp caught in the lagoon were three to four months old.)

A study conducted by van Zalinge and Naamin (1975) during the trawl era indicated that it took five months from the spawning and residence time in the nursery grounds to the time of recruitment to the offshore fishery. This means that most of the shrimp caught by the trawlers were about five months old. The findings also indicate that the average size of shrimp caught during the trawl era was smaller than that of shrimp caught by trammel net.

The role of the lagoon as a nursery ground

Aside from having an important role as a nursery ground, the lagoon also has an ecological significance for supporting a large and productive mangrove ecosystem. Mangroves are among the most productive ecosystems on earth. Their primary productivity is up to 14 gC/m^2/day under favorable conditions (Snedaker and Getter 1985); this ranges from 430 to 5,000 gC/m^2/year (White 1987).

A prominent role of mangrove communities is the production of leaf litter and detrital matter that are exported, during the flushing process, to the adjacent brackish lagoon and nearshore marine environment. Through a process of microbial breakdown and enrichment, the detrital particles become a nutritious food resource for a variety of marine animals (including shrimp). The role of mangroves in the production and maintenance of a nearshore fishery is widely acknowledged (Snedaker and Getter 1985).

There is enough literature (MacNae 1974; Martosubroto and Naamin 1977; Saenger et al. 1983; Hamilton and Snedaker 1984; Salm and Clark 1984; Snedaker and Getter 1985) that refers to mangroves as important nursery grounds for a great number of shrimp and fish species. According to Salm and Clark (1984), for instance, at least 550,000 t of shrimp and fish worth US$194 million caught in Indonesia in 1978 were species closely associated with mangroves, lagoons and estuaries during some phases of their life cycles.

Water quality and stability of the lagoon greatly influence the sustainability of the role of the lagoon and its surrounding mangrove areas as a nursery ground of shrimp. Even though the water quality in Segara Anakan is reported to be unpolluted and good for fisheries, there is some threat of water pollution in the future.

Some other factors also endanger the stability of Segara Anakan. The water area of the lagoon decreases from year to year due to heavy siltation brought about by the flow of water from upland areas. In 1900, the area of the lagoon was estimated at about 6,675 ha; this declined to 3,638 ha in 1980 and then further declined to 2,761 by 1984. During the period 1980-1984, the average loss of water area was 200 ha/year (Gamaco 1984).

The area covered by mangroves has also been decreasing from year to year due to the illegal cutting of trees and the conversion of portions of the mangroves for other purposes such as human settlement, rice farming and coconut farming. In 1942, the area of mangroves was estimated at about 22,512 ha; this was cut down to 14,000 ha in 1982.

About 74% of Segara Anakan's catches come from tidal traps and the rest come from push-net (9%), *wadong* or crab trap (8%), trammel net (7%) and *pintur* or small lift net for catching crab (3%). For shrimp, the bag net, *wide*, trammel net and push-net are used. Of these, the *wide* has the biggest percentage of shrimp in total catch (Table 10).

Total landings of shrimp during the period July 1987-July 1988 amounted to 932.21 t, worth Rp 627.23 million (US$349,431.75) or about 75% of the total value of fish landed in Segara Anakan. This value is relatively small compared to the value of offshore shrimp catch in the same period (about Rp20.44 trillion or US$12.39 million).

The lagoon fishery is important to the people of the area. About 74% of the Kampung Laut population is dependent on fisheries. During the trawl era, many Segara Anakan fishermen worked as crew of trawlers in the offshore area, but they came back again as traditional lagoon fishermen after the trawl ban. Much effort has been exerted by the Central Java Provincial Government to reduce the number of fishermen in Segara Anakan through a program of transmigration out of Java or a shift from fishing to farming jobs, but these did not work. Most of the fishermen went back to fishing.

Possible consequences

The siltation of the lagoon and its surrounding areas will consequently reduce not only the size of the lagoon and the mangrove forests, but also the size of the nursery ground. The condition of the nursery ground will influence the recruitment of adult shrimp from the offshore area and then affect its population size and the magnitude of the catch.

Two things can happen to the lagoon. The lagoon can be completely or partially closed. If the lagoon will be completely closed, the nursery ground will be lost, and the artisanal fisheries in the lagoon and the offshore commercial shrimp population will be reduced by up to 80% (since about 80% of the offshore shrimp population uses Segara Anakan as nursery ground). With partial closure, the lagoon and the offshore shrimp populations will decrease in proportion to the percentage of closure.

Complete closure of the lagoon will have a severe impact on the livelihood of about 5,780 people (74% of the total population of Segara Anakan) whose income comes from fisheries activities. The more serious impact on the Cilacap economy is the reduction of the commercially important offshore shrimp population, equivalent to 2,256 t/year. If the average price of shrimp is Rp12,000/kg, the total loss from the offshore shrimp fishery will be Rp27.072 billion or US$16.51 million, which is about 43 times the total loss from the lagoon.

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Table 1. Main species of fish, shrimp, crab and mollusk juveniles occurring in Segara Anakan and the offshore area of Cilacap.

Common (English) name	Scientific name	Indonesian name
Fish		
Anchovy	*Stolephorus* spp.	*Ikan teri*
Sardine	*Sardinella fimbriata*	*Tembang*
Ponyfish	*Leognathus* spp.	*Petek*
Mullet	*Mugil* spp.	*Belanak*
Croaker	*Johnius* spp.	*Gulamah*
Hairtail	*Trichlurus* spp.	*Layur*
Sole	*Cynoglossus* spp.	*Ikan lidah*
Lizardfish	*Saurida* spp.	*Bloso*
Wolf herring	*Chirocentrus* spp.	*Parang-parang*
Bombay duck	*Harpodon nehereus*	*Lomsi*
Shrimp		
White shrimp	*Penaeus merguiensis*	*Udang jerbung*
White shrimp	*P. chinensis*	*Udang jerbung*
Tiger shrimp	*P. monodon*	*Udang windu*
Endeavor shrimp	*Metapenaeus ensis*	*Udang dogol*
Endeavor shrimp	*M. elegans*	*Udang dogol*
Western shrimp	*M. dobsoni*	*Udang krosok*
Crab		
Mangrove or mud crab	*Scylla serrata*	*Kepiting*
Mollusk		
Squid	*Loligo* spp.	*Cumi-cumi*
Cuttlefish	*Sepia* spp.	*Sontong*
Cockle	*Anadara granosa*	*Kerang darah*
Cockle	*A. antiguata*	*Kerang bulu*

Table 2. List of larvae and postlarvae of shrimp and fish found in the samples at the east and west entrances of Segara Anakan.

Genus or species	Life stage or type of organism
Penaeus merguiensis	Shrimp
P. chinensis	Shrimp
P. monodon	Shrimp
Metapenaeus ensis	Shrimp
M. elegans	Shrimp
M. dobsoni	Shrimp
Metapenaeus spp.	Shrimp
Acetes	Sergestid
Mycidacea	Mysid
Cyclops spp.	Copepod/zooplankton
Lucifer	Zooplankton
Amphipod	Zooplankton
Nauplius spp.	Zooplankton
Calanus	Zooplankton
Mesogastropoda	Zooplankton
Bivalve larvae	Zooplankton
Annelida	Zooplankton
Rotifera	Zooplankton
Sagitta spp.	Zooplankton
Clupeidae	Fish postlarvae
Leognathidae	Fish postlarvae
Saurida spp.	Fish postlarvae
Scianidae	Fish postlarvae
Gerridae	Fish postlarvae
Engraulida	Fish postlarvae
Loligo spp.	Squid
Sepia spp.	Cuttlefish
Jellyfish	Blastuia
Megaloppa	Crab

Table 3. Yearly shrimp catches and nominal effort in the offshore area of Cilacap, 1971-1987.

Year	Catch (t/yr) *Penaeus* group	*Metapenaeus* group	Others	Total	Effort	Remarks
1971	-	-	-	195	50	Before trawl era (Before 1972)
1972	722	1,405	1,671	3,798	356	
1973	448	870	1,169	2,487	1,395	
1974	466	902	1,543	2,911	1,414	Trawl era (1972-1980)
1975	481	932	1,592	3,005	1,421	
1976	489	977	1,588	3,054	1,959[a]	
1977	784	1,568	2,548	4,900	2,225	
1978	833	1,666	2,707	5,206	2,094	
1979	839	1,782	2,621	5,242	2,124	
1980	355	646	613	1,614		
1981	262	497	144	903	19,285	
1982	323	613	178	1,114	24,726	
1983	242	485	139	866	23,222	
1984	226	430	119	775	28,052	After trawl ban (1981-1987)
1985	252	639	227	1,118	45,134	
1986	245	668	98	1,011	63,554[b]	
1987	493	919	291	1,703	87,640	

- Data not available.

[a]Effort in boat-month.

[b]Effort in boat-day.

Table 4. Yearly shrimp catch in Segara Anakan, 1976-1987.

Year	Catch (t) Shrimp	Fish and others	Total
1976	432	232	664
1977	661	356	1,017
1978	404	218	622
1979	183	99	282
1980	129	70	199
1981	153	83	236
1982	161	87	248
1983	259	140	399
1984	253	127	380
1985	319	172	491
1986	445	240	685
1987	932	491	1,423

Source: 1976-1984 figures - after Mangrove Ecosystem Team; 1985-1987 figures - estimated from CPUE and effort data.

Table 5. Number of shrimp larvae and postlarvae caught by plankton net per hour during high tide at the east and west entrances of Segara Anakan.

Month	East entrance			West entrance		
	Mysis	Postlarvae	Total	Mysis	Postlarvae	Total
1987						
May	144	-	144	12,550	4	12,554
June	822	459	1,281	127	120	247
July	350	11	361	76	20	96
August	1,019	20	1,039	-	4	4
September	14	3	17	-	-	-
October	26	-	26	3	-	3
November	37	5	42	24	-	24
December	69	6	75	13	146	159
1988						
January	128	10	138	9	2	11
February	130	39	169	2	6	8
March	121	44	165	300	18	318
April	135	30	165	6,570	19	6,589

Table 6. Average number (per month) of juveniles emigrating from Segara Anakan to the offshore area, June 1987-September 1988.

Month	*P. merguiensis*	*M. ensis*	Total	Average
January	24	60	84	42.0
February	210	284	494	247.0
March	98	274	372	186.0
April	0	252	252	126.0
May	20	206	226	113.0
June	56	260	316	158.0
July	78	200	278	139.0
August	82	621	703	351.5
September	15	10	25	12.5
October	0	40	40	20.0
November	0	1,050	1,050	525.0
December	276	500	776	388.0

Table 7. Estimates of growth and mortality parameters of *P. merguiensis* in the offshore area of Cilacap, 1977-1984.

Period	Sex	L_∞ (CL, mm)	K (yearly)	Z (yearly)	M (yearly)
1977-1979	females	53.1	1.15	4.5	-
	males	43.8	1.60	11.1	-
1982-1984	females	53.8	0.90	4.9	-
	males	42.4	1.50	9.5	-
1977-1984	females	51.5	1.05	-	3.1
	males	44.5	1.31	-	3.7
Average	both sexes	49.9	1.25	7.5	3.4

Source: Sumiono (1987).

Table 8. Percentage of *P. merguiensis* and *M. ensis* in their gonadal maturity stage caught in the offshore area of Cilacap, 1977-1979 and 1984-1988 (monthly averages).

Month	*P. merguiensis*	*M. ensis*
January	25.7	53.0
February	21.2	60.8
March	24.2	41.2
April	29.8	29.4
May	32.4	20.1
June	28.8	24.3
July	26.8	47.1
August	30.7	44.4
September	16.6	29.4
October	18.3	7.1
November	17.8	15.6
December	22.9	35.5

Table 9. Monthly rainfall in the Cilacap and Segara Anakan areas for the period 1984-1987.

Month	Rainfall (mm)				
	1984	1985	1986	1987	Average
January	292	331	420	371	353.50
February	332	174	152	170	207.00
March	258	296	611	202	341.75
April	406	257	423	380	366.50
May	345	221	158	226	237.50
June	228	367	573	58	306.50
July	115	246	458	193	253.00
August	59	56	388	35	134.50
September	998	121	560	27	426.50
October	511	293	614	170	384.50
November	349	466	575	476	466.50
December	268	468	683	580	499.75
Total	4,161	3,296	5,615	2,838	

Table 10. Catch-and-effort data for different types of fishing gear in Segara Anakan, July 1987-July 1988.

Fishing gear	Effort		Catch						
	No. of units	No. of trips	Volume (t)			value (Rp)		CPUE (kg)	
			Shrimp	%	Total	Shrimp	Total	Shrimp	Total
Tidal traps									
Apong	320	74,880	330.80	(42.4)	780.75	314.250	350.026	7.16	15.06
Wide	421	103,987	303.39	(75.7)	401.04	169.280	178.260	7.74	10.03
Trammel net	195	32,955	204.01	(26.1)	104.59	77.352	92.884	1.54	5.89
Push-net	289	41,756	94.01	(68.6)	137.06	66.345	73.161	5.24	7.11
Total			932.21		1,423.44	627.227	694.331		

Notes: 1. The percentage of shrimp catch to total catch is 47.5.
2. Total value of landings of fish, shrimp, crabs and others from July 1987 to July 1988 was Rp841.7 million.

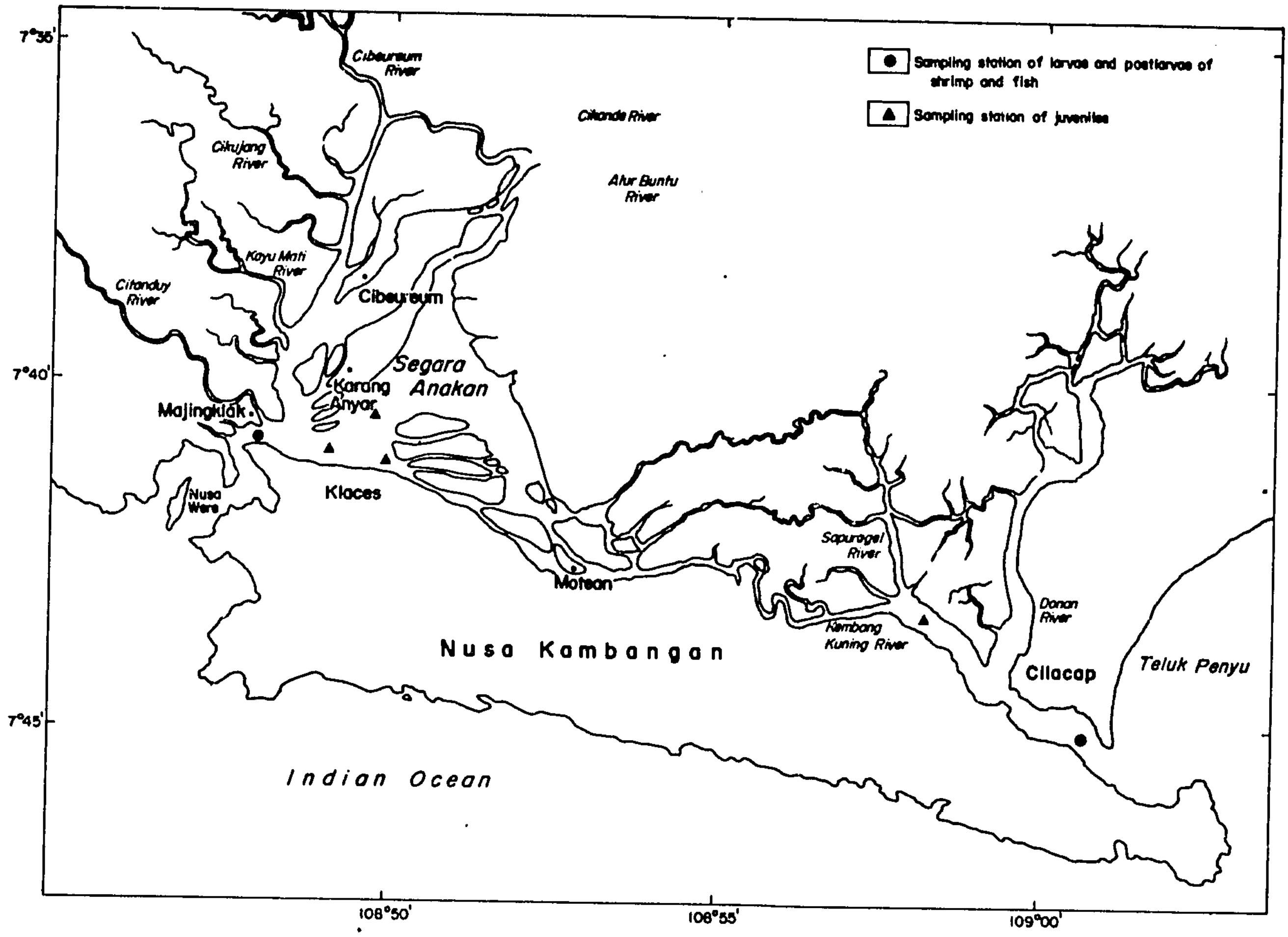

Fig. 1. Map of Segara Anakan and adjacent areas showing two channels (entrances) and sampling stations.

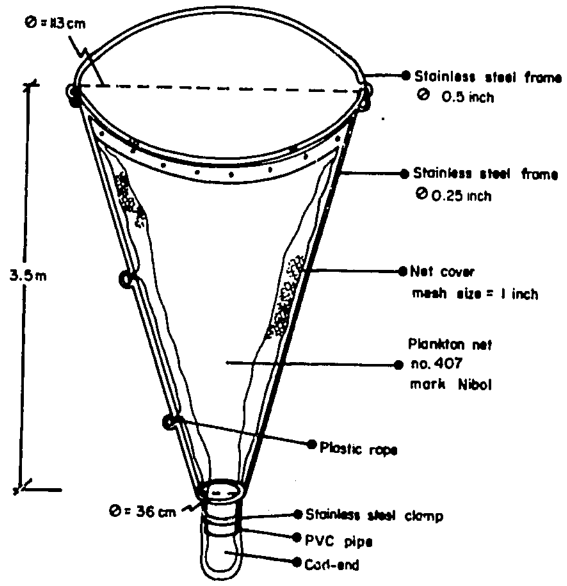

Fig. 2. Plankton net used for sampling larvae and postlarvae.

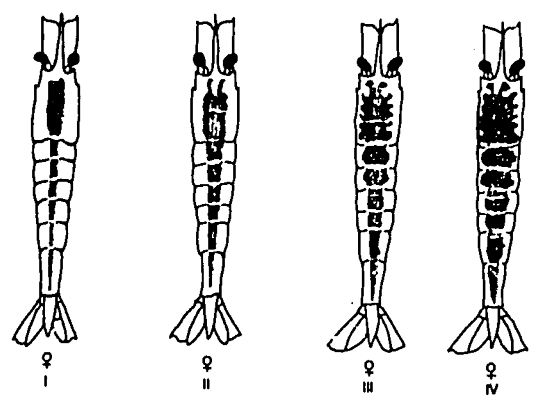

Fig. 3. Gonadal maturity stages of the penaeid shrimp.

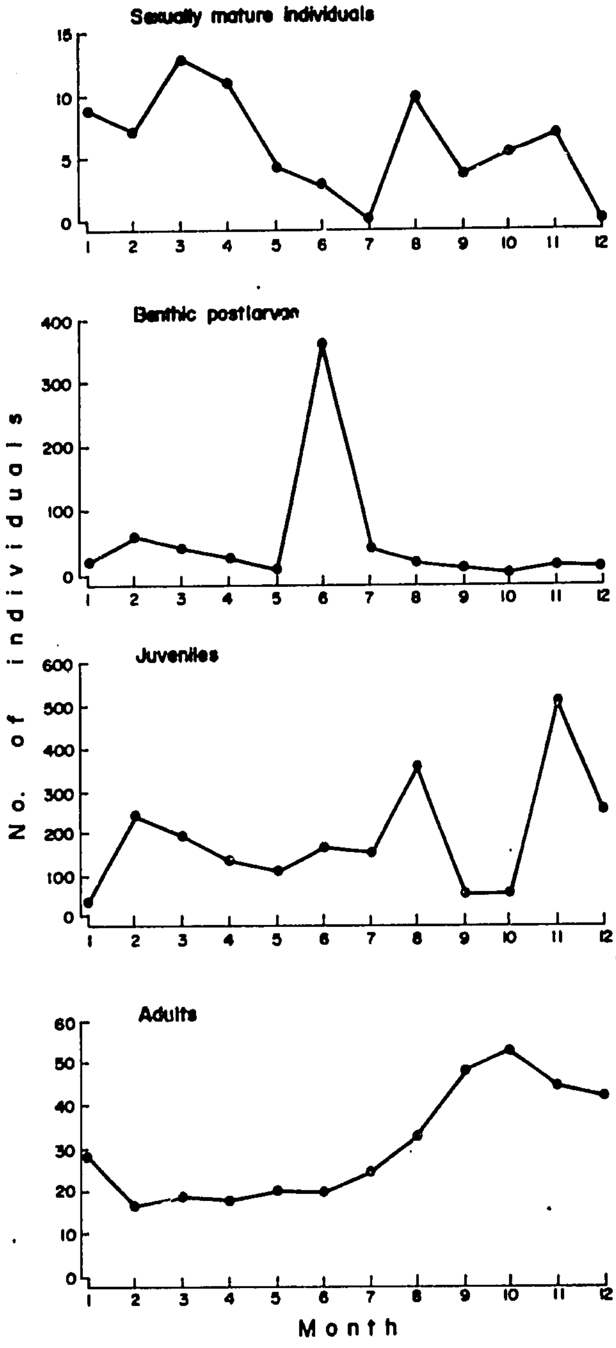

Fig. 4. Seasonality and correlation between sexually mature larvae and postlarvae, juvenile and adult shrimp in Segara Anakan and the offshore area of Cilacap.

Water quality of Segara Anakan-Cilacap (Central Java, Indonesia) with a note on lagoon fishery

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ABSTRACT

The study of Cilacap's semi-enclosed (lagoon) waters, particularly of Segara Anakan-Cilacap (Central Java), was carried out in relation to the effort of making use of this lagoon as a fisheries resource of the area.

Water quality parameters measured and analyzed were temperature, acidity, dissolved oxygen, sulfate, calcium, magnesium, phosphate, nitrate, heavy metals (Pb, Cd, Fe, Ni and Hg), pesticides and hydrocarbons. The results of the study indicated that the oceanographic conditions of Segara Anakan varied considerably according to seasons and tides.

The pollutant levels of the lagoon are attributed more to several rivers discharging into it than to the industrial wastes coming from the eastern part (Cilacap waters). In general, the pollutant levels were below the upper limits allowed by the Indonesian water quality standards established for conservation.

Sedimentation, which is decreasing the water area, and the influence of the incoming tide on the water quality are also discussed.

INTRODUCTION

The environment of Segara Anakan-Cilacap and its adjacent waters, especially of Donan River and its surroundings, are currently subject to land-based pollution and local industrial activities. However, pollution from these sources is considered negligible; seen to be dominant are the effects of tides and rivers.

The importance of Segara Anakan for local and offshore fisheries has long been known. To sustain these resources, good water quality must be maintained.

The key water quality parameters of the lagoon are oceanographic salinity, temperature, inorganic pollutants (heavy metals), organic pollutants (oil and pesticides) and bacteriological pollutants.

Segara Anakan and its adjacent waters

Segara Anakan is a brackishwater lagoon protected from the sea by Nusa (meaning "island") Kambangan. Two openings connect this lagoon with the Indian Ocean: one in the southwest corner, close to the mouth of the Citanduy River and the other, a narrow, long, branched and meandering channel known as Kembang Kuning River, in the southeast corner, connecting a wider and branched channel to Penyu Bay of the Indian Ocean. Joining the latter channel is the Donan River-Jeruk Legi River, which runs in the north-south direction (Fig. 1). Situated along the eastern bank of this river, from north to south, are a cement factory, an oil refinery, a fertilizer packing factory and the Cilacap Harbor--which are suspected to be sources of pollutants.

The Segara Anakan water system is influenced by a daily mixed semidiurnal tide and river inputs. The rivers that empty into the lagoon are Citanduy and Kayu Mati in the west; Cikujang, Cibeureum, Kawunganten and Cikonde in the north; and Udjung Alang, Dangal and Kembang Kuning in the east. The lagoon is threatened by sediment brought in by these rivers at an alarming rate. The decrease in the water area of Segara Anakan by about 3,000 ha during the past 84 years is shown in Table 1 (Abadi 1984). The water quality is also affected by the four seasons, two being transitional. The dry season prevails from June to August and is followed by a transitional period from September to November. The rainy season prevails from December to February, bringing considerable precipitation and very often causing floods in the region. This season is followed by another transitional period from March to May.

MATERIALS AND METHOD

Based on the assumption that pollutants from the industrial complex are brought in to Segara Anakan by the Donan and Kembang Kuning Rivers, among other rivers, 12 stations were established: Stations A, B and C in the eastern part (Cilacap Harbor or Donan River), Stations 1-7 in the western part (Segara Anakan) and Stations D and E, in Kembang Kuning River, which connect the two other areas (Fig. 1).

Samples were collected from these stations once every two months from May 1987 to March 1988, and monthly, from November 1987 to January 1988. To study the influence of tides on the oceanographic condition of the lagoon, one diurnal sampling station (No. 2) was chosen in Klaces where three hourly samplings were carried out.

For the analyses of water quality, water samples were collected using Nansen bottles. But these were collected at near-surface because of the shallowness of the area. Table 2 presents the water quality parameters and methods of analysis.

RESULTS AND DISCUSSION

The results of the study show monthly variations in the oceanographic parameters measured in the three areas (Table 3). In these waters and in other areas of Indonesia, the seasons have much influence on the oceanographic condition. Thus, the rainy season brings high precipitation and the dry season often causes drought in the area.

Spatial and seasonal distributions

The nine oceanographic parameters measured in Segara Anakan during the sampling period are shown in Tables 4-12 and Figs. 2-4. The water temperature of this lagoon varied very slightly from station to station. Monthly observations, however, show significant variations seasonally (Table 4). Two maxima (29-31°C) were observed in May and November 1987, both of which are within the transition period. The minimum temperature (about 25°C) occurred in December 1987 during the rainy season. Birowo and Uktolseya (1980) reported that the mean surface water temperature of the south coastal waters near Cilacap from July to October was 26°C and in April, 29°C. This range of temperature was within the values of the present observation, except in December when the temperature was lower but was not reported in the previous observation.

The salinity, sulfate, calcium and magnesium contents show a great variation among stations as well as seasonally (Tables 5-8). From May to July, these parameters showed increasing values. There were no salinity data in September, but based on the maximum values of sulfate, calcium and magnesium that occurred this month, the maximum value of salinity should have also occurred this month. In December and January, when the rainy season prevailed, these four parameters had lower values. The salinity throughout the lagoon reached almost 0 ppt, which indicated that Segara Anakan almost became a freshwater lagoon. The sources of dilution are mainly from three rivers: Citanduy, Kawunganten and Cibeureum Rivers (Fig. 1). The Citanduy River has the largest contribution of freshwater to the lagoon (ET 1984). By the end of the rainy season, when the transition period began, i.e., in March, a slight increase in salinity occurred in stations 1-3 (Table 5). Therefore, from May 1987 until March 1988, the Segara Anakan waters showed three aquatic characteristics, i.e., coastal, brackishwater and freshwater (Fig. 5).

Spatially, almost throughout the observation, salinity, sulfate, calcium and magnesium indicated the lowest values near the mouth of the Citanduy River (Station 4) compared to other stations (Figs. 2 and 3), indicating that this river contributed significantly to the Segara Anakan waters.

The pH level and oxygen content did not always show lower values at the river mouths than at the other stations. Lower values were observed during December to March, compared to the other months (Tables 9 and 10, Fig. 2). In general, the pH and the oxygen content of Segara Anakan were lower in the rainy season than in the dry season. At the Kawunganten Estuary, the lowest pH in these waters was recorded at 6.5 in January 1988 and the lowest oxygen content, 3.45 ppm, in January and March 1988.

The highest values of phosphate and nitrate were found in the mouth of the Citanduy River (i.e., 23-33 ppb in November-December and 337-695 ppb in December-January, respectively) (Tables 11 and 12, Fig. 4). These indicate that the Citanduy River is a potential source of these nutrients. Brahmana (1984) stated that the sources of these nutrients in Segara Anakan were mostly fertilizers and domestic waste.

Based on the fluctuations of salinity, calcium and magnesium (presented as $\bar{x} \pm$ s.d.) at each station, it can be concluded that the water quality at Stations 1, 2, 3, 5, 6 and 7 was more stable than that at Station 4 (Citanduy River's mouth). This suggests that the water quality of the former six stations is predominantly affected by tides, while that at Station 4, by both tides and river flow.

Diurnal variations

The results of the 24-hour observation of temperature, salinity, oxygen content and pH of the waters of Segara Anakan conducted in 22-23 May; 22-23 July; 25-26 September; 15-16 November; 12-13 December 1987; 26-27 January and 24-25 March 1988 at Station 2 are presented in Tables 13-16 and Fig. 6.

Among the four parameters, temperature had little variation except in September when it showed a maximum value in the late afternoon, which coincided with extremely low tide, and a minimum value at night, which coincided with extremely high tide (Figs. 6 and 7). The effect of solar radiation during the day coupled with the shallowness of the lagoon's water due to extreme low tide should explain why an extremely high temperature (>31°C) occurred at that hour. Generally, temperatures of the lagoon were kept high, between 29 and 30°C, except in December 1987 when the rainy season reached its peak and temperatures varied between 25 and 27°C.

Salinity of the lagoon, on the contrary, varied greatly. One or two peaks were found during the 24-hour period. These peaks seemed to coincide with the occurrence of high tides (Figs. 6 and 7). An extraordinary condition occurred in December 1987 in that the salinity of the lagoon reached zero value throughout the observation and tides seemed to have little influence. This is probably due to the occurrence of a flood and the excessive freshwater brought into the lagoon.

A high pH was observed during high tide. In the lagoon, the pH hardly reached below 7 during the study except in January 1988 at night (Figs. 6 and 7). A relatively high oxygen content was detected during high tide (Figs. 6 and 7). The above observations indicate that during high tide, the Indian Ocean had brought oceanwater of relatively good quality into the lagoon.

Pollution

The pollutants detected in Segara Anakan were heavy metals, pesticides, hydrocarbons and sediment. The possible sources were the water from Donan where a harbor area is located, the Indian Ocean and other rivers that flowed into the lagoon. The first source seemed to be unimportant since the current pattern of the Cilacap waters was such that the chances of the pollutants from the Donan River to enter the lagoon were very low. The Ecology Team (ET 1984) explained that during the rising tide, inflowing tidal currents flowed into the lagoon through the eastern and western passages and met at a point (equilibrium point) east of Motean. Water flowed back with the receding tides from this point eastward and westward on the same course that it entered. This means that the water from the harbor would reach that point only and not flow further into the lagoon.

The concentration of heavy metals in Segara Anakan fluctuated with the seasons and diurnally (Tables 17-20). However, the concentrations in the water were generally very low and below the upper limits allowed by the Indonesian water quality standards for conservation (Anon. 1988). Pesticide and hydrocarbon contents were negligible (Table 21).

Unlike the three other groups of pollutants, sediment were potentially dangerous for fisheries activities in this lagoon. Among the three locations (i.e., mouths of the Citanduy, Cibeureum and Kawunganten Rivers), the last two were much more turbid than the mouth of the Citanduy River (Table 22). However, this latter river contributed the most amount of sediment to the lagoon. It was likely then that the soil particles brought in by the Citanduy River were transported by the incoming tide toward the two river mouths and deposited somewhere around those areas.

At high tide, turbidity at Klaces (Station 2) was always higher than at Majingklak (Station 4). Purba (1988) noted that standing water occurred between Klaces and Motean where horizontal water movement was lacking, and this area was favorable for the deposition of soil particles. Turbidity also fluctuated with the tides; it was relatively lower during high tide but higher during low tide (Fig. 8).

Fisheries

The study of the quality of the lagoon water showed that Segara Anakan is still favorable for lagoon fisheries. Pollution is negligible though occasionally, certain pollutants can be found. Also, the long-lasting siltation that causes turbidity and decreases the lagoon's area and water depth in many places is of concern.

The Ecology Team (ET 1984) indicated that the fisheries resources of Segara Anakan have long been exploited. Their inventory recorded 45 lagoon species while 17 other species were migratory. The number of species ratio between migratory and resident species was 4 to 1. Various kinds of fishing gear, such as fish weirs and fish nets, have been used. Fish catch composition was such that migratory species constituted 60%.

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Table 1. Decrease in water area (ha) of Segara Anakan in 84 years.

Year	Lagoon area and island	Island area	Lagoon area	Decrease of lagoon area	
				Total	Annual
1900	6,898	223	6,675		
1924	6,791	346	6,445	230	10
1940	6,645	596	6,049	396	25
1946	6,061	649	5,412	637	106
1961	5,444	707	4,737	675	45
1978	4,431	979	3,852	885	52
1980	4,680	1,042	3,638	214	107
1982	4,375	1,169	3,206	432	216
1983	4,313	1,354	2,959	247	247
1984	4,050	1,289	2,761	198	198

Source: Abadi 1984.

Table 2. Water quality parameters and methods of analysis.

Parameter	Method	Instrumentation
Oceanographic		
Temperature	Mercury expansion	Reversing thermometer
Acidity	Potentiometric	pH meter, "La Motte"
Salinity	Electrical conductometry	Conductometer
Dissolved oxygen	Winkler modification (iodometry)	
Calcium, Ca^{2+}	EDTA titrimetry, pH = 12-13	
Magnesium, Mg^{2+}	EDTA titrimetry, pH = 10	
Sulfate, So_4^{2-}	Gravimetry, $BaSo_4$	Sartorius balance
Phosphate, PO_4	Ascorbic acid method	UV-Vis, spectrophotometer, L = 880 nm
Nitrate, NO_3	Cadmium reduction method	UV-Vis, spectrophotometer, L = 543 nm
Inorganic pollutants		
Heavy metals		
a. Pb, Cd	Extraction APDC-MIBK, spectrophotometric	Flame AAS
b. Hg	Oxidation with $KMnO_4$ H_2SO_4, spectrophotometric	Flameless AAS
Turbidity	Nephelometric	Nephelometer
Organic pollutants		
Pesticides	Gas-chromatographic	Gas-chromatography
Hydrocarbons	Concave 1/72, spectrophotometric	I.R. spectrophotometer

Table 3. Water quality of Cilacap and Segara Anakan, May 1987-March 1988.
I-Segara Anakan; II-Kembang Kuning River, III-Cilacap Harbor.

Parameter		May I	May II	May III	July I	July II	July III	September I	September II	September III
Temperature, °C	x̄	29.8	29.5	30.3	27.7	28.8	28.1	27	28	26.7
	sd	0.5	0.2	0.5	0.5	0.3	0.5	1.4	0.6	1.6
Salinity, ppt	x̄	17.7	11.5	29.5	23.2	28	28	-	-	-
	sd	5.8	2.1	2.1	7.4	1.4	2.7	-	-	-
pH	x̄	7.5	7	7.8	7.5	7.5	7.6	7.6	7.6	7.8
	sd	0.4	0	0.2	0.4	0.3	0.3	0.2	0	0.3
DO, ppm	x̄	5.8	5.1	5.5	5.7	6.4	6.3	5.6	4.8	5.3
	sd	0.6	0.1	0.6	0.1	0.3	0.1	0.8	0.1	0.7
Sulfate (SO_4), ppm	x̄	1,171	1,009	2,066	1,641	1,973	2,161	2,406	2,772	2,654
	sd	341	146	174	540	197	125	106	104	43
Calcium (Ca), ppm	x̄	190	138	269	238	263	259	317	361	377
	sd	64	20	36	56	31	39	36	28	28
Magnesium (Mg), ppm	x̄	576	409	1,079	891	1,086	1,134	1,295	2,106	1,318
	sd	186	71	150	316	66	104	50	1,077	10
Phosphate (PO_4), ppb	x̄	8.5	24.9	3.9	16.1	11.6	8.1	22.2	21.6	13.6
	sd	4.2	2.2	0.9	2.5	4.9	0.8	5.2	8.2	20.6
Nitrate (NO_3), ppb	x̄	50	15.9	7.9	111	ND	8.3	8	10.1	8.2
	sd	71	5.3	10	82	ND	12.3	9	1.8	5
Lead (Pb), ppb	x̄	12.2	11.3	11.7	9.1	7.9	9.9	11.1	10.6	9.3
	sd	3.5	4.9	2.7	3.5	1.8	0.7	2.2	0	1.2
Cadmium (Cd), ppb	x̄	1.1	1.1	0.6	2.6	7.4	3.5	0.9	0.8	0.7
	sd	0.3	0.1	0	4.1	8.6	5.2	0.2	0	0.1
Iron (Fe), ppb	x̄	200	109	43	536	406	215	776	264	284
	sd	215	24	14	353	112	68	225	139	155
Nickel (Ni), ppb	x̄	3.3	4.3	3	3.9	4	3.1	4.8	2.4	3.6
	sd	1.6	4.5	2	0.7	0.6	0.5	1.1	0	1.4
Mercury (Hg), ppb	x̄									
	sd									

ND - Not detected.
x̄ - mean
sd - standard deviation

Parameter		November I	November II	November III	December 1987 I	December 1987 II	December 1987 III	January I	January II	January III	March 1988 I	March 1988 III
Temperature, °C	x̄	29.8	30.1	29.5	25.4	25.5	28.5	28	28.9	29.1	27.4	28.8
	sd	0.4	0	0.5	0.2	0.5	0.3	1.0	0.1	0.3	0.4	1.4
Salinity, ppt	x̄	12	20	24	0	0	11	0	15	18	1.9	14
	sd	6.5	0	3.2	0	0	8.2	0	0	5.3	2.7	8.7
pH	x̄	7.3	7.2	7.4	7.2	7	7.3	7.0	7	7.4	7.1	7.6
	sd	0.3	0.1	0.1	0.1	0	0.1	0.3	0	0.1	0.3	0.2
DO, ppm	x̄	6.3	5.3	5.7	5.2	6.0	5.7	5.0	3.6	4.8	4.9	5.3
	sd	0.4	0	0.7	1.0	0.3	0.9	0.8	0.6	0.1	0.9	0.3
Sulfate (SO_4), ppm	x̄	1,359	1,687	1,660	95	77	1.130	122	257	745	194	989
	sd	350	74	561	47	14	280	57	23	497	188	439
Calcium (Ca), ppm	x̄	235	377	397	25	30	172	30	44	65	-	-
	sd	94	3	21	6	27	91	12	28	4	-	-
Magnesium (Mg), ppm	x̄	704	895	1,075	20	34	583	29	105	604	-	-
	sd	238	16	102	14	10	157	19	12	167	-	-
Phosphate (PO_4), ppb	x̄	18	12.9	7.5	13.9	38.5	12.2	6.4	7.8	3.2	11	10.1
	sd	8.5	0	2.3	6.0	52.5	3.7	3.0	0.7	0.7	2.2	7.9
Nitrate (NO_3), ppb	x̄	138	73	46	347	81	106	156	143	73.4	84	38
	sd	103	8	43	273	0	60	107	2	41	49	32
Lead (Pb), ppb	x̄	10.3	9.4	9.9	9.9	11.4	7.4	7.8	10.5	5.7	14.8	7.2
	sd	2.3	0	2.6	5.2	4.5	1.4	2.3	2.1	1.4	5.2	4.7
Cadmium (Cd), ppb	x̄	1.7	1.6	1.2	0.7	1.4	0.3	0.3	0.3	0.3	0.3	0.5
	sd	0.4	1.1	0.2	0.7	1.3	0.1	0.1	0.1	0.1	0.1	0.1
Iron (Fe), ppb	x̄	448	298	234	1,190	1,593	398	904	821	204	1,112	414
	sd	323	61	64	601	241	39	372	312	53	248	73
Nickel (Ni), ppb	x̄	9.4	8.8	12	8.5	11.6	8	12.2	7.9	9.7	23.7	16.2
	sd	2.2	2	2.4	2.8	8.4	2.8	2.7	0.8	0	10.6	2.1
Mercury (Hg), ppb	x̄							0.3	ND	0.3	0.3	0.3
	sd							0.1	-	0.1	0.1	0

ND - Not detected.
x̄ - mean
sd - standard deviation

Table 4. Water temperature (°C) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	29.7	28.4	27.9	29.8	25.2	28.5	27.3
2	29.5	28.1	26.0	29.8	25.4	28.0	27.3
3	29.1	27.5	25.5	29.2	25.1	28.3	28.3
4	29.7	27.3	25.3	30.0	25.6	28.6	27.0
5	29.8	27.2	28.1	29.5	25.5	28.7	27.3
6	30.1	-	27.9	30.2	-	26.1	27.2
7	30.8	-	26.5	-	-	-	27.6
x̄	29.8	27.7	27.0	29.8	25.4	28.0	27.4
sd	0.5	0.5	1.4	0.4	0.2	1.0	0.4

Table 5. Salinity (ppt) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	18.0	26.0	-	18.0	0.0	0.0	4.0
2	25.0	26.0	-	15.0	0.0	0.0	2
3	23.0	27.0	-	10.0	0.0	0.0	7.0
4	8.0	10.0	-	0.0	0.0	0.0	0.0
5	20.0	27.0	-	16.0	0.0	0.0	0.0
6	13.0	-	-	14.0	0.0	0.0	0.0
7	17.0	-	-	-	0.0	0.0	0.0
x̄	17.7	23.2	-	12.0	0.0	0.0	0.9
sd	5.8	7.4	-	6.5	0.0	0.0	2.7

Table 6. Sulfate concentration (ppm) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	1,200	1,954	2,239	1,742	128	119	254
2	1,665	1,964	2,305	1,262	151	153	150
3	1,427	1,959	2,557	1,325	66	86	595
4	667	712	2,468	763	35	64	45
5	1,315	1,614	2,400	1,672	94	88	113
6	841	-	2,425	1,388	-	219	97
7	1,088	-	2,450	-	-	-	105
x̄	1,171	1,641	2,406	1,359	95	115	194
sd	341	540	106	350	47	61	188

Table 7. Calcium concentration (ppm) in Segara Anakan, May 1987-January 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.
1	172	289	337	324	22	28
2	232	281	329	289	28	54
3	216	259	337	214	30	26
4	92	160	241	60	28	20
5	208	200	309	281	18	26
6	128	-	345	244	-	24
7	280	-	325	-	-	-
x̄	190	238	235	317	25	30
sd	64	56	94	36	5	12

Table 8. Magnesium concentration (ppm) in Segara Anakan, May 1987-January 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.
1	587	1,030	1,259	857	26	41
2	855	961	1,274	765	39	16
3	728	1,063	1,327	754	21	23
4	331	331	1,391	225	2	2
5	648	1,069	1,296	837	13	33
6	399	-	1,245	788	-	56
7	482	-	1,276	-	-	-
x̄	576	891	1,295	704	20	29
sd	186	316	50	238	14	19

Table 9. pH in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	7.0	6.9	7.6	7.4	7.1	7.2	7.2
2	7.9	7.2	7.5	7.5	7.3	7.1	7.1
3	7.8	7.9	7.7	7.5	7.2	7.3	7.4
4	6.8	7.6	7.8	6.8	7.3	7.2	7.5
5	7.8	7.8	7.6	7.5	7.0	6.7	6.8
6	7.6	-	7.3	7.4	-	6.5	6.9
7	7.5	-	7.6	-	-	-	7.1
x̄	7.5	7.5	7.6	7.3	7.2	7.1	7.1
sd	0.4	0.4	0.2	0.3	0.1	0.3	0.3

Table 10. Dissolved oxygen (ppm) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	5.2	5.8	5.3	6.1	5.5	5.1	5.4
2	4.8	5.8	5.9	6.3	5.0	5.0	3.7
3	6.1	5.8	5.5	6.8	5.5	5.5	5.8
4	5.8	5.8	5.7	6.2	5.7	5.7	5.9
5	6.0	5.6	5.7	6.6	5.1	5.1	4.4
6	6.4	-	4.3	5.5	3.5	3.5	3.5
7	6.4	-	6.9	-	5.8	5.8	5.8
x̄	5.8	5.7	5.6	6.3	5.0	5.0	4.9
sd	0.6	0.1	0.8	0.4	0.8	0.8	0.9

Table 11. Phosphate concentration (ppb as P) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	9.2	12.3	17.4	10.2	11.2	1.3	13.2
2	4.5	17.8	30.7	22.3	6.8	7.1	6.9
3	7.6	15.0	24.0	15.6	15.6	10.0	10.1
4	17.1	17.8	22.4	33.0	23.0	5.6	11.7
5	6.0	17.8	15.8	11.6	12.7	8.5	10.1
6	9.2	-	25.7	15.6	-	5.6	13.2
7	6.0	-	19.1	-	-	-	11.7
x̄	8.5	16.1	22.2	18.0	13.9	6.4	11.0
sd	4.2	2.5	5.2	8.5	6.0	3.0	2.2

Table 12. Nitrate concentration (ppb as N) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	5	16	2	93	96	97	47
2	13	107	2	75	105	61	17
3	69	87	19	232	269	133	109
4	203	241	23	298	695	337	147
5	42	106	2	94	569	228	82
6	18	-	9	35	-	79	50
7	ud	-	1	-	-	-	135
x̄	50	111	8	138	156	156	84
sd	71	82	9	103	107	107	49

Table 13. Fluctuation of water temperature (°C) in Segara Anakan, May 1987-March 1988.

Time	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
13.30	30	30	30	30	26	30	30
16.30	30	29	31	29	26	30	30
19.30	30	28	29	29	26	29	28
22.30	30	28	25	30	26	29	27
01.30	30	28	28	29	26	28	27
04.30	29	27	26	29	26	28	28
07.30	30	27	26	30	25	28	27
10.30	30	28	27	30	25	29	28
13.30	32	31	29	30	26	29	29
x̄	30	28	28	30	26	29	28
sd	1	1	2	1	0	1	1

Table 14. Fluctuation of salinity (ppt) in Segara Anakan, May 1987-March 1988.

Time	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
13.30	18	18	-	19	0	19	18
16.30	24	16	-	22	0	15	9
19.30	22	19	-	19	0	5	4
22.30	18	21	-	16	0	3	4
01.30	10	22	-	8	0	3	2
04.30	27	23	-	15	0	2	2
07.30	25	30	-	15	0	0	2
10.30	18	26	-	15	0	0	5
13.30	17	19	-	8	0	1	27
x̄	20	22	-	15	0	5	0
sd	5	4	-	5	0	7	9

Table 15. Fluctuation of dissolved oxygen (ppm) in Segara Anakan, May 1987-March 1988.

Time	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
13.30	-	-	8.1	6.8	6.5	6.3	6.0
16.30	6.4	-	7.3	7.0	6.3	5.7	5.5
19.30	7.3	6.8	6.9	6.1	6.1	4.7	5.8
22.30	5.8	6.4	6.3	6.9	6.0	5.1	6.0
01.30	6.1	6.6	6.1	7.0	5.6	5.7	5.4
04.30	5.8	5.0	-	6.6	5.6	5.3	5.2
07.30	4.8	6.0	5.9	6.3	5.7	5.0	3.7
10.30	5.4	5.8	6.1	6.6	5.4	5.0	5.3
13.30	8.6	7.0	7.3	8.0	5.0	5.3	5.9
x̄	6.3	6.2	6.7	8.8	5.8	5.3	5.4
sd	1.2	0.7	0.8	0.5	0.5	0.5	0.7

Table 16. Fluctuation of pH in Segara Anakan, May 1987-March 1988.

Time	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
13.30	7.2	7.2	8.0	7.6	7.2	7.5	7.8
16.30	7.9	7.3	7.5	7.3	7.2	7.4	7.2
19.30	7.9	7.5	7.6	7.2	7.3	6.9	7.1
22.30	7.5	7.6	8.0	7.5	7.1	7.1	7.2
01.30	7.6	7.7	7.9	7.3	7.1	7.1	7.3
04.30	7.9	7.7	7.4	7.3	7.1	7.0	7.2
07.30	7.9	7.8	7.5	7.5	7.3	7.1	7.1
10.30	7.4	7.2	7.7	7.3	7.0	7.2	7.2
13.30	7.7	7.6	7.8	7.4	7.1	7.3	7.3
x̄	7.7	7.5	7.7	7.4	7.2	7.2	7.2
sd	0.2	0.2	0.2	0.1	0.1	0.2	0.2

Table 17. Lead concentration (ppb) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	10.1	14.0	12.5	11.1	8.2	6.5	15.0
2	12.4	11.5	8.6	11.1	19.0	6.5	9.9
3	10.1	6.6	14.5	9.4	8.2	12.0	17.8
4	18.4	6.6	12.5	6.0	8.2	6.5	23.2
5	14.8	6.6	10.6	12.8	5.7	9.0	17.8
6	7.8	-	10.6	11.1	-	6.5	9.9
7	12.4	-	8.6	-	-	-	9.9
x̄	12.2	9.1	11.1	10.3	9.9.	7.8	14.8
sd	3.5	3.5	2.2	2.3	5.2	2.3	5.2

Table 18. Cadmium concentration (ppb) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	1.0	0.7	0.8	1.4	0.6	0.2	0.4
2	0.6	-	0.8	1.6	1.9	0.4	0.6
3	1.0	8.7	0.8	1.1	0.4	0.2	0.4
4	1.5	0.7	1.0	1.8	0.2	0.2	0.2
5	1.2	0.4	1.2	2.0	0.2	0.2	0.2
6	1.2	-	1.2	2.2	-	0.3	0.4
7	1.2	-	0.8	-	-	-	0.2
x̄	1.1	2.6	0.9	1.7	0.7	0.3	0.3
sd	0.3	4.1	0.2	0.4	0.7	0.1	0.1

Table 19. Iron concentration (ppb) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	92	1,076	748	489	1,575	1,007	1,117
2	64	702	336	190	301	1,089	666
3	49	349	792	247	1,592	1,063	989
4	423	206	717	450	829	821	1,378
5	73	350	920	250	1,652	1,247	1,272
6	115	-	1,053	1,030	-	199	1,025
7	588	-	864	-	-	-	1,338
x̄	200	536	776	448	1,190	904	1,112
sd	215	353	225	323	601	372	248

Table 20. Nickel concentration (ppb) in Segara Anakan, May 1987-March 1988.

No.	May	Jul.	Sep.	Nov.	Dec.	Jan.	Mar.
1	1.1	4.4	3.3	8.3	5.6	13.4	13.8
2	4.3	4.4	6.2	7.4	9.2	12.2	24.7
3	2.7	3.6	4.3	9.3	11.1	15.9	6.6
4	3.5	4.4	6.2	12.1	5.6	8.5	28.3
5	3.5	2.8	4.3	12.1	11.1	13.4	24.7
6	1.9	-	5.2	7.4	-	9.7	28.3
7	5.9	-	4.3	-	-	-	39.2
$\bar{x}$	3.3	3.9	4.8	9.4	8.5	12.2	23.6
sd	1.6	0.7	1.1	2.2	2.8	2.7	10.6

Table 21. Variation in the ranges of the average values of environmental parameters and pollutants in Segara Anakan, Kembang Kuning River and the harbor area.

Parameter	Segara Anakan	Kembang Kuning River	Harbor area	Standard quality
Oceanographic				
Temperature, °C	25.1 - 30.8	25.1 - 30.1	26.4 - 30.3	Natural condition
Salinity, ppt	0 - 25.1	0 - 28	11 - 33	10% - Alami
pH	7.0 - 7.8	7.0 - 7.6	7.3 - 7.9	6 - 9
Dissolved oxygen, ppm	4.6 - 6.3	3.6 - 6.4	4.6 - 6.3	> 4
SO_4, mg/l	95 - 2,406	77 - 2,772	745 - 2,654	
Ca, mg/l	25 - 317	30 - 377	65 - 397	
Mg, mg/l	20 - 1,295	34 - 2,106	583 - 1,318	
PO_4, ppb	6.4 - 61.7	7.8 - 38.5	0.5 - 29.6	
NO_2, ppb	ND - 8.1	ND - 4.3	ND - 6.5	nil
NO_3, ppb	8 - 347	ND - 143	7.4 - 122	
Inorganic pollutants				
Pb, ppb	7.8 - 19.8	7.9 - 11.4	5.7 - 32.4	< 75
Cd, ppb	0.3 - 3.0	0.3 - 7.4	0.3 - 3.5	< 10
Fe, ppb	200 - 1,190	109 - 1,593	43 - 536	< 10
Ni, ppb	3.3 - 23.6	2.4 - 11.6	3 - 20.8	< 100
Hg, ppb	0.1 - 0.6	0.2 - 0.6	0.2 - 0.6	< 6
Organic pesticides				
Organochlorine				
Eldrin, ppb	0.010 - 0.019	-	-	< 20
pp DDT	ND	-	-	< 20
pp DDT	ND	-	-	< 20
pp DDE	ND - 0.015	-	-	
BHC	ND	-	-	< 20
Endosulfan	ND	-	-	< 20
DDE	ND	-	-	< 20
Organophosphate				
Diazinon	0.067 - 0.36	-	-	
Carbamat	ND	-	-	< 20
Hydrocarbon, ppm	0.12 - 1.05	-	0.04 - 0.97	< 5

Source: Anon. 1988 ND - Not detected.

Table 22. Turbidity (NTU) in Segara Anakan, March-August 1988.

No.	Mar.	May	Jun.	Jul.	Aug.
1	21	58	210	19	56
2	76	23	21	86	117
3	16	22	82	29	18
4	364	27	25	3	8
5	80	23	167	4	16
6	94	38	40	21	57
7	22	45	28	61	21
x	96	34	82	32	42
sd	113	13	77	31	39

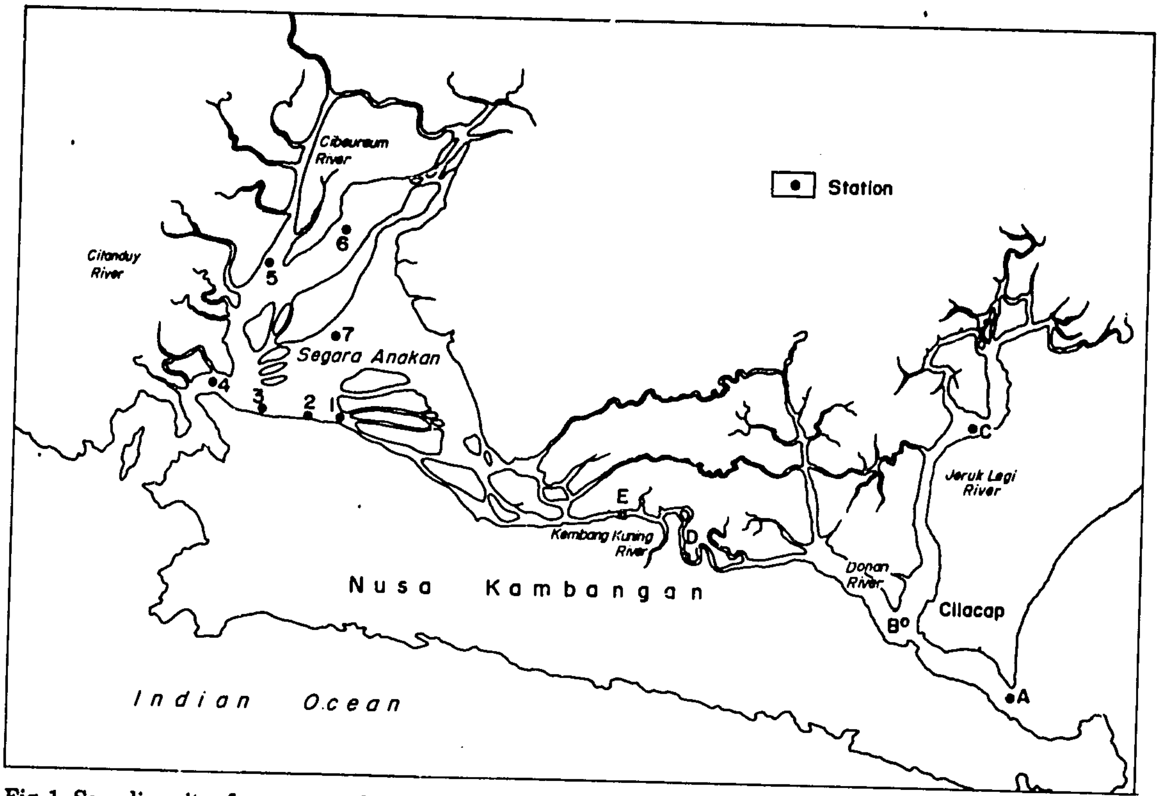

Fig. 1. Sampling sites for water quality.

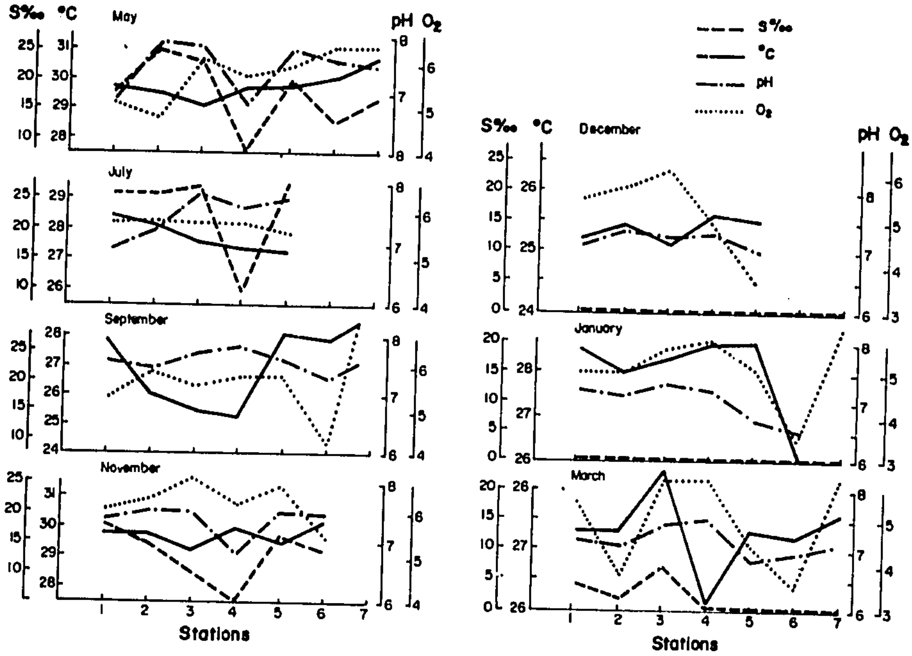

Fig. 2. Distribution of temperature, salinity, pH and dissolved oxygen in Segara Anakan waters, May 1987-March 1988.

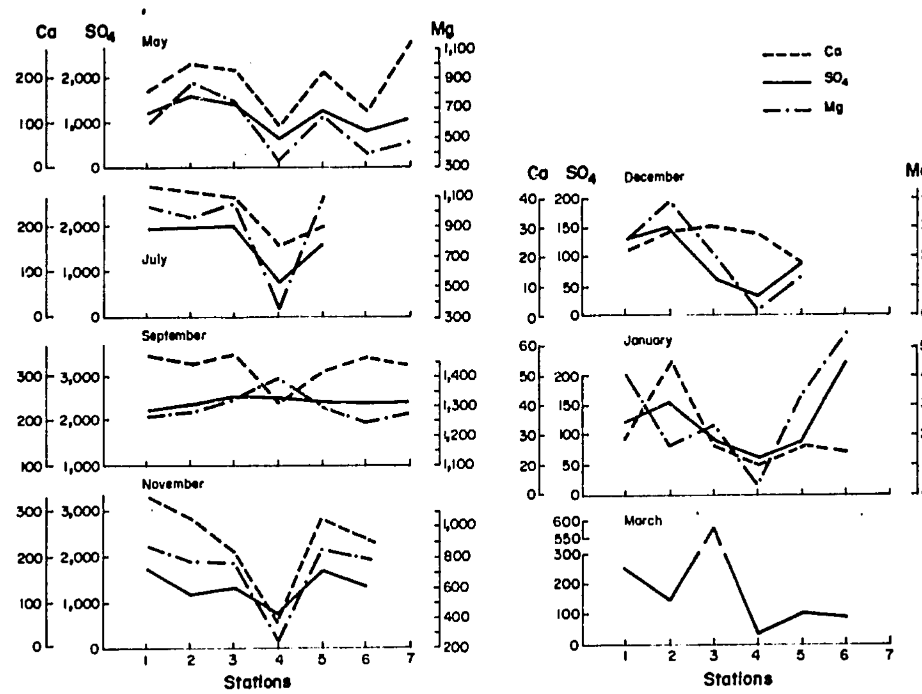

Fig. 3. Distribution of calcium, magnesium and sulfate in Segara Anakan waters, May 1987-March 1988.

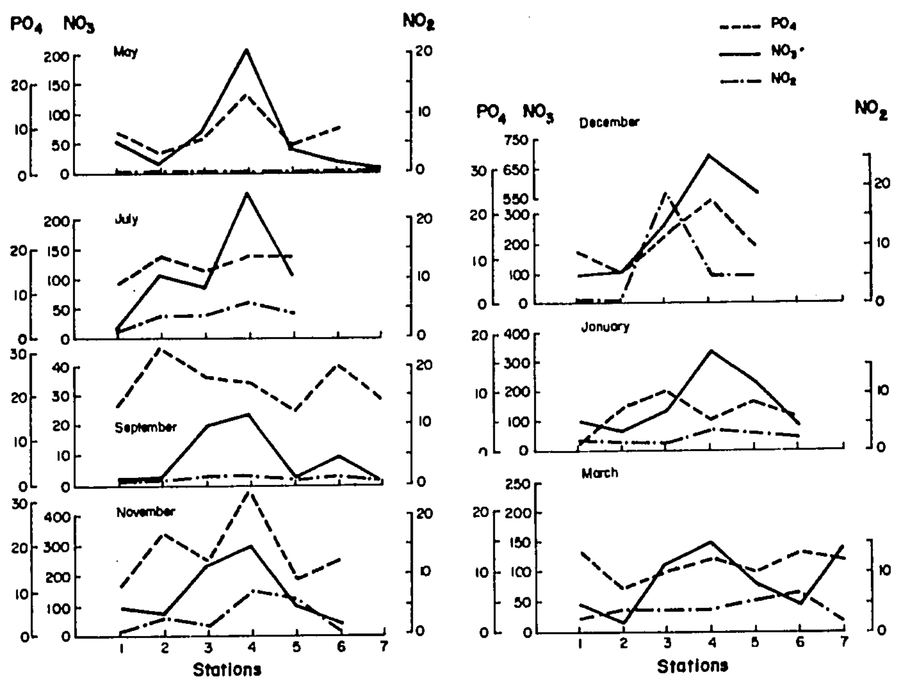

Fig. 4. Distribution of phosphate, nitrate and nitrite in Segara Anakan waters, May 1987-March 1988.

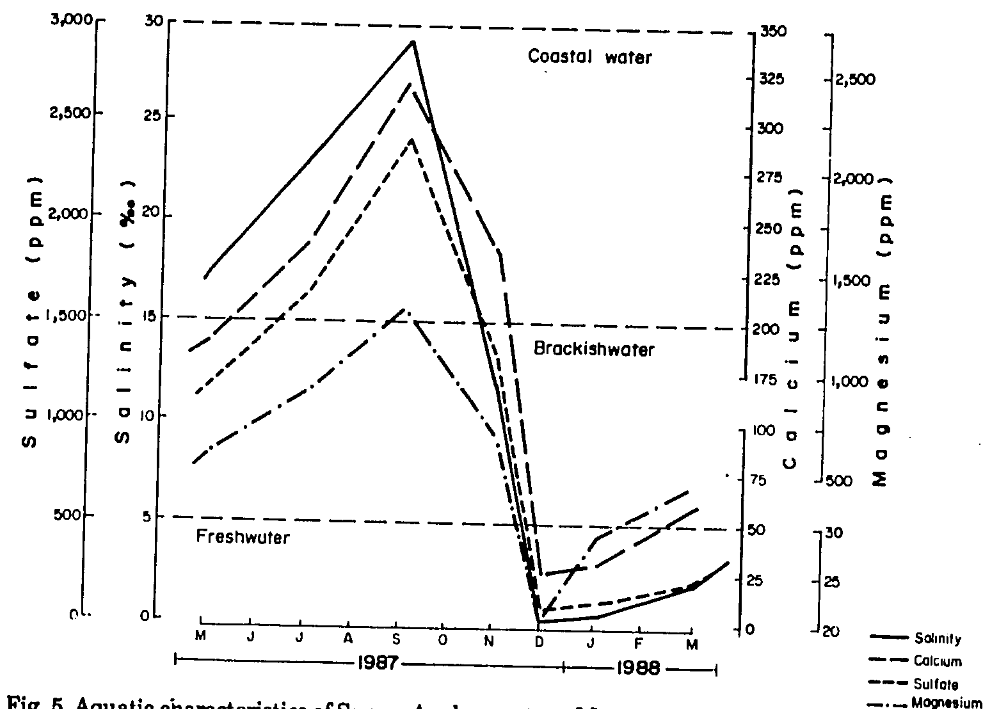

Fig. 5. Aquatic characteristics of Segara Anakan waters, May 1987-March 1988.

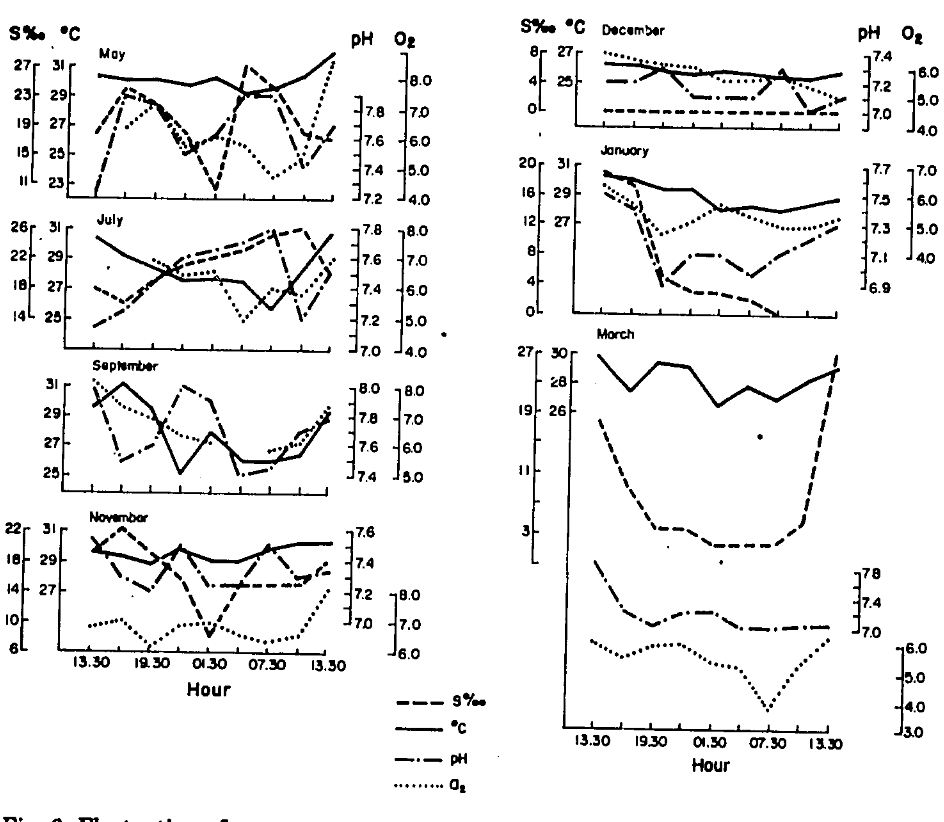

Fig. 6. Fluctuation of temperature, salinity, pH and dissolved oxygen during the 24-hour observation at the diurnal station in Segara Anakan, May 1987-March 1988.

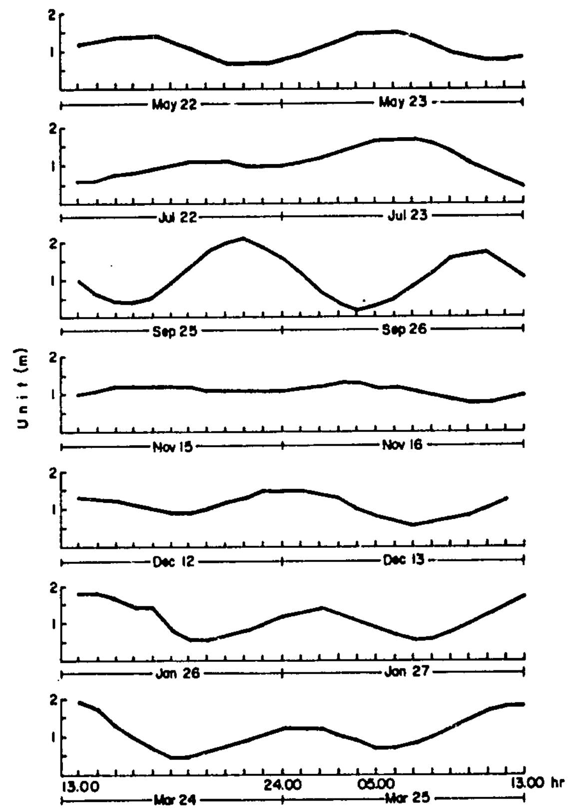

Fig. 7. Variation of tidal current at the diurnal station in Segara Anakan, May 1987-March 1988.

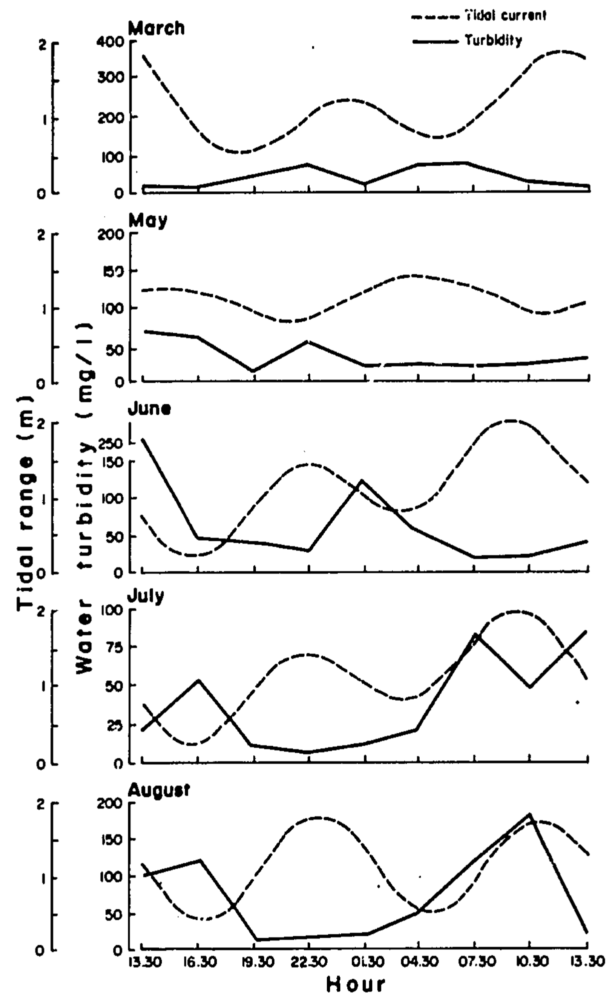

Fig. 8. Fluctuation of water turbidity during the 24-hour observation at the diurnal station in Segara Anakan, March-August 1988.

Impact of high sedimentation rates on the coastal resources of Segara Anakan, Indonesia

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PURBA, M. 1991. Impact of high sedimentation rates on the coastal resources of Segara Anakan, Indonesia, p. 143-152. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

Segara Anakan is a unique coastal ecosystem and an important coastal resource. However, its ecological functions are deteriorating due to poor upland management and high sedimentation rates. This study was conducted to be able to predict its sedimentation patterns and future physical changes for management considerations.

The major source of sediment into the lagoon is the Citanduy River. The distribution of sediment is governed by water circulation patterns, which are mainly driven by tide and freshwater discharge. Sediment is deposited mostly in the northern, northeastern and eastern shores of the lagoon and in the northern side of the Karang Anyar Island. It is predicted that land accretion will continue and that the lagoon will be reduced to only tidal inlets and waterways if no action is taken to prevent siltation.

INTRODUCTION

Segara Anakan is a unique coastal ecosystem located in Java (Fig. 1). Geologically, the lagoon and its environs differ from the general coastal features of southern Java. Located in a lowland area surrounded by mangrove forests, the lagoon has two connections with the ocean and several rivers and tributaries that pour their waters in, causing it to become brackish.

The lagoon has come under stress in the past decade due to the increasing rate of sedimentation from natural processes, poor upland management and the development of lowland areas for paddy cultivation. The high sedimentation rate is causing its ecological functions to deteriorate gradually. Because of its location, uniqueness and ecological value, government policy has been focused on its preservation.

The lagoon has rapidly decreased in area and depth as sediment has been filling it in the past decade. As it decreases in size, water movement in and out of the area has been affected by sediment shoals, and water movement patterns have been disturbed, thus causing sediment accretion to accelerate. The waterways have grown smaller and drainage has become more difficult. Thus, flooding in the surrounding lowlands is more common. Navigation waterways must be dredged more frequently. Fish production has also declined with the decrease in the fishing area.

The recent decline in water volume and surface area has given way to the identification of measures to minimize detrimental changes. General flow patterns of water in the lagoon have been determined so that the patterns of accretion resulting from sediment and the projection of future physical changes can be predicted.

A number of studies have documented the causes of deterioration, although determining a practical solution has been difficult. In this paper, the impact of sedimentation on the lagoon and its resources is discussed. Recommendations on how to minimize detrimental changes from sedimentation are also presented.

METHODS

Various studies on Segara Anakan's physical processes by several institutions and consultants were reviewed. Field measurements were not necessary to satisfy the objectives of the study. Rather, a complete review of all literature and reports related to the lagoon and its physical processes was made. Visits were also made to institutes and agencies that did the studies or that possess the relevant information. One field survey helped gain a general understanding of the lagoon's environment.

RESULTS

The Segara Anakan/Citanduy geological features and land uses

Segara Anakan, which is part of the southern coastal plain of Central Java, is a landlocked embayment with two tidal inlets. One is at the southeast end of a sandy coastal barrier and the other, to the west of Nusa Kambangan, a rocky island (Fig. 1) (Hamidjojo 1982).

The main tidal connection to the ocean is a short, narrow and deep strait between the hills of both sides of Nusa Kambangan and the mainland of western Java. It is probably a former meandering river valley crossing the southern range now inundated due to sea level rise. In contrast, the eastern connection, which is a narrow, shallow and meandering tidal inlet, traverses a broad coastal plain with almost flat topography.

Several rivers flow to the lagoon from the northwestern to the northeastern uplands. These rivers belong to the Citanduy and the Segara Anakan Basins.

The Citanduy River Basin covers an area of 350,000 ha, of which 290,000 ha are upland and 60,000 ha are lowland. Of this total area, 30% is flat, 50% is undulating/hilly topography (between 35 and 500 m high) and the remaining 20% has a steep slope above 500 m with fine textured soil, which easily erodes if not covered with vegetation. Some 74,000 ha of this area was categorized as a "critical erosion" zone in 1975 (PRC-ECI 1975). The watershed is used for agriculture (57%), forest and plantation (33%) and others (10%) (RMI and PRC-ECI 1985).

On the other hand, the Segara Anakan Basin has an area of 96,000 ha, of which 63,500 ha are upland (Sidareja East and North) and 32,500 ha are its environs (PRC-ECI 1975). Napitupulu and Ramu (1980) estimated the land use pattern of the basin as follows: forest and plantation, 27,000 ha (28%); upland, 11,000 ha (11.5%); lowland rice, 23,000 ha (24%); and mangrove and lagoon, 24,000 ha (25%).

Physical characteristics of lagoon water

Segara Anakan consists of a main body of brackishwater, two inlets from the sea and tributaries. Freshwater is supplied to Segara Anakan through stream flow and direct rainfall over its main body and adjacent mangrove forests. Annually, the total volume of freshwater inflow to Segara Anakan is at least 5 x $10^9 m^3$ (Table 1).

Seawater supply to the lagoon is driven by tidal flow through its two inlets. The western inlet, however, supplies most of the seawater. The volume of water passing through the mouth of the western entrance during flood tide is about 29 x $10^6 m^3$ for spring tide and 10 x $10^6 m^3$ for neap tide. Since the mouth of Citanduy River is located at the end of the western inlet of the lagoon, the water passing through this inlet during flood tide is a mixture of freshwater and seawater. This is distributed up the Citanduy and other rivers and into the mangrove forests through the lagoon's main body.

The lagoon's water properties vary in space and time. Vertical stratification does not occur in the lagoon's main body, except in the vicinity of the Citanduy River estuary, which shows a clear stratification (PRC-ECI 1987). Long-term variation is caused by seasonal climate. During the dry season when freshwater inflow to the lagoon is minimal, its waters can be very saline (Table 2). In contrast, salinity can be low during the wet season when freshwater inflow is at a maximum (ET 1984; IHE 1984; Ludwig 1985; LON-LIPI 1986).

Tidal records in the lagoon show that the tide is mixed and predominantly semidiurnal (Fig. 2). Harmonic analysis to determine the type of tide showed that the F (Formzahl) number of 0.40 indicated that the mixed category of the tide is semidiurnal (Birowo and Uktolseya 1982). Typical tidal records show a minimum tidal range of 0.20 m during neap tide and a maximum tidal range of 1.50 m in spring tide.

Sediment source and rate

Sediment supply to Segara Anakan comes from the Citanduy River, the upper watershed of Segara Anakan (mainly Cibeureum and Cikonde Rivers) and shoreline sediment (which is negligible). The Institute of Hydraulic Engineering (IHE) conducted several studies to estimate the rate of sediment supply to the lagoon (Ludwig 1985). PRC Engineering Consultants, Inc. (PRC-ECI 1987) reviewed these studies and found a large error in the method used to compute the sediment transport. Nevertheless, based on that review, the sediment transport to the lagoon was estimated to be somewhere in the range of 5-10 million t/year. A considerably larger estimate was made by

Napitupulu and Ramu (1980). By using an analytical method on the sediment measurement data of the lagoon in the 1960s and 1970s, they found that the sediment supply was about 17.4 million t/year with 15.2 million t from the Citanduy Watershed and 2.2 million t from the Segara Anakan Watershed.

Most of the sediment supply to the lagoon comes from the Citanduy River and the Segara Anakan Watershed. However, during the past few years, development on the tributaries in the Segara Anakan Basin, especially those on Cikonde River, has increased the sediment supply from the basin.

Water circulation and sedimentation patterns

The water circulation of the lagoon is driven mostly by tidal energy and drainage discharge and guided by its morphology. The effect of the wind is minimal since it does not generate any basin oscillation.

Since no study was conducted to determine systematically currents in the lagoon, PRC-ECI (1987) applied a one-dimensional mathematical model to estimate the characteristics of the lagoon's water movement. The model computed the response of Segara Anakan from a combination of the vertical tides at the western and the eastern outlets, and the freshwater discharge from the rivers. Since there was no current information during the study, the model has only been partially calibrated for water level. In view of this and the fact that the one-dimensional homogeneous flow model is a very crude representation of the complex three-dimensional flow of saltwater and freshwater into the lagoon, the results are only indicative, but they provide a useful tool for understanding the characteristics of water circulation.

The model was run to estimate simultaneous flow rates within the entire lagoon after a scheme was made to formulate a network of branches and junctions representing the drainage system. Results of the model for spring tide condition (using tidal records on 17-18 October 1986) are shown in Fig. 3 for the flood tide stage and in Fig. 4 for the ebb tide stage.

Figs. 3 and 4 show that the real nodal point (almost no horizontal water movement) is found along the northern and eastern lagoons between junctions 20 and 22 during both the flood tide and ebb tide stages. Other nodal points are also found between junctions 17 and 20 (Fig. 3) during flood tide and between junctions 14, 18 and 19 (Fig. 4) during ebb tide. In general, the places for nodal points will always be in the northeastern part of the lagoon and somewhere between the islands in the southeastern portion and Motean.

The model also estimated the tidal excursion of water particles. It was found that the water particles, starting at slack low tide in the mouth of the Citanduy River, traveled about 7 km into the sea during spring ebb tide and about 2.8 km during neap ebb tide. During flood tide, the tidal excursion is about 4 km into the lagoon for spring tide and 2 km for neap tide. Water particles downstream of this ebb tide flow will be pushed even further into the northern and eastern portions of the lagoon. However, due to the effects of the river discharge from the Segara Anakan Watershed and of the tidal excursion from the eastern entrance, the water particles will eventually be stagnant at the point of their meeting, as shown in Figs. 3 and 4.

The general sedimentation pattern within the lagoon is very much dictated by water circulation, while the fate of sediment particles within the water mass depends on the energy contained in the latter. If the energy reflected in the water mass movement is high, then the sediment will stay suspended and move with the water mass. If the water movement slows so that the energy is not strong enough to keep the sediment in suspension, then it will start to fall and deposition will begin. Moreover, the energy of the water movement will also act to limit the size of sediment that will be deposited along the flow paths. The distribution of the bed sediment size (coarseness) of the lagoon (Fig. 5) agrees with the pattern of the flow rate (or energy) of its water movement (Figs. 3 and 4). It is interesting to note that fine bed sediments extend from the southeastern portion of the lagoon, as expected, to the center of its main body. Medium-bed size sediments are found along the eastern border of the Karang Anyar Island to the Cikonde River and extend along half the eastern shore of the lagoon, which implies that the water moves in these places faster than at the center.

The highest deposition occurred in places where bed sediment size is fine (Fig. 5). Other places are the intertidal zones in the northern, northeastern and eastern shores of the lagoon. During flood tide, these places are inundated by the tidal current. However, horizontal water movement is very limited since the tide and the current meet the freshwater discharge from the rivers and tributaries. Deposition then occurs.

DISCUSSION

The sedimentation patterns in the lagoon follow those of water circulation. Deposition occurs in the place where the horizontal water movement is very limited. Once deposition takes place, it will continue until the area is shallow enough for the mangroves to grow. Sedimentation will also continue under new mangroves until the water can no longer reach them.

As a consequence of sedimentation, Segara Anakan's morphology has changed. The encroachment of mangrove forests follows shoreline accretion or the shoaling of mudflats. Several studies on the changes of the lagoon's configuration were made in the past. PRC-ECI (1987) compiled shoreline changes and mangrove forest growth data since 1903 (Fig. 6). In that year, there were only three islands, which were all located in the southeastern corner of the lagoon. All the villages were situated on the water. The surface area of the lagoon at high tide was 6,450 ha, excluding the villages.

During the period 1903-1986, sediment deposits covered 3,540 ha on which new mangroves had grown. Another 210 ha was converted to tidal waterways, leaving the lagoon with a water surface of 2,700 ha at high tide in 1986. This represented only 42% of the total surface area in 1903. During a field survey conducted by the author in December 1987, new young mangroves had spread in the northern and northeastern parts of the lagoon. The northern end of Karang Anyar Island has become attached to the northern shore of the lagoon. The Cikonde River has extended its mouth in the lagoon by building up natural levels. Mangrove seedlings were sprouting on both sides of its mouth.

Based on this historic land accretion growth, water circulation and sedimentation patterns, a prediction of future physical changes is shown in Fig. 7. The patterns of sedimentation, which resulted in shoreline growth and the encroachment of mangrove forests, will continue in the direction of their historic growth.

Using the same historic data, a projection of the filling rate of the lagoon was also made. A filling rate of 1.4-2.1 million t/year was estimated. The new mangroves have been increasing at 2 km^2/year for the last few years. It was predicted that the lagoon will be left with only tidal inlets and waterways (Fig. 8) by the turn of the century (PRC-ECI 1987).

It is clear that if no action is taken to prevent siltation, the shrinkage of the lagoon's water body is unavoidable. The implications of this rapid sediment accretion include decreasing ecological functions of the lagoon, loss of income and drainage and navigation impediments.

Segara Anakan serves as a nursery and feeding ground for marine fish and shrimp (ET 1984; Guarin and White 1988). Most people use it as a fishing ground. However, its real economic value is fisheries production in the coastal and offshore waters of Cilacap. Thus, coastal fisheries will decline, especially in offshore shrimp, as a result of its shrinkage. Naamin (this vol.) estimated that about 80% of the shrimp caught off the coast of Cilacap occupied the lagoon during the early stage of their life cycle.

If the shape of the lagoon becomes that shown in Fig. 8, the local inhabitants will have to change their livelihood from fishing to farming.

Another impact of siltation on the lagoon is on its drainage and navigation. As the lagoon is replaced by smaller waterways and tidal inlets, drainage from the two lower watersheds will become a problem. There are several irrigation projects in the lower Citanduy and Segara Anakan Watershed that end in the lagoon. These projects prevent the spillage of the floodwater and thus, bring more water and sediment into the lagoon. Poor drainage due to siltation will jeopardize these irrigation projects. Frequent flooding and the possible formation of a swampland are thus two serious threats.

Boat and ferry navigation will become a problem too as the depth of the lagoon decreases. Dredging is necessary to maintain the depth of the navigation channel.

One way to prevent siltation is to divert the Citanduy River from entering the lagoon. In this way, its sediment supply will be reduced considerably. But diversion of the Citanduy River would also drastically reduce the freshwater supply to the lagoon. One consideration in maintaining the ecology of Segara Anakan is to avoid altering the freshwater supply as this would reduce the natural supply of nutrients and change salinity (Clark 1977). The diversion of Citanduy River should thus be avoided if the estuary is to be kept intact.

Another way to control siltation is by altering the water circulation pattern so that the capacity of the natural water movement to carry out the sediment is enhanced. The flushing capacity of the water flow through the western outlet could be enhanced during ebb tide if the mouth of the eastern entrance is closed at slack high water. In this way, more water would flow through the western outlet. The construction of a gate in the eastern entrance would alter the water circulation pattern. The water from the eastern entrance would enter it during flood tide, but during ebb tide, no water would flow through the eastern entrance. Although water circulation would be disturbed, it may not be serious. However, the immigration of marine organisms from both entrances into the lagoon would be affected. The emigration of juveniles through the eastern entrance would also be blocked and possibly more juveniles would flow through the eastern entrance. The ecological impact of these occurrences on the lagoon, navigation and coastline changes are several factors that should be considered before the construction of such a gate.

The third alternative to control siltation is by using water movement to carry more sediment to the ocean without disturbing the water circulation pattern. The deposited sediment could be resuspended by agitation dredging at slack high water so that sediment-laden water would recede to the ocean during ebb tide. This method may not be as effective as the previous one in controlling lagoon siltation, but it would cause the least ecological impact. PRC-ECI (1987), however, found in its prefeasibility study that the most effective measure to control lagoon siltation is a combination of enhanced flushing and agitation dredging.

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Table 1. Annual freshwater supply to Segara Anakan (PRC-ECI 1987).

Sources	Volume (m^3)
Citanduy River	3.5×10^9
Other rivers and tributaries	1.5×10^9
Direct rainfall	0.07×10^9
Total	5.07×10^9

Table 2. Surface salinities of Segara Anakan from different sources.

Sources	Surface salinities (ppt) Dry season	Wet season
IHE 1984	13-33 (May 1980)	-
ET 1984	24-30 (1983)	14-19 (1983)
Ludwig 1985	24-25 (1983)	-
LON-LIPI 1986	25-33 (22 Aug. 1985)	12-31 (19 Dec. 1983)
PRC-ECI 1987	6-20 (19 Aug. 1987)	-

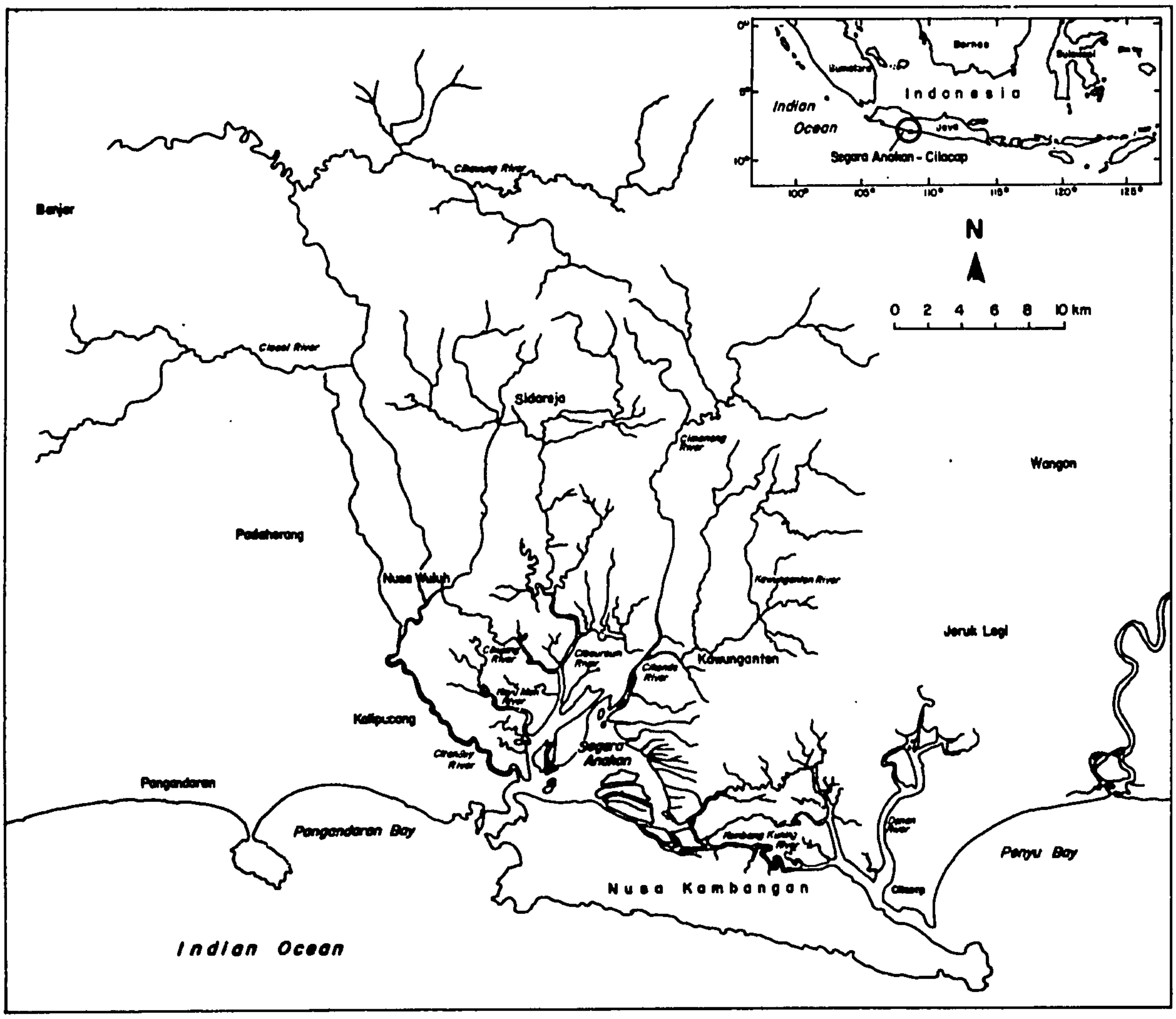

Fig. 1. Map of Segara Anakan-Cilacap showing the study site (PRC-ECI 1987).

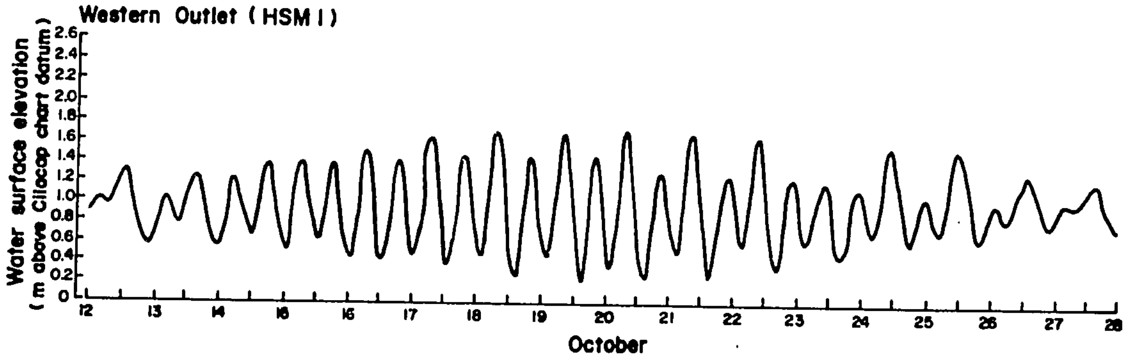

Fig. 2. Tidal records at the western outlet (PRC-ECI 1987).

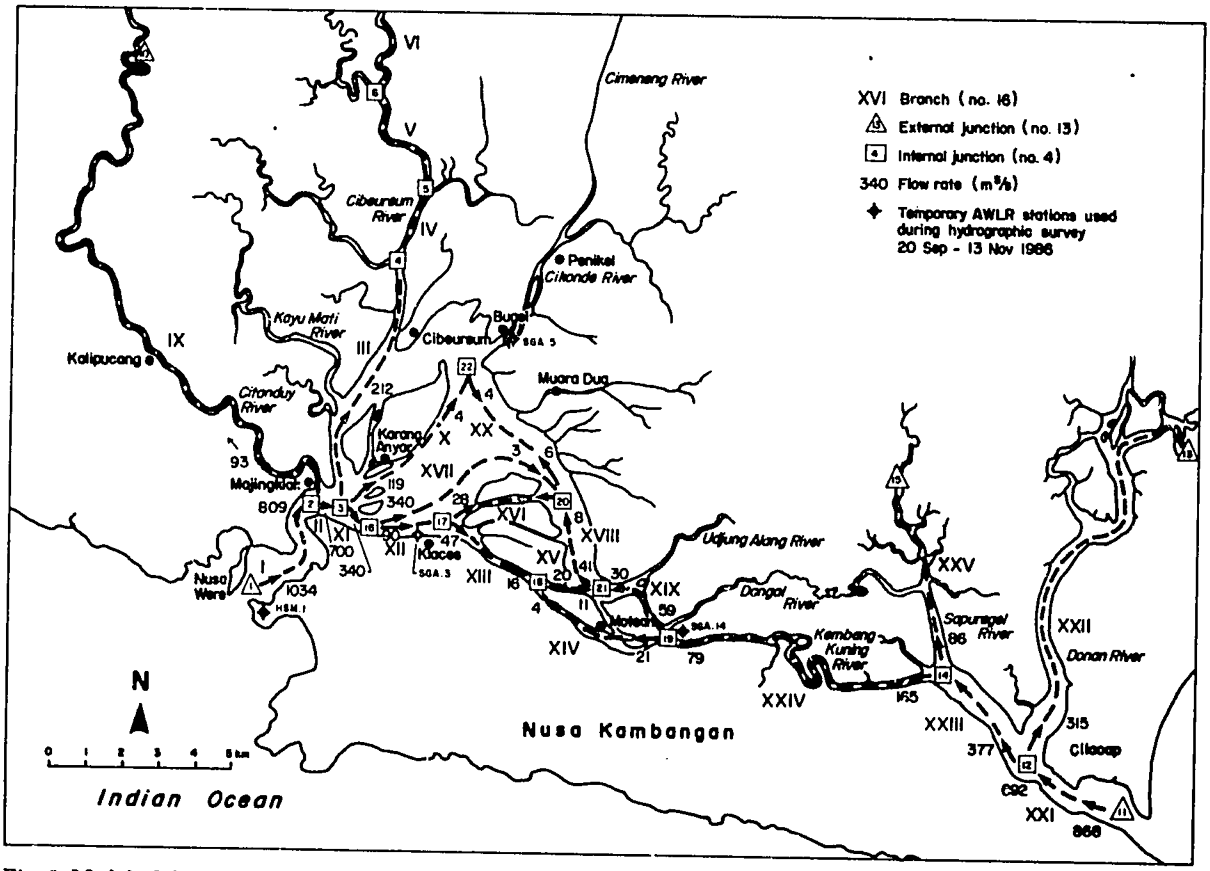

Fig. 3. Model of the flow rate distribution during a spring flood tide (PRC-ECI 1987).

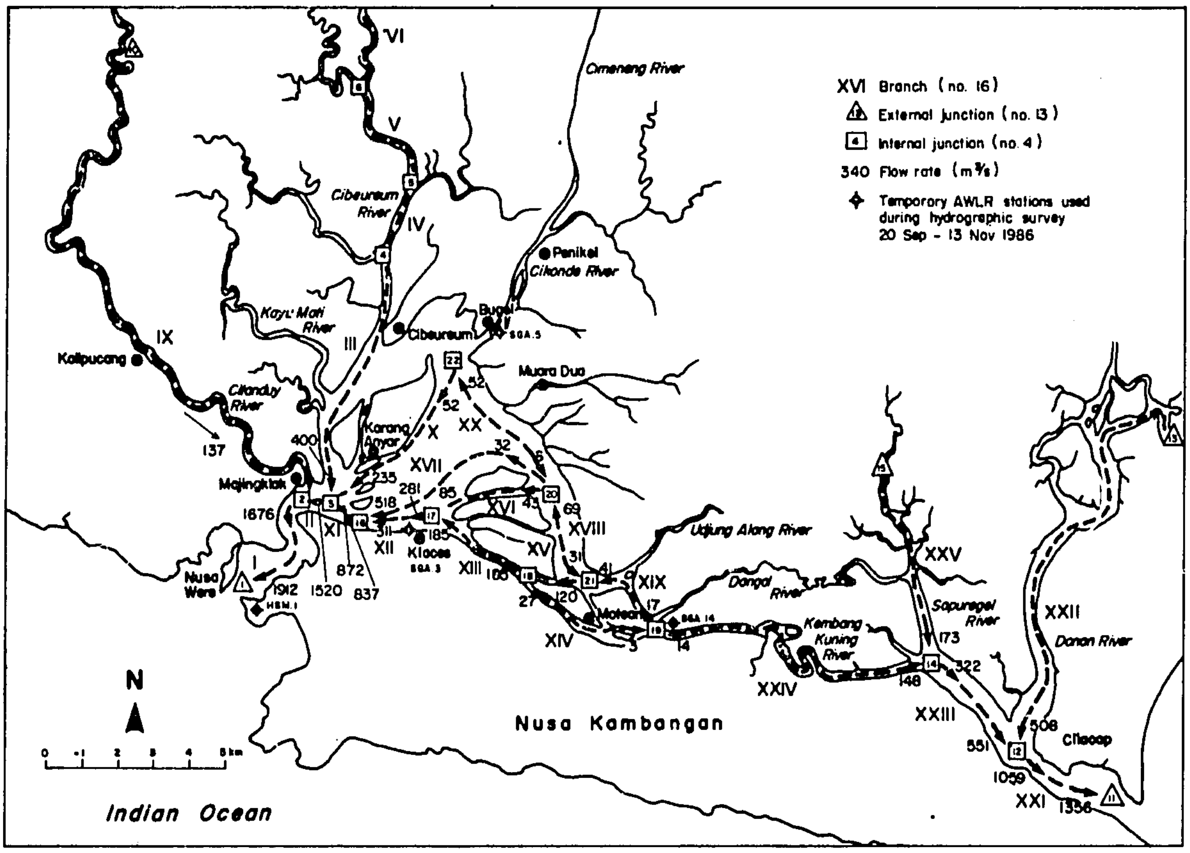

Fig. 4. Model of the flow rate distribution during a spring ebb tide (PRC-ECI 1987).

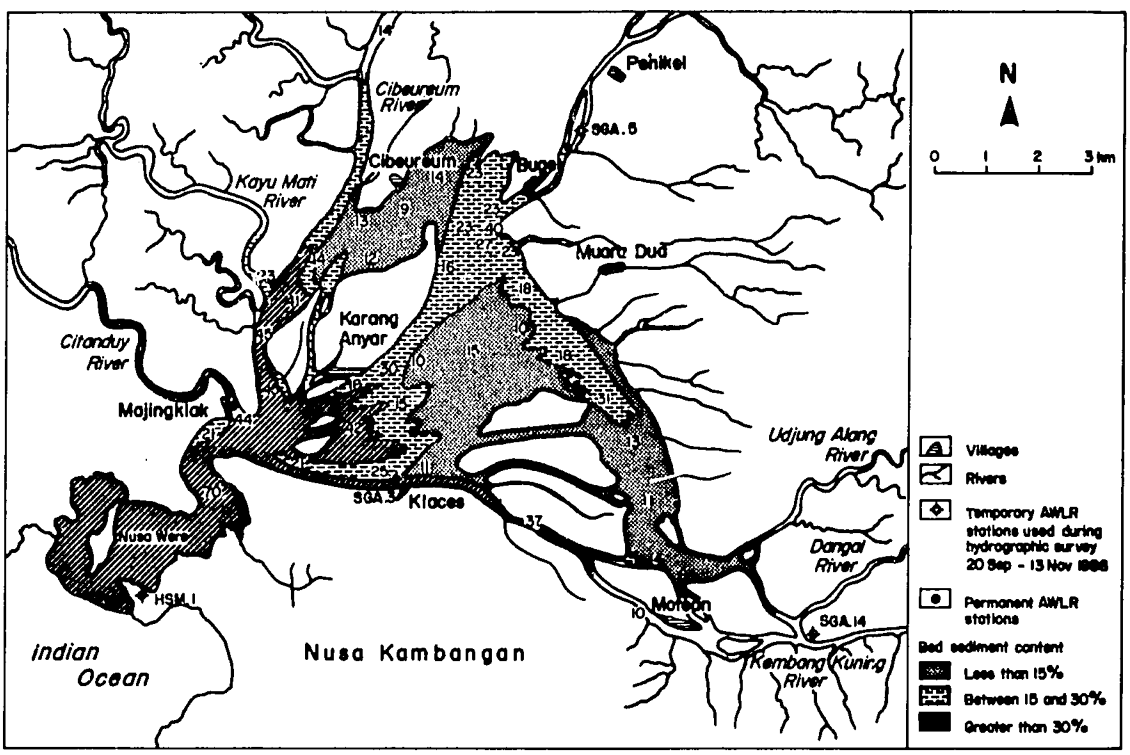

Fig. 5. Bed sediment size distribution (PRC-ECI 1987).

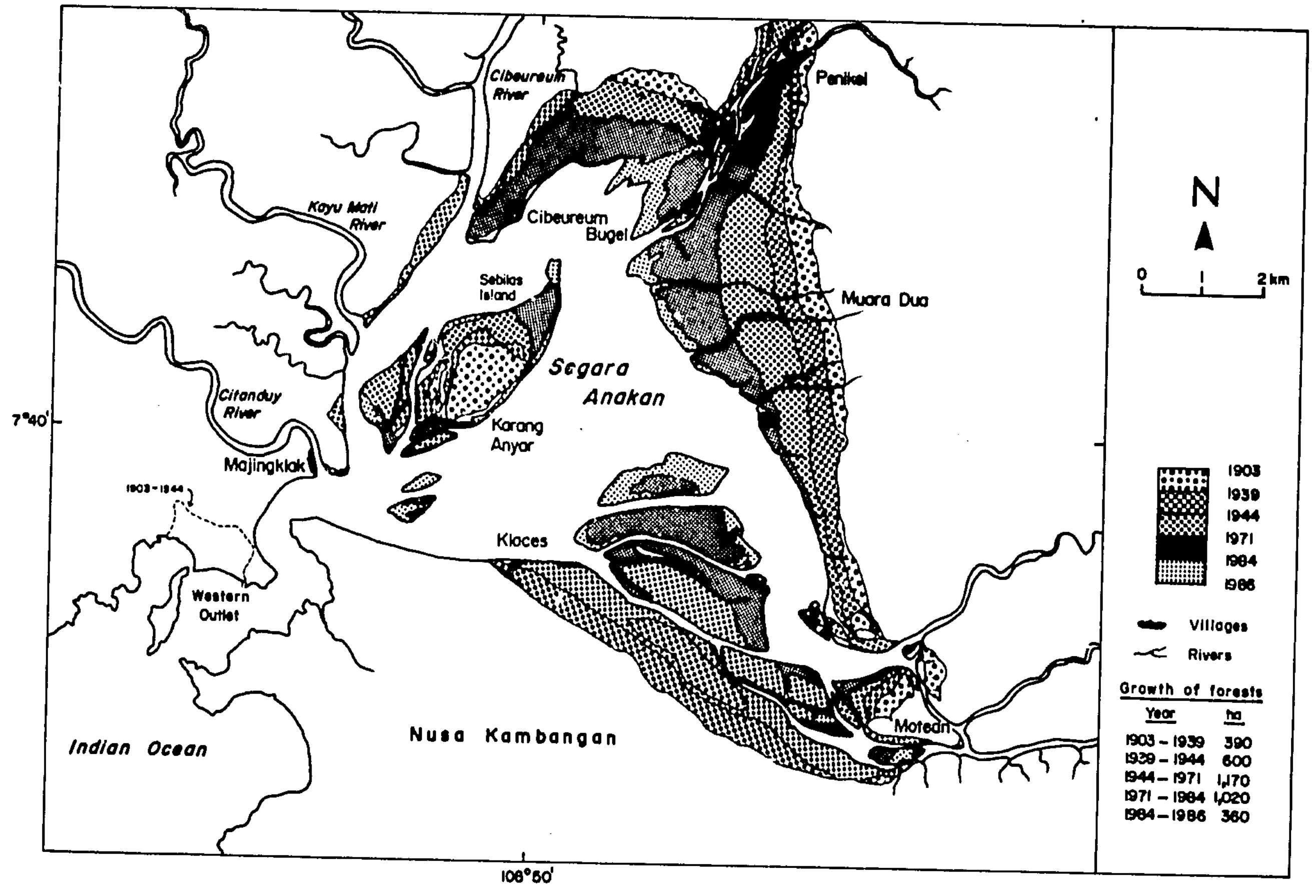

Fig. 6. Historical shoreline and mangrove forest growth, 1903-1986 (PRC-ECI 1987).

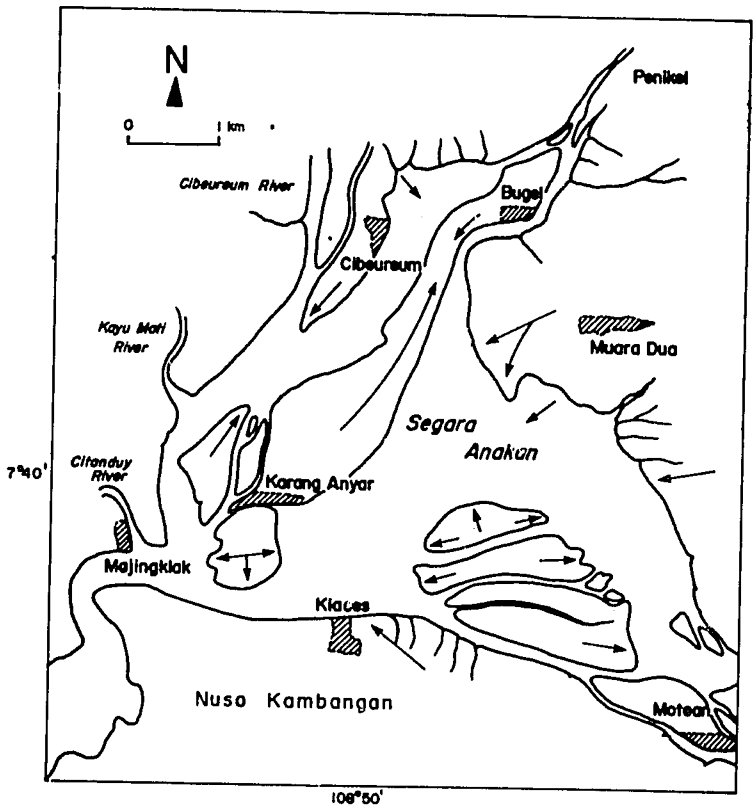

Fig. 7. Prediction of future shoreline changes (LON-LIPI 1986).

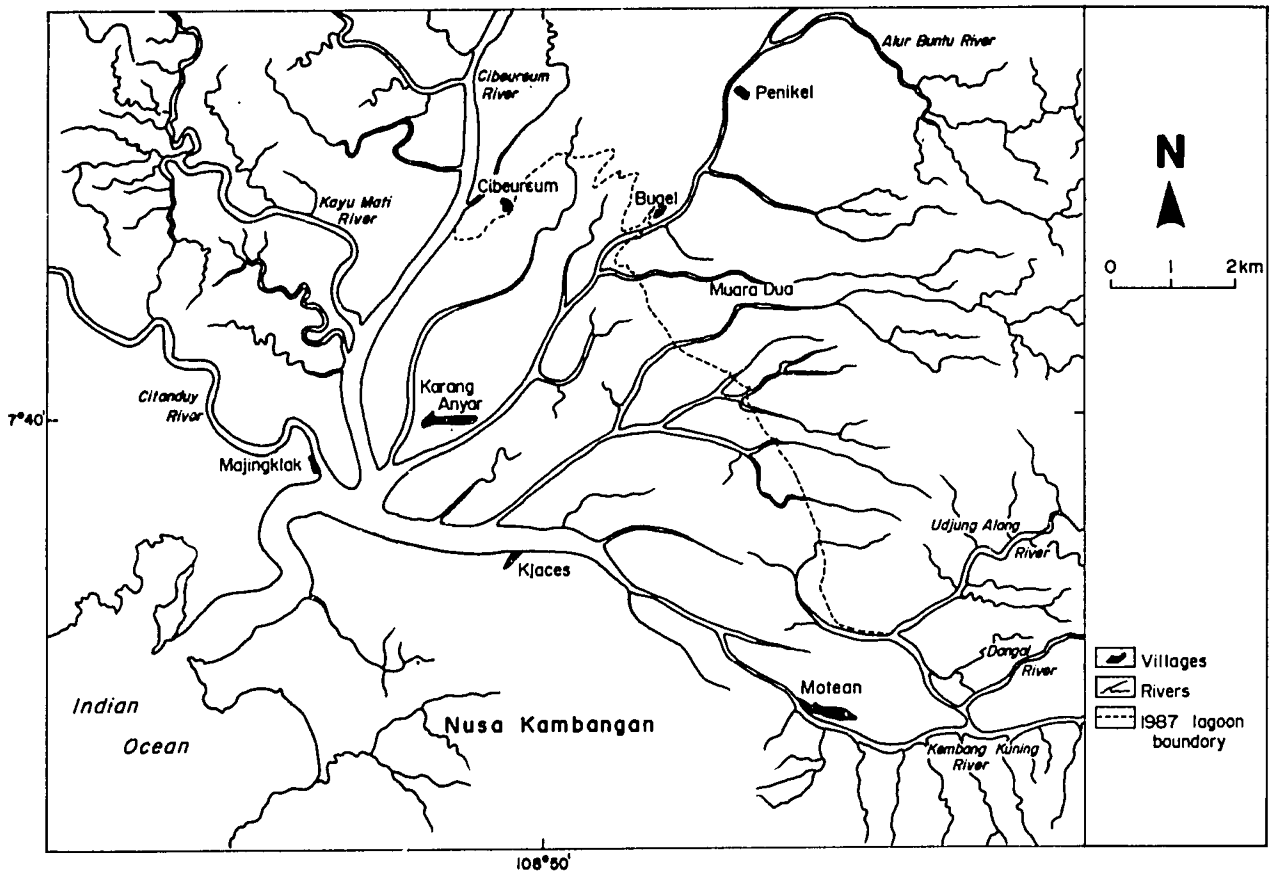

Fig. 8. Predicted shape of Segara Anakan (PRC-ECI 1987).

Water quality of Ban Don Bay

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ABSTRACT

The water quality of Ban Don Bay and the Tapi River was studied during the dry and wet seasons.

The water quality parameters studied were salinity, dissolved oxygen, pH, alkalinity, ammonia, nitrite, nitrate, phosphate, silicate, total nitrogen, total phosphorus, pesticide residues, dissolved petroleum hydrocarbons and microbiological qualities of the bivalve-growing areas. Trace metals such as mercury, cadmium, chromium, copper, lead and zinc were also determined.

INTRODUCTION

The water quality of Ban Don Bay was studied during the period December 1986 to August 1987. Ban Don Bay, located on the eastern coast of Southern Thailand, is about 1,200 km^2 in area with a maximum depth of less than 7 m (Fig. 1). On the eastern side of the bay, at Tha Chang, are extensive cockle farms. On the southern part of the bay, at Kanchanadit, are extensive oyster culture farms *(Crassostrea lugubris)* for which Surat Thani is famous. The bay itself used to be abundant with short-necked clams, *Paphia undulata*, but recently, these are fast decreasing.

Realizing the importance of conserving the marine environment of the bay and the aquatic environment of the adjoining rivers and canals, the Thai government initiated the Upper South Project in 1986. It involves an intensive study of Ban Don Bay, the Tapi River and some canals. Several types of industries, such as palm oil, fish landing and marine food canning, are situated on the banks of the Tapi River. Some of these still have no proper wastewater treatment system. Thus, the stress on the aquatic environment can be great especially during the low flow season. The commissioning, since 1987, of a multipurpose dam, the Chiew Larn or Ratchaprapa Dam, on the upper Tapi River has aggravated the situation. On two occasions, it was found that the deoxygenated, high-organic-content water discharged from the dam had rendered the low-flow oxygenated water in the Tapi River anaerobic so that the water became smelly and unable to support aquatic life.

MATERIALS AND METHODS

Field surveys

Three surveys were conducted in Ban Don Bay, with a preliminary survey by the Fisheries Group in December 1986. Thirteen sampling stations were set up from which some water samples for analysis were taken. The dry season survey was made during 20-25 March 1987, while the flood season survey was preplanned and conducted during the normal rainy season from 31 July to 3 August 1987. However, it was realized later that the latter period was not very suitable as the rainy season in the south, which usually starts in May, did not actually begin until late July, thus only the characteristics of the early rainy season were observed.

Two surveys were conducted on March 20 and August 1 in the estuarine section of the Tapi River, which provides the most input into Ban Don Bay (Fig. 2). In both survey periods, zero salinity was observed at about the same place, at Surat Thani town, but freshwater reached out farther into the bay in August.

Water quality of the aquaculture areas was investigated on a limited scale in March and more extensively in August.

Chemical analysis

Reactive nutrient analyses were performed on the same day after filtration of the water samples (Strickland and Parsons 1972). Total nitrogen and total phosphorus contents were analyzed in the laboratory in Bangkok (Koroleff 1976 a and b). Samples were analyzed for their dissolved organic carbon, using a Shimadzu total carbon analyzer.

To determine the presence of trace metals, water samples were filtered as soon as possible through a Nuclepore membrane filter under nitrogen pressure. The filters were kept for analysis of particulate metals by digestion with concentrated nitric acid (HNO_3) in a teflon bomb. The filtrate was acidified with metal-free HNO_3 to pH 3 and then kept in thoroughly cleaned Nalgene bottles for later analysis by coprecipitation with $CoCl_2$-APDC (Huizenga 1981). Measurements were made in an atomic absorption spectrophotometer, using an acetylene flame for zinc (Zn) and a flameless graphite furnace for cadmium (Cd), chromium (Cr), copper (Cu) and lead (Pb). For mercury (Hg), the water sample was made to react with sulfuric acid (H_2SO_4) and potassium permanganate ($KMnO_4$) and then treated with tin chloride ($SnCl_2$) before measured by a Hiranuma Mercury Analyzer model HG-1 (Hatch and Ott 1968).

Dissolved petroleum hydrocarbons in water were extracted with the help of n-hexane and the concentrations were measured in a spectrofluorimeter against the chrysene standard.

RESULTS AND DISCUSSION

Study sites

Tapi River Estuary. Samples taken from nine stations in the Tapi River Estuary registered approximate salinities of 0, 2, 4, 6, 8, 10, 15, 20 and 25 ppt. Zero salinity was observed in a station about 10 km away from the river's mouth (Fig. 2) at Surat Thani town. Table 1 presents the water quality of Tapi River, which was measured by several parameters. Based on the March 1987 survey, the ranges of these parameters are as follows: temperature (29.0-30.5°C), pH (7.5-8.1), salinity (0.2-27.3 ppt), dissolved oxygen (3.6-4.9 mg/l), dissolved organic carbon (3.43-11.37 mg/l), ammonia (0.70.-7.65 μM/l), nitrite (0.15-1.36 μM/l), nitrate (0.21-6.63 μM/l), phosphate (0.17.-0.74 μM/l) and silicate (16.99-158.79 μM/l) (Table 1). Other water parameters studied were alkalinity, total nitrogen, total phosphate, chlorinated hydrocarbons and heavy metals (e.g., Cd, Cr, Cu, Pb and Zn).

The second field survey of the Tapi River Estuary took place on 1 August 1987. Since the rainy season had just begun, the effect of high flow was not yet evident and the zero salinity was observed at about the same place up the river but the saltwater end of the river (TP2-9) reached farther into the bay (Fig. 2 and Table 1). Most nutrient concentrations were also higher in August than in March (Table 2).

Moreover, in March, the dissolved oxygen levels were considerably below saturation levels--from 8% to 30% below (Table 1). A similar occurrence was observed in Khlong (it means "river") Mae during the dry season (Hungspreugs et al. 1987). However, in early August, the situation somewhat improved although stations TP2-1 to TP2-6 still contained dissolved oxygen between 13% to 30% below the saturation level. On the other hand, stations TP2-7, TP2-8 and TP2-9 showed some oxygen supersaturation from 2 to 32%, probably because of strong winds stirring the water off the river's mouth, thus increasing the dissolution of oxygen into the water. These generally low dissolved oxygen levels in the lower reach of the Tapi River were worsened by the release of deoxygenated water from the Chiew Larn Dam up the river. This occurred at least twice in 1987 when the portion of the river down Phun Phin became highly polluted for a few days. From Table 1 and Fig. 3, it appears that the decrease in dissolved oxygen coincided with the increases in phosphate, ammonia, nitrite and nitrate downstream of the town where fish landings and some organic releasing industries are situated.

In both surveys, the concentrations of dissolved metals were in the ranges of: trace-0.270 μg/l for Hg, 0.001-0.031 μg/l for Cd, 0.011-0.318 μg/l for Cr, 0.286-1.507 μg/l for Cu, 0.042-0.479 μg/l for Pb and 2.01-7.81 μg/l for Zn (Tables 3-5). There appears to be no source for the metal pollution in the estuarine section of the Tapi River. A comparison of the levels of some trace metals in other rivers of the world is shown in Table 6.

Ban Don Bay. The bay is quite shallow with a maximum depth of about 6 m. The water appeared to be well-mixed and well-oxygenated (Table 7). The influence of freshwater in August reduced salinity slightly from a mean of 31.01 ppt that month compared to 32.03 ppt in March (Table 8). The concentration of all nutrients decreased (Table 7) as did phytoplankton density at most stations at an average of 7,566 cells/l in March to 5,766 cells/l in August (Wisessang 1988). The nutrient concentration in the Tapi River increased considerably in August but the increase was not observed in the bay since the nutrients might have been chemically bonded in the estuarine sediment along the way.

Aquaculture Areas. Results of the water quality surveys in the oyster, cockle and shrimp farms as well as in the adjacent canals in the Ban Don Bay vicinity are shown in Tables 9 and 10. It appeared that in August, the water samples from the nearshore station off Kanchanadit contained more nutrients than the outer area. Shrimp farm no. 19, where additional feed was placed, also contained a considerable amount of nutrients released from the leftover feed. Human-made effects on the densely populated Tha Thong and Kradae Canals were seen in the high nitrate and phosphate and low dissolved oxygen concentrations. The sparsely populated Khlong Ram had a high dissolved oxygen of 4.9 mg/l.

The seasonal variation of nutrients in the farm was affected by Kradae Canal. There did not seem to be an adverse impact on water quality caused by shrimp or oyster farming as long as no extra nutrients were put in the farm. The deterioration of water quality in canals seems to be affected more by human activities.

Water in canals that flow through populated villages contained high total coliforms (more than 2,000 MPN/100 ml). The canals were: Kaejae Canal (2,400 MPN/100 ml), Kradae Canal (more than 11,000 MPN/100 ml), Tha Thong Canal (4,600 MPN/100 ml) and Don Sak Canal (11,000 MPN/100 ml). Other farms and canal water contained total coliform of 3.6-430 MPN/100 ml or a mean of 123 MPN/100 ml. Natural shrimp farms did not cause bacterial pollution.

Near the mouth of Tha Chang Canal (Fig. 2), the levels of dissolved Pb seemed to be comparatively high (4.156 µg/l) as against those in the Tapi River (0.042-.0479 µg/l) or in the other canals (mean of 0.039 µg/l) (Tables 3 and 4). The influence of Tha Chang Canal was also seen in the Tha Chang (inner line) cockle-growing area which had 2.163 µg/l of Pb. It was possible that there was a source of Pb in that canal that made the level of this metal higher.

Samples of oysters *(Crassostrea lugubris)* taken in March contained total coliform within acceptable levels but 40% of the samples collected in August contained total coliform higher than the recommended US standard. The oysters were taken from the station off the mouth of Kradae Canal.

Other water quality parameters

Chlorophylls. The measurement results of chlorophylls a, b and c are shown in Table 11. The overall mean value of chlorophyll a for both March and August was quite similar although the nutrient concentration in the bay was much lower in August. The increase in chlorophyll b in the bay might have been caused by residual chlorophyll b from freshwater influx. Wisessang (1988) studied phytoplankton densities in March, August and November 1987 and found an overall decrease in cell density in August from the values in March (24%). In November, however, the values were approximately seven times more than those in March. No nutrient data for November were available.

In comparison, the overall mean value of surface chlorophyll a off Trengganu coast, Malaysia, was low, at 0.08 mg/m^3. Ahmad and Ichikawa (1986) explain that this was a consequence of low phosphate off that coast (Law and Kamil 1986), i.e., an overall mean value of 0.07 µM. Temiyavanish (1984) reports a mean value of chlorophyll a in the Upper Gulf of Thailand at 3.87 mg/m^3; chlorophyll b, 1.55 mg/m^3; and chlorophyll c, 5.41 mg/m^3 while Silpipat et al. (1984) report a mean phosphate at 1.35 µM. The Middle Gulf of Thailand had a mean phosphate of 0.28 µM; nitrate, 1.80 µM; and nitrite, 0.10 µM in April 1983. In the flood season of September 1983, the Upper Gulf of Thailand showed a mean value of phosphate at 1.00 µM; nitrate, 0.69 µM; and nitrite, 0.17 µM.

Chlorinated Hydrocarbons. Vongbuddhapitak and Atisook (1988) found that only two water samples out of 58 were contaminated by low levels of endrin. DDT and dieldrin were the only residues found in marine organisms (cockles, oysters, fish, short-necked clams, shrimp and squid) at and below the quantifiable limit of 0.1 mg/kg. No difference in contamination was found between seasons, and the levels were comparable to those in the Upper Gulf of Thailand that had declined significantly since 1973 (Vongbuddhapitak and Atisook 1985).

Dissolved Petroleum Hydrocarbons. Dissolved petroleum hydrocarbons in the waters of Ban Don Bay and bivalve-rearing areas were determined by extraction with n-hexane. The concentrations were measured spectrofluorimetrically. The overall range in March was 0.788-2.370 and in August 0.070-2.963 µg/l (Table 12). Sompongchaiyakul et al. (1986) found a range of 0.08-5.65 µg/l in the Upper Gulf of Thailand. The nearshore areas (oyster and cockle-growing areas) showed a higher range at 0.805-3.611 µg/l due to human uses, terrestrial drainage, canal traffic, etc.

Law and Mahmood (1987) found the overall mean hydrocarbon levels in the South China Sea from Kuantan to Pulau Tioman at 1 m depth to be 37.77 ppb, which is interpreted as being slightly polluted with petroleum hydrocarbon, but still much lower than the levels detected in the coastal water off Kuala Trengganu (110-1,750 ppb), which was probably polluted due to the oil exploration in the adjacent area. Oppenheimer (1980) considered 100 ppb hazardous to living organisms. Unpolluted seawater contains a hydrocarbon level less than 2.5 µg/l (FAO 1982).

Trace metals. Trace metal results are shown in Tables 3 and 4. Comparative data are shown in Table 5.

MANAGEMENT RECOMMENDATIONS

Based on the assessment of the marine environment of Ban Don Bay and adjacent areas, the following management actions are recommended:

1. The water quality of Tapi River needs to be improved. It is clear from the comparatively low dissolved oxygen content of the lower reach of the river that the capacity of the river water to accommodate more organic waste is very limited. The dam water to be released must be oxygenated and stringent control must be put on the wastewater released from industries generating organic waste along the river.
2. There is a need to set up appropriate microbiological standards for shellfish and coastal areas in the tropics suitable for shellfish culture.
3. The quality of shellfish should be improved by:
   a. educating the local people on the importance of hygienic products and the possible danger that can arise from consuming unhygienic ones;
   b. setting up inspection services as a joint effort between the government and private farmers; these would cover cultivation, harvesting and distribution; and
   c. developing and demonstrating to the local people a purification pond technique to cleanse the microbiologically contaminated living bivalves; suitable sites should be chosen and maintained for this purpose.

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Table 1. Water quality in the Tapi River Estuary.
Survey: 21 March 1987.

Station	Date	Time	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Alkalinity (meq/l)	DO (mg/l)	DOC (mg/l)	Salinity (ppt)
Chiew Larn Dam	20	-	1.0	-	-	7.84	1.813	-	10.55	-
TP1-1	21	13.50	4.5	30.0	0.16	7.71	1.713	4.94	3.43	0.16
TP1-2	21	13.15	2.5	30.2	1.31	7.49	1.625	3.63	4.89	1.31
TP1-3	21	12.52	3.0	30.2	2.93	7.46	1.738	3.63	11.37	2.93
TP1-4	21	12.45	1.5	30.0	4.37	7.52	1.788	3.71	4.66	4.37
TP1-5	21	12.30	4.5	30.5	6.78	7.56	1.788	3.78	6.03	6.78
TP1-6	21	12.10	4.5	30.0	10.44	7.60	1.919	3.63	4.05	10.44
TP1-7	21	11.50	4.5	29.0	14.22	7.69	2.050	4.09	5.70	14.22
TP1-8	21	11.15	3.5	30.0	21.61	8.05	2.125	3.94	6.77	21.61
TP1-9	21	10.15	2.0	29.0	27.33	8.08	2.225	4.25	5.96	27.33

Station	(µM/l)						
	Ammonia	Nitrite	Nitrate	Total N	Phosphate	Total P	Silicate
Chiew Larn Dam	-	0.25	1.92	7.38	N.D.	0.85	109.31
TP1-1	N.D.	1.36	4.16	16.75	0.64	1.30	158.79
TP1-2	3.75	1.34	2.21	19.75	0.64	1.55	127.77
TP1-3	6.75	1.34	N.D.	19.25	0.40	2.65	132.94
TP1-4	3.05	1.06	2.77	17.75	0.34	2.25	114.48
TP1-5	2.55	0.93	6.51	9.12	N.D.	1.90	99.71
TP1-6	7.65	0.73	6.63	12.00	0.74	2.15	103.40
TP1-7	5.00	0.50	1.18	6.19	0.29	1.85	83.46
TP1-8	1.00	0.18	1.18	2.47	0.17	1.60	40.62
TP1-9	0.70	0.15	0.21	1.75	0.17	1.40	16.99

N.D. - No data.

Continued

Table 1. (continued)

Survey: 1 August 1987.

Station	Time	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Alkalinity (meq/l)	DO (mg/l)	(μM/l) Ammonia	Nitrite	Nitrate	Total N	Phosphate	Total P	Silicate
TP2-1	17.10	3.9	29	0.11	7.44	1.400	4.32	10.01	0.03	5.13	18.76	0.27	0.67	231.74
TP2-2	16.10	3.9	30	1.37	7.37	1.350	3.74	16.97	0.12	14.72	27.28	1.04	1.20	215.65
TP2-3	15.56	2.5	30	3.51	7.38	1.375	3.62	16.97	0.10	14.02	40.22	1.46	1.63	193.52
TP2-4	15.36	3.5	30	6.35	7.43	1.450	3.80	14.83	0.06	12.12	19.53	0.96	1.24	181.45
TP2-5	15.25	5.2	30	6.94	7.61	1.538	4.40	15.74	0.05	10.73	28.13	0.84	1.20	153.29
TP2-6	15.09	6.0	30	10.07	7.64	1.575	4.31	15.51	0.05	8.01	27.44	0.73	1.27	132.70
TP2-7	14.45	6.0	32	15.14	7.86	1.588	4.95	4.77	0.02	4.05	17.64	0.61	1.44	95.75
TP2-8	14.25	2.5	32	19.77	8.13	1.788	5.58	1.45	0.02	0.28	14.42	0.35	1.17	36.76
TP2-9	10.45	2.0	28	22.87	8.01	1.888	4.92	0.38	0.01	N.D.	9.03	0.38	0.93	13.78

Table 2. Comparison of the water quality in the Tapi River Estuary, March and August 1987. Mean values are enclosed in parentheses.

Parameter	March			August		
Salinity, ppt	0.16	-	27.33	0.11	-	22.87
pH	7.46	- (7.68)	8.08	7.37	- (7.65)	8.13
DO, mg/l	3.63	- (4.03)	4.94	3.62	- (4.40)	5.58
Alkalinity, meq/l	1.63	- (1.89)	2.23	1.35	- (1.55)	1.89
Ammonia, μM/l	<0.03	- (3.39)	7.65	0.38	- (10.74)	16.97
Nitrite, μM/l	0.15	- (0.84)	1.36	0.01	- (0.05)	0.12
Nitrate, μM/l	<0.03	- (2.77)	6.63	<0.03	- (7.67)	14.72
Total N, μM/l	1.75	- (11.88)	19.75	9.03	- (22.49)	40.22
Phosphate, μM/l	<0.10	- (0.39)	0.74	0.27	- (0.74)	1.46
Total P, μM/l	1.30	- (1.85)	2.65	0.67	- (1.19)	1.46
Silicate, μM/l	16.99	- (95.57)	158.79	13.78	- (139.40)	231.74

Table 3. Trace metals in oyster, cockle and shrimp farms in Ban Don Bay and the Tapi River, 23-25 March 1987. Units are in μg/l. (D: dissolved form; P: particulate form).

Ban Don Bay

Station	Hg	Cd		Cr		Cu		Pb		Zn	
		D	P	D	P	D	P	D	P	D	P
BD-01-S	0.110	0.024	0.002	0.093	0.904	0.565	0.107	0.136	0.065	4.81	0.33
BD-01-B	0.150	-	-	-	-	-	-	-	-	-	-
BD-02-S	0.130	0.018	0.002	0.076	0.288	0.831	0.109	0.040	0.027	4.76	0.11
BD-02-B	0.145	0.020	-	0.067	-	0.615	-	0.026	-	4.57	-
BD-03-S	0.115	0.026	0.001	0.102	0.288	0.931	0.070	0.052	0.081	5.27	0.24
BD-03-B	0.130	0.050	-	0.093	-	-	-	0.092	-	5.53	-
BD-04-S	0.210	0.044	0.003	0.076	2.327	0.583	0.309	0.163	0.314	6.49	1.49
BD-04-B	0.150	0.025	-	0.056	-	0.516	-	0.099	-	4.39	-
BD-05-S	0.145	-	-	-	-	-	-	-	-	-	-
BD-05-B	0.145	-	-	-	-	-	-	-	-	-	-
BD-06-S	0.250	0.042	0.002	0.094	0.452	0.596	0.168	0.193	0.227	4.90	0.75
BD-06-B	0.155	0.020	0.002	0.080	0.429	0.484	0.161	0.150	0.217	4.25	0.54
BD-07	0.135	0.026	0.006	0.092	0.480	1.050	0.256	0.184	0.106	4.79	1.29
BD-08-S	0.110	0.029	0.001	0.108	0.170	1.151	0.064	0.223	0.009	5.29	0.06
BD-08-B	0.130	0.035	-	0.060	-	1.183	-	0.134	-	4.57	-
BD-10	0.105	0.042	0.003	0.086	0.810	1.758	0.134	0.116	0.079	4.74	0.60
BD-11	0.110	0.026	0.006	0.083	1.031	1.183	-	0.147	0.810	4.78	2.86
BD-12	0.430	-	0.008	-	0.741	-	0.195	-	0.148	-	0.81
BD-13	0.100	0.041	0.004	0.095	0.406	0.768	0.152	0.091	0.125	4.75	1.32
Range	0.100- 0.430	0.018- 0.050	0.001- 0.008	0.056- 0.108	0.170- 2.327	0.484- 1.758	0.070- 0.309	0.026- 0.193	0.009- 0.810	4.25- 6.49	0.056- 2.86
Mean	0.155	0.031	0.003	0.084	0.694	0.872	0.157	0.123	0.184	4.93	0.87

Tapi River

Station	Hg	Cd		Cr		Cu		Pb		Zn	
		D	P	D	P	D	P	D	P	D	P
Chiew Larn Dam	-	0.031	0.061	0.011	0.636	0.462	0.406	0.171	0.204	3.22	3.37
TP1-1	0.060	0.017	0.011	0.024	1.033	0.286	0.858	0.118	1.659	2.20	2.78
TP1-2	-	-	-	-	-	-	-	-	-	-	-
TP1-3	0.120	0.004	0.011	0.038	2.074	0.644	1.292	0.164	1.855	4.95	3.87
TP1-4	-	-	-	-	-	-	-	-	-	-	-
TP1-5	trace	0.013	0.007	0.043	1.586	0.867	0.758	0.118	-	3.32	2.15
TP1-6	-	-	-	-	-	-	-	-	-	-	-
TP1-7	trace	0.032	0.003	0.061	0.719	0.917	0.312	0.197	0.248	3.70	0.77
TP1-8	-	-	-	-	-	-	-	-	-	-	-
TP1-9	trace	0.010	0.003	0.073	1.013	0.862	0.458	0.479	0.377	4.13	1.11

Oyster and cockle farms and some canals leading to the shrimp farms.

Station	Cd		Cr		Cu		Pb		Zn	
	D	P	D	P	D	P	D	P	D	P
Tha Chang shrimp farm	0.027	0.009	0.065	0.798	0.670	-	0.118	1.640	3.88	3.53
Fisheries Station cockle farm										
Inner	0.044	0.010	0.088	1.528	0.602	0.856	0.361	0.164	5.14	3.53
Outer	0.031	0.015	0.099	1.322	0.695	0.542	0.370	1.029	4.92	2.34
Kanchanadit oyster farm										
Inner	0.030	0.006	0.069	1.174	1.092	0.992	0.173	1.080	4.87	3.31
Outer	0.028	0.007	0.066	-	0.674	0.544	0.186	0.526	4.21	1.84
Tha Chang cockle farm										
Inner	0.046	0.009	0.088	3.230	0.602	1.199	0.289	2.393	4.35	4.41
Outer	0.069	0.146	0.092	1.282	0.525	0.806	0.246	0.518	4.37	2.73

Table 4. Trace metals in Ban Don Bay, the Tapi River, the oyster and cockle farms and some canals leading to the shrimp farms, August 1987. Units are in µg/l. (D: dissolved form; P: particulate form).

Ban Don Bay

Station	Hg	Cd		Cr		Cu		Pb		Zn	
		D	P	D	P	D	P	D	P	D	P
BD-01-S	trace	0.003	0.002	0.474	1.043	0.193	0.038	0.030	N.D.	3.60	0.03
BD-01-B	trace	0.001	0.001	0.455	1.883	0.161	0.056	0.020	0.057	3.66	0.10
BD-02-S	0.040	0.004	0.002	0.536	1.061	0.107	0.111	0.027	0.039	3.66	0.23
BD-02-B	0.040	0.004	0.001	0.174	1.101	0.193	0.067	0.027	N.D.	2.87	0.17
BD-03-S	0.015	0.003	0.004	0.567	1.049	0.318	0.069	0.079	0.068	4.06	0.07
BD-03-B	0.035	0.005	0.001	0.498	1.216	0.227	0.047	0.019	0.043	4.07	0.09
BD-04-S	0.090	0.014	0.001	0.351	1.630	0.372	0.095	0.186	0.188	3.06	0.38
BD-04-B	0.020	0.007	0.001	0.180	1.421	0.223	0.103	0.055	0.207	3.62	0.68
BD-05-S	0.085	0.006	0.002	0.209	1.332	0.300	0.087	0.012	0.024	2.84	0.10
BD-05-B	0.030	0.005	0.002	0.407	1.260	0.303	0.117	0.034	0.173	3.50	0.30
BD-06-S	0.110	0.003	0.001	0.354	0.751	0.434	0.111	0.022	0.096	3.42	0.27
BD-06-B	0.040	0.035	0.003	0.112	1.832	0.377	0.124	0.063	0.184	3.45	0.58
BD-07-S	0.010	0.011	0.001	0.421	1.175	0.361	0.106	0.017	0.181	3.22	0.29
BD-07-B	0.005	0.012	0.002	0.313	1.189	0.318	0.099	0.055	0.121	3.87	0.24
BD-08	0.010	0.006	0.002	0.381	1.348	0.338	0.118	0.019	0.158	3.49	0.51
BD-09	-	0.039	0.002	0.118	4.887	0.666	0.401	0.235	0.189	12.68	1.53
BD-10	0.115	0.018	0.002	0.278	2.309	1.190	0.256	0.003	0.452	3.16	0.89
BD-11	0.085	0.020	0.002	0.178	1.386	0.730	0.055	0.176	0.014	3.68	0.01
BD-12	0.270	0.013	0.005	0.207	3.478	0.513	0.281	0.013	0.632	2.82	1.40
BD-13	0.080	0.010	0.002	0.236	1.546	0.453	0.120	0.049	0.628	3.01	0.30
Range	trace 0.270	0.003- 0.039	0.001- 0.005	0.112- 0.536	0.751- 3.478	0.107- 1.190	0.038- 0.256	0.003- 0.235	N.D. 0.628	2.82- 4.07	0.01- 1.40
Mean	0.057	0.011	0.002	0.321	1.432	0.374	0.123	0.057	0.172	3.34	0.29

Tapi River

Station	Hg	Cd		Cr		Cu		Pb		Zn	
		D	P	D	P	D	P	D	P	D	P
TP2-1	0.220	0.001	0.003	0.056	3.500	0.628	0.277	0.227	0.234	7.81	0.58
TP2-2	-	0.016	0.004	0.165	3.675	1.507	0.290	0.477	N.D.	2.01	1.01
TP2-3	-	0.011	0.003	0.022	2.566	0.983	0.334	0.126	0.444	2.05	1.22
TP2-4	0.095	0.013	0.002	0.052	1.944	0.895	0.314	0.043	0.642	2.36	1.48
TP2-5	-	0.008	0.002	0.068	4.367	1.222	0.168	0.220	0.095	2.59	0.32
TP2-6	0.100	0.011	0.001	0.086	1.790	0.802	0.191	0.018	0.373	2.56	0.83
TP2-7	0.160	0.011	0.005	0.235	4.202	0.827	0.707	0.164	1.682	3.05	4.34
TP2-8	-	0.013	0.005	0.218	2.545	0.849	0.357	0.042	0.853	2.53	2.59
TP2-9	0.270	0.016	0.005	0.318	2.015	0.610	0.251	0.094	0.358	3.74	0.98

Oyster and cockle farms and some canals leading to the shrimp farms.

Station	Cd		Cr		Cu		Pb		Zn	
	D	P	D	P	D	P	D	P	D	P
Fisheries Station Cha-ngoe cockle farm										
Inner	0.023	0.001	0.300	2.595	1.189	0.162	0.568	0.040	2.48	0.52
Outer	0.012	0.003	0.391	4.549	0.659	0.551	0.049	1.057	4.26	3.84
Kanchanadit oyster farm										
Inner	0.012	0.013	0.090	9.257	2.275	5.178	0.036	4.032	2.22	12.82
Outer	0.008	0.002	0.316	2.185	0.719	0.262	0.072	0.614	3.11	1.40
Tha Chang cockle farm										
Inner	0.030	0.001	0.455	1.306	1.520	0.177	2.163	0.806	5.79	0.58
Outer	0.039	0.002	0.118	4.887	0.666	0.401	0.235	0.189	12.68	1.53
No. 3 Khlong Kaejae	0.016	0.009	14.070	0.983	2.691	0.055	6.511	2.57	14.87	
No. 7 Khlong Kradae	0.009	0.010	2.752	2.886	2.386	0.074	1.626	1.24	5.31	
No. 10 Khlong Ram	0.018	0.001		1.549	0.463	0.277	0.032	0.491	2.98	1.61
No. 12 Khlong Tha Tong	0.009	0.005		1.430	0.702	0.271	0.035	0.530	2.19	1.43
No. 13 Khlong next to Don Sak farm	0.043	0.004		9.375	2.272	1.645	N.D.	2.246	4.73	5.30
No. 14 Don Sak farm	0.006	0.001		0.835	0.385	0.041	0.854	0.066	4.19	0.03
No. 16 Khlong Tha Chang	0.040	0.017		4.127	1.762	0.264	4.156	1.455	14.77	6.00

Table 5. Comparison of dissolved trace metals in Ban Don Bay and the Tapi River Estuary between December 1986 and March and August 1987 surveys. Units are in μg/l.

Ban Don Bay

Parameter		December	March	August
Hg	Range	-	0.100-0.430	trace-0.270
	Mean		0.155	0.057
Cd	Range	0.018-0.029	0.018-0.050	0.003-0.039
	Mean	0.024	0.031	0.011
Cr	Range	0.046-0.091	0.056-0.108	0.112-0.536
	Mean	0.064	0.084	0.321
Cu	Range	0.370-1.002	0.484-1.758	0.107-1.190
	Mean	0.807	0.872	0.374
Pb	Range	0.037-0.194	0.026-0.193	0.003-0.235
	Mean	0.119	0.123	0.057
Zn	Range	3.45-5.63	4.25-6.49	2.82-4.07
	Mean	4.69	4.93	3.34

Tapi River Estuary

Parameter		March	August
Hg	Range	trace-0.120	0.095-0.270
	Mean	0.036	0.169
Cd	Range	0.004-0.032	0.001-0.016
	Mean	0.015	0.011
Cr	Range	0.024-0.073	0.022-0.318
	Mean	0.048	0.136
Cu	Range	0.286-0.917	0.610-1.507
	Mean	0.715	0.924
Pb	Range	0.118-0.479	0.018-0.477
	Mean	0.218	0.157
Zn	Range	2.20-4.95	2.01-7.81
	Mean	3.66	3.19

Table 6. Comparison of the levels of some trace metals in the Chao Phraya, Mae Khlong, Bang Pakong and Tapi Rivers of Thailand with the Danube and Rhine Rivers in Europe and the Amazon River in South America. Units are in μg/l.

Element	Typical values	Danube River[a]	Rhine River[a]	Amazon River[a]	Chao Phraya River[b] (1983)	Mae Khlong River[c] (Nov. 1985)	Bang Pakong River[d] (Feb. 1987)	Tapi River[e] (1987)
Cd	0.07	0.07-2.60	3.7	-	0.005	0.005-0.080	0.020-0.057	0.010-0.032
Cr	0.5	0.4-1.0	11	2.02		0.06-0.40		0.011-0.318
Co	0.05			0.06	33+6.5	0.03	0.047	
Cu	2	3-7	17	1.77	1.100	0.21-0.54	0.09-1.93	0.286-1.507
Pb	0.2	2-4	4.2		N.D.-3.18	0.01-0.34	0.02-0.50	N.D.-0.409
Mn	<5	2-9	62	19	1.1-60.1	4.0	N.D.-21.0	
Fe			67	34	14.5-203.1	29.0	3.1-102.0	
Hg	0.01	0.1-1.0	0.49		N.D.-0.43			
Ni	0.3	1-7		0.27	1.100	0.46	1.30	
Zn	10	7-28	201		0.55-2.74		1.69-3.38	2.01-7.81

Sources:

[a]Forstner and Wittman (1981).

[b]Umnuay (1984).

[c]Hungspreugs et al. (1985).

[d]Hungspreugs et al. (1987).

[e]This paper.

Table 7. Water quality in Ban Don Bay.
Survey: 23-25 March 1987.

Station	Date	Time	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Alkalinity (meq/l)	DO (mg/l)	TOC	Chlorophyll	(µM/l) Nitrite	Nitrate	Phosphate	Total P	Silicate
BD-01-S	25	11.30	5.0	30.0	32.33	8.18	2.287	4.38	2.74	1.264	0.1	0.26	<0.1	0.45	19.51
BD-01-B	25			29.8	32.32	8.16	2.262	4.38	2.51		<0.1	0.26	<0.1	0.55	22.60
BD-02-S	24	14.50	4.9	30.0	32.35	8.24	2.325	4.59	2.90	1.456	0.15	0.11	0.35	0.46	33.07
BD-02-B	24			30.0	32.34	8.25	2.337	4.67	2.94		0.29	<0.1	0.55	0.69	15.65
BD-03-S	24	13.32	5.0	30.0	32.36	8.31	2.287	4.78	3.35	1.232	<0.1	<0.1	0.30	0.34	9.04
BD-03-B	24			29.8	32.34	8.31	2.275	4.82	2.66		<0.1	2.63	0.46	0.55	10.47
BD-04-S	24	10.35	5.0	29.0	32.26	8.29	2.325	4.54	2.75	-	<0.1	<0.1	0.46	0.75	9.70
BD-04-B	24			29.0	32.26	8.30	2.362	4.39	4.75		<0.1	<0.1	0.97	1.45	11.46
BD-05-S	25	13.05	5.0	29.9	32.27	8.19	2.275	4.32	3.27	1.424	<0.1	<0.1	<0.1	0.55	19.07
BD-05-B	25			29.9	32.29	8.21	2.225	4.32	2.02		0.05	<0.1	<0.1	0.65	19.84
BD-06-S	25	13.12	4.0	29.0	32.38	8.22	2.250	4.42	2.35	2.272	0.14	0.65	<0.1	0.80	22.71
BD-06-B	25			29.0	32.39	8.22	2.325	4.54	-		0.31	<0.1	<0.1	1.00	24.69
BD-07	23	12.50	4.9	29.2	32.39	8.13	2.387	3.94	6.38	1.184	0.28	0.23	0.40	0.75	27.33
BD-08-S	24	9.05	5.5	29.0	32.29	8.23	2.237	4.28	2.96	2.288	<0.1	0.79	0.17	1.10	21.05
BD-08-B	24			32.0	32.30	8.23	2.337	4.59	3.26		0.03	<0.1	0.17	2.30	19.51
BD-10	25	16.20	2.5	30.7	28.50	8.21	2.225	4.56	3.28	2.784	0.10	<0.1	0.34	0.95	14.55
BD-11	25	15.10	3.0	30.0	32.48	8.30	2.350	4.88	3.69	3.392	0.15	<0.1	<0.1	1.70	8.16
BD-12	23	10.30	3.0	28.0	32.41	8.28	2.425	4.75	8.75		0.18	0.29	0.40	0.75	9.48
BD-13	23	14.10	2.5	29.0	32.46	8.26	2.344	3.94	4.49		0.20	0.96	0.40	0.55	5.84

Survey: August 1987.

Station	Date	Time	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Alkalinity (meq/l)	DO (mg/l)	(µM/l) Ammonia	Nitrite	Nitrate	Total N	Phosphate	Total P	Silicate
BD-01-S	3	15.50	6.8	29.5	32.59	8.22	2.250	4.37	<0.1	0.07	0.32	8.68	<0.1	0.50	4.13
BD-01-B				29.0	32.59	8.25	2.238	4.26	<0.1	<0.1	0.46	6.09	0.21	0.50	17.50
BD-02-S	3	14.40	6.0	30.0	32.54	8.18	2.213	4.32	0.67	0.04	0.39	7.49	<0.1	0.50	13.91
BD-02-B				30.0	32.50	8.19	2.150	4.29	0.49	0.04	0.23	8.54	<0.1	0.50	41.85
BD-03-S	5	11.36	5.1	30.3	32.47	8.19	2.225	4.77	0.25	0.04	<0.1	6.37	<0.1	0.62	24.29
BD-03-B				30.0	32.50	8.30	2.225	4.76	0.30	0.04	<0.1	8.40	<0.1	0.62	2.67
BD-04-S	5	10.20	5.8	29.5	32.29	8.21	2.200	4.74	0.20	0.04	0.15	7.14	<0.1	0.50	10.19
BD-04-B				29.5	32.32	8.20	2.163	4.64	0.25	0.05	0.05	8.82	<0.1	0.67	11.24
BD-05-S	3	17.00	6.0	30.0	32.81	8.27	2.275	4.37	<0.1	<0.1	0.16	8.54	<0.1	0.62	8.59
BD-05-B				30.0	32.65	8.18	2.250	4.32	0.23	0.11	0.09	12.18	0.21	0.69	16.09
BD-06-S	3	11.45	4.5	30.0	32.49	8.20	2.225	4.33	0.30	0.12	0.07	12.46	0.12	0.53	3.59
BD-06-B				30.0	32.45	8.23	2.238	4.28	0.11	0.12	0.30	12.67	0.63	0.60	8.04
BD-07-S	5	12.27	4.9	30.0	31.23	8.20	2.125	4.74	0.23	0.05	<0.1	10.08	<0.1	0.50	14.29
BD-07-B				29.8	31.34	8.22	1.963	4.58	0.25	0.12	0.68	11.41	<0.1	0.53	23.05
BD-08	5	9.14	4.2	29.5	31.45	8.21	2.131	4.49	0.30	0.11	0.10	11.69	<0.1	0.57	19.43
BD-09	6	-9.00	-	-	27.45	8.01	1.925	4.14	0.29	0.06	0.12	14.49	0.48	0.84	80.82
BD-10	3	18.15	3.5	29.5	32.43	8.10	2.188	4.06	0.11	0.14	0.12	14.57	<0.1	0.69	11.74
BD-11	3	-	3.6	29.8	27.04	8.03	1.913	4.39	0.30	0.02	0.07	11.55	<-0.1	0.65	27.06
BD-12	5	13.35	3.0	29.8	28.56	8.19	2.038	4.72	0.25	0.09	0.05	17.01	<0.1	0.77	12.86
BD-13	5	14.22	3.0	30.0	29.74	8.21	2.063	4.84	0.23	0.07	<0.1	18.62	<0.1	0.57	22.48

Table 8. Comparison of some surface parameters in Ban Don Bay, March and August 1987 surveys. Mean values are enclosed in parentheses.

Parameter	March	August
Temperature, °C	28.0-30.7 (29.5)	29.5-30.3 (29.8)
Salinity, ppt	28.50-32.46 (32.03)	27.40-32.59 (31.01)
pH	8.13-8.31 (8.24)	8.03-8.27 (8.18)
DO, mg/l	3.94-4.88 (4.48)	4.06-4.84 (4.47)
Alkalinity, meq/l	2.23-2.43 (2.31)	1.91-2.28 (2.14)
Nitrite, µM/l	<0.03-0.20 (0.10)	<0.03-0.14 (0.06)
Nitrate, µM/l	<0.03-0.96 (0.28)	<0.03-0.39 (0.12)
Total N, µM/l	- -	6.37-18.62 (11.44)
Phosphate, µM/l	<0.10-0.46 (0.25)	<0.10-0.48 (0.03)
Total P, µM/l	0.30-1.70 (0.75)	0.50-0.84 (0.62)
Silicate, µM/l	5.84-33.07 (16.63)	3.59-24.29 (14.38)

Table 9. Water quality in the oyster, cockle and shrimp farms, March 1987.

Station	Date	Salinity (ppt)	pH	Alkalinity (meq/l)	TOC	DOC (mg/l)	(µM/l) Ammonia	Nitrite	Nitrate	Total N	Phosphate	Total P	Silicate
Tha Chang shrimp farm	20	-	7.25	0.750	11.63	12.47	0.50	0.20	0.48	0.72	N.D.	1.30	96.01
Tha Chang cockle farm													
Inner	22	23.95	7.78	1.962	5.63	5.71	0.77	0.20	0.20	0.82	0.51	1.55	27.37
Outer	22	24.62	7.98	1.875	8.83	5.61	0.82	0.18	N.D.	1.55	0.80	3.25	274.74
Fisheries Station													
Cha-ngoe cockle farm													
Inner	22	31.19	8.22	2.375	6.11	4.37	0.70	0.10	0.82	1.13	1.03	2.30	16.84
Outer	22	31.17	8.25	2.312	5.87	5.42	0.64	0.30	0.30	N.D.	0.57	1.80	158.95
Kanchanadit oyster farm													
Inner	22	28.71	7.67	2.350	6.18	4.07	1.73	0.22	0.35	5.15	1.89	3.20	269.47
Outer	22	30.34	8.00	2.300	7.48	4.31	1.05	0.10	0.59	2.58	1.26	1.85	190.53

Table 10. Water quality in the cockle and shrimp farms and adjacent canals, 3-5 August 1987.

Station	Salinity (ppt)	pH	Alkalinity (meq/l)	DO (mg/l)	(µM/l) Ammonia	Nitrite	Nitrate	Phosphate	Silicate
Kanchanadit oyster farm									
Inner	5.5	7.16	1.43	4.35	5.62	0.48	23.78	0.58	272.8
Outer	21.5	7.45	1.44	3.27	1.06	0.24	0.27	0.36	79.2
Fisheries Station									
Cha-ngoe cockle farm									
Inner	22.5	7.66	1.68	4.46	0.34	0.09	0.21	1.14	80.8
Outer	22.5	7.48	1.61	5.17	0.20	0.09	0.07	0.42	27.3
Tha Chang cockle farm									
Inner	30.0	7.44	1.75	3.63	1.35	0.07	0.16	0.18	166.6
Shrimp farms									
No.1 Chit's Farm	20.0	7.28	1.50	-	0.34	0.68	0.09	0.06	120.1
No.4 Fisheries Station	19.5	7.04	0.98	-	2.75	0.13	-	0.30	85.2
No.6 Sutat's Farm	20.0	7.18	1.39	-	0.60	0.13	4.46	-	54.6
No.9 Sawas's Farm	14.5	7.36	2.28	-	0.17	0.07	0.12	0.24	222.2
No.14 Don Sak Farm	34.5	8.01	2.29	-	N.D.	0.06	0.20	-	46.8
No.18 Tha Chang Farm	-	-	-	-	0.09	0.07	0.09	-	18.5
No.19 New Farm	30.0	6.98	1.28	-	14.34	1.80	40.09	0.30	29.5
No. 20 Vong Kacha Farm	36.0	7.19	2.28	-	5.79	0.18	0.13	0.12	176.6
No .22 Natural Farm	32.0	7.23	2.04	-	1.26	0.18	0.02	-	75.1
Adjacent canals									
No.3 Khlong Kaejae	10.0	6.99	1.13	3.43	6.08	0.68	2.56	0.84	246.4
No.7 Khlong Kradae	3.5	7.60	1.49	3.79	1.95	0.44	25.99	2.70	287.0
No.10 Khlong Ram	15.0	7.37	2.40	4.91	-	0.09	0.02	0.12	215.1
No.12 Khlong Tha Tong	7.5	7.48	1.95	2.84	1.15	0.87	36.42	-	192.3
No.13 Khlong next to Don Sak Farm	35.0	7.35	2.53	3.67	5.33	0.48	2.37	0.06	56.2
No.16 Khlong Tha Chang	29.0	7.29	1.79	3.79	0.77	0.18	4.74	-	189.5

Table 11. Chlorophylls a, b, and c content of phytoplankton in Ban Don Bay, March and August 1987. Units in mg/m^3.

Station	March a	March b	March c	August a	August b	August c
BD-01	1.264	N.D.	N.D.	2.960	1.686	-
BD-02	1.456	1.088	2.992	2.067	0.463	1.708
BD-03	1.232	0.112	0.640	1.537	1.250	1.485
BD-04	-	-	-	2.122	0.943	2.835
BD-05	1.424	0.112	N.D.	1.464	0.834	2.378
BD-06	2.272	0.288	1.376	1.380	1.598	2.870
BD-07	1.184	0.208	3.872	1.451	0.007	0.463
BD-08	2.288	N.D.	11.152	2.448	1.108	1.437
BD-09	-	-	-	-	-	-
BD-10	2.784	0.096	1.104	-	-	-
BD-11	3.392	N.D.	N.D.	3.468	2.148	6.038
BD-12	-	-	-	2.237	0.940	2.237
BD-13	-	-	-	2.312	1.284	2.428
Range	1.184-3.392	0.096 1.088	0.0640 3.872	1.380-3.468	0.007-2.148	0.463-6.038
Mean	1.922	0.212	2.348	2.131	1.115	2.171

Table 12. Dissolved petroleum hydrocarbons in Ban Don Bay, March and August 1987. Units in µg/l.

Station	Petroleum hydrocarbons March	August	Station	Petroleum hydrocarbons March	August
BD-01	1.391	0.070	Fisheries Station		
BD-02	1.690	0.107	Cha-ngoe		
BD-03	1.820	1.172	Inner	1.415	3.106
BD-04	2.370	2.900	Outer	1.725	-
BD-05	1.772	0.332	Kanchanadit		
BD-06	1.568	0.928	Inner	0.933	3.611
BD-07	0.788	2.846	Outer	0.869	-
BD-08	1.600	1.341	Tha Chang		
BD-09	-	2.963	Inner	0.805	2.963
BD-10	1.408	0.696	Outer	0.966	(= BD-09)
BD-11	1.610	0.175			
BD-12	0.942	1.468			
BD-13	0.837	0.676			
Range	0.788-2.370	0.070-2.973			
Mean	1.483	1.206			

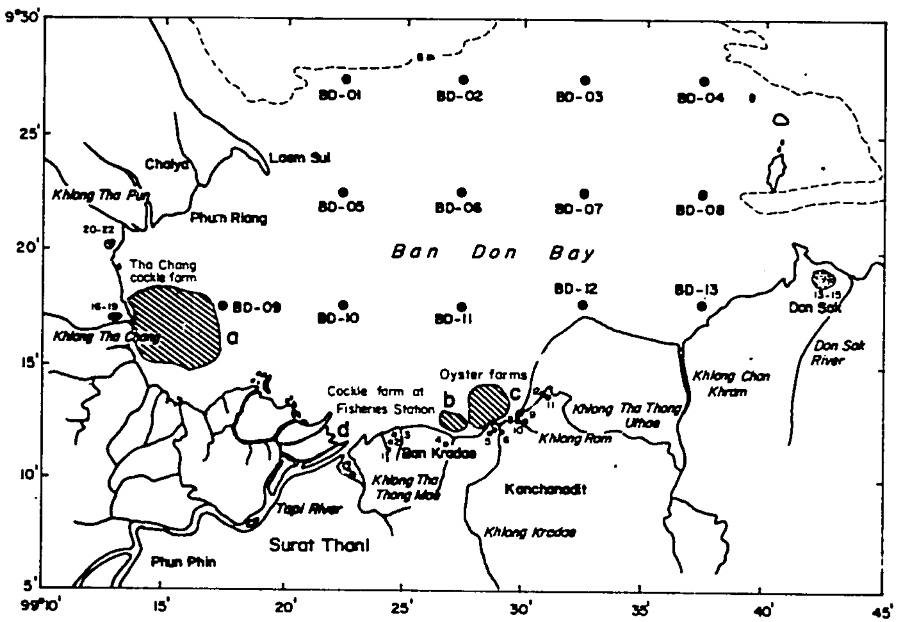

Fig. 1. Sampling stations in Ban Don Bay.

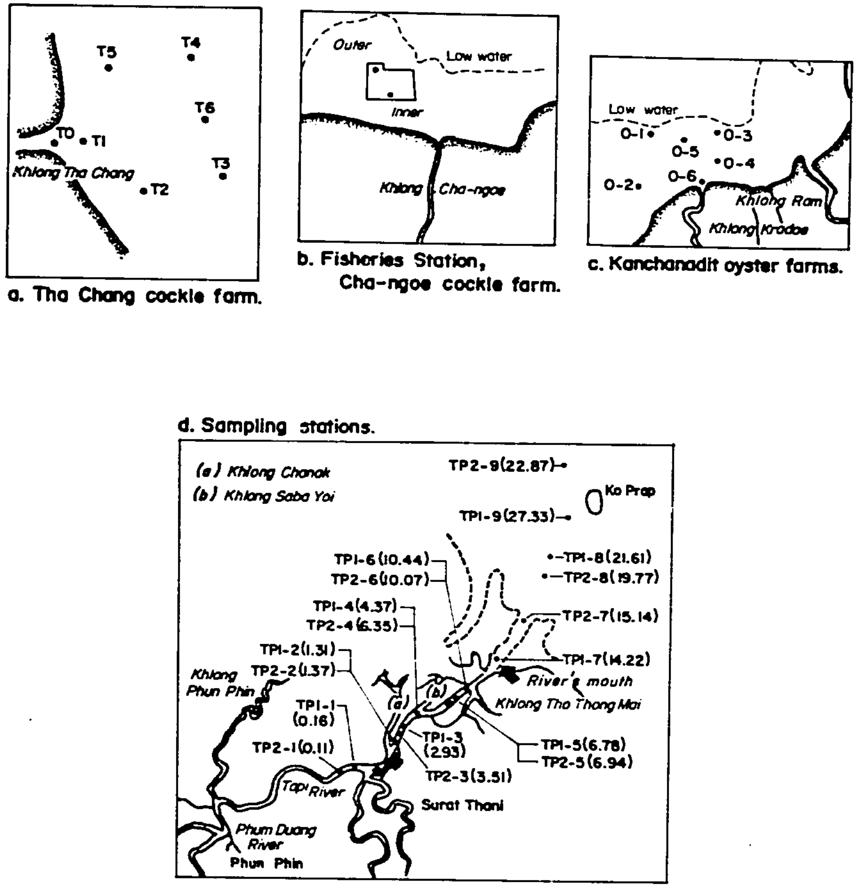

Fig. 2. Sampling stations in the Tapi River Estuary and in the cockle and oyster farms in Ban Don Bay. (See shaded areas of Fig. 1.)

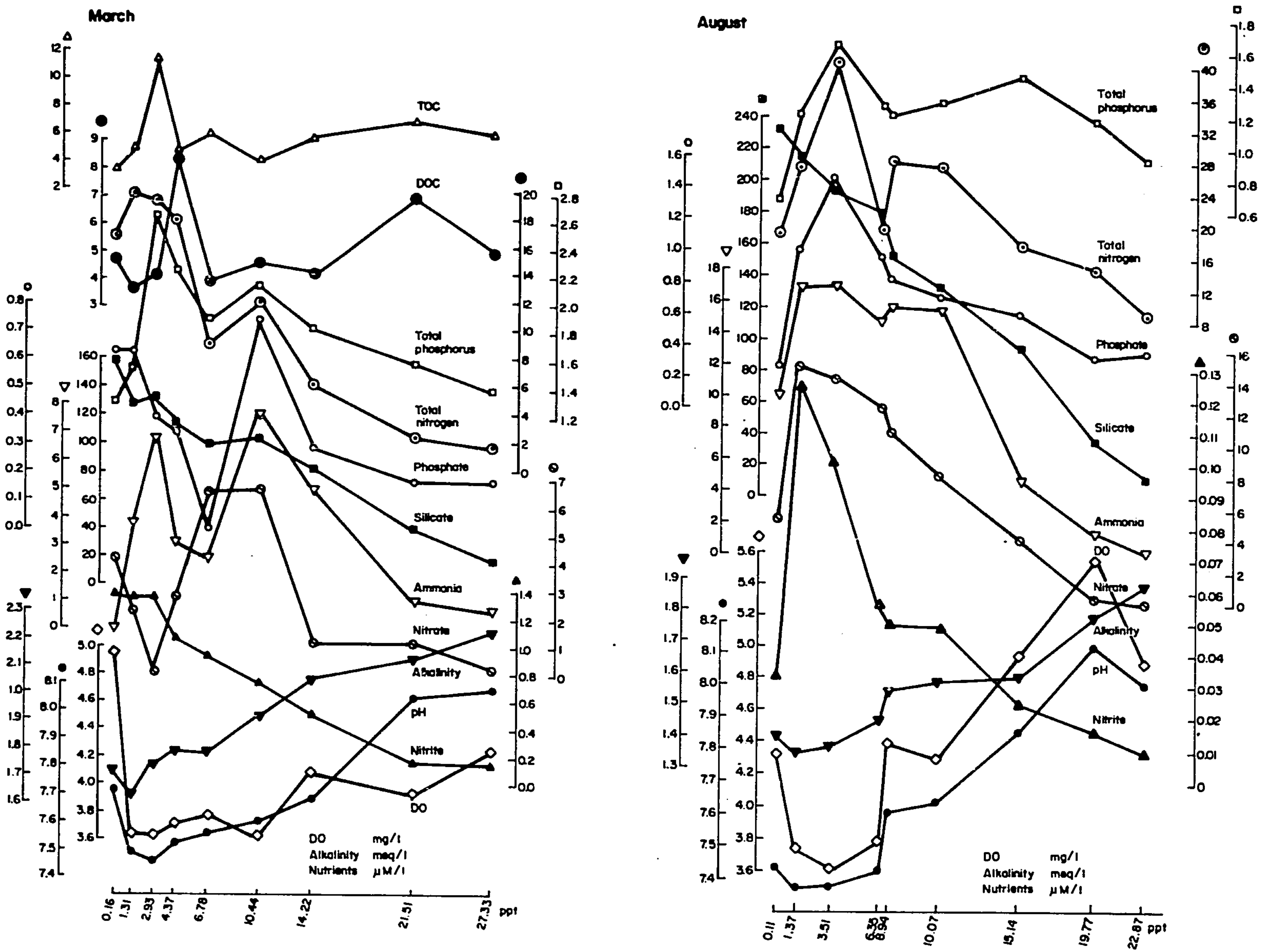

Fig. 3. Water quality of the Tapi River Estuary in March and August 1987.

Land-based pollution sources in the Upper South, Thailand

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KOSITRATANA, N. and S. KAJORNATIYUDH. 1991. Land-based pollution sources in the Upper South, Thailand, p. 167-175. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

This study evaluated water pollution problems arising from land-based sources in the Upper South, Thailand, which includes areas in Surat Thani (Ban Don Bay), Phangnga and Krabi Provinces (Phangnga Bay). The study showed that most of the major pollution sources were point sources (i.e., wastewater from communities, industries, mines and ports). Major environmental issues identified in Ban Don Bay were the deterioration of the water quality of Tapi-Phum Duang River and the direct discharge of sewage into natural receiving waters. In Phangnga Bay, on the other hand, the high concentration of suspended solids in mine tailings was the main issue.

Wasteloads from various pollution sources, which included the total generated waste from the point source or the so-called potential load and the actual loads that entered both bays, were also estimated. There are immediate and long-term plans to manage the water quality of natural receiving waters by controlling pollution point sources or land-based pollution sources to minimize their impact on the water quality and the coastal resources.

INTRODUCTION

The Upper South region of Thailand was chosen as the pilot site for the ASEAN/US Coastal Resources Management Project (CRMP) for its rich natural resources. Like all developing areas in Thailand, the region has been degraded through industrialization, urbanization and upland activities. Many of its rivers and canals (*khlong*) are contaminated with sewage discharge, organic waste, mine tailings and agricultural runoff.

To protect the natural resources along the coastal zone of the Upper South, this study on land-based pollution sources was conducted. The results of the study include recommendations on how to mitigate the impact of those pollution sources on natural resources.

OBJECTIVES

The study's primary objectives are as follows:

1. evaluate pollution problems arising from land-based sources that contribute to coastal resources degradation; and
2. propose a management plan and mitigation measures to reduce the environmental impact caused by land-based pollution sources.

SCOPE OF WORK

The study focused on the inventory of pollution sources and their wasteloads and the impact of those sources on the water quality of natural receiving waters. The scope of work included studies on the water quality of natural receiving waters and on the wastewater characteristics, including the quality and quantity from various pollution sources (i.e., communities, industries, fishing ports and mines).

SITES AND METHODS

The study area shown in Fig. 1 includes a "land bridge" and coastal areas between Surat Thani in the northeast and Phangnga in the southwest. However, the major focus of the study was on the receiving waters that discharge into the coastal provinces of Surat Thani (Ban Don Bay) and

Phangnga and Krabi (Phangnga Bay). In Ban Don Bay, the study area was that between Sui and Thaut Peninsula including Samui Island, and in Phangnga Bay, it was the area between Thai Muang District (Phangnga) and Klongtom District (Krabi).

Samples of wastewater from pollution sources and natural receiving waters were analyzed for physical, chemical and biochemical properties. The sampling was carried out four times in 1987, twice during the dry season and twice during the wet season. The analytical methods used followed the Standard Methods for Water and Wastewater Analysis of the Office of the National Environment Board (ONEB), Thailand.

For the study of the water quality of natural receiving waters, the parameters analyzed were air temperature, water temperature, pH, conductivity, salinity, hardness, alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total phosphorus, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, suspended solids, total coliform bacteria and fecal coliform bacteria.

Sampling and analysis of wastewater from selected pollution sources (i.e., communities, industries, ports and mines) were carried out to determine wastewater characteristics and to evaluate the generated wasteloads. The analysis was mostly for BOD and COD and the measurement of wastewater flow rates. The evaluation of the total wasteloads from various sources is the total generated load (TGL). The actual discharge load (ADL) into natural receiving waters was calculated from information on the efficiency and availability of the existing drainage systems in the area.

RESULTS AND DISCUSSION

Land-based pollution sources

Land-based pollution sources were found to be scattered throughout the Upper South area, especially along the banks of major receiving waters. The problem associated with land-based pollution sources was the direct discharge of wastewater into natural receiving waters. Pollution sources discharged wastewater directly into the river or this was collected in the sewer lines that have open ends at the riverbanks. Therefore, the TGL-to-ADL ratio depended on the number of sewer lines in the community. Sewer lines servicing Muang Surat Thani and Phun Phin Districts were only 13.6% and 8.2% of the district area, respectively.

In Surat Thani, the major sources of pollution were industries, fishing ports and communities, especially the small communities and small-scale industries along the coast. Sediment from mines was the only major source of pollution in Phangnga. In Krabi, communities and industries, especially oil palm mills and rubber plants, were also the major sources of pollution.

The communities of Phum Riang, Tha Chang, Kanchanadit, Tha Thong and Don Sak along Ban Don Bay discharged wasteloads of 10.6, 40.6, 100.8, 11.3 and 54 kg BOD/day, respectively (Fig. 2). Muang Surat Thani and Phun Phin generated only 13.6% and 8.2% of the total wasteload, respectively, and discharged into Tapi-Phum Duang River. For the fishing port, the TGL equalled the ADL, which means that all the generated wasteload of 2,049 kg BOD/day was dumped into the receiving water. This is one of the major sources of pollution in Ban Don Bay.

Major industries in Surat Thani that generated a large amount of wasteload were the distillery plant, the Phun Phin industrial complex, fish mills near the mouth of Tapi River and the dried shrimp factories at Don Sak. The potential wasteloads were estimated at 13,200; 26,295; 21; and 171 kg BOD/day, respectively. However, the wastes from the distillery plant were not discharged into natural receiving waters because of national regulations and enforcement.

The TGL from all the land-based sources which are potential waste sources in Ban Don Bay were calculated at 32,240 kg BOD/day while the ADL was 3,439 kg BOD/day. Based on these, only 9-10% of the potential wasteload had an impact on the receiving waters. Even with this small amount of waste discharged, immediate effects occurred and the quality of the water and of life and sanitation of the local people in some areas deteriorated.

In Phangnga Bay, the major land-based pollution sources were from communities, industries (oil palm mills and rubber plants) and mine tailings (Fig. 3). Waste generated by the Muang Phangnga and Muang Krabi communities were small in amount and wastes from oil palm mills and smoked rubber plants were retained within the plants. These sources did not have a significant impact on the water quality of the natural receiving waters. However, solids from mine tailings with a TGL and ADL of 280,000 kg suspended solids/day or approximately 50,400 t/year were significant. It was assumed that each mine operated approximately 6 months/year and the water supply was 70,000 m^2/day for 14 mines whose effluents affected Phangnga Bay with suspended solid concentrations of 4,000 mg/l, which caused the shallowness of Khlong Phangnga. This rate of sedimentation can affect the inner part of Phangnga Bay or 280 km^2 of the coastal zone in Phangnga and Krabi (Fig. 4). The approximate silt load was 180 t/km^2/year. Besides causing shallowness and creating a problem for navigation, the suspended solids affected living organisms in the coastal zone such as corals and mangroves.

The TGL from all land-based pollution sources except mine tailings within Phangnga Bay was calculated at 9,540 kg BOD/day and the ADL, 154 kg BOD/ day, representing only 1.6% of the total potential wasteload. Even though the organic pollution problem was considered small, important point sources from the islands of Pan Yee and Phi Phi, which are tourist attractions, should be controlled.

Organic waste generated and actual load discharged into the receiving waters were higher in Ban Don Bay than in Phangnga Bay. However, sediment accumulation due to mine tailings in Phangnga was much more serious than the organic wasteload discharged by the communities and industrial sources.

Water quality of natural receiving waters

The water quality indicated by the concentration of DO and BOD in the natural receiving waters in both Ban Don and Phangnga Bays was within acceptable ranges compared to the National Surface Water Quality Standards (Fig. 5). However, occasional contamination of the receiving waters by sewage discharges is shown by the high number of total coliform bacteria especially during low tides and the wet season. The water quality of Tapi, Phangnga and Krabi Rivers at the section near the communities of Muang Surat Thani District, Muang Phangnga and Muang Krabi deteriorated due to coliform, with the highest intensity occurring during the wet season. This could be caused by a flushing of the soil and other impurities which contained coliform during the storms into the natural receiving waters.

RECOMMENDATIONS

Ban Don Bay had more organic pollution sources, thus the water quality of its natural receiving waters was deteriorating. The pollution sources in Phangnga Bay were the mine tailings and, partly, the communities. Management of these areas must then consider the improvement and maintenance of the receiving waters in Ban Don, Phangnga and Krabi while reducing the sediments' transport from the mining areas.

To achieve the management objectives in the long-term, the control strategies should minimize the wasteload at the sources and prevent the direct discharge of the wasteload into the natural receiving waters.

Table 1 presents the preliminary recommendations and the mitigating measures for the management of the coastal resources along Ban Don and Phangnga Bays in relation to land-based pollution sources. These are immediate and long-term plans.

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Table 1. Preliminary recommendations and mitigation measures for water quality management.

Management schemes	Justification	Brief description	Major environmental effects	Agencies responsible
Ban Don Bay *Intermediate programs*				
1. Strengthening of law enforcement.	Effluents discharged from the following industries do not meet the standards and regulations: frozen food and seafood processing; smoked rubber processing; distillery plant; and fish mill. Encroachment of public waterways. Direct disposal of solid waste into waterways.	Concerned agencies, both government and nongovernment, must cooperate in strengthening law enforcement.	Improvement of natural receiving waters and effluent quality entering waterways.	Ministry of Industry (MOInd.), Harbour Department (HD), local government
2. Strict implementation of land use development plan.	Only town planning has been done and implemented on the regional level. This can be applied in other areas. In addition, local activities, such as aquaculture and land exploitation for a residential purpose, are common in the area.	Areas free from pollution and encroachment should be specified.	Preservation of raw water for supply to ensure that its quality complies with the standards.	Local government, HD, Department of Land Development (DOLD)
3. Coordination and public relations to stimulate environmental awareness.	Lack of education and public awareness in environmental issues cause failure in the implementation phase.	Public awareness campaign. The people to be approached are the local *tambon*, *amphoe* and *changwat* groups and the central government officers.	Enabling the local people to understand management approaches to control pollution and local garbage problems.	Local government, Nongovernmental Organization (NGO), Office of the National Environment Board (ONEB), Committee on Public Health Ministry (COPHM)
4. Development of community sanitation.	Population and activities in dense communities and developing areas will increase rapidly, thus, creating more waste.	Low-cost system, (i.e., on-site or interceptors system on main drains and diversion to waste treatment systems) should be applied. Effluent, at least the primary one treated, is discharged into natural receiving waters or collected and recycled for other uses. No direct discharge will be allowed.	Improvement of the water quality of natural receiving waters. If no treatment system is in operation, the water quality of Tapi River will continue to deteriorate, especially when mitigation measures or the impact of water released from the Rachaprapa Dam are not enforced.	Ministry of Interior (MOInt), ONEB, local government
• Water quality management for Amphoe Muang, Amphoe Phun Phin, Ko Samui and the submuncipalities of Don Sak, Kradae and Kanchanadit.	A water quality management plan must be developed for Upper South, Thailand.	Concerned agencies must coordinate in setting up the plan which must focus on the control of pollution point sources and the improvement of water quality of natural receiving waters.	Improvement of environmental quality and quality of life.	ONEB, local sanitation office
• Solid waste management at Amphoe Muang, Amphoe Phun Phin and Amphoe Ko Samui.	Solid wastes are not properly disposed and production tends to increase.	Solid waste disposal is not properly managed. Management must be cyclic (i.e., collection, treatment and the disposal of garbage must be done).	Improvement of urban environment and sanitation.	Local government, ONEB, COPHM
5. Development of on-site wastewater treatment facilities for dense communities and small-scale marine industries at the Surat Thani Fishery Port, dried shrimp factories and fish mills.	Dense communities, dried shrimp factories and fish mills are not equipped with appropriate wastewater treatment plants. In addition, the effluent from these sources is highly organic and is expected to become a major pollution source.	To be developed in certain pollution sources such as houses in dense communities and fisheries ports. Priority should be given to areas with a serious problem of pollution point sources.	Prevention of wastewater from major pollution sources from entering natural receiving waters.	ONEB, local government

6. Setting of surface water quality classification and standards.	The aims are the beneficial use of water and maintenance of water quality. The program includes activities to be allowed along natural receiving waters and setting of surface water quality standards.	Review of the beneficial uses of Ban Don Bay's environmental components and the setting of a surface water quality classification and standards to protect these uses.	Improvement and sustenance of environmental quality such as medium clean surface water resources for water supply and agriculture.	ONEB
7. Environmental monitoring program for the Tapi-Phum Duang River and industrial pollution sources.	Seasonal data should be collected and compared in time and with the developed model. • Effluent discharge from industry does not meet the standards. • Encroachment of public waterways and regulations. • Direct disposal of solid waste into the waterways.	A comprehensive environmental monitoring program to: • produce a water quality status report on the natural receiving waters; • detect any contamination of natural receiving waters; • ensure that the wastewater discharged from pollution sources complies with effluent standards.	Ensuring the maintenance of environmental quality in the long-term.	Phangnga Fishery Office, Surat Thani Environmental Health Center #8, ONEB, Electricity Generating Authority of Thailand (EGAT), agricultural coopetives
8. Conservation plan for raw water supply at catchment areas at Amphoe Muang and Amphoe Phun Phin.	Due to the increased demand for raw water supply, the water quality at Phun Phin pumping station is deteriorating.	Limit and inhibit the construction of certain industries in the Tapi-Phum Duang catchment area. Control the quality of wastewater discharged from communities and industries. Conservation plan for the Tapi-Phum Duang catchment area.	Improvement of raw water quality.	ONEB, PWWA
Long-term plans				
1. Zonation of industrial areas for Amphoe Muang, Amphoe Phun Phin and a distillery plant.	Previous scattering of industrial sites is difficult to control and creates more impact to society and the environment.	Grouping large- and small-scale industries in specified areas. Common or central waste treatment system will be shared by these industries.	Improvement of water quality of natural receiving waters and wastewater discharged from industries.	MOInd
2. Management of aquaculture activities.	The wasteloads from aquaculture activities tend to have an impact on coastal water use, especially with more than 12,200 ha of land developed for aquaculture in Ban Don Bay.	Organic (and inorganic) load(s) in aquaculture effluent, especially from shrimp farms, must be minimized. Zoning of aquaculture farms.	Control and improvement of the quality of water supply for aquaculture and natural receiving waters.	Ministry of Agriculture and Cooperatives, ONEB (Upper South Project, Tasks 210-T and 260-T)
3. Initial environmental examination of further development projects.	Initial environmental examination will be useful for setting up control measures.	Examination of existing environmental conditions before any project can be developed. The first phase of implementation should be focused on small development projects.	Improvement of environmental quality and preparation of mitigation measures for any impact that development projects might make.	Ministry of Industry, ONEB
4. Further study and development of water quality model.	There is a lack of relationship between water quality and waste quantity in the stream and coastal waters which will influence future development action in both river and aquaculture. There is no information on the relationship between upstream and downstream water quality from pollution sources and the strength of these sources. The model will be able to evaluate these relationships and the assimilative capacity of the receiving waters.	Based on existing information and data on tidal effects, water quality should be developed and tested for future plans. To test the model, the results developed from it and actual monitoring data should be compared.	Improvement and prediction of natural receiving water quality. The results from the model can b used as guidelines for setting up environmental quality control for other development projects.	ONEB, EGAT

Continued

Table 1. continued

Management schemes	Justification	Brief description	Major environmental effects	Agencies responsible
Phangnga Bay *Intermediate programs*				
1. Setting of surface water quality classification and standards.	All rivers and their connecting streams are turbid and shallow from mining sediments.	Review of the beneficial uses of Phangnga's environmental components and the setting up of a surface water quality classification and standards to protect those uses.	Improvement, maintenance and sustenance of environmental quality. Fresh surface water resources for water supply, fisheries, recreation and conservation of aquaculture organisms.	ONEB
2. Study of mine effluents. Review of the standards for suspended and settleable solids in mining effluents.	Only total solids in mine effluents are controlled but the level is too arbitrary with respect to existing standards. It is expected that suspended solids, after a period of time, will settle at the bottom of the receiving water, causing shallowness. In addition, suspended solids are the major factors affecting the quality of life of living marine organisms such as corals.	Effluent standards should be developed for both settleable and suspended solids. At present, the existing standard is only applied to total solids. Suspended and settleable solids are the main factors that cause shallowness and create impact on agricultural areas.	Elimination of shallowness in waterways and its impact on agricultural areas and corals.	Mineral Resources Department
3. Development of community sanitation at Pan Yee and Phi Phi Islands.	On-site environmental impact affects specific areas such as densely populated areas and tourist spots.	Interceptors system on main drains and diversion to waste treatment system will be used. Treated effluent will be discharged into the natural receiving waters. No direct discharge will be allowed (e.g., on-site and ponding before disposal).	Maintenance of the water quality of natural receiving waters.	MOInt, ONEB, local governments, regional public health office
4. Solid waste management at Pan Yee Island	Solid wastes are directly discharged into the receiving waters.	Small-scale incinerator should be installed on the island.	Minimization of solid waste dumped into the natural receiving waters.	Pan Yee Local Health Center
5. Development of on-site wastewater treatment facilities at Amphoe Muang Krabi, Amphoe Muang and Phangnga.	On-site treatment seems appropriate for scattering a specific type of waste.	The facilities are to be developed in certain pollution sources such as hospitals, markets and hotels. The system must have low capital and operating costs and be easy to maintain.	Prevention of wastewater (from motor pollution sources) from entering natural receiving waters.	ONEB, local government, local authority, Public Works Department (PWD)
6. Environmental monitoring program at Phangnga and Krabi Rivers	To maintain and evaluate the efficiency of the management plan, an environmental monitoring program must be enforced at selected major waters.	A comprehensive environmental monitoring program is needed to enable a water quality status report on the natural receiving waters.	Although the existing water quality of natural receiving waters is within the acceptable range, the contamination of suspended solids (from mining activities) and total coliform bacteria (from community wastewater) may take place.	Local fisheries office, ONEB
Long-term plans				
1. Study for management of unused mines.	Unused mines and road construction cause erosion and sediment transport into main streams and the coastal zone.	To be studied.	Prevention of sedimentation and shallowness at the mouth of the river, coastal area and in the bay.	MOInd
2. Study for management of road construction, especially the road to the mining site.	Nearshore road construction causes the erosion of sediments.	Guidelines and criteria to control erosion caused by road construction.	High turbidity in coastal waters.	PWD

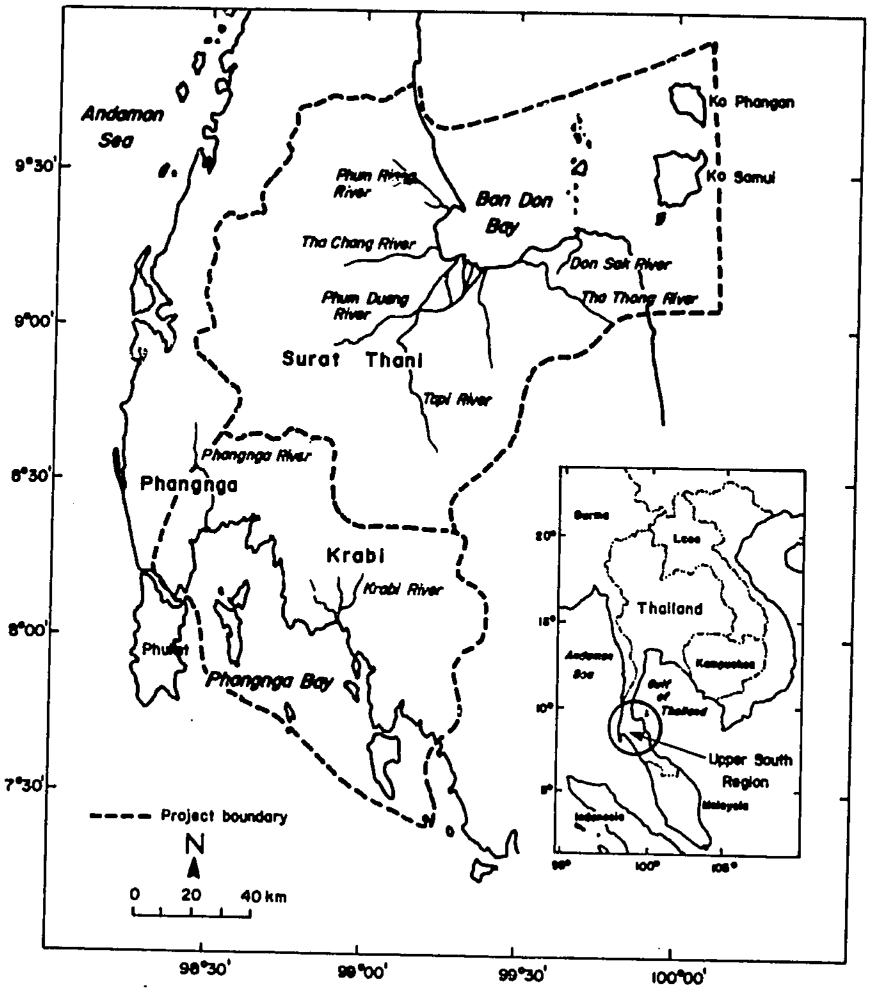

Fig. 1. Upper South CRMP sites showing watersheds affecting Phangnga and Ban Don Bays.

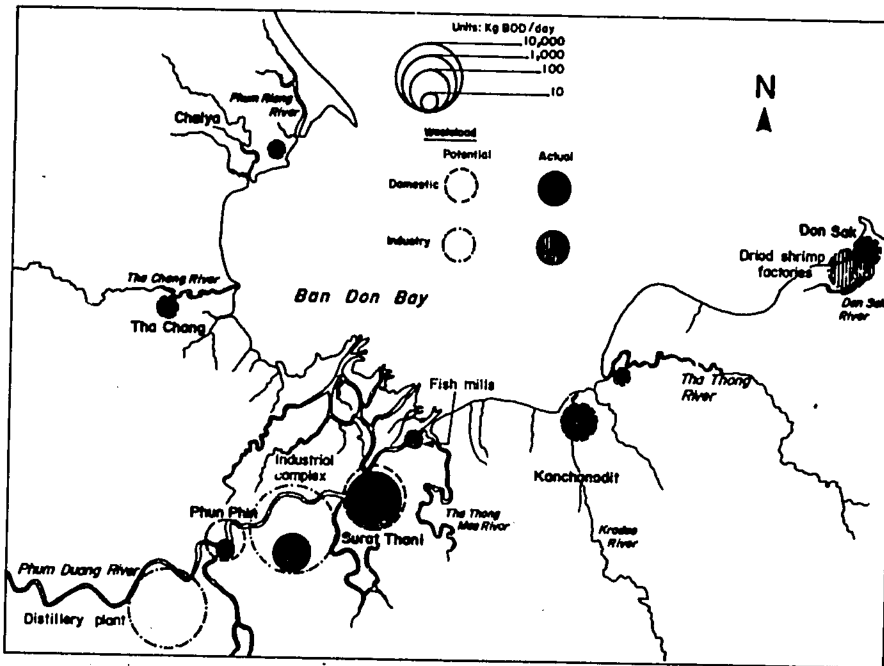

Fig. 2. Potential and actual wasteload from land-based pollution sources in Ban Don Bay.

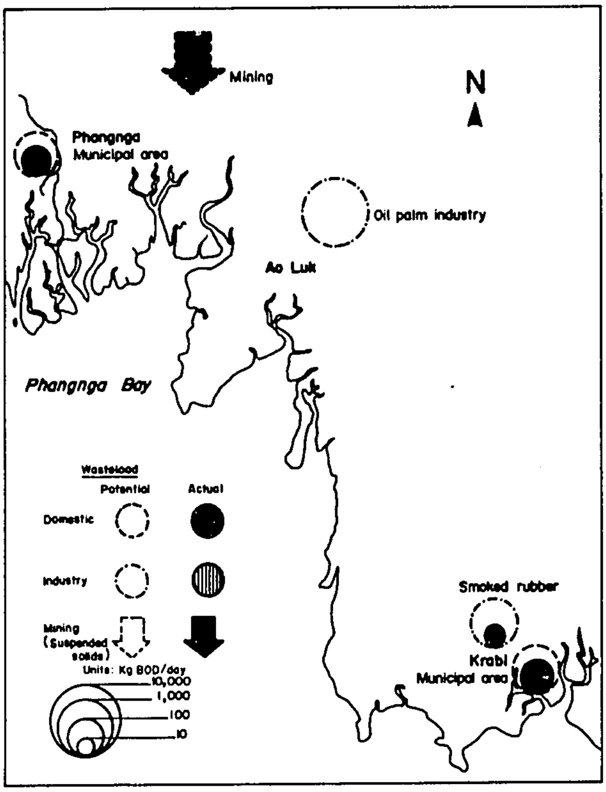

Fig. 3. Potential and actual wasteload from land-based pollution sources in Phangnga Bay.

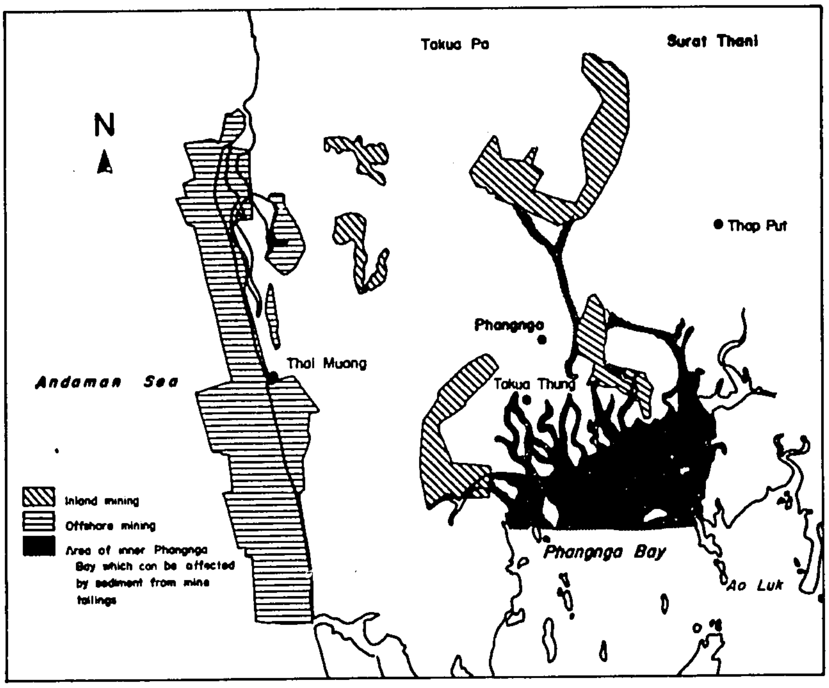

Fig. 4. Map showing location of mining activities and areas of the inner Phangnga Bay which can be affected by suspended solid concentrations of 4,000 mg/l from mine tailings.

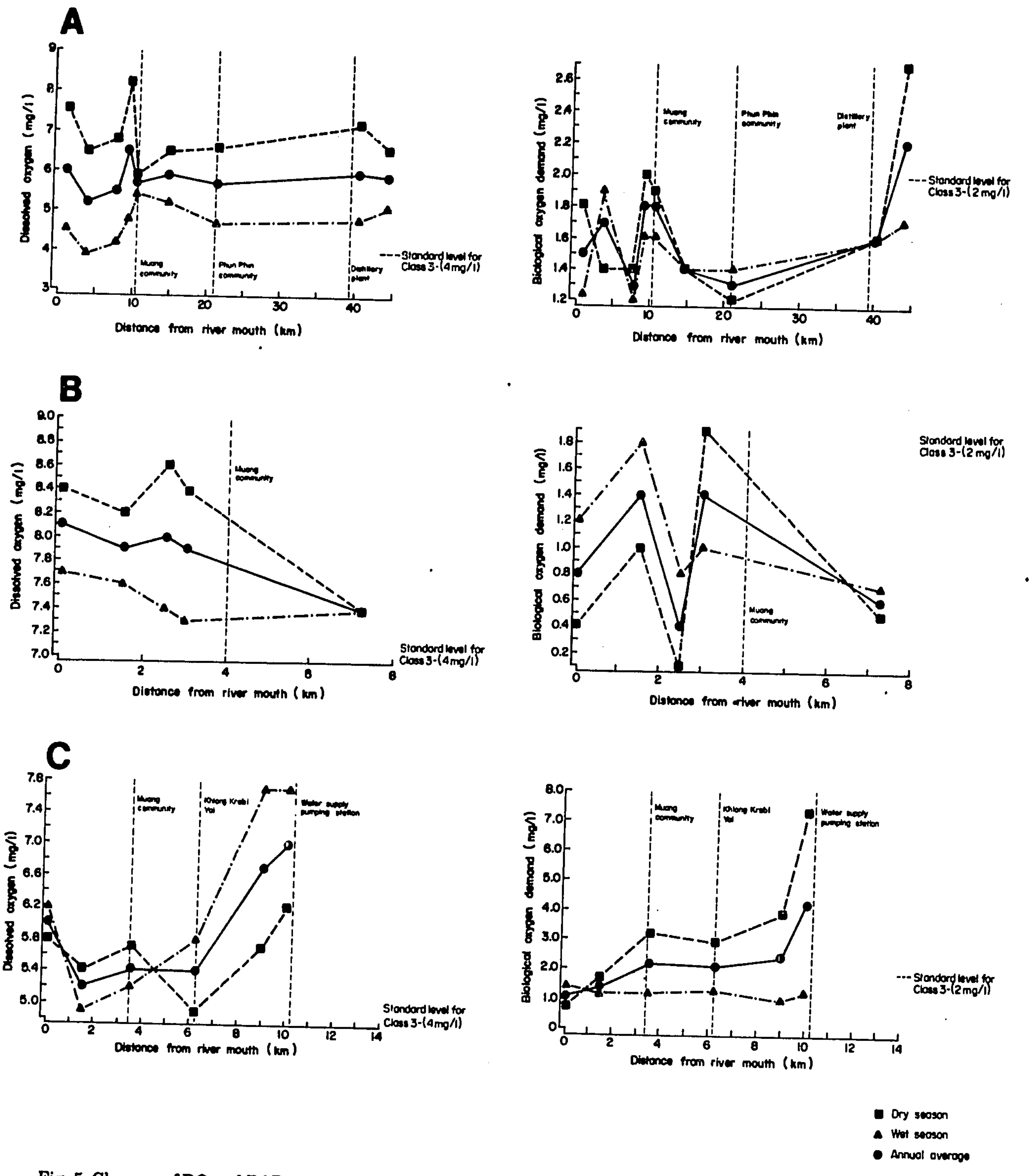

Fig. 5. Changes of DO and BOD concentrations in: A - Tapi River; B - Phangnga River; and C - Krabi River.

Oil pollution in Ban Don Bay, Upper South, Thailand

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ABSTRACT

Oil pollution poses a potential threat to the Ban Don Bay area where several oil terminals and ports are located. The area, which is rich in coastal resources, is economically important. However, there is as yet no detailed plan that will deal with possible oil pollution problems, especially oil spill incidents. The National Oil Spill Contingency Plan (NOSCP) is still being formulated. The existing safeguards may not be able to cope with such an eventuality on a major scale.

This paper looks into oil-related activities and proposes ways to control and prevent oil pollution in the Ban Don Bay area.

INTRODUCTION

The Ban Don Bay area, which is rich in coastal resources, is the main focus of environmental and resources management of the ASEAN/US Coastal Resources Management Project (CRMP) of the Upper South, Thailand. A potential problem of the area is oil pollution coming from oil terminals or tank farms and the coastal ports of Southern Thailand. Although temporarily shut, offshore oil wells, located about 160 km northeast of Ban Don Bay, make the area susceptible to oil pollution.

The study area is limited to the vicinity of Ban Don Bay (Tha Chana District to Don Sak District), Surat Thani Province, Mu Ko Ang Thong National Park, Phangan Island and Samui Island (Fig. 1).

The objective of the study is to formulate guidelines for the abatement and prevention of oil pollution in the area for consideration of relevant agencies.

AREA, RESOURCES AND ENVIRONMENT

Ban Don Bay is a rather shallow bay. Coastal tankers and passenger, fishing and cargo boats have to use the channel dredged by the Harbour Department to go to Surat Thani via the Tapi River. The general pattern of surface currents in the bay are shown in Fig. 2. From January to March, circulation is counterclockwise while from April to December, the surface current flows from Chumphon Province to Surat Thani and Don Sak. Northeast winds blow from October to April while a southwest wind prevails from May to November.

The area is rich both biologically and ecologically and is thus economically important. Environmental and fisheries studies of the Upper South Project have shown that primary and benthos production is high. The bay also serves as spawning and nursery grounds for valuable marine animals. The Indo-Pacific mackerel (*Rastrelliger brachysoma*), which is the major pelagic commercial fish of Thailand, has spawning and nursery grounds in the upper part of the bay (Fig. 3).

Capture fishery activities, such as small otter trawl, push-net, crab trap, squid lure and carpet shell (*Paphia undulata*) harvesting, are common in the bay. In addition to capture fisheries, there are 316.48 ha of shrimp ponds, 259.2 ha of large oysters, 12.8 ha of fish ponds, 250 fish cages and 388 ha of blood clam (*Anadara* spp.), all of which are major activities along the coastline of the bay (Fig. 4).

Within the study area, coral reefs are found fringing the islands of Samui and Phangan. Others are in Mu Ko Ang Thong National Park (Fig. 5). Beaches used for tourism activities are also found on Samui and Phangan.

OIL-RELATED ACTIVITIES

Surat Thani has numerous oil-related activities (Fig. 6). There are ports for both commercial and passenger use and 320 oil tankers ranging from 500 to 2,000 GT entering the bay each year. The Electricity Generating Authority of Thailand (EGAT) has 36 oil tankers ranging from 1,000 to 2,000 GT in Ka Nam District in Changuat, Surat Thani (Table 1). Apart from this, a large number of fishing boats enter the area annually.

ANTICIPATED OIL POLLUTION PROBLEMS

Oil spills have a serious impact on coastal environments and resources either by physical contamination and smothering or toxicity and oil tainting. The contamination of coastal amenities and beach areas causes interference to public use patterns (Perkin 1972).

In Thailand, the National Oil Spill Contingency Plan (NOSCP) is still at the formulation stage. In case of an oil spill incident, the Industrial Environmental Safety Group (IESG) plays an active role in combatting the resulting oil pollution.[a] It has the capability to deal with a spill of over 1,000 tons (mostly in the area of the inner gulf). The combat equipment of the group rely mainly on the use of chemicals to disperse the oil.

In the study area, which has extensive coastal resources, it is doubtful that the existing system could cope with a major oil spill since the lack of a contingency plan or a detailed action plan that defines cooperation between the government and the private sectors is apparent. Table 2 presents the equipment presently used to combat oil spills in Surat Thani. These are limited to only 360 ft of river booms, 400 l of dispersants and 1 backpack sprayer stationed at one tank farm at the mouth of Tapi River. However small the amounts that they discharge, dispersants still play a major role in combatting oil spills. Moreover, there is no Harbour Department officer who has direct responsibility for administering a clearance for the operations at Surat Thani.

Considering the proposals for a deepsea port at Ka Nam District, an industrial site at Phun Phin District and at the mouth of the Tapi River, attention to oil spill contingencies is a must, especially in terms of the equipment required, which is totally lacking in the Upper South region.

Guidelines to combat oil spills

1. Set up an NOSCP, giving priority to Surat Thani as a substation.
2. Set up a detailed action plan for Surat Thani. This will require a detailed coastal resources and environmental map combined with oil spill movement from water movement models. A policy for dispersant use should also be agreed upon in advance (i.e., its use should be limited and controlled in sensitive areas).
3. Provide sufficient equipment for oil spill clean-up.
4. Provide technical training for private and government sectors to combat oil spills.
5. Set up a provincial office of the Harbour Department to administer a contingency plan.
6. Arrange a simple communication network among responsible private and government agencies in the province and in Bangkok.
7. Convince EGAT to join forces with IESG for greater efficiency in case of an emergency.
8. Review and update the information and recommendations proposed in the report on the NOSCP.

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[a]The IESG is a private sector group, which consists of the Bangkok Petroleum Company Ltd., Caltex Oil (Thailand) Ltd., Department of Defense Energy, Ministry of Defense, Esso Standard Thailand Ltd., Mobil Oil Thailand Ltd., Petroleum Authority of Thailand, Thai Petroleum Transports Company Ltd., Thai Shell Exploration and Production Company Ltd., The Shell Company of Thailand Ltd. and The Thai Oil Refinery Company Ltd.

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Table 1. Number, size and capacity of petroleum-related vessels in Changwat, Surat Thani.

Oil company	Capacity (m^3)	Size of vessel (GT)	Number of vessels (per year)
Shell	11,900	500-5,000	84
Esso	3,430	1,000	120
PAT[a]	-	1,000	56
Caltex	-	-	-
EGAT[b]	-	1,000-2,000	36
Siam United Service	19,500	1,000-1,500	60
Siam Gas Industry	2,307	1,000-1,500	-

[a]Petroleum Authority of Thailand.
[b]Electricity Generating Authority of Thailand.

Table 2. Equipment for combatting oil spills (Oil Chem. Ltd. 1985).

Equipment	Existing in Surat Thani
Antipollution vessel	
Barge	
Workboat	1
Transfer pump set	
Flexible storage barge	
Inert gas system	
Whale fencers	
Ocean boom	
Bay boom	1,200 mlrs
Harbor boom	
River boom	500 mlrs
Transfer screw pumps	
Flexible container	10
Screw pump skimmer	3
Vacuum system	
Disc skimmer	2
Rope mop skimmer	2
Oil sweep	
Oil trawl	1
Sweep arm system	
Dispersant sprayer	1
Dispersant	10,0001

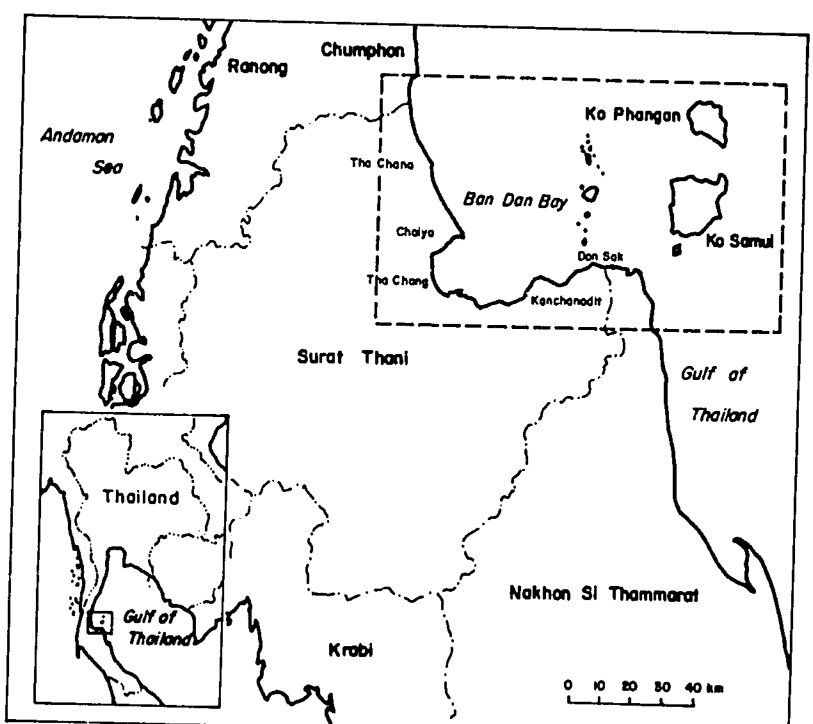

Fig. 1. Study area.

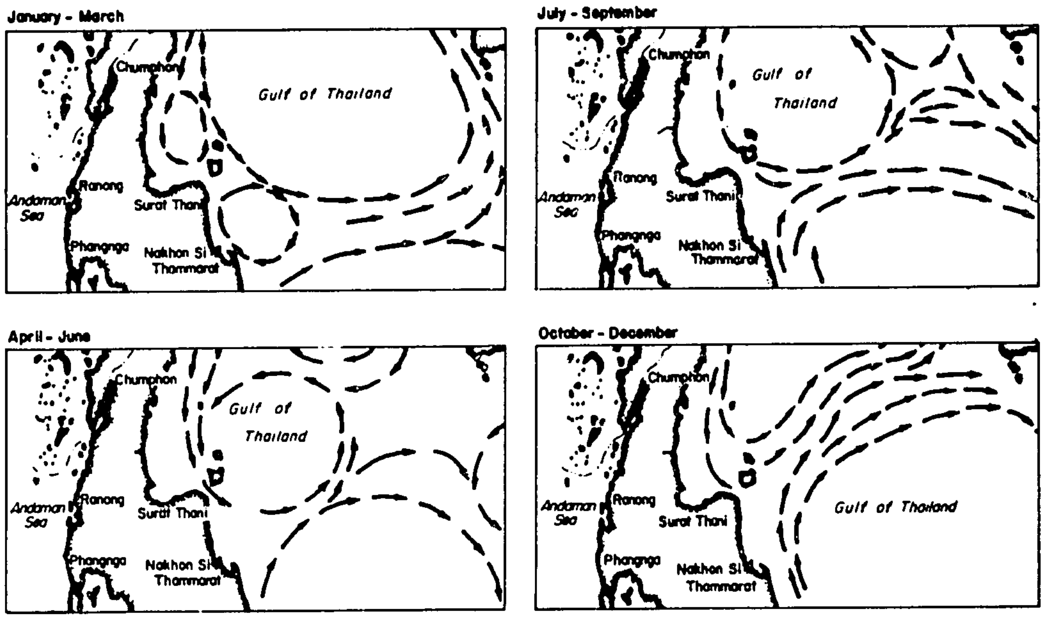

Fig. 2. Surface currents in Ban Don Bay (Oil Chem. Ltd. 1985).

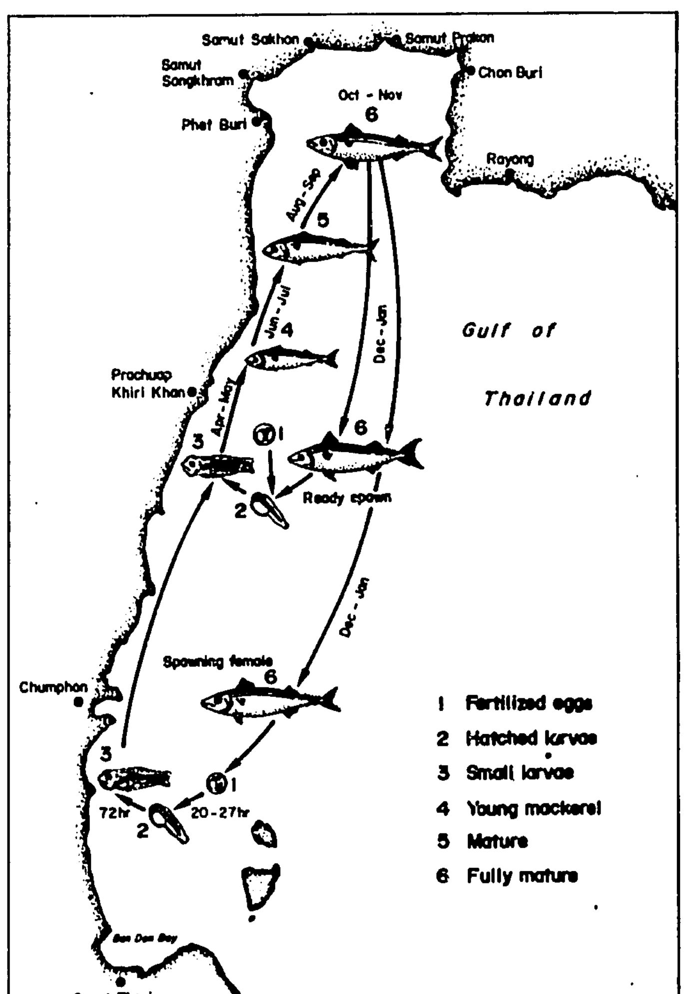

Fig. 3. Life cycle of the west coast stock of the Indo-Pacific mackerel *(Rastrelliger brachysoma)* in the Gulf of Thailand (Oil Chem. Ltd. 1985).

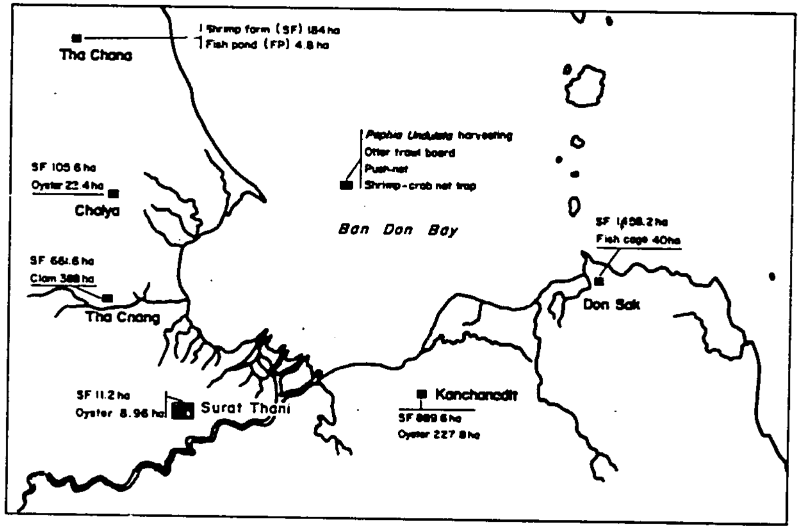

Fig. 4. Fisheries and aquaculture sites in Ban Don Bay (ONEB 1987).

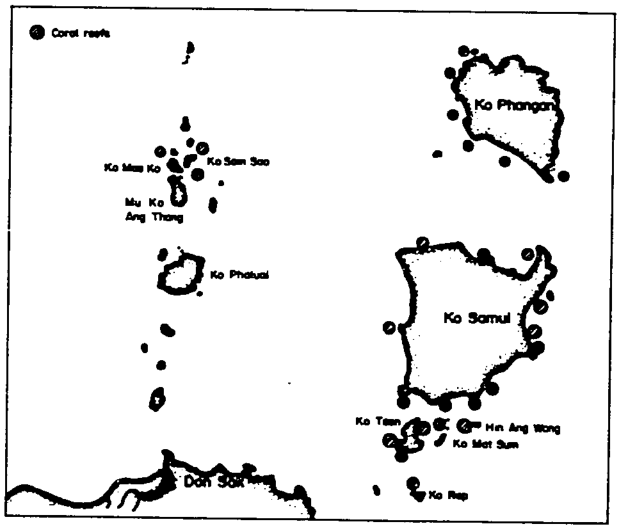

Fig. 5. Coral reefs in Ban Don Bay (TISTR 1985).

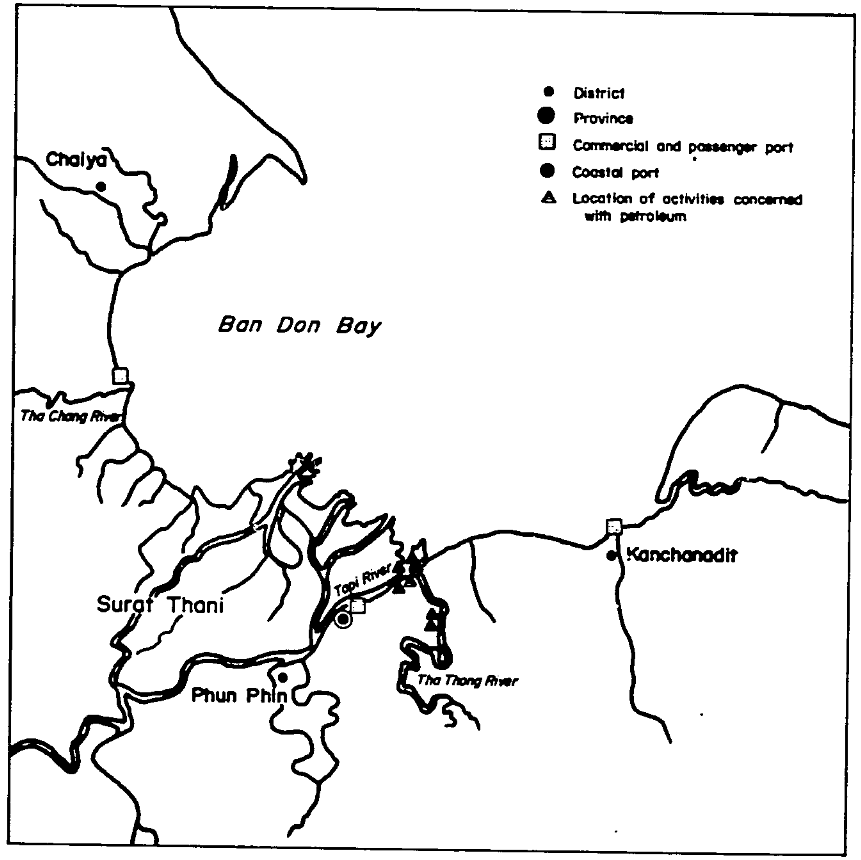

Fig. 6. Location of petroleum-related activities in Changwat, Surat Thani.

Local coastal natural resources utilization: a case study of Pun Yi Island, Phangnga Bay, Thailand

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ABSTRACT

Pun Yi Island in Phangnga Bay, Thailand, was studied as a case in natural resources use and dependence of a small community that is transiting to a tourism-based economy. This village of 900 inhabitants was formed over a century ago by Muslim immigrants from Malaysia. Traditional economic activities include fishing, fish culture, trading and mangrove harvesting. In recent years, because of its location in Phangnga Bay, the village has attracted increasing numbers of day visitors who come to get a noon meal and to purchase souvenirs. This influx of visitors has significantly changed the activities of many residents and affected their historical dependence on marine resources for livelihood and subsistence. It is thus necessary to maintain the island's environmental quality, scenery and traditional culture to continue to attract tourists and, at the same time, to manage properly the tourism-based economy to sustain the livelihood of its residents.

INTRODUCTION

One major environmental problem facing Phangnga Bay is the rapid decline and deterioration of its natural coastal resources. Thus, a study of its natural resources utilization is required to formulate rational and reliable policy recommendations and management strategies for nature conservation and sustained economic growth.

To achieve this purpose, Pun Yi Island was chosen as the study site. For some time now, its natural resources base has been utilized by the resident population. In addition, the island's scenic beauty is attracting tourists and encouraging tourist organizations to promote and utilize the island.

Data obtained in this study were collected from the residents using a series of key research questions as guidelines. The primary user groups were interviewed concerning the nature of their resource dependency, seasonality and frequency of resource utilization, including traditional practices and changes in resources use over time. The assistant researcher lived in the community for approximately six months applying anthropological methods (i.e., participant observation, in-depth interviews with key informants, life history interviews and focus group sessions) to collect data.

The underlying theme, which the preliminary results bring to light, is that Pun Yi Island's past and future rest on the preservation of its natural coastal resources and the careful diversification of economic activities. Although traditionally exhibiting a largely subsistence-level economy based on fishing over the last ten years, this island has now evolved a cash-based economy centering on both tourism and market activities (i.e., the sale of seafood).

The tourism industry is beginning to offer the local people several alternative economic opportunities other than fishing. Thus, the population's direct dependence on the harvesting of its natural coastal resources is being reduced gradually. The use of more stable nonmangrove resources (e.g., gas for firewood) is being encouraged.

GENERAL SETTING

Pun Yi Island has a total of 121 households and approximately 900 inhabitants. Every house is built on the sand dune, partially fringed with mangrove forests. A shuttle boat serves as the main source of transportation.

The island community was established over a century ago by Muslim immigrants from Malaysia. At present, Islam is the predominant religion. Since the people traditionally depend on the island's natural resources, their indigenous knowledge of the sea, weather, aquatic animals and plants and mangrove forests is relatively extensive.

Overall, there are two types of natural coastal resources that the people rely on heavily for their living, namely mangroves and fisheries. Mangroves serve as the major material for the construction of houses and community pathways (e.g., sidewalks). Additionally, they provide firewood for cooking and materials for making boats, fixed bag nets and portable traps. Thus, the islanders could harvest shrimp, fish and shellfish, which abound around the community and in the mangrove forests.

PRIMARY USER GROUPS AND THEIR RESOURCE DEPENDENCY

Natural resources utilization patterns are directly related to the island's evolving economic structure.

Coastal fishing

Coastal fishing is the major occupation on the island. It is usually conducted using such tools as hand lines, white board catching boats (which attract fish due to their color), fixed bag nets and portable traps. Labor is secured largely from the family. About 50 years ago, coastal fishing activities were conducted almost solely for home consumption rather than for trade. Any surplus was, and to an extent still is, preserved as shrimp paste, dried shrimp and salted fish. Islanders could utilize fisheries resources throughout the year since fish were abundant. Fishing activities were restricted to the inshore area. Deep-sea fishing was not necessary. Competition for aquatic resources did not exist.

As time passed, however, the economic feasibility of inshore fishing declined due to adverse environmental changes. Increasing demand for sea products has intensified fishing efforts and led to increased competition among fishermen.

Fish culture

Eight to ten years ago, realizing that overfishing might severely reduce available fisheries resources, the government, through the Agriculture and Cooperatives Bank, offered a loan to develop and promote fish culture. Only a few families were interested then because a high investment was required and fish were still relatively abundant. But as fisheries resources decreased, more and more families turned to fish culture. These were, generally, wealthier families because of high investment and operating costs.

Fish culture, however, is not contributing to environmental stability since the fingerlings being used are usually caught in mangrove swamps or in nearby canals. Also, to make fish cages, mangroves are often cut down. With the increasing loss of mangroves and natural breeding areas, the small fish are becoming more difficult to find. This adds to the operational cost of fish culture.

Traders

In the last ten years, natural coastal resources have generated new economic opportunities for the islanders. In particular, the island's scenic beauty is attracting tourists in ever-increasing numbers as well as the interest of various tourist organizations. To accommodate these visitors, about 102 local families have totally abandoned fishing and are beginning to undertake new business ventures (i.e., food shops, gift shops, shuttle boat services). Even though the tourist season is relatively short (December-March), families must plan, schedule and sign contracts with various middlemen to prepare for the next season. They, therefore, have little time to spend on fishing and often resort to purchasing fish in the local market.

The local people are not sure whether the tourist industry will improve their quality of life. However, they are quick to note that tourism generates more income and offers more economic opportunities than fishing since they can earn enough during the tourist season to last them the rest of the year.

In summary, the island's occupational structure and economy have undergone several shifts in the past decade, the most recent being a shift from subsistence-based fishing to cash-based market and tourist activities. Changes in resources availability and the desire of people to maintain and/or promote the family's economic stability have led to experiments in new ways of making a living.

Overall, new fishing technologies and tourist-related businesses are being tried by people who are relatively wealthy in terms of the island's economy. These people often have secondary sources of income and other resources, so they can gamble with their future. They are no longer directly dependent on the island's natural resources for food, shelter and livelihood. Instead, for many of them, natural resources are a means to an end; that is, they attract tourists and diversify directly or indirectly the local economy.

SEASONALITY OF NATURAL COASTAL RESOURCES UTILIZATION

Shrimp harvesting season (January-May)

During this period, shrimp are abundant in the mangrove swamp and the shallow areas in and around the island. Community members are able to harvest 2 to 3 kg/day for home consumption, barter exchange with neighbors and friends and/or sale. Due to its relatively high price (i.e., 80 to 150 baht/kg)[a], increasing market demand and indigenous value as a family food item, shrimp is considered an economically important commodity, if not the most important. The community readily acknowledges these values and is willing to undertake preservation and conservation practices that concern its livelihood, especially if such practices will ensure the long-term supply of shrimp.

Monsoon season (June-September)

Since fishing is the traditional occupation in the island, community members observe tides, waves and the weather to determine if they can fish safely. Ideally, fishing is viewed as a year-round activity. But realistically, the monsoon season with its strong winds and high waves often halts fishing activities involving small boats. Fishing is thus usually conducted closer to shore during this season, so that the fishermen can return safely if a storm blows in. Fish prices are also higher during this season, which help to offset the restricted period.

Tourist season (December-March)

This season is generally characterized by clear skies, low wave activity and the celebration of several festivals. In addition, schools are at intersession and many students are free to assist in family activities. Islanders who conduct tourist-related businesses are open only from 10 A.M. to 4 P.M. since access to and from the island is controlled for tourists who must return to the mainland before midafternoon. If overnight accommodations are to be constructed by tourist organizations, they must also consider improving the other facilities, such as health services and personnel, to avoid future problems.

These three main seasons regulate the island and its families' economy and activities, although in different manners. Subsistence fishermen, for example, are relatively unaffected by the tourist season, while traders/businesspersons are often not concerned with the shrimp season. It appears that only market fishermen profit, in various ways, from each season. Furthermore, within the island's economic and environmental structures, the fishermen are also the ones who intensively use natural coastal resources to supply the most number of people during each season, be it in terms of coastal fishing or fish culture. Subsistence fishermen, however, are naturally regulated in their activities by sea and weather conditions. Thus, they intensively use natural coastal resources only on a sporadic basis.

PEOPLE'S PERSPECTIVES

Before any form of environmental intervention strategy can be imposed, it must consider the community's views of the problem or risk an ineffective or possibly destructive plan. The Pun Yi Island community equates natural coastal resources, be they mangroves or fisheries, with their "rice pot," and they are aware of the problems of resource depletion and environmental degradation. They also have ideas about how to solve them.

Overall, the islanders see their coastal resources as essential components of their way of life. They are quick to point out that they could not consciously or unconsciously destroy their means of livelihood; "it would be like taking food from our mouths."

Islanders very often point, not to themselves but, to "outside agents" (semigovernment or government officials) and new technologies as the main causes of the current environmental instability they are experiencing. While they do not view all such persons as negligent, they do cite such persons as generally unaware or insensitive

[a]March 1990: 25.83 baht = US$1.00

to local conditions. To compensate for this, the people are willing to work with informed officials to protect their environment. With the proper information, guidance and support, they can take the appropriate action. However, they do not want governmental "dole-outs". For example, they suggest that a restricted area around the island be imposed in which deep-sea fishing technologies (i.e., trawlers) are prohibited. They have also expressed willingness to patrol and manage this area themselves, without continual government input, except for periodic monitoring and supervision.

The islanders also cite an important target group that could be especially motivated--the young males (15-25 years of age). This group is in need of occupational development in areas in which they have interest and experience. Meanwhile, the island's new occupational alternatives, such as trading and servicing, are beginning to affect the community structure. Traditionally, males played the breadwinner's role in the family. But these new occupations encourage the equal division of labor between the sexes, thus increasing the size of the labor force. Unfortunately, compared to the past, unemployment is considered to be higher now. There is also an increase in the use of drugs by young people, especially men.

Additionally, male household heads formerly centered their lives only around fishing, an occupation whose skill they transmitted to their sons. Now that fishing is being deemphasized in favor of other occupations, social practices have changed. And because fathers can not teach their sons the skills needed for these new occupations, vocational training is suggested to be an answer. Furthermore, since young men are still familiar with aquaculture and other coastal resource activities, appropriate technical guidance and assistance could be redirected toward productive and environmentally related occupations.

Local people also realize that tourism is a means to promote and diversify the local economy. Yet, they also see it as a double-edged sword. They fear that indiscriminate tourist activities, which largely occur in the beach areas, can compound the environmental problem, as is happening in other tourist resort locations in southern Thailand. They are concerned that they are being singled out as the current agents of destruction, a stereotype that might be carried over when tourism increases. Moreover, islanders feel that all actual and potential primary user groups should be equitably assessed, using appropriate measurements before any changes are made.

SUMMARY: COASTAL RESOURCES USE PATTERNS

In assessing how natural coastal resources use patterns have changed, it can be said that the relationship between man and nature is less symbiotic now than in the past. In traditional times, the islanders depended almost solely on nature to provide them with their needs and livelihood. From it, they secured food, shelter and the means to obtain other necessities. Energy transfer between these resource components was such that each could take from the other without any significant ecosystem impairment.

The link that supported almost every component was (and is) the mangrove. It provides food and shelter for both animals and man. This link was extended to other purposes in more recent times--for firewood, building materials and making fishing gear. Indeed, man's subsistence needs were fully met in this type of ecosystem management. Since technologies were rather unsophisticated and not environmentally damaging, resources overuse was not a problem, although the use of mangroves for firewood also contributed to mangrove decline.

At present, while gas has replaced firewood for cooking, the mangrove forest is increasingly under threat from a different activity. It is no longer only a natural fish habitat but is also used for fish culture practices. Unfortunately, this often entails the destruction of the forest to make room for new technologies (e.g., fish cages). In addition, the increasing market demand for sea products, beyond subsistence needs, and the use of modern harvesting technologies (e.g., trawlers along the island coast rather than in the deep-sea area) are also depleting the local fish stock.

Thus, an interesting paradox surrounds Pun Yi Island and its future. Its natural coastal resources and scenic beauty must be preserved to attract tourists and support the socioeconomic structure. Yet, these resources must also be developed to meet the demands of other consumers (non-islanders).

RECOMMENDATIONS

To improve the island's current economic and natural resources use trends, the following policy and planning measures are recommended:

1. Alternative economic activities that support the preservation of natural resources while offering the local population a relatively stable economic base such as tourism and its related activities. These should involve the occupational development of the youth in activities that are locally valuable to reduce outmigration.
2. Alternative resources and technologies that are environmentally sound, socially acceptable and financially feasible for island families must be promoted and, where necessary, supplied to replace those activities that threaten the natural coastal resources.
3. Sustainable practices involving coastal resources must be determined. The analysis should consider each primary user group and its direct and indirect roles and needs in resource consumption.
4. Where primary user groups need additional resources to support new industries, off-island suppliers should be found and locally promoted.
5. Any environmental intervention program must involve the people. As in rural development, the ultimate motivators and beneficiaries of development efforts are the rural people. They will insure the program's sustainability over time. Hence, they must be organized and taught to recognize and solve their own problems, to provide their own means of livelihood and to manage their own resources for development. Indeed, the community's involvement in the decisionmaking and implementation processes is extremely important in solving existing problems. Program models might be found in similar community development approaches such as primary health care and quality of life improvement.
6. Rigid environmental sanitation activities and regulations must be developed to avoid the potential effects of tourism (e.g., pollution). These, however, should not be implemented in a top-down manner and forced on the people without their understanding. Rather, the inputs of the local people should be encouraged in the formulation of these rules and regulations.

Pun Yi Island, with its well-defined and dedicated population, the interaction of its traditional and modern fishing activities along with the growing tourism industry, offers an ideal opportunity for an integrated community development and a model for environmental preservation. The model's applicability and principles can be used in other areas in Thailand or perhaps in the ASEAN region. However, its success and sustainability will rest on how well planners manage both the people and the environment.

Water quality of Brunei River and Estuary

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ABSTRACT

Brunei River has a catchment area of approximately 360 km^2. Within this area, more than 75,000 people reside. The Brunei River Estuary, which drains into Brunei Bay, is utilized for transportation, small-scale commercial fishing, recreation and waste disposal. The estuary receives major portions of the capital city's stormwater runoff along with treated and untreated sewage. It is treated like a "sink" to assimilate all nature- and human-related solids, liquids and gases without regard for the risks to its ecosystem.

A 1987 study concluded that the existing level of sewage discharged into the river did not have any apparent effect on its ecosystem. However, the amount of household litter and other refuse from Kampong Ayer and other small villages (*kampong*) scattered along the estuary and its tributaries has reduced the aesthetic value of the estuary. The high level of bacteriological contamination near Kampong Ayer and Pintu Malim Sewage Outfall could also create a health hazard if it is not controlled.

Findings indicated that the river's water quality has deteriorated in terms of bacteriological quality and suspended solids. Other parameters did not show significant changes because of the dilution and self-purification capacity of the river.

INTRODUCTION

Brunei Bay lies on the northern coast of Borneo between Brunei Darussalam and the East Malaysian State of Sarawak (Fig. 1). The three main rivers that drain into the bay are Limbang, Temburong and Brunei Rivers. Of the three, the latter has the smallest flow.

The Brunei River system has a catchment area of approximately 360 km^2. The population in this area is around 75,000 and is expected to increase to 114,500 by the year 2000 (MHCE 1987). The river is of immense aesthetic importance to the people. On the other hand, Kampong Ayer (Water Village) is of national and cultural importance and has always been associated with the city's past and present development, both socially and economically.

The Brunei River Estuary is 15-km long from its upstream, which branches with the Damuan River into Chermin Island at the entrance to the inner bay. The estuary is utilized for transportation, small-scale commercial fishing and recreation. Its entire length is influenced by tides. Salinity ranges from 16 to 23 parts per thousand (ppt), depending on the freshwater flow, the influence of adjoining water masses and the amount of rainfall. At the upstream boundary, the tributary waters are still saline (typically 16 ppt). Flow data for Brunei River are unavailable. However, estimates of freshwater flows have been made based on the data from other catchments in Brunei Darussalam (Binnie and Partners 1971).

Brunei River has been treated as a "sink" of infinite capacity, assimilating all nature- and human-related solids, liquids and gases. However, the possible risks to the ecosystem have been ignored. Recently, concern has increased on the environmental state of the Brunei River Estuary. Actions taken by the government to alleviate the possible ecological consequences are:

1. a study on the water quality and pollution effects of Brunei River (MHCE 1987);
2. preliminary engineering studies to determine options for the provision of sanitation facilities for Kampong Ayer (MHCE 1985; SFCG 1986);
3. the development of a proposal for national water quality standards including the Brunei River (WHA 1987);
4. preliminary studies on solid waste management facilities for Kampong Ayer (SFCG 1986);

5. the development of a solid waste master plan for Brunei Darussalam (JTLES 1987); and
6. the ongoing monitoring of the estuary and Brunei Bay by the government.

Pollutants entering the Brunei River and its estuary include:

1. effluent and sludge from the Pintu Malim Sewage Works and other sewage treatment works within the catchment (Fig. 1);
2. sullage waste and direct disposal of sewage from Kampong Ayer (Fig. 1);
3. the city's stormwater runoff;
4. point and nonpoint pollutant loads from various subcatchment uses, including agricultural, residential and industrial; and
5. solid waste directly discharged by villages along the river.

MATERIALS AND METHODS

Monthly water sampling was done in the Brunei River at high and low tides. Tide tables and staff availability determined the sampling schedule.

There were 15 water sampling stations (A-Q) in the water samplings (Fig. 1). In general, seven stations were sampled during each monthly survey run. However, all 15 stations were sampled quarterly.

Monitoring work is ongoing. The data available for analysis were collected during a five-month period in 1988.

Measurements were taken in situ, whenever possible, using the Hydrolab 8000, a multifunctional water quality analyzer with digital output and capable of measuring depths below the surface (m); temperature (°C); conductivity (µS/cm); dissolved oxygen (DO) (mg/l); oxidation reduction potential (mV); and pH.

All parameters were measured at the surface, mid-depth and near the riverbed. A subjective measurement of the background turbidity and degree of transparency were also taken using a home-made Secchi disc. Other relevant observations were also recorded during the water samplings.

Water samples were generally taken at mid-depth in each station. Previous studies revealed that the river system showed little stratification and almost full vertical mixing (MHCE 1987). The sample was obtained (using the Alpha vertical water sampler, a special depth sampler) suitably marked and stored in a cool box prior to its return to the laboratory. Fifty percent of the samples were taken to the Department of Agriculture's Kilanas Research Station Soil Laboratory for the following tests in accordance with standard methods (APHA 1985):

1. Ammonia-nitrogen (NH_4-N)
2. Nitrite-nitrogen (NO_2-N)
3. Nitrate-nitrogen (NO_3-N)
4. Organic nitrogen (Org. N)
5. Total phosphorus (P)

The remaining samples were analyzed by the Pintu Malim Sewage Works Laboratory for suspended solids (SS), volatile suspended solids (VSS), turbidity, biological oxygen demand for five days at 20°C (BOD_5, 20°C), DO, conductivity, plate count, total coliforms and fecal coliforms.

RESULTS AND DISCUSSION

The results obtained during the 1988 Brunei River survey are presented in Figs. 2-5 and Table 1. The average overall mid-depth temperature (Fig. 4) is relatively constant with little variation. The salinity has a gradient along the channel and decreases gradually upstream (Fig. 2). Generally, the salinity value at a particular site increases during flood tide due to the influence of seawater. The freshwater inflow (in this case, into the Brunei River) also affects salinity. A salinity difference of 6 ppt was observed between stations A and Q (Fig. 2).

The pH values which exhibit a gradient along the channel (Fig. 3) are influenced by the mangrove ecosytem and the presence of various ions. In the upstream sections of the estuary, the pH levels averaged 6.5 as a result of decaying humic materials, high carbon dioxide content and acidic runoff (commonly found in the mangrove areas in the upstream reaches of the catchment). In the downstream sections of the estuary, the pH levels were closer to seawater level (pH 7.5) due to the latter's greater buffer capacity.

The transparency of the estuary was measured somewhat subjectively. Generally, Secchi depths of 0.62-1.21 m at low tide and 0.83-1.42 m at high tide were recorded. The degree of transparency is related to the color of the water and the amount of SS (Figs. 2 and 3). The degree of light penetration is affected by the color and turbidity of the water which absorbs and scatters the light. Therefore, only a fraction of the light is transmitted through the water which, in turn, affects the rate of photosynthesis and thus, the dissolved oxygen.

Fig. 4 shows the mean percentage saturation of DO along the channel of Brunei River from stations A-Q. The percentages of DO in the upper and middle reaches are somewhat less than in the lower ones. This is due to the anoxic water, organic matter from the mangrove area and organic inputs from Kampong Ayer and nearby rivers. It was observed that the BOD_5 (Fig. 5) is higher in the upstream sections and lower in the downstream sections and generally lower during high tide than at low tide. A contributory factor is the amount of seawater flooding in, thus causing the natural dilution.

Table 1 shows that the average phosphorus concentration (tests carried out by the Department of Agriculture's Kilanas Research Station) is 2.28 mg/l and is higher during low tide. Nitrogen is present in different forms. From the average concentration of the four main forms of nitrogen, it was observed that NO_2-N averaged 15.09 µg/l and NO_3-N averaged 0.04 mg/l (final oxidation of nitrogen). On the basis of these data, it can be concluded that nitrification has substantially occurred. In general, it appears that there is an abundant supply of both oxidized nitrogen and phosphorus in the estuary for the growth of phytoplankton.

The water quality of the estuary in terms of fecal coliform indicates that the river is polluted by human waste. The highest fecal coliform levels were recorded at stations G, J, N, P and Q. This condition resulted from the direct discharge of fecal waste from Kampong Ayer and other point and nonpoint discharges from septic tanks and unsewered areas on land. The higher incidence of eye, ear, nose and throat infections among the children of Kampong Ayer compared to other areas can probably be linked to the bacteria-contaminated riverwater. However, there is no evidence to confirm that these infections are actually the results of primary contact with the water (e.g., leisure swimming in the river).

In general, the highest concentrations of pollutants were recorded between stations G and P near Kampong Ayer and the confluence of the Kedayan and Kianggeh River tributaries, which carry fecal waste, sullage, etc. Fecal coliform was not detected at all for certain samples at low tide for unknown reasons (Table 1). A cause may be attributed to the taking of a single snap sample instead of multiple snap samples. Other probable causes for the undetected fecal coliform are nutrient deficiency, sedimentation, intensity of solar radiation and predation by larger organisms.

CONCLUSION

The Brunei River is receiving the discharges of untreated sewage from more than 75,000 people and sewage treatment works, the city's stormwater runoff and point and nonpoint pollutant loads from various subcatchments. Organic loads and other pollutants are also increasing with the development of the Bandar Seri Begawan area.

Generally, the impact of environmental degradation could be broadly classified into four stages: visual, ecological, economical and health. The status of Brunei River can be classified under the first and second stages of degradation. The deterioration of the river's water quality and environment has been ascertained by this study. The Government of Brunei Darussalam is beginning to take preventive steps to manage properly the disposal of the sewage and solid waste in the Kampong Ayer area to avoid further deterioration of the river's ecosystem.

Water quality standards need to be set and implemented for phosphorus, nitrogen and bacteriological and other parameters to improve or maintain the river's water quality. The declining water quality in Brunei River illustrates the need for comprehensive pollution control. Sewerage facilities should be given priority along with the improved management of surface water.

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Table 1. Summary of the results of routine water quality surveys in Brunei River in 1988.

Sampling station	NO_2-N µg/l H	NO_2-N µg/l L	NO_3-N mg/l H	NO_3-N mg/l L	Org. N mg/l H	Org. N mg/l L	NH_4 - N µg/l H	NH_4 - N µg/l L	P mg/l H	P mg/l L	Plate count no. H	Plate count no. L	Total coli MPN/100 ml H	Total coli MPN/100 ml L	Fecal coli MPN/100 ml H	Fecal coli MPN/100 ml L
B	11.05	3.23	ND	0.18	0.16	0.02	0.11	ND	1.32	4.63	10.30 k	77.5 k	17 k	26 k	3.67 k	0.00
D	11.17	8.41	ND	ND	0.50	0.02	0.18	ND	0.45	6.09	0.40 k	1.2 k	59 k	12 k	0.00	0.00
G	27.11	7.72	ND	0.08	0.05	0.03	0.16	ND	0.45	6.34	0.92 k	70.0 k	13 k	9.2 k	2.33 k	6.5 k
J	28.45	8.24	ND	0.09	0.12	0.05	0.11	ND	ND	3.34	0.27 k	56.0 k	31 k	17.0 k	0.67 k	4.5 k
N	30.63	6.18	ND	0.08	0.49	0.08	0.11	ND	0.45	2.94	2.43 k	32.0 k	532 k	18.0 k	403.0 k	2.5 k
P	32.01	7.00	ND	0.11	0.25	ND	0.16	ND	ND	2.94	2.67 k	67.0 k	851 k	12.0 k	684.0 k	0.00
Q	25.39	4.68	ND	ND	0.28	0.04	0.16	0.07	ND	2.94	1.92 k	45.0 k	323 k	41.0 k	26.7 k	4.0 k
Average	15.09		0.04		0.15		0.08		2.28		26.3 k		134 k		81.3 k	

Notes:
ND - not detectable.
k - (1,000)
H - High tide.
L - Low tide.

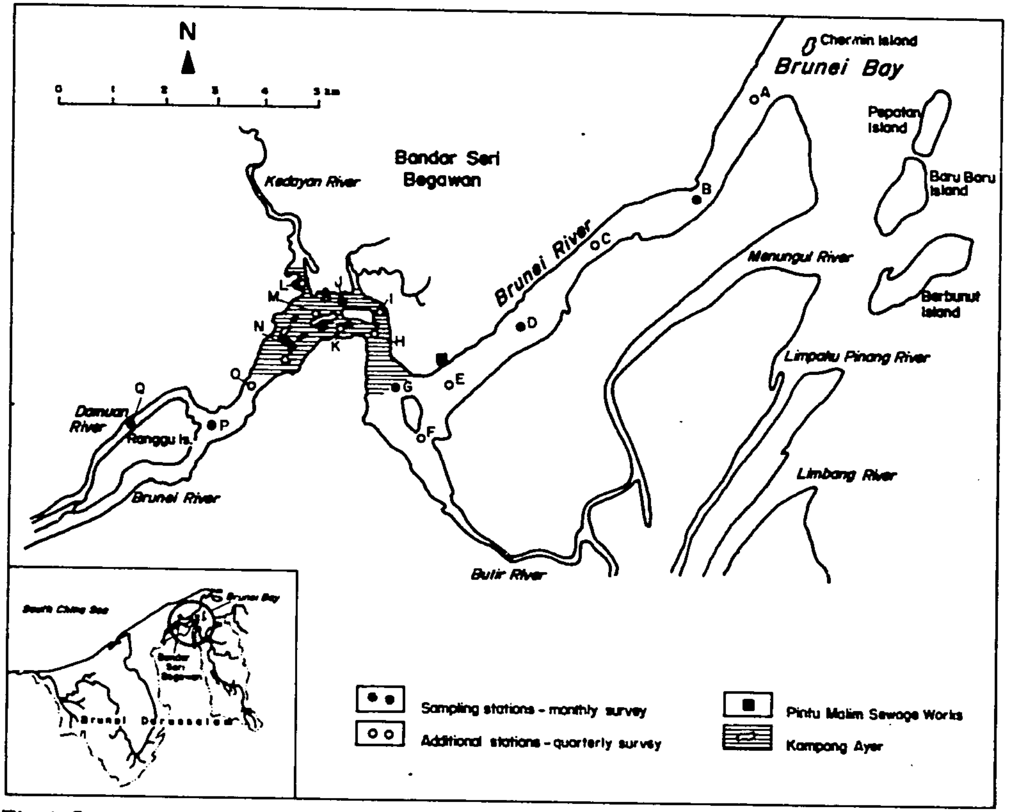

Fig. 1. Location of sampling stations for Brunei River's pollution monitoring.

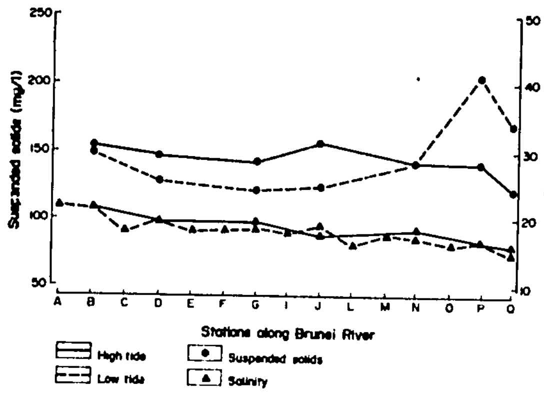

Fig. 2. Salinity and suspended solids along Brunei River (1988 survey).

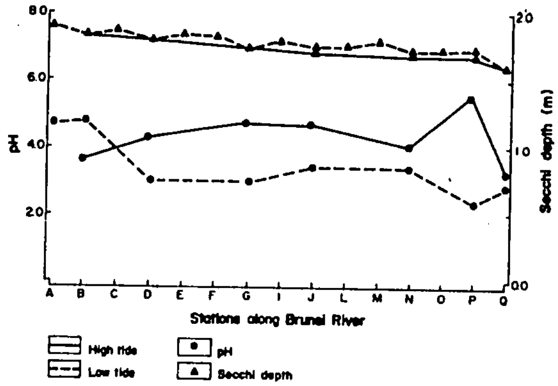

Fig. 3. Secchi depth and pH along Brunei River (1988 survey).

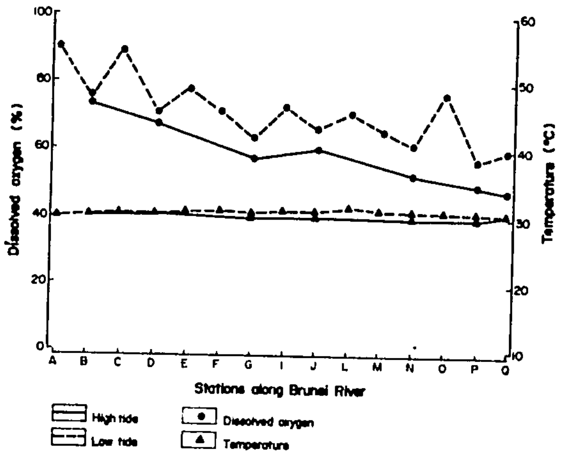

Fig. 4. Percentage saturation of DO and temperature along Brunei River (1988 survey).

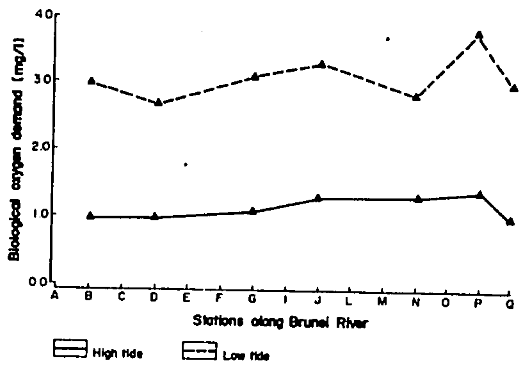

Fig. 5. BOD_5 along Brunei River (1988 survey).

The effects of floating fishfarms on the enhancement of coastal fish communities

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ABSTRACT

A one-year study covering two monsoon and three intermonsoon seasons was completed on the fish (including crustacean) communities around floating fishfarms, mangrove and cleared mangrove areas off Pulau Ubin in East Johore Strait. Fish captured by traps were counted, weighed and identified.

While there was no apparent difference in fish number and species during the two seasons among the sites, the mangrove area provided the best shelter for fish fauna. Floating fishfarms, however, also provided artificial ecological niches. The cleared mangrove area had less fish abundance, but a greater variety was recorded. This could be due to the presence of visiting species.

The dominant fish families in the three ecological areas were similar. These were Apogonidae (cardinalfish), Balistidae (filefish), Sciaenidae (jewfish), Plotosidae (catfish) and Batrachoididae (toadfish). The dominant crustaceans were the crabs (Portunidae and Xanthidae). Families and species of fish found in the three study sites were listed.

INTRODUCTION

Most of Singapore's coastline has already been cleared for urban development and the creation of new and more aesthetic shorelines. Only patches of mangroves remain. Coastal fisheries resources are expected to decline with time due to the destruction of natural ecological niches.

The culture of fish in floating cages along the coast can increase the productivity of the environment and provide an alternative to the placement of fishfarms in mangrove areas. As a baseline for this study, Tham (1953, 1973) describes fish catches of local palisade traps *(kelong)* and fish from Singapore waters. The feeding relationships of the fish and of the inshore fish population in Singapore Straits are described by Tham (1950) and LeMare and Tham (1954), respectively.

This study documents the floating fishfarms' effects on the enhancement of coastal fish communities by providing artificial ecological niches.

MATERIALS AND METHODS

Study sites

The three ecological sites selected (Fig. 1) were the following:

1. The area at the northwestern part of Pulau Ketam because it has one of the few relatively undisturbed mangrove patches left in East Johore Strait. As the mangrove edge is totally exposed during low tide, fish traps *(bubu)* could be set in the Ketam Channel, about 4-6 m away from the mangroves.
2. The floating fishfarm at the Primary Production Department (PPD), which covers a water area of 0.5 ha off South Pulau Ubin in East Johore Strait.
3. The cleared mangrove area along the South Pulau Ubin coast, facing PPD's floating fishfarm.

Methods of fish fauna assessment

Fish traps of galvanized wire mesh of 1.25 and 2.5 cm mesh size and 85 cm x 62 cm x 31 cm (depth) were constructed. Design conformed to that of traditional fish traps used by local fishermen.

Six to 12 traps were set at each site during the study period. In the fishfarm area (A), these traps were tied individually and secured to the farm structure to suspend 6-8 m below the water surface. In the mangrove (C) and cleared mangrove (B) areas, they were grouped into sets of three and secured by a 5-kg metal anchor to depths of 1-4 m from the sea bottom. Each set of three fish traps covered a distance of 25 m. Two sets were placed in each area initially, but these were increased to four sets when more traps were available.

The traps were retrieved two to four days after setting and the fish caught were identified, weighed and counted; their number of species and families were recorded.

Data presentation was according to fish (and crustaceans) and biomass caught per 10 fish traps, and fish variety by family and species identified, according to the seasons.

Other fishing gear used were the long line and apollo net, which were not as efficient as fish traps. Thus, the catches of these gear are not included.

Fishermen surveys were done weekly by a team of two men who interviewed the fishermen of East Johore Strait on the types of fish caught.

Two monsoon periods (southwest monsoon and northeast monsoon) and three intermonsoon periods (April and October 1987, and April 1988) were covered during the study.

RESULTS AND DISCUSSION

Fish fauna assessment by trapping

Table 1 records the average number of fish and their biomass caught per 10 fish traps. The highest average number and biomass of fish was caught in the mangrove area (54 pcs or 3.35 kg per 10 fish traps, comprising 47 pcs or 3.02 kg of fish and 7 pcs or 0.33 kg of crustaceans). The floating fishfarm area yielded the next highest average number/biomass (23 pcs or 1.17 kg per 10 fish traps, comprising 16 pcs or 0.87 kg of fish and 7 pcs or 0.3 kg of crustaceans). The average catch from the cleared mangrove area was the lowest (20 pcs or 0.91 kg per 10 fish traps, comprising 15 pcs or 0.69 kg of fish and 5 pcs or 0.22 kg of crustaceans).

Student T-Test showed that there was a significant difference between the mangrove area and the other two areas for finfish and total fish fauna, including crustaceans (Table 1). There was, however, no significant difference between the fishfarm and cleared mangrove area.

The fish families and species from all three areas were similar. There appeared to be no simple correlation at this stage in fish numbers per trapping operation. According to the monsoon and intermonsoon periods (Table 2), there was no significant difference among them. These results were likewise seen in the analysis of variance for family and species.

Fish diversity was highest for the mangrove area (19 families, 24 species) when assessed on a standard of total number of families and species caught per trapping operation. This was followed by the floating fishfarm area (18 families, 23 species) and the cleared mangrove area (17 families, 21 species) (Table 2).

However, when all five periods (two monsoons and three intermonsoons) were considered, diversity was highest for the cleared mangrove area (39 families, 70 species) (Table 3). This could have been due to the visiting species that frequented the openwater space. The numbers for the fishfarm area (34 families, 61 species) were more or less similar to those for the mangrove area (36 families, 60 species).

Dominant families and species

There were no significant differences in the data from all three sites (Table 2). Table 4 records the dominant families and species of fish and crustaceans according to locality and season. In all three areas, the dominant fish families were Apogonidae (cardinalfish), Balistidae (filefish), Batrachoididae (toadfish), Plotosidae (catfish), Sciaenidae (jewfish) and Gerreidae (mojarras), while crabs (Portunidae and Xanthidae) were most dominant among crustaceans. Scatophagidae (scads) were especially abundant in the mangrove area.

A total of 95 species representing 44 families were caught by trapping during the study period (Table 3). This includes five families (11 species) of crustaceans and other animals such as coelenterates, echinoderms, merostomes (horseshoe crab) and mollusks.

Fish fauna assessment by fishermen surveys

Catch information from fishermen surveys was scarce because only a few fishermen were available for interview, despite frequent attempts to look for them. Existing results were also not accurate because it was not possible to verify the total catch since many of the smaller species had been discarded by the time the fishermen were located.

CONCLUSION

The mangrove area had the greatest number of fish species and families on the average, while the cleared mangrove area gave the lowest number. However, when considering the total number of fish families and species caught during the study period from April 1987 to April 1988, the cleared mangrove area showed the highest number of families and species. Fish that did not occur in sufficiently large numbers to affect the average figures may have been the visiting species from openwater.

The dominant families and species of fish and crustaceans were generally similar for all three ecological areas. This suggests that the coastal fish community is fairly homogeneous for dominant species. However, a checklist of fish families and species of the coastal zone will be useful for future reference and comparison.

The fish trap appeared to be the most efficient gear in fish fauna sampling for this study. Catch information from fishermen was not a reliable means of fish fauna assessment because only a few regular fishermen were available.

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Table 1. Fish trap catches (number and biomass) at the three selected sites off Pulau Ubin and Pulau Ketam, April 1987 to April 1988.

Date	Period	Fish caught/10 fish traps[a]																	
		Finfish only						Crustaceans only						Total fish (including crustaceans)					
		Mangrove area		Floating fishfarm area		Cleared mangrove area		Mangrove area		Floating fishfarm area		Cleared mangrove area		Mangrove area		Floating fishfarm area		Cleared mangrove area	
		no.	kg	no.	kg	no.	kg	no.	kg	no.	kg	no.	kg	no.	kg	no.	kg	no.	kg
April 1987 (Intermonsoon)	1	17	0.66	23	1.23	14	0.41	4	0.07	4	0.16	0	0	21	0.73	27	1.39	14	0.41
May 1987 (Southwest monsoon)	2	39	1.06	13	0.25	11	0.49	12	0.27	3	0.19	2	0.04	51	1.35	16	0.47	13	0.53
October 1987 (Intermonsoon)	3	129	11.15	14	0.78	14	0.87	5	0.55	8	0.32	6	0.37	134	11.70	22	1.1	20	1.24
November-December 1987 (Northeast monsoon)	4	41	2.22	16	0.91	24	1.08	6	0.32	8	0.42	8	0.42	47	2.54	24	1.33	32	1.50
March 1988 (Northeast monsoon)	5	33	1.50	20	1.36	13	0.64	6	0.37	9	0.42	7	0.24	39	1.87	29	1.78	20	0.88
April 1988 (Intermonsoon)	6	24	1.49	10	0.64	11	0.65	7	0.44	7	0.31	8	0.27	31	1.93	17	0.96	20	0.91
Mean ± SD		47[ab] ±41	3.02 ±4.02	16[b] ±5	0.87 ±0.4	15[b] ±5	0.69 ±0.25	7 ±3	0.33 ±0.16	7 ±2	0.30 ±0.11	5 ±3	0.22 ±0.17	54[ab] ±41	3.35 ±4.13	23[b] ±5	1.17 ±0.44	20[b] ±7	0.91 ±0.41

[a]Fish trap dimension = 85 x 62 x 31 cm (depth).
[b]Student T-Test - means (fish number and total number of fish fauna) having the same letter are not significantly different at the .05 level.

Table 2. Number of families, species and dominant fish species caught by fish traps[a] during the five study periods at the three study sites, April 1987 to April 1988.

Date	Period	No. of families[b] Mangrove area	Floating fishfarm area	Cleared mangrove area	No. of species[b] Mangrove area	Floating fishfarm area	Cleared mangrove area	Dominant species[b,c] Mangrove area	Floating fishfarm area	Cleared mangrove area
April 1987 (Intermonsoon)	1	12	15	8	12	16	9	6	10	3
May 1987 (Southwest monsoon)	2	16	18	12	19	21	16	11	6	4
October 1987 (Intermonsoon)	3	17	16	21	20	23	27	9	9	8
November-December 1987 (Northeast monsoon)	4	21	24	23	22	31	27	10	7	9
March 1988 (Northeast monsoon)	5	29	22	23	41	27	29	7	6	4
April 1988 (Intermonsoon)	6	20	15	17	26	19	20	8	5	6
Mean ±SD		19 ±6	18 ±4	17 ±6	24 ±10	23 ±6	21 ±8	9 ±2	7 ±2	6 ±2

[a]Fish trap dimension = 85 x 62 x 31 cm (depth).
[b]There is no significant difference at the .05 level at the three study sites.
[c]Dominance arbitrarily defined as >5 fish caught/50 fish traps.

Table 3. Fish species and other organisms caught by fish traps at the three study sites, April 1987 to April 1988.

Families and species	Mangrove area	Floating fishfarm area	Cleared mangrove area
A. Finfish			
1. Antennariidae			
Antennarius coccineus	·	+	+
2. Apogonidae			
Apogon amboinensis	·	+	+
Apogon robustus	+	+	+
3. Ariidae			
Arius thalassinus	+	+	+
4. Balistidae			
Monocanthus chinensis	+	+	+
5. Batrachoididae			
Batrachomoeus trispinosus	+	+	+
6. Carangidae			
Selar sp.	·	+	·
7. Centropomidae			
Chanda gymnocephalus	·	+	+
Lates calcarifer	·	+	+
Psammoperca sp.	·	·	+
8. Chaetodontidae			
Coradion chrysozonus	·	·	+
Parachaetodon ocellatus	+	+	·
9. Dasyatidae			
Dasyatis kuhli	+	·	·
Dasyatis zugei	+	+	+
10 Gerreidae			
Gerres abbreviatus	+	+	+
Gerres filamentosus	+	+	+
Pentaprion longimanus	+	+	+
11. Labridae			
Cheilinus chlorurus	+	·	·
Choerodon schoenleini	+	·	+
Choerodon sp.	+	+	+
Halichoeres sp.	+	+	+
12. Leiognathidae			
Leiognathus fasciatus	·		+
Leiognathus splendens	·	+	·
13. Lethrinidae			
Lethrinus lentjan	·	·	+
Lethrinus nebulosus	·	·	+
Lethrinus ornatus	·	·	+
Lethrinus sp.	·	+	+
14. Lutjanidae			
Caesio chrysozona	+	·	·
Lutjanus altifrontalis	·	·	+
Lutjanus erythropterus	·	·	+
Lutjanus johnii	+	+	+
Lutjanus lineolatus	·	+	+
Lutjanus monostigma	·	+	+
Lutjanus russelli	·	·	+
Lutjanus sp.	+	+	·
Pinjalo sp.	·	·	+
15. Mullidae			
Upeneus tragula	+	·	+
16. Muraenidae			
Gymnothorax sp.	+	+	+
17. Nemipteridae			
Nemipterus bleekeri	·	+	·
Nemipterus furcosus	·	+	·
Scolopsis taeniopterus	+	·	+
18. Parapercidae			
Parapercis filamentosus	+	+	+
Parapercis sp.	+	+	+
19. Pentapodidae			
Pentapodus sp.	+	·	+
20. Platacidae			
Platax batavianus	+	·	·
21. Platycephalidae			
Platycephalus scaber	+	+	+
22. Plotosidae			
Plotosus anguillaris	+	+	+
Plotosus canius	+	+	+
Plotosus lineolatus	·	+	·
23. Pomadasyidae			
Plectorhynchus pictus	+	·	·
Pomadasys argyreus	+	+	+
Pomadasys cuvieri	+	+	·
Pomadasys hasta	·	+	+
Pomadasys maculata	·	+	·
Pomadasys sp.	+	+	·
24. Scatophagidae			
Scatophagus argus	+	+	+
25. Sciaenidae			
Johnius belangerii	+	+	+
Pennahia argentata	+	·	·
Pennahia macrophthalmus	·	·	+
26. Scorpaenidae			
Pterois volitans	·	·	+
27. Serranidae			
Centrogenys vaigiensis	·	+	·
Epinephelus bleekeri	·	+	+
Epinephelus chlorostigma	·	+	·
Epinephelus tauvina	+	+	+
Plectropoma leopardus	·	+	·
28. Siganidae			
Siganus cannaliculatus	·	+	+
Siganus javus	+	+	+
29. Synanceiidae			
Synanceja horrida	+	·	·
30. Syngnathidae			
Hippocampus kuda	+	·	+
31. Tetraodontidae			
Arothron immaculatus	+	+	+
Arothron reticulatus	+	+	+
Arothron sp.	+	+	+
32. Theraponidae			
Therapon jarbua	+	·	·
Therapon theraps	+	+	+
Subtotal A (finfish)	26 families 44 species	26 families 49 species	29 families 54 species
B. Crustaceans			
33. Dromiidae			
Dromia sp.	+	+	+
34. Paguridae			
Clibanarius sp.	+	+	·

Continued

Table 3. (continued)

Families and species		Mangrove area	Floating fishfarm area	Cleared mangrove area
35.	Penaeidae			
	Metapenaeus ensis	-	-	+
	Parapenaeopsis sp.	+	-	-
	Penaeus merguiensis	+	-	+
	Penaeus semisulcatus	-	-	+
36.	Portunidae			
	Charybdis natator	+	+	+
	Charybdis sp.	+	+	+
	Portunus pelagicus	+	+	+
	Scylla serrata	+	+	+
	Thalamita spinimana	+	+	+
	Thalamita crenata	+	+	-
37.	Xanthidae	+	-	-
	Myomenippe granulosa	+	+	+
	Subtotal B (crustaceans)	5 families 11 species	4 families 8 species	4 families 9 species
C.	Coelenterates			
38.	Phoichaetidae			
	Cerianthus sp.	+	-	-
D.	Echinoderms			
39.	Archasteridae			
	Archaster typicus	+	+	+
40.	Goniasteridae			
	Anthenea acuta	-	-	+
41.	Temnopleuridae			
	Temnopleurus toreumaticus	+	+	+
	Subtotal D (echinoderms)	2 families 2 species	2 families 2 species	3 families 3 species
E.	Merostomes (horseshoe crab)			
42.	Order: Xiphosura			
	Tachypleus gigas	+	-	+
F.	Mollusks			
43.	Octopodidae			
	Octopus filamentosus	-	-	+
	Octopus sp.	-	+	+
44.	Sepiidae			
	Sepia esculenta	+	+	+
	Subtotal F (mollusks)	1 family 1 species	2 families 2 species	2 families 2 species
Grand total		36 families 60 species	34 families 61 species	39 families 70 species

Note: + means present, - means absent.

Table 4. Dominant fish (including crustacean) species[a] caught by fish traps from the three study sites during monsoon and intermonsoon periods[b] (April 1987 to April 1988).

Family and species		Mangrove area I1	I2	I3	M1	M2	Floating fishfarm area I1	I2	I3	M1	M2	Cleared mangrove area I1	I2	I3	M1	M2
		No. of individuals per 50 fish traps/Study sites														
1.	Apogonidae															
	Apogon robustus	25	48	18	57	45	14	9	ND	ND	6	ND	ND	19	ND	20.5
	Apogon sp.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
2.	Ariidae															
	Arius thalassinus	ND	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	ND	ND
3.	Balistidae															
	Monacanthus chinensis	ND	10	ND	15	14	11	11	ND	7	6.5	6	9	10	10	7.5
4.	Batrachoididae															
	Batrachomoeus trispinosus	8	28	13	23	21	8	ND	9	5	7	15	ND	11	29	8.5
5.	Gerreidae															
	Gerres filamentosus	8	ND	ND	ND	5.5	11	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Pentaprion longimanus	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6.	Labridae															
	Choerodon sp.	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND
7.	Lutjanidae															
	Lutjanus johnii	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8.	Parapercidae															
	Parapercis filamentosus	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9.	Pentapodidae															
	Pentapodus sp.	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	6	ND	ND	10
10.	Platycephalidae															
	Platycephalus scaber	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND
11.	Plotosidae															
	Plotosus anguillaris	476	ND	ND	ND	69	8	13	10	ND	15.5	42	7	ND	5	ND
12.	Pomadasidae															
	Pomadasys argyreus	ND	ND	6	ND	12	6	ND	ND	ND	ND	ND	ND	ND	ND	ND
13.	Portunidae															
	Charybdis natator	ND	6	5	ND	13	ND	11	6	ND	27	ND	17	19	ND	ND
	Portunus pelagicus	ND	16	14	12	8	11	6	ND	ND	7	ND	ND	8	ND	6
	Scylla serrata	ND	ND	ND	12	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND
14.	Scatophagidae															
	Scatophagus argus	8	32	6	20	12	ND	ND	ND	ND	ND	ND	6	ND	ND	ND
15.	Sciaenidae															
	Johnius belangerii	22	19	59	42	39.5	28	7	13	7	22	ND	ND	ND	ND	7
	Pennahia argentata	ND	17	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND
16.	Serranidae															
	Epinephalus tauvina	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND
17.	Siganidae															
	Siganus javus	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND
18.	Tetradontidae															
	Arothron immaculctus	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND	ND	ND	ND	ND
19.	Theraponidae															
	Therapon theraps	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	18
20.	Xanthidae															
	Myomenippe granulosa	6	ND	9	35	7	8	8	11	10	ND	ND	6	7	5	ND

[a]>5 fish caught per 50 fish traps.
[b]I1 = April 1987; I2 = October 1987; I3 = April 1988; M1 = May 1987, southwest monsoon; M2 = average of November to December 1987 and March 1988, northeast monsoon.
[c]ND = Not dominant.

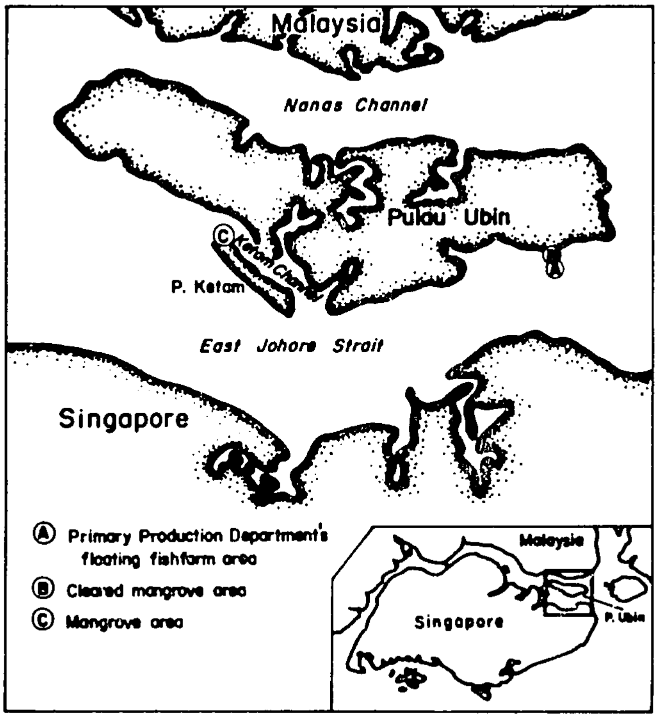

Fig. 1. Map showing location of fish traps set in mangrove, floating fishfarm and cleared mangrove areas.

An assessment of the ecological and economic impact of mangrove conversion in Southeast Asia

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ABSTRACT

More than a quarter of the world's mangrove forests is found in the ASEAN (Association of Southeast Asian Nations) region. Traditionally exploited by coastal communities for fuel, building materials, medicines and food, mangrove forests are denuded rapidly as a consequence of increased population and economic development pressures. The lack of understanding of the ecological impact of mangrove forests and the persistent notion that they are "wastelands," which must be reclaimed for economic development, are reasons for their large-scale denudation.

The ecological significance of mangrove forests on fisheries and other coastal resources is reviewed as well as the economic impact of mangrove exploitation and conversion on agriculture, aquaculture, and urban and industrial areas. Historical trends in mangrove exploitation and conversion are also traced. Moreover, the need for more research on the ecological importance of mangrove ecosystems is stressed. Zoning and other measures for the sustainable use and delineation of mangrove reserves are recommended to conserve these resources.

INTRODUCTION

The mangrove or mangal forest is one of the most important and productive ecosystems found along coastal zones and islands. It consists of intertidal flora and fauna occurring in tropical and subtropical regions of the world (Por 1984a; Rao 1986; Tomlinson 1986). More than a quarter of the world's mangrove forests is found in the ASEAN region (Gomez 1980a; Snedaker and Getter 1985; Aksornkoae 1986; Corlett 1986; Soemodihardjo 1986; Zamora 1987a). Table 1 shows the areal extent of mangroves worldwide and in the ASEAN region. For centuries, they have contributed significantly to the socioeconomic well-being of coastal communities in the region. Mangroves have been traditionally exploited as sources of charcoal, firewood, building materials, tannin (from the barks of *Rhizophora* and *Ceriops*), herbal medicines and food (Hamilton and Snedaker 1984; FAO 1985; Tomlinson 1986; Aksornkoae 1987).

Population increase and rapid economic development in the region, especially during the post-World War II era, have severely reduced the mangrove areas due to unrestrained clear-cutting for timber; land reclamation and development for agriculture, aquaculture and human settlement; siltation from mining activities; and coastal water pollution from oil spills, and domestic and industrial effluents (Gomez 1980b; Sasekumar 1980; Saenger et al. 1983; Aksornkoae 1937). The rapid denudation of mangrove forests is due partly to the lack of understanding of their ecological impact on other natural resources in the coastal zone, especially coastal fisheries. Furthermore, mangrove forests are viewed as "wastelands" that must be reclaimed for development to be economically viable (Burbridge 1982; Hamilton and Snedaker 1984; Rao 1986).

ECOLOGICAL SIGNIFICANCE OF MANGROVES

Most of the mangrove forests in the ASEAN region are hardly pristine. These have been disturbed by both natural and human-made factors. However, large tracts of mangrove forests still exist in many areas of the region: Sabah, Sarawak, Brunei Darussalam, Indonesia, the Upper South of Thailand and Peninsular Malaysia. Except for Peninsular Malaysia, where a mangrove reserve has been instituted as early as 1904 in Perak (Chan 1986b), most countries in the ASEAN region established some mangrove management measures only in the 1960s (Christensen 1982; Aksornkoae 1986; Soemodihardjo 1986; Zamora 1987b). As early as 1885, Singapore established mangrove reserves but these no longer exist today (Corlett 1986). This general lack of knowledge on the ecological importance of mangrove forests is one factor in the slow institution of management measures in the region.

The mangrove ecosystem is important ecologically (Zamora 1987a). It serves as: (1) a buffer against storm surges and strong winds; (2) habitat for many species of flora and fauna and nursery ground for many economically important aquatic organisms like crustaceans and finfish; (3) a major producer of detritus (chiefly from leaf litter) that contributes to nearshore and offshore productivity; and (4) a contributor to coastal accretion by trapping debris, filtering land runoff and removing terrestrial organic matter (Table 2). The degree of importance of these functions depends largely on prevailing local conditions, which vary from one place to another.

MANGROVE EXPLOITATION AND CONVERSION

The traditional small-scale exploitation of mangroves (i.e., for charcoal and firewood production), which has been practised for centuries, was sustainable because it allowed the mangrove areas sufficient time to regenerate (Christensen 1982; Burbridge and Koesoebiono 1984). This includes the clear-cutting of mangroves for timber. However, the increase in demand for timber and other wood products in the postwar era and in the reclamation undertaken for agriculture, aquaculture, and urban and industrial sites have diminished the regeneration of denuded mangroves.

In Indonesia, the large-scale conversion of mangrove areas was due to human settlement and agriculture as a consequence of the Transmigration Program of the government since 1969. About 800,000 ha have been converted for this purpose (Naamin 1986; Soemodihardjo 1986). Both Indonesia and the Philippines have extensive fishponds that were originally mangrove areas. As of 1984, Indonesia had 211,000 ha of *tambak* (earthen fishponds) mainly for the culture of milkfish (55.5% of the total brackishwater production comes from milkfish; in the Philippines, brackishwater ponds have increased productivity by 29% from 1968 to 1986) (Burbridge and Maragos 1985; Camacho and Bagarinao 1986; BFAR 1986). This increase was due to the high economic return from shrimp farming, especially from exports, which has replaced milkfish culture in many areas of the Philippines. In Thailand, about 30% of the total mangrove areas have been destroyed over the past 25 years; 38% of these were converted to shrimp farms (Aksornkoae 1987). In Malaysia, coastal aquaculture is still new. Hence, most of the mangrove denudation is attributed to agriculture, but 20-25% of the mangrove forests in Sabah and Peninsular Malaysia are earmarked for aquaculture (Chan 1986a).

Historically, the basis for mangrove management in the region is mostly economic rather than ecological or both (Table 3). In Indonesia, the 1933 regulation on the prohibition of mangrove cutting within 3 km from a village was enacted to control the mosquito population responsible for malaria (Burbridge and Koesoebiono 1984). In Malaysia, the socioeconomic benefits derived from mangrove exploitation by coastal communities resulted in the establishment of a mangrove reserve as early as 1904 (Chan 1986b). The case of the Philippines was quite different from Malaysia and Singapore. Although there had been some efforts toward reforestation and management before World War II, most of these were highly localized (Table 3). In 1918, there were 450,000 ha of mangrove forests in the Philippines; 67.5% of these have been denuded over a span of 59 years (Zamora 1981). Denudation was placed at 6,231 ha/year. As of 1984, about 46% of the total mangrove area in the country was converted to brackishwater ponds; this conversion took place mostly in the 1970s (Zamora 1987b).

In contrast to other ASEAN countries, Singapore's mangrove forests have been largely destroyed for urban development. In 1819, 13% of its area was covered with mangroves. Only 500 ha of mangrove forests remain today and are in varying disturbed or degraded conditions (Corlett 1986; ZD-US 1980). Similar to Indonesia and the Philippines, the rapid destruction of mangroves in Thailand occurred in the 1960s. Prior to 1961, mangrove exploitation was generally for charcoal-making. Thereafter, large tracts of mangroves paved the way for aquaculture and agricultural farms, human settlement, tin mines, industrial sites and salt ponds. Mangrove forests were denuded at the rate of 3,943 ha/year from 1961 to 1975 and increased by 1.6% from 1975 to 1979 (Piyakarnchana 1980a, 1980b; Aksornkoae 1986, 1987). Among the ASEAN member-countries, the mangrove forests of Brunei Darussalam are among the best preserved in the region and are not intensely exploited. Present exploitation is largely for charcoal and poles for the building industry. Resources use conflict is minimal. However, future urban development similar to that of Singapore and the conversion of mangroves to aquaculture farms will be the major issues that will affect the mangrove forests of Brunei Darussalam (Zamora 1987a). A summary of the economic activities pertaining to mangrove exploitation is shown in Table 4.

ECOLOGICAL AND ECONOMIC IMPACT OF MANGROVE CONVERSION

The mangrove forest contributes to both terrestrial and aquatic productivity, especially on the detritic energy pathway through leaf litter. Hence, many productive fishing grounds are found adjacent to mangrove areas (Chansang 1984). The mangrove ecosystem has numerous ecological functions (Table 2) that are seriously affected when denudation or conversion takes place.

Impact on fisheries

The mangrove area is a nursery ground for many commercially important species of finfish and crustaceans. Mangroves are also rich feeding grounds for many species from various trophic levels. An analysis of the 1981 fish landings in Malaysia shows that 32% may be associated with mangroves (Jothy 1984). In the Philippines, municipal catch representing 71.9% of the total catch from 1982 to 1986 has some close association with mangroves (BFAR 1986). There is a positive logarithmic relationship ($r = 0.63$, $P<0.01$) between the annual total municipal landings of 34 coastal provinces (BFAR 1976, 1977, 1984; SSC 1988) and existing mangrove areas from 1976 to 1984, as shown in Table 5. Correlation with total mangrove and low-density logged-over areas from 39 coastal provinces was also statistically significant. However, this relationship is not predictive as other factors can influence the catch. For instance, many of the provincial fishing grounds have extensive coral reefs and seagrass beds, in addition to the mangroves, which also contribute to the overall productivity of these areas.

Mangal mollusks are characteristically eurybiotic species with very few genera considered mangal-exclusive (Plaziat 1984). Nevertheless, some species of oysters and cockles are associated with mangroves (Gomez 1980b; Jothy 1984; Rao 1986). Several species of shrimp, notably penaeids, also depend on mangroves from their larval to juvenile stages. Like crustaceans and mollusks, many species of finfish are closely associated with mangroves but very few species are truly mangal residents. Numerous studies have been conducted on the finfish composition of mangrove areas worldwide (MacNae 1974; Gundermann and Popper 1984; Hamilton and Snedaker 1984; Por 1984a, 1984b; Rao 1986). In Florida, USA, about 80% of the marine commercial and recreational catch are dependent on mangroves for at least some critical stages of the species' life cycles. In Fiji, 60% of commercial landings are from mangrove areas (Hamilton and Snedaker 1984).

The conversion of mangroves for aquaculture and other land uses is detrimental to many mangrove-dependent species. In Ecuador, the large-scale reclamation of mangrove areas for shrimp ponds has contributed to the decrease in shrimp fry availability for stocking because most shrimp farms still depend on natural wild fry collection (Snedaker et al. 1986). In the ASEAN region, the impact of mangrove conversion on fisheries has not been assessed qualitatively and quantitatively. However, many aquaculture operations rely on the collection of naturally occurring seed stock of penaeid shrimp and finfish like milkfish, groupers, snappers and sea bass. Although the commercial hatchery production of penaeid shrimp and sea bass has been attained, many hatcheries still depend on their wild broodstock. Thus, the destruction of mangroves--as in the Ecuador experience--could affect the availability of fry and broodstock and, consequently, aquaculture production. In terms of capture fisheries, the same can also be said. Low recruitment will consequently affect production. With many overexploited fishing grounds in the region, the loss of habitat through mangrove destruction will further compound stock recruitment and production.

Economic impact will most likely be localized. The decrease or subsequent depletion of seed stock of penaeid shrimp and milkfish can displace fishermen and fry gatherers who depend on the fisheries for sustenance. Mollusk culture beds will also be directly and indirectly affected. The decrease in aquatic productivity as a result of mangrove destruction directly affects the settling and growth of mollusks like oysters and cockles. Indirectly, it affects the culture beds through high sedimentation resulting from shoreline erosion and terrestrial runoff since there will be no barriers against these forces.

Shrimp catch, especially the penaeid species, has been correlated significantly with existing mangrove areas (Martosubroto and Naamin 1977; Turner 1977, 1986; Gedney et al. 1982; Staples et al. 1985; Pauly and Ingles 1986; Sasekumar and Chong 1987). In the Philippines, the logarithmic relationship between shrimp catch and mangrove areas in 18 provinces is significant (Table 5, Fig. 1). This relationship, however, is not predictive. Finfish, on the other hand, have not been easily correlated with mangrove areas, although many finfish species have been recorded in these areas (Gomez 1980a; De la Paz and Aragones 1985; Pinto 1987). According to Gundermann and Popper (1984), very few species are mangal-exclusive. Many of these fish belong to the Gobiidae, Eleotriidae and Blenniidae families. As in shrimp catch, the relationship between fish and adjacent mangrove areas was assessed based on five fish species groups (families Carangidae, Lutjanidae, Serranidae, Mugilidae and Siganidae) from several Philippine coastal provinces. Except for the snappers, the logarithmic relationships are positively correlated ($P<0.01$), as shown in Table 5. This relationship is not conclusive, however. Longer time-series data on catch, species composition, hydrographic factors and precise resource inventory of mangroves and other coastal resources are needed to establish such a relationship, if it exists.

The valuation of mangroves is very difficult for two reasons (Hamilton and Snedaker 1984): (1) many goods and services derived from the mangrove ecosystem are not easily monetized and (2) many of these goods and services are considered economic externalities. Financial analysis of mangrove conversion considers only its profitability from the investor's point of view. The social benefits are almost always ignored. One of the reasons is that many mangrove areas in the region are privately owned and developed as the owners please. Many of the coastal communities dependent on coastal resources tend to be politically and economically marginal.

Shrimp farming has dramatically increased since the 1970s because of the impetus from governments and international agencies and the high profitability of such a venture. In reality, only a few people or groups of people benefit from it. Furthermore, such a venture generally involves the expropriation of resources over which communities have traditional rights based on long-standing patterns of usage (Bailey 1988).

An economic analysis of mangroves is not easy, particularly on intangible aspects such as the conservation of genetic diversity. Indirectly, some workers have attempted to put monetary values on charcoal, poles and other traditional uses of mangroves; resources associated with mangroves like fisheries and those obtained from their sustainable use. This explains why there are different values obtained in the economic valuation of mangrove resources (Table 6). On the whole, there is a need for research to determine the impact of mangrove conversion on fisheries resources, its socioeconomic repercussions and the other resources associated with mangroves (Untawale 1986b).

Impact on coastal areas

The impact of mangrove conversion on coastal areas varies from place to place, depending on the prevailing local conditions. In typhoon-prone areas, the destruction of mangroves increases the risk of coastal erosion from storm surges and winds. Along estuarine systems, their denudation accelerates the erosion of riverbanks, especially where water traffic is heavy. When large areas of mangroves have been converted to shrimp ponds, the process results in the following: acid sulfate soils are exposed, leading to poor production and mass mortality of stocks as well as the discharge of toxic substances into nearby waters.

The destruction of mangroves for coastal development (i.e., residential and industrial sites), will affect the freshwater supply through salt intrusion upstream, particularly under low-rainfall conditions; on the other hand, flooding will occur under high-rainfall conditions. In Jakarta, the construction of *tambak* resulted in the diversion of stream channels, causing major changes in hydrologic regime and siltation, thereby altering the coastal sedimentation process (Burbridge and Koesoebiono 1984). Conversion to salt ponds also alters soil structure and increases salt content, thereby rendering the area difficult to reclaim, especially for agriculture or silviculture. Some

Artemia ponds in Thailand and the numerous salt ponds in the region can become unproductive should these areas be abandoned for various reasons. Conversion of mangroves to mining areas--as in Indonesia and Thailand--not only affects other resources (i.e., coral reefs, coastal waters, beaches, fisheries) but could also render the areas irreversibly damaged, if not costly to reclaim for more productive purposes.

An economic analysis of the mangrove conversion in coastal areas such as residential lots or mining sites is difficult. For example, the damage caused by storm surges or cyclones with and without mangroves fringing the coast can be quantified in monetary terms, provided there are structures such as residential houses or factories that could be valuated. Otherwise, the cost of storm damage will be small. In conversion, the value of mangrove use is lost as the conditions are altered. These conditions are sometimes irreversible or costly to mitigate. Hence, an economic analysis of mangrove conversion must consider the goods and services that would be lost in the process, many of which are naturally accessible.

MANGROVE MANAGEMENT AND CONSERVATION

Baseline information on the mangrove ecosystem is still insufficient, especially on its relationship with other ecosystems and resources within the coastal zone. There is also a need to assess the extent of the use of mangroves to quantify their socioeconomic benefits. Many countries in the ASEAN region have established committees to conduct multidisciplinary research on various aspects of the mangrove ecosystem. There are now many tools that can provide better baseline information than in the past. These include remote sensing, a geographic information system and environmental impact assessment techniques (Umali et al. 1986; Untawale 1986b). However, very few studies have been conducted to assess the economics of mangroves as a resource. Mangrove inventories are needed in such areas as Indonesia, Sabah and Sarawak in Malaysia.

Management and conservation of mangrove forests entail the delineation of areas or zones. Areas must be allocated for conservation purposes to protect the mangrove ecosystem, conserve genetic diversity and provide areas for scientific research and aesthetic considerations. The institution of conservation zones means that options are open, particularly for the future development of the resource should the need arise (Hamilton and Snedaker 1984). It is, of course, not an easy task since many government forestry programs (mangroves included) in the region are sectorally polarized with two or three agencies having completely opposite mandates over one resource.

Areas for the sustainable management of mangroves have been established in many countries in the region. This covers silvicultural practices for timber harvesting and for the production of charcoal, poles and wood chips. Usually about 15 to 30 year-cutting rotations are applied. Most of these practices are found within the reserves. However, some clear-cutting activities occur in concession areas with little silvicultural measures being taken, thereby causing large-scale denudation. No single use can be intensified without effects on the other uses. Activities must, therefore, be balanced. Otherwise, irreversible damage will occur. At least with sustainable management, the option to conserve or convert is not foreclosed. Sustainable management should also ensure that the ecological integrity of the ecosystem and its closely associated resources are intact.

Population and economic development pressures have been responsible in part for the conversion of mangroves to various land uses. The indiscriminate clear-cutting of mangroves for aquaculture, salt ponds and other uses--especially those within privately owned lands--must be minimized. As much as possible, conversion should be restricted to areas that will not affect adversely other resources. In that way, adverse environmental impact such as flooding, salt intrusion in aquifers, erosion and others can be prevented. Traditional use rights of coastal communities must be given due consideration (e.g., provide a tenurial system to make use of mangrove areas on a sustainable basis). Too often, governments easily provide lease permits for the conversion of mangroves to other land uses, thereby effectively destroying the ecosystem. But it is very difficult to provide the same to communities or individuals who would want to manage the mangrove areas without adversely affecting the ecosystem.

Within the ASEAN region, there are many areas with intact mangroves that are at present being converted to other land uses. Examples of these are those in Kalimantan and Irian Jaya (Indonesia), Sabah and Sarawak (Malaysia), Palawan (Philippines) and Upper South (Thailand). These areas should either be managed for sustainable development or conserved. Some can be converted into national parks for tourism purposes, which, in turn, could provide an alternative livelihood for many sustenance communities living within the mangrove areas. However, areas that have been denuded or converted to other land uses but later abandoned for some reason should be rehabilitated through reforestation. Many areas in the Philippines and Thailand have been denuded, especially those fringing the coasts. Here, reforestation activities would be appropriate. Already, several such programs have been initiated (Table 3).

Implementation of conservation and management measures require both political and public support. Too often, conversion of mangroves to alternative land uses is politically motivated and, at times, dictated by private interests. Awareness of the ecological importance of the very valuable and productive mangrove ecosystem is a step toward an appreciation of it.

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Table 1. Mangrove areal extent (ha) in the ASEAN region and worldwide.

Geographical location	Mangrove areal extent	
Asia and the Orient		6,517,000
Brunei Darussalam*	18,418	
Indonesia*	4,251,011	
Malaysia (Peninsular)*	105,537	
Sabah*	350,342	
Sarawak*	172,792	
Philippines*	220,243[a]	
Singapore*	500	
Thailand*	287,308	
Africa		5,117,000
South America		4,105,000
North America		1,670,000
Oceania		1,515,000
Caribbean		962,000
Central America		888,000
Total		20,774,000

*For the ASEAN countries only.
[a]Includes low density, logged-over areas.
Sources: Gomez (1980b); Snedaker and Getter (1985); Aksornkoae (1986); Chan (1986a); Corlett (1986); Soemodihardjo (1986); Zamora (1987a).

Table 2. Some aspects of the ecological importance of the mangrove ecosystem.

1. High aquatic productivity
   - Major energy pathway is detritic through leaf fall.
   - Leaf fall value:
     - (Malaysia) *Avicennia*, 15.4 t/ha/yr; *Sonneratia*, 14.0 t/ha/yr; *Rhizophora*, 15.8 t/ha/yr (all are 15-yr-olds)
     - (Indonesia) 8.53 t/ha/yr
     - (Philippines) *Avicennia*, 5.22 t/ha/yr; *Ceriops*, 4.29 t/ha/yr
     - (Thailand, Phuket) 15-yr *Rhizophora*, 6.7 t/ha/yr

2. Habitat for many terrestrial flora and aquatic fauna
   - Brunei Darussalam
     - Flora 49 species of flowering plants
     - Fauna 28 genera (crustaceans, mollusks and other invertebrates; fish - not assessed)
   - Indonesia
     - Flora 91 species
     - Fauna 25 species (crustaceans - South Sumatra)
       - 22 species (mollusks - Central Sulawesi)
   - Malaysia
     - Flora 86 species
     - Fauna 30 species (fish)
       - 13 species (crustaceans)
       - 5 species (mollusks)
   - Philippines
     - Flora 155 species
     - Fauna 235 species (fish).
       - 54 species (crustaceans)
       - 63 species (mollusks)
   - Thailand
     - Flora 136 species
     - Fauna 72 species (fish)
       - 37 species (shrimp)
       - 54 species (crab)
       - 20 species (mollusks)

   Nursery ground

   Many shallow areas exist in mangrove forests and have a high productivity that favors the congregation of fish and crustacean larvae and juveniles. Shading from trees serves as a protection for larvae and juveniles against natural hazards and predators.

   Feeding ground

   Being a productive ecosystem, many species of fish, crustaceans and invertebrates migrate seasonally into the mangal waters to feed.

   Some mangal fish
   - True resident fish
     - Eleotriidae, Gobiidae, Blenniidae (mudskippers)
     - Ariidae (sea catfish)
   - Closely associated fish
     - Mugilidae (mullets)
     - Sciaenidae (croakers)
     - Siganidae (rabbitfish)
   - Loosely associated fish
     - Chanidae (milkfish)
     - Serranidae (groupers)
     - Lutjanidae (snappers)
     - Carangidae (cavalla, crevalles)
     - Polynemidae (threadfins)
     - Leiognathidae (slipmouth)

Sources: Gomez (1980a); Gundermann and Popper (1984); Por (1984b); Aksornkoae (1986); Chan (1986a); Soemodihardjo (1986); TS-PMC (1986); Zamora (1987a).

Table 3. Historical development of mangrove utilization and management in the ASEAN region.

Indonesia	
1933	A regulation was enacted prohibiting the cutting of mangroves within 3 km from a village to control the mosquito (malaria carrier) population.
1937	The Transmigration Program in South Kalimantan (tidal swampland) was started.
1938	The regulation of basic silvicultural practice was enacted, commonly referred to as the "seed tree method."
Prior to 1942	Mangroves were exploited for charcoal (Riau Province), the sugar industry and the railway system.
1945-1950 (Java)	Mangrove destruction at the time of the War of Independence was uncontrolled.
After 1950	A forestry regulation to halt the rapid denudation of mangrove forests was enforced.
1969	The Ministry of Public Works and Electric Power launched a pilot project to open areas in Sumatra and Kalimantan. For its first Five-Year Development Plan, which was carried out between 1969 and 1974, about 200,000 ha of tidal forests, which included mangroves, were converted to agricultural lands.
1975	A regulation was enacted establishing a 400-m wide mangrove greenbelt along the Indonesian coast.
1978	The 1938 Act was amended to cover the requirements for the maintenance and replacement of cut-over areas by concessionaires.
1980	The Indonesian Mangrove Committee was created.
1982	Lease permits were issued to timber corporations to exploit mangroves in Irian Jaya, Kalimantan, Sulawesi, Sumatra and Riau.
1984	A regulation was enacted by the Ministry of Forestry establishing a 200-m wide mangrove greenbelt along the Indonesian coast.
Sources: Burbridge and Koesoebiono (1984); Hamilton and Snedaker (1984); Soemodihardjo (1986).	
Malaysia	
1904	The 40,000-ha Matang mangrove reserve in Perak was established by the Forestry Department.
1933 (and 1982)	The Sarawak mangrove reserve (4,000 ha) in the first division was diverted from agricultural uses.
1955	Mangrove areas were converted: 10,500 ha into a plantation for cash crops (up to 1980); 1,300 ha for urban and residential purposes.
1960s	There was a gradual change from traditional to conventional uses of the mangrove ecosystem for coastal development.
1968 and 1970	Wood chipping plants in Malaysia, Sarawak and Sabah were established.
1970	Some 123,000 ha (40%) in Sabah and 6,200 ha in Sarawak were allocated for wood chip production for export to Japan.
1972	The Forest Management Policy and Strategy of the National Forestry Policy was approved by the National Forestry Council and endorsed by the National Land Council (1978). It was aimed at ensuring the conservation, management, utilization and development of forest resources.
1977	The shrimp culture project in Tawau, Sabah (80 ha) was established.
1978	An ad hoc Mangrove Research Coordinating Committee was formed.
1983	A research and management strategy for the mangrove ecosystem was drawn up, following a workshop held at the Universiti Pertanian Malaysia on the production of the mangrove ecosystem: management indications.
Sources: Sasekumar (1980); Chan (1986a and b); Salleh and Chan (1986).	
Philippines	
1918	The mangrove forests in the country were estimated to be between 400,000 and 500,000 ha; the reforestation of *Rhizophora* and *Nypa* in some areas around Manila was undertaken to assure the supply of the city market.
1952 (to 1975)	Some 87,351 ha of mangrove areas were converted to fishponds (milkfish).
1968	The reforestation of 562.83 ha in Bohol was initiated.
1975	The Forestry Reform Code was issued: "Strips of mangroves that protect the shorelines or coastal communities against destructive forces from the sea shall be maintained and not be alienated."
1976	The Philippines' National Mangrove Committee was created.
1972-1976	A mangrove inventory was done by Landsat 1 and 2.
1978	A mangrove inventory was made by aerial photography.
1981	A Presidential Proclamation authorizes the creation of mangrove reserves in 14 provinces (aggregate total of 74,267 ha). First large-scale mangrove reforestation was initiated in nine islands of Marungas, Sulu (total area: 4,560 ha; 150 ha reforested) by the Bureau of Forestry Development.

1982 and 1985	A mangrove inventory was made by aerial photography.
1984	Reforestation was done in Cebu (364.98 ha).
1987-1988	A SPOT mapping of land uses was undertaken by the Swedish Space Corporation; the total mangrove area covered was 1,494 km^2.

Sources: TS-PMC (1986); Zamora (1987b); SSC (1988).

Singapore

1819	Some 7,500 ha or 13% of the total area was covered with mangroves.
1822	Reclamation work began at the south bank of the Singapore River.
1885	Since the mangroves were already degraded, a forest reserve was established.
1900s	Prawn farming was started.
1938	Mangrove reserves were abolished.
1951	Pandan and Kranji were developed as national reserves for botanical interest. However, in 1968 and 1975, respectively, they ceased to be so.
1960s	The Jurong Industrial Estate was established.
1970	All major nonurban estuaries were barraged to create freshwater reservoirs; thus, resulting in the destruction of mangroves.

Sources: ZD-US (1980); Corlett (1986).

Thailand

Prior to 1961	Logging of mangroves for charcoal.
1961	The working plans on mangroves were revised to suit the Royal Forestry Department's method of monopolized auction licensing.
1961 (to 1979)	Some 80,592 ha of mangroves were converted for aquaculture tin mining, salt ponds, etc.
1976	The National Research Council, which was formed during the Workshop on Ecosystem of Mangrove Resources in Phuket, acted as the central body in the establishment of the National Committee on Mangrove Reserve (NATMANCOM).
1977	The Government cabinet approved the proposal to create NATMANCOM.
1979	A Landsat inventory of a 287,308-ha mangrove area was made. The committee was composed of the: Royal Forestry Department; Department of Fisheries; Departments of Hydrography, Mineral Resources, Land Development, Meteorology and Army Survey; Prince of Songkhla University; Chulalongkorn University; Mahidol University; and Kasetsart University.

Source: Aksornkoae (1986).

Table 4. Summary of some economic activities pertaining to mangrove utilization and conversion.

Utilization
- Food and drugs
- Charcoal
- Timber products (poles, construction materials)
- Fuelwood
- Wood chips (for paper products)
- Industrial chemicals (dye, tannin, cellulose, alcohol)
- Fodder

Conversion
- Agriculture (coconut, rice and other cash crops)
- Mining (tin, iron-sand, bauxite, construction materials, nickel and coal)
- Residential and industrial sites
- Salt ponds
- Ports and harbors
- Aquaculture (shrimp and finfish)

Sources: Piyakarnchana (1980b); Saenger et al. (1983); Hamilton and Snedaker (1984); FAO (1985); Chan (1986b); Aksornkoae (1987).

Table 5. Regression values of municipal total catch by species groups and corresponding mangrove area from several coastal provinces in the Philippines.

Species group	a	b	n	r
Cavalla	0.9896	0.8082	18	0.73**
Mullets	-0.4091	0.7361	20	0.63**
Siganids	1.1462	0.9505	12	0.81**
Groupers	1.1530	0.4734	18	0.63**
Snappers	0.7972	0.5337	15	0.58*
White shrimp[1]	1.2263	0.7623	18	0.81**
Total shrimp[2]	-0.0575	0.8706	18	0.78**
Total catch[3]	2.5482	0.4304	34	0.63**
Total catch[4]	1.8045	0.5948	39	0.67**

$\text{Log}_{10}(\text{catch}) = a + b\,\text{Log}_{10}(\text{mangrove area})$

where a = intercept
b = slope
n = number of samples
r = correlation coefficient

**Highly significant ($P < 0.01$) *Significant ($P < 0.05$)

[1]Catch was predominantly *Penaeus indicus* (municipal and commercial).

[2]Catch included all shrimp species caught by municipal fisheries and penaeid commercial catch.

[3]Data from SPOT inventory; did not include fishponds and low-density logged-over areas (SSC 1988).

[4]Data from SPOT inventory; included fishponds derived from mangrove conversion (SSC 1988).

Note: Species group catch represented the maximum catch for any one-year period from 1976 to 1977 while total catch represented the average catch for nine years from 1976 to 1984. Data are from BFAR (1976), (1977), (1984) and (1986). Data on mangrove areas are from Gomez (1980b).

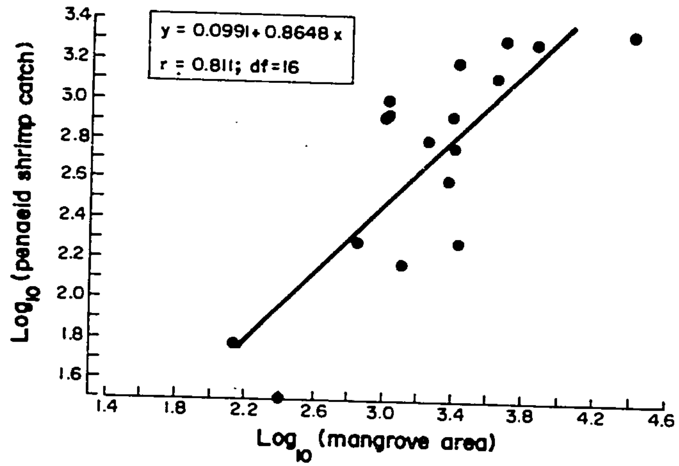

Fig. 1. Relationship between the mangrove area and the annual penaeid shrimp catch ($P < 0.01$) in various areas of the Philippines.

Table 6. Some examples of economic values for the mangrove ecosystem and its products.

Type of resource or product	Location	Year	Value of resource (US$/ha/yr)
Complete mangrove ecosystem	Trinidad	1974	500
	Fiji	1983	482
	India	1985	11,819
Forestry products	Malaysia	1986	604-3,067 (charcoal, poles, firewood)
	Thailand	1982	30-400
Fishery products	Indonesia	1978	50
	Thailand	1982	30-100 (fish) 200-2,000 (shrimp)

Sources: Hamilton and Snedaker (1984); FMC (1986); Rao (1986); Salleh and Chan (1986); Untawale (1986a).

The mangroves of Segara Anakan: an assessment of their condition and prospects

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ABSTRACT

The mangrove forest of Segara Anakan is the largest such area in Java. Common mangrove species occurring in the area are *Rhizophora apiculata, Bruguiera gymnorrhiza* and *Aegiceras corniculatum*. *Avicennia* and *Sonneratia* constitute the pioneering species in the sediment accretion areas.

The forest's condition has declined in recent years, as clearly reflected by young trees and sprouts that make up most of the vegetation. Very often, the areas are covered heavily by creepers like *Derris trifoliata, Finlaysonia maritima* and *Acanthus ilicifolius*. Trees having a diameter equal to or greater than 10 cm are rarely seen, except at the periphery of the lagoon.

Illegal cutting and conversion to other uses (ricefields and coconut groves) are the main stresses that affect the Segara Anakan mangroves.

Efforts to rehabilitate the degraded land have been made by the State Forest Corporation (Perum Perhutani). The species planted include *R. apiculata* for the muddy floor and *B. gymnorrhiza* for the hard substratum. The results seem quite satisfactory in some localities. For the program to be more successful, however, prevention of human interference, particularly with the rehabilitated area, is necessary.

INTRODUCTION

Conflicts in the use of coastal resources are a worldwide phenomenon. In Segara Anakan, Cilacap, Central Java, the lack of an authorized coordinating body aggravates the problem of managing mangrove resources.

The approximately 20,000-ha mangrove forest of Segara Anakan is the largest remaining such area in Java. However, observation indicates that this resource has undergone much deterioration. A significant proportion of the area has been and is being converted to agriculture. Administratively, the area is under the jurisdiction of the government-owned Perum Perhutani, but in the past few decades, it has been the subject of various conflicting interests. The result is a depleted resource.

The government through Perum Perhutani tried to rectify the situation. Measures were taken to prevent illegal cutting and conversion to other uses while the rehabilitation of degraded forests was carried out. There have been some encouraging results.

This paper assesses the present condition of the mangrove resources of Segara Anakan. A zonation scheme and development and management prospects are presented.

STUDY APPROACH

This study is an extension of the one reported by Soemodihardjo and Suroyo (in press). In the course of this study, it became apparent that the criteria for determining the mangrove management zones had to be made more flexible and applicable. In the modified approach, the criteria used were mainly qualitative in character, instead of quantitative. Five categories of forest condition were established, namely:

1. Undisturbed to slightly undisturbed. This category includes forest sections that show insignificant human interference or none at all. Forest canopy properly covers the area. Mangrove stands can consist of mature trees in the long-established area

or young trees in the newly accreted area. Undergrowths and creepers are minimal.
2. Moderately disturbed. Frequent signs of human activities are evident. Some gaps occur in the forest canopy. Tree stumps are encountered in some places. Undergrowths and creepers begin to occupy the open space.
3. Substantially disturbed. There is a pronounced sign of human disturbance. Due to the removal of trees, open spaces, which are invaded by undergrowths and creepers, are common. Mangrove stands, consisting of young trees and sprouts, are less dense.
4. Heavily disturbed. Mangrove stands have undergone much deterioration. Nearly all the trees are cut down. Only uneconomically important and bushy plants are left. The area looks like an open land dotted with clumps of shrubby formations. Undergrowths and creepers occupy most of the area.
5. Significantly disturbed. In terms of forest condition, this category is much like category 2 or 3, although its most prevalent characteristic is the occurrence of marginal species like *Heritiera littoralis, Excoecaria agallocha, Xylocarpus* spp. and *Scyphiphora hydrophyllacea*.

This modified approach, being founded largely on qualitative valuation, is necessarily subjective. It depends much on the perception and judgment of the surveyors. Indeed, some quantitative measurements by way of the transect method were made as bases for the calculation of some community indices, i.e., the importance value.

Fig. 1 shows a working map of Segara Anakan and its environs, as modified from the one originally prepared by Perum Perhutani. For easy reference, Perhutani divides the mangrove forest into small plots and numbers these from 1 in the west to 57 in the east.

RESOURCE STATUS

In the past few decades, the mangrove resources of Segara Anakan have been subjected to various disturbances, most of which are traceable to human activities. Sedimentation, for example, results from natural and human activities in the upper reaches of the Citanduy watershed.

Species composition

Several studies on the vegetation of Segara Anakan mangroves show varying species composition from one locality to another. This is not unusual considering the prevalent variation of the microhabitats in the area.

Table 1 shows the mangrove species reported to be occurring around Segara Anakan. The true mangrove components were most commonly represented by: *Rhizophora apiculata, Aegiceras corniculatum, Brugiera gymnorrhiza, Ceriops tagal, Avicennia alba, Sonneratia alba* and *Nypa fruticans*. In the somewhat drier places, *Heritiera littoralis, Xylocarpus granatum* and *Excoecaria agallocha* were abundant. The dominant undergrowths included *Acanthus ilicifolius, Derris trifoliata* and *Finlaysonia maritima*. On the elevated ground, *Acrostichum aureum* and *Wedelia biflora* were usually the common undergrowths.

The variation in species composition from place to place was quite distinctive. In the accretion area, a pure stand of *Avicennia, Sonneratia* or both usually occurred. The nonaccreted area, in contrast, was normally populated by mixed mangrove communities of several species. The most complex community contained up to 19 mangrove species (ET 1984). It was observed from plots 44, 46 and 47 that *R. apiculata, B. gymnorrhiza* or *A. corniculatum* (Table 2) usually dominated the community. In the transitional areas, the plant community included some salt-tolerant dryland vegetation like *Dolichandrone spathacea, Intsia bijuga, Barringtonia racemosa, Cerbera odollam* and *Ficus* sp.

Community structure

The Ecology Team (ET 1984) identified three species associations: pure stand, paired association and mixed association. Pure stands, like paired association, occurred primarily in accreted areas, often in the form of discrete patches occurring within other associations. *A. alba, A. marina* and *A. corniculatum* formed pure stands. The mixed association, by contrast, was distributed nearly all over the Segara Anakan mangrove area.

Geomorphologically, the mangrove areas can be categorized into three in terms of the community structure: transition area, accreted area and nonaccreted area. The last two categories were introduced by Hardjosuwarno (1979).

Transition areas are wetland or dryland ecosystems. In the north of the eastern coastal plain, these areas are mostly in the form of open land with bushy shrubs. Common species found were *Scyphiphora hydrophyllacea* and *Dalbergia junghuhnii*, interspersed by *A. aureum*. Closer to the land, *Phragmites karka* and *Imperata cylindrica* grew. The swampy transition area had *N. fruticans* and in an open swamp, *Acanthus* sedges or undergrowths. In the north of Segara Anakan proper, vegetation was different. Along the river from Penikel toward Kawunganten, there was a rich growth of *Barringtonia racemosa, Cerbera manghas* and *Ficus* sp.; *Dolichandrome spathacea* and *Intsia bijuga* were also common. These species were rare or absent in the transition area of the eastern coastal plain.

The accreted areas cover the northern and eastern coasts of Segara Anakan, including the islands. One important characteristic of these areas is the occurrence of a zonation pattern (Soemodihardjo and Suroyo, in press).

The nonaccreted areas embrace the entire coastal plain east of Segara Anakan, excluding the accreted area in the west and the transition area in the north. The nonaccreted areas are extensive, crisscrossed by an intensive network of tidal channels that join the Sapuregel-Donan system and ends up in the Indian Ocean through the eastern opening. In some places, the land is elevated and utilized by Perum Perhutani to grow teak *(Tectona grandis)*, mahogany *(Swietenia mahagoni)* or *lamtoro*. In other places, the land is uneven or undulated, leaving the tip of the crest out of the reach of high tides. On this high ground, *H. littoralis, D. spathacea, X. granatum* or *Ficus* sp. develop. Undergrowths such as *A. aureum, Wedelia biflora, Lantana* sp. and *Flagellaria indica* normally grow too.

Condition

Not a single area of Segara Anakan's mangrove forest is still intact. Every part has experienced some form of human disturbance, most of which are negative. In nearly all study plots, illegal cuttings are recorded (Table 3).

Fig. 2 shows the boundary lines of Segara Anakan's mangrove forest in 1982 and 1988. Reduction of the area was due to conversion, particularly for agriculture. Mangrove degradation was due to illegal exploitation for fuelwood and housing materials.

In the east of Segara Anakan, for instance, all the mangrove areas were in Category 3, 4 or 5. Very little were in Category 1 or 2 (Fig. 3). No trees with a diameter greater than 10 cm were found (Soemodihardjo and Suroyo, in press). The general physiognomy of the community consisted of small and young trees 4 to 5 m high. In some places, such as along the east bank of Sapuregel River (Plot 46), the plant density can be very high, i.e., 1,050 saplings/ha and 6,500 seedlings/ha. Farther down the river (Plot 45), the mangroves consisted of young saplings and sprouts. Heavy undergrowth of *Derris* and *Sarcolobus* covered the open space indicating that damage has already occurred for a long period.

From Sapuregel River to the eastern periphery of Segara Anakan, Category 5 of mangrove forest condition occurred. A smaller proportion was in Categories 3 and 4. *H. littoralis* and/or *S. hydrophyllacea* significantly constituted Category 5, probably because of its being a dryland (Table 4).

Mangrove condition in the accretion area was relatively good. Young plants of *Avicennia* and *Sonneratia* occurred. Meanwhile, plant density in the newly accreted land was very high.

Along the northeastern coastline of the lagoon, mangrove was also relatively good. Trees with a diameter greater than 10 cm were still available. Category 2 or 3 occurred. However, some parts of the land (Plots 28 and 29) were being converted to ricefields and coconut plantations.

Recently, a newly developed mangrove formation united Karang Anyar Islands in the south with Bugel village in the north (Fig. 3). This resulted from the high rate of sedimentation. By contrast, practically no mangrove forest was left except along the coastline and riverbanks.

STRESS FACTORS AND ISSUES

The three main factors affecting mangroves in Segara Anakan and the surrounding area are sedimentation, illegal harvesting and conversion to other uses. Water pollution poses no problem at present but may be an issue in the future. Tim Ekosistem Mangrove (TEM 1986) showed that minimum standards for water quality for marine organisms and human health were met. However, with plans to develop Cilacap into an industrial estate, pollution problems will arise. Thus, pollution monitoring should be conducted on a routine basis.

Sedimentation

Apart from their freshwater input, Citanduy and Cibeureum Rivers bring in an enormous quantity of suspended sediment. Napitupulu and Ramu (1982) estimated an average filling rate of 6.2 million m^3/year during 1971-1980. Land accretion increased from 17 m to 30 m/year. The highest rate, 75 m/year, was recorded for the period 1940-1946 (TEM 1986). According to Bird (1982), the rate of accretion in Segara Anakan was among the highest in the world. Napitupulu and Ramu (1982) asserted that unless filling is slowed, the lagoon will be silted in 10 years, leaving only tidal canals. Bird (1982) predicted that the lagoon will be entirely covered by mangroves by 2000. Rahardjo (1982) predicted that it will take only a few decades for that to happen.

From the standpoint of mangrove growth, silting of Segara Anakan could be considered beneficial since it provides new land. However, this may be on a short-term basis. The configuration of Segara Anakan will not allow an endless accretion process. In addition, the silting process will raise the forest floor higher and higher until the newly formed land emerges above sea level at high tide.

Illegal harvesting

The extent of the degradation of Segara Anakan's mangroves is such that it becomes impossible to maintain a sustainable production forest. Trees with a diameter greater than 10 cm are found only in the periphery of the lagoon. In the other areas, the mangroves consist of young trees and sprouts. Thus, no cutting of mangrove wood at Segara Anakan is currently allowed. In this way, a new generation of harvestable mangrove forests is expected to develop.

Experience has shown that regulations and laws are not enough to halt illegal wood cutting. The needs of the people seemed greater than the risks. Mangrove wood was harvested for personal and commercial use. To avoid confrontation with forest guards, cutting was often done at night.

Another mangrove product are nipa leaves. The demand for nipa thatches is high. Boatloads are collected every day. Soemodihardjo and Suroyo (in press) pointed out that the harvesting was so intensive that every nipa tree in the area has been left with only a few leaves. In such a state, they will not grow at normal rates. However, until now, there is no legal restriction for the harvesting of nipa leaves.

Conversion to other uses

Of all human interferences to the mangrove ecosystem, the most devastating is its conversion to other uses such as agriculture, brackishwater fishpond or human settlement. In Segara Anakan, the most prevalent conversion was to agriculture (ricefields and coconut groves). Attempts were made to open the swamp for shrimp culture, but it did not succeed. Abandoned shrimp ponds now lie in the vicinity of Klaces village, in the northern coast of Nusa Kambangan.

Nearly all mangrove lands to the west and north of Segara Anakan (Plots 1 to 27) were converted to ricefields, leaving only a narrow mangrove belt along the water's edge. Karang Anyar, referred to as Plot 8 in Fig. 1, was not exempted. Its interior part was and is still being converted to coconut groves and ricefields. To the east of the lagoon (Plots 28 and 29), conversion activities also took place.

In Nusa Kambangan, conversion activities occurred along the north coast. The narrow belt of coastal wetland was opened for agriculture. In 1982, the opened land constituted only a small patch in the vicinity of Klaces village. Now, it has spread to the west and far to the east. As the opening progresses, so does the development of new human settlement.

Legal status

The mangrove resources of Segara Anakan constitute an integral part of the coastal ecosystem. Therefore, their management should complement that of the whole system. However, such a holistic management approach is still not practised in Indonesia. Perhaps it is not so much of conflicting interests but more of the system. For example, there are at least four agencies sharing equal responsibility for the management of the Segara Anakan watershed, namely, the Department of Forestry for the mangrove, the Department of Agriculture for the fishery, the Department of Public Works for the hydrology and the Department of Communication for the waterways. An integrated management of the watershed would require the goodwill of all concerned so that work can proceed in a coordinated manner.

There are three conflicting opinions on the unauthorized opening of the mangrove forest. The land openers insist that what they have been doing is legal, with the assumption that the forest they have opened was originally newly established land formed by sedimentation. They further believe that newly formed lands are God-given and should be best utilized for the benefit of the landless farmers. Perum Perhutani, on the other hand, asserts that according to the existing regulation, any newly formed land on which vegetation has developed is public land under the jurisdiction of Perum Perhutani. However, the Land Use Service of the Department of Home Affairs claims that the utilization of newly formed land, even by Perum Perhutani, can not be done without the official consent of the Service. It should be noted that these land use discrepancies have, for the most part, been resolved through a new agreement among the agencies in a planning workshop held in early 1990.

LAND USE OPTIONS AND MANAGEMENT STRATEGY

Resources use and management planning must take into account development trends and prospects. Because of rapid changes in the physical environment, the existence of fish and mangroves is affected. Therefore, the physical changes in the Segara Anakan ecosystem should always be linked to its biological resources.

Trends and prospects

There are indications that Segara Anakan will eventually disappear in its present state. The silting process will eventually allow mangroves to cover the area. As the forest floor gets higher and drier, the mangrove vegetation will die and be replaced by dryland species.

If the lagoon disappears, so will the nursery grounds for shrimp and fish. It is difficult to say how much this would affect the offshore fisheries. Traditional fishermen will lose their livelihood. The development of Cilacap into an industrial estate will exert some influence on the Segara Anakan ecosystem. Apart from the possible hazards to be brought by the estate's waste products, there will be demands for space.

These are the general development trends and prospects for Segara Anakan. The question is whether the process should be hastened or delayed. Napitupulu and Ramu (1982) believe that siltation will make the complete preservation of Segara Anakan's mangroves a diminishing return. Thus, speeding up the process will minimize the transition period.

Suggested land use zoning

Fig. 4 represents the suggested zoning pattern of Segara Anakan and the surrounding area to accommodate the existing needs. Zoning was made on the following bases: geomorphological setting and location, apparent transformation trends, current utilization patterns, existing and predicted future needs, variability of resource components and security and maintenance aspects.

The mangrove land of Segara Anakan and Cilacap shall be divided into five zones: industrial zone (Zone I), utility zone (Zone II), conservation zone (Zone III), production forest zone (Zone IV) and agriculture zone (Zone V).

There shall also be a buffer zone that would separate the mangrove land from the dryland along the northern border.

Industrial Zone. This constitutes an integral part of Cilacap town with Donan River as the western borderline. This would limit the spread of the possible negative impact and allow the Segara Anakan area to develop according to the targeted land use scheme.

Utility Zone. This covers the area between Donan and Sapuregel Rivers, which has been subjected to relatively intensive human activities. The high grounds are used for human settlement, ricefields and dry crops. Meantime, Perhutani is developing plantations of dryland species, i.e., teak and mahogany. Poor mangrove vegetation occupies the lowland, a swampy area. But in time, the products should be able to provide fuelwood and housing material. This utility zone is also appropriate for aquaculture. Its close proximity to Cilacap is beneficial since this provides security and easy access to marketing and facilitates maintenance.

Conservation Zone. This includes the area bordered by the Sapuregel River in the east, Kembang Kuning River in the south and Udjung Alang River in the north. This area is nonaccreted, hence, is more or less stable. Nearly all mangrove components and microhabitats are available here. Although signs of human interference are common, no conversion to other uses was made. This area should also be feasible to manage since it is easily accessible from Cilacap, and the canal network serves as a waterway for inspection.

Production Forest Zone. This zone covers the mangrove area along the east and north coasts of the lagoon. Cibeureum River is the western borderline. This zone also includes all the islands in the lagoon; in effect, it covers the accreted land. A 200-m wide strip of mangrove along the lagoon is designated as a mangrove greenbelt that should be kept intact.

The term *production forest* implies that mangrove products can be harvested here on sustainable and commercial bases. The determining factors for the selection of this area as the production forest are the occurrence of good natural regeneration and the expanding mangrove land due to accretion. Invasion of accreted land is generally by seedlings of *Avicennia* and/or *Sonneratia*, which are not in much demand by the local population. The favored species are *Rhizophora* for fuelwood and *Bruguiera* for housing material.

Agricultural Zone. This zone covers the land area west of the lagoon and the Cibeureum River. Nearly all the lands here have been transformed into ricefields except a narrow strip along the coast and the riverbanks. At the transition area from mangrove land to dryland along the northern fringe, there are sparse occurrences of bushy shrubs, small trees or undergrowths like *Derris, Acanthus* or *Acrostichum*. In some areas, there is *N. fruticans*. In the zonation scheme, this transition land along the northern borderline will be considered a buffer zone where the traditional utilization of mangrove resources will be allowed.

Alternative uses and strategy

The eventual drying of Segara Anakan will require an alternative management strategy. Closely linked with this is that of employment for those who will have to change jobs. The land use zoning is one strategy where alternative resource uses can be developed.

Most researchers are of the opinion that the lagoon fisheries have passed the maximum sustainable yield (MSY). Capture fisheries in the lagoon should thus be kept at a minimum level. It is also unlikely that the development of the fisheries will generate significant economic reforms. In any case, the most appropriate strategy is to maintain the function of the lagoon as a nursery ground so that the feasible alternative would be offshore fisheries. These are currently below the MSY level.

Another alternative to be developed is aquaculture. Brackishwater fishponds are considered uneconomically feasible. High porosity and unstable soil are two unfavorable factors (ET 1984). Thus, aquaculture should be focused on cage and pen systems. Recommended for cultivation are shrimp, mangrove crab *(Scylla serrata)* and *kerapu (Epinephelus tauvina)*. Culture of mollusks such as oysters, green mussels and cockles is also worth exploring.

In the utility zone, the mangrove plantation can be integrated with brackishwater fishponds. This combined system is known in Indonesia as *tambak tumpang sari* or the forest canal pond system (Soemodihardjo 1987). In essence, it consists of a series of mangrove plantation plots, each located in the middle of a large brackishwater pond. When the mangrove trees grow big, the pond appears like a canal encircling a patch of mangrove forest, hence, the English term for the system. The pond or canal is used to grow fish or shrimp, while the bund is used to grow dryland plant species for fuelwood like *Leucaena, Acacia* and *Hibiscus*. The system can be managed by the local people who obtain their income from the fish culture.

In brief, the development strategy for Segara Anakan is:

1. to maintain the ecological function of the lagoon as a nursery ground by limiting its fisheries, rehabilitating degraded mangroves, limiting the number of fishing gear and fishermen and introducing selective fishing gear regulations;
2. to provide support and facilities for local fishermen to upgrade themselves into offshore fishermen;
3. to develop an appropriate aquaculture technology for the local fishermen and assist in its implementation;
4. to develop infrastructure and facilities for open nature tourism;
5. to assist the local population in meeting the need for fuelwood by developing a plantation of fast-growing trees like *lamtoro, caliandra* and *Acacia*; and
6. to develop alternative employment opportunities for the local population in anticipation of the changing environment.

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Table 1. Species of mangroves and associated plants from Segara Anakan-Cilacap. Nomenclature follows that of Backer and van den Brink (1968) and Steenis (1978).

Apocynaceae	Sonneratiaceae
Cerbera manghas L.	*Sonneratia alba* Smith
C. odollam Gaertn	*S. griffithii* Kurz.
Arecaceae	*S. caseolaris* (L.) Engl.
Nypa fruticans Wurmb.	Sterculiaceae
Livistona rotundifolia (Lmk.) Mart.	*Heritiera littoralis* (Dryand.) Ait.
Bignoniaceae	Verbenaceae
Dolichandrone spathacea Schum.	*Avicennia alba* Bl.
Combretaceae	*A. marina* Vurh.
Lumnitzera racemosa Willd.	*A. officinalis* L.
Convolvulaceae	Acanthaceae
Argyreia mollis (Burm.f.) Choisy.	*Acanthus ilicifolius* L.
Euphorbiaceae	Asteraceae
Breynia cernua (Poir.) M.A.	*Eupatorium odoratum* L.
Excoecaria agallocha L.	Cyperaceae
Glochidion littorale Blume.	*Cyperus difformis* L.
Fabaceae	*C. digitatus* L.
Cynometra ramiflora L.	*C. halpan* L.
Dalbergia junghuhnii Bth.	*Cyperus* sp.
Lecythidaceae	*Eleucharis* sp.
Barringtonia racemosa (L.) Blwc.ex DC.	*Fimbristylis annua* R&S.
Leguminosae	*F. globulosa* (Retz.) Kunth.
Derris trifoliata Laur.	Gramineae
Intsia bijuga (Colerb.) O.Ktzo	*Echinochloa crusgalli* (L.) Baur.
Lythraceae	*E. colomon* (L.) Link.
Pemphis acidula Forst	*Imperata cylindrica* Beauv.
Malvaceae	*Paspalum vaginatum* Swartz.
Hibiscus tiliaceus L.	*Phragmites karka* Trin.
Thespesia populnea (L.) Sol. ex Corr.	*Saccharum spontaneum* L.
Meliaceae	Melastomataceae
Xylocarpus granatum Koen	*Memecylon edule* Roxb.
X. moluccensis Roem.	Moraceae
Myrsinaceae	*Poikilospermum suaveolens* (Bl.)
Aegiceras corniculatum (L.) Blanco	Orchidaceae
Myrtaceae	*Trixspermum raciborshii* JJS.
Eugeina sp.	Pittosporaceae
Syzygium sp.	*Pittosporum ferruginium* W.Ait.
Rhizophoraceae	Pteridaceae
Bruguiera cylindrica (L.) Bl.	*Acrostichum aureum* L.
B. gymnorrhiza (L.) Lamk.	*A. speciosum* Willd.
B. parviflora (Roxb.) W.&A. ex Griff.	Sapindaceae
B. sexangula Poir.	*Mischocarpus sundaicus* Blume
Ceriops decandra Griff.	Schizaeaceae
C. tagal Perr.	*Lygodium flexuosum* (L.) Sw.
Rhizophora apiculata L.	Asclepiadaceae
R. mucronata Lam	*Finlaysonia maritima* (Bl.) Backer.
R. stylosa Griff.	*Hoya browniana* Keds.
Rubiaceae	*Sarcolobus globosus* Wall.
Scyphiphora hydrophyllacea Gaertn.	*S. banksii* R&S.
Rutaceae	Compositae
Merope angulata (Willd.) Swingle.	*Wedelia biflora* (L.) DC.
	Flagellariaceae
	Flagellaria indica L.

Sources: Sunaryo(1982); ET(1984); Setyono(1984); and the present study.

Table 2. Species composition and importance values of mangroves in Plots 44, 46 and 47.

Species/plot	Importance values 44	46	47
Rhizophora apiculata	9.88	131.72[a]	46.11
R. mucronata	64.39	0	0
Sonneratia alba	0	31.27	0
Bruguiera gymnorrhiza	22.77	40.79	89.56[a]
Ceriops tagal	0	0	23.61
Aegiceras corniculatum	198.61[a]	96.22	0
Scyphiphora hydrophyllacea	0	0	78.73
Nypa fruticans	4.99	0	61.91

[a]Dominant species.

Table 3. Average number of trees, saplings and tree stumps per hectare in the plots sampled.

Plot	Trees	Saplings	Tree stumps	Illegal cuttings (%)
32	706	2,053	160	5.48
34	-	2,000	356	15.11
35	-	3,000	990	24.81
36	-	4,080	600	12.80
40	220	2,480	660	23.90
41	126	2,176	1,243	35.10
42	-	711	489	40.75
43	-	640	-	-
44	-	9,879	4,514	31.36
45	-	543	93	14.60
46	-	1,050	75	6.70
49	-	967	317	24.69
50	-	743	27	3.29
51	-	962	175	15.39
55	-	800	350	30.43

Table 4. Species composition and community indices (%) of the mangrove community in Plot 41.

Species	Relative dominance	Relative density	Relative frequency	Relative value
Heritiera littoralis	81.56	73.81	56.25	211.62
Aegiceras corniculatum	0.29	2.38	6.25	8.92
Xylocarpus moluccensis	8.17	11.90	18.75	38.82
X. granatum	5.90	7.15	12.50	25.55
Scyphyphora hydrophyllacea	4.08	4.76	6.25	15.09

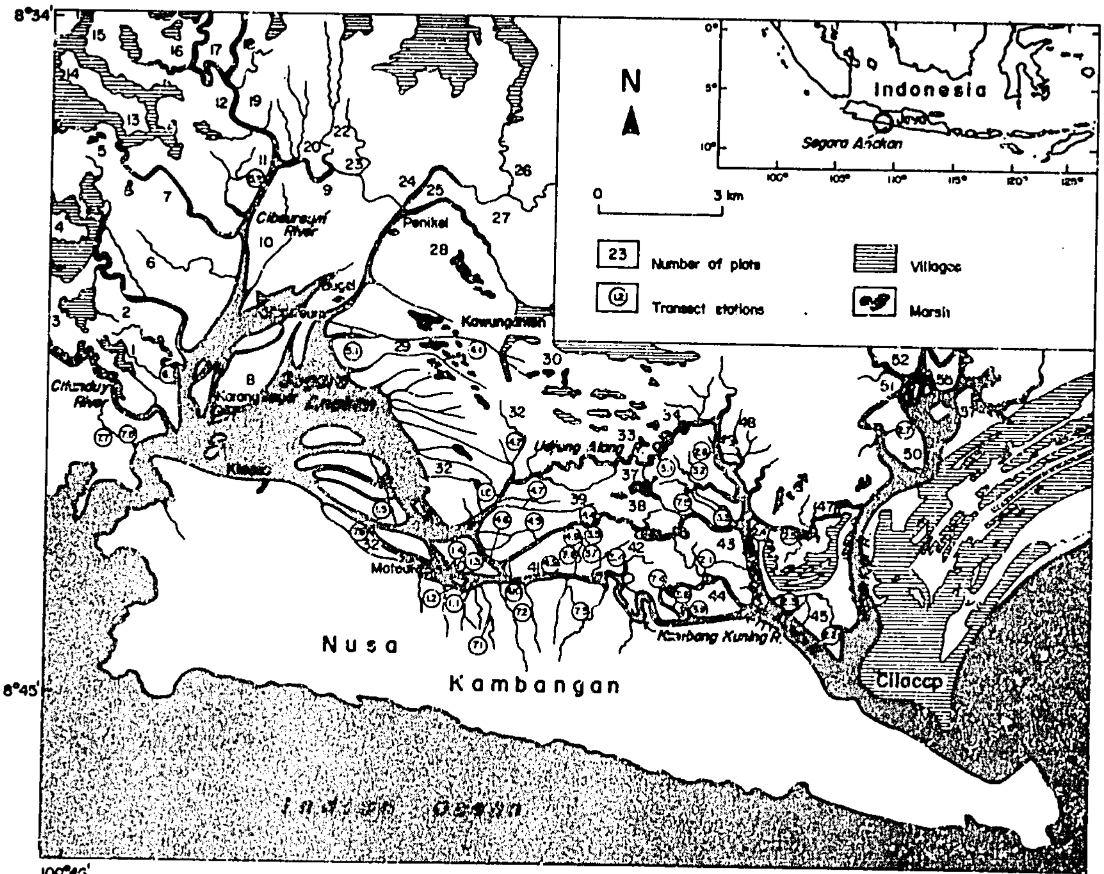

Fig. 1. Segara Anakan and transect stations.

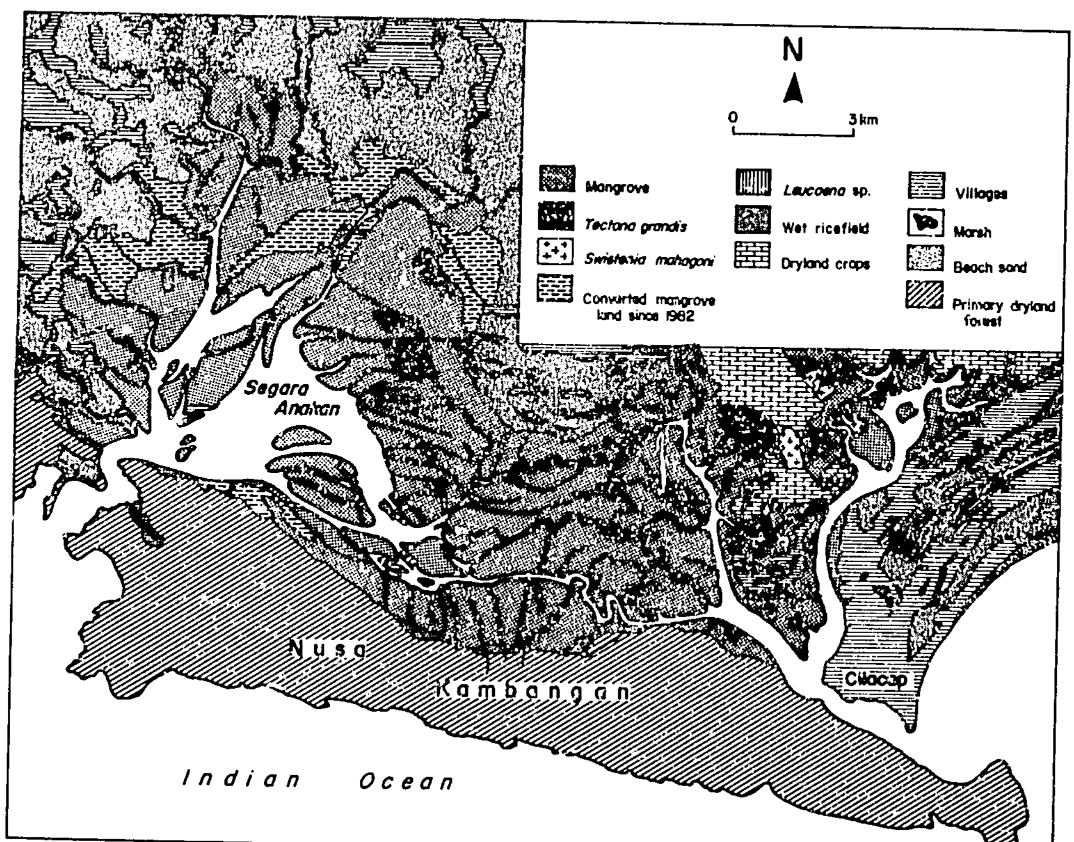

Fig. 2. Segara Anakan mangrove land of 1988 (stippled) and conversions made during the period 1982-1988.

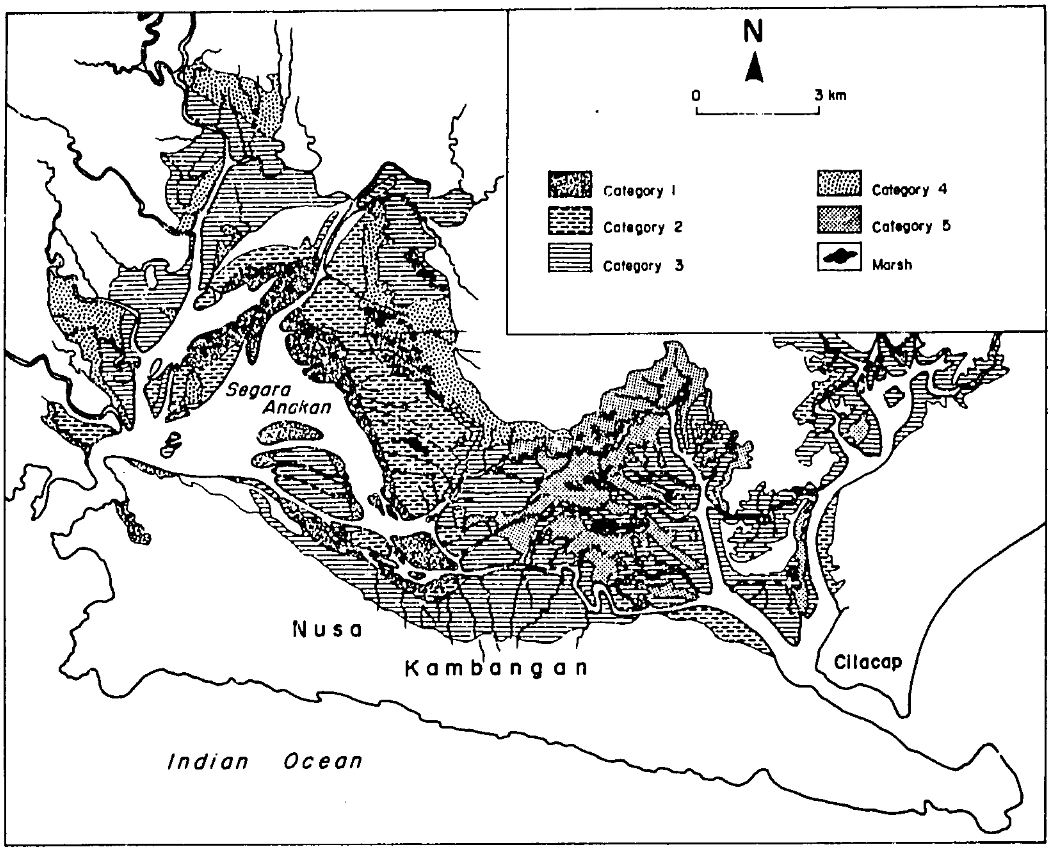

Fig. 3. Classification of Segara Anakan mangroves according to their prevailing forest conditions.

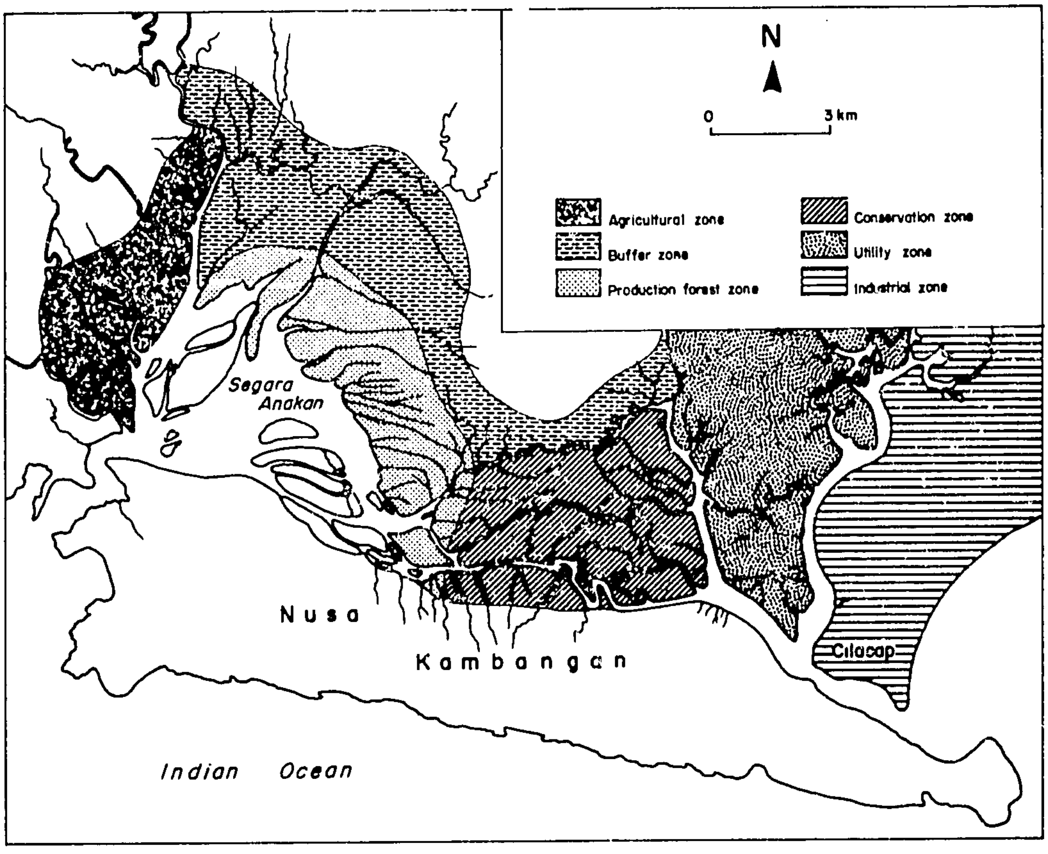

Fig. 4. Suggested land use zonation for the Segara Anakan mangrove areas.

Mangrove deforestation and uses in Ban Don Bay, Thailand

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ABSTRACT

Ban Don Bay is a biologically productive area undergoing rapid development of various human activities. It is estimated that during the past ten years more than 60% of the total mangrove forests along the coast of the bay have been converted for other land uses (Aksornkoae et al. 1988): 5,331 and 2,723 ha have been converted to shrimp farms and agricultural lands, respectively, leaving only 4,160 ha of mangrove forests. The continuous exploitation of mangrove forests at Ban Don Bay has caused various problems that need immediate attention by concerned agencies if future beneficial uses are to be sustained. About 160 questionnaires were given out in three communities. The survey showed that the respondents' knowledge and attitude toward mangrove forest conservation and management were far from satisfactory.

Mangrove forests have been cleared in Types 1 and 2 communities for aquaculture and fisheries-related uses. In Type 3 communities, charcoal production and firewood activities were the main causes of the destruction of mangrove forests while waiting for the government approval to clear them for shrimp farms. Some respondents also cut mangrove trees for house construction. It was recommended that public and private sectors work together to maintain and manage the remaining mangroves and to increase the forested area through replanting. A management plan also needs public awareness, public participation, public relations and support programs.

INTRODUCTION

The rate of uncontrolled forest destruction along the coast of Ban Don Bay is alarming. More than 8,000 ha have been cleared during the past decade for economic activities. Mangrove forest destruction and pollution along the coast of Ban Don Bay threaten the survival of mangrove species such as *Rhizophora* spp. and marine animals such as *Penaeus indicus* or *Penaeus merguiensis* (banana shrimp) and *Penaeus monodon* (jumbo tiger shrimp).

This paper highlights the findings of a field study on the socioeconomic aspects of mangrove deforestation and uses in Ban Don Bay. The data were obtained in 1987 and 1988. The current uses of mangrove forests by communities along the coast of Ban Don Bay; the knowledge, attitude and behavior of local people toward mangrove forests; and their receptivity toward policies and management plans laid down by concerned agencies are assessed and evaluated.

METHODS

Villages and target groups

Villagers from three communities with different degrees of mangrove forest destruction were selected as target groups for the study. They are:

Type 1: villagers who lived where most mangrove forests have been destroyed by human activities (Amphoe Don Sak);
Type 2: villagers who lived where some mangrove forests have been destroyed by human activities (Amphoe Muang); and
Type 3: villagers who lived where abundant mangrove forests remain (Amphoe Chaiya).

Sampling

Questionnaire surveys, focus groups and key-informant interviews were used for gathering sociocultural data for mangrove deforestation and uses in the selected communities.

Purposive sampling technique was used to identify target groups in the selected communities. The study adopted a simple near-random sampling method in selecting heads of households as respondents. Altogether, 157 people living in the three selected communities were interviewed. The respective sample sizes of the three target communities are shown in Table 1.

In each type of the target communities, a focus group, consisting of four men and four women, was selected and interviewed for in-depth information on mangrove deforestation and uses for qualitative analysis. The selection criteria of the focus group were: nonmigrants, local people; those between 45-65 years old who have intensive and long experience in shrimp farming, or fishcage culture or other fisheries activities, or charcoal business; and volunteers. Key informants were village or subdistrict heads.

The collected data under different groups of the questionnaires were expressed, where appropriate, in total score, subject to a one-way analysis of their variance or, in terms of percentage.

RESULTS AND DISCUSSIONS

Figs. 1 to 4 depict the location of the communities and their existing land uses. Of the existing land uses at the different districts in Ban Don Bay, mangrove forests have a total area of 4,160 ha; aquaculture (shrimp ponds), 5,331 ha; and agriculture, 2,723 ha (Table 2).

Demography

The proportion of immigrants increased with the level of development in the selected community. The respective percentage of immigrants in Types 1, 2 and 3 communities were found to be 60.8, 46.4 and 26.0. The immigrants moved into the Types 1, 2 and 3 communities for the past 21.1, 22.0 and 15.5 years, respectively. The great majority of the immigrants came to these communities because of job opportunities (Table 3).

During the sample year, the mobility of the population was low. The percentages of nonimmigrants were 94.0, 98.2 and 96.0 and nonmigrants, 88.2, 94.6, 98.0 for Types 1, 2 and 3 communities, respectively.

Occupation

Previous immigrants were engaged in the fisheries-related business with 54.8, 84.6 and 69.2% of the respondents from Types 1, 2 and 3 communities, respectively (Table 4).

At present, the majority of the villagers in Types 1 and 3 communities (58.8% and 72.0%, respectively) are engaged in the fisheries-related business, whereas in Type 2 community, the main occupation is shellfish culture (73.2%).

The shrimp farms in Types 1 and 2 communities are the largest single cause of mangrove destruction. In the Type 3 community, where there are still mangrove forests, 14.0% of the villagers earn their living making charcoal.

Landownership and land uses

Types 1, 2 and 3 respondents, on the average, owned 8.6, 6.4 and 6.0 rai (1 ha = 6.25 rai) of land, respectively. The great majority of the respondents (94.1%, 92.9% and 90.9% of Types 1, 2 and 3, respectively) would not think of changing their land uses in the coming three years. In addition, about three quarters (78.4, 75.0 and 74.0%) of the respondents of the three communities would not think of buying additional land. Other details on the potential land use patterns are shown in Table 5.

Income, expenditure and debt

Table 6 gives the income, expenditure and debt of the respondents. Those in Types 1 and 2 communities earned almost four to five times of the annual income of Type 3 respondents. However, those who earned much more also spent more than half of their annual incomes on investments in careers and payment of debts, (i.e., Types 1 and 2 respondents spent 148,045 and 106,350 baht, respectively).

Governmental services

In general, majority of the respondents were satisfied with the governmental services in their respective communities (Table 7). More than 98% were satisfied with the government's schooling services, 82.4-100% with the local administration, 62.5-74.5% with police services and safety, and 78-90.2% with health services.

Needs

The needs expressed by the respondents in the three types of communities vary (Table 8). For Type 1 respondents, the needs were water supply

(27.5%) and price control on goods (19.6%). About 34.0% of Type 2 respondents needed electricity. However, Type 3 respondents (44.0%) needed the government to provide them information and training, and to promote and develop their occupations, while 36.0% expected the government to grant them legal landownership in their community. Other details on expressed needs are shown in Table 8.

Knowledge on conservation and management

The local people's knowledge of mangrove forests was assessed by five groups of questions, namely, ecosystems, diversity and uses, living organisms in these forests, land use zones of these forests and governmental regulations and laws related to their management and shrimp farming systems. Table 9 shows the details.

The respondents of the three community types had a very low score in general knowledge of mangrove forests. The total average score was 35.3%. Type 1 respondents had a slightly higher score (39.3%) because they had experienced large-scale mangrove forest destruction in their community due to economic and human activities.

Type 3 respondents had the highest score (59.3%) in naming 15 species of mangrove trees and their respective uses. Mangrove forests in Types 1 and 2 communities had been extensively destroyed, so there is no charcoal-making business there, whereas in the Type 3 community, charcoal-making is still an occupation of some residents. As fisheries is the main occupation in the three types of communities, the respondents scored 90.0%, 83.3% and 81.7%, respectively, in naming the living aquatic animals in the mangrove forest.

About 49.0%, 44.6% and 62.0% of the Types 1, 2 and 3 villagers, respectively, gave the proper width of greenbelt or buffer zone of the mangrove forest. Type 3 had the highest percentage because the respondents were interested in this issue; many were awaiting the government's approval of shrimp farming in economic zone A of the existing mangrove forests. However, only a few respondents could define and identify the conservation zone, economic zone A and economic zone B of the mangrove forests. This is because the regulations for mangrove forest classification were proclaimed by the government only on 29 July 1987.

Also, only a low percentage (below 50%) of the respondents had knowledge of extensive, semiextensive and intensive shrimp farming systems.

In the survey to assess the villagers' knowledge of mangrove laws and regulations, 23.5%, 19.6% and 38.0% of Types 1, 2 and 3 respondents, respectively, gave the correct answers. Type 3 respondents knew more about the laws and regulations because their village head has been active in providing them official news and information; some said that the local government officers even visited them.

The reasons given by respondents who did not know about mangrove laws and regulations were:

1. the local government officers had not disseminated the information to them;
2. they were not interested in the laws and regulations because these are difficult to enforce; and
3. they had no time to seek such information.

Attitude toward mangrove resources

Respondents of Types 1, 2 and 3 communities scored 76.0%, 73.0% and 66.7%, respectively, in evaluating their attitude toward mangrove forest conservation. Type 1 respondents scored the highest because they had a bad experience with mangrove forest destruction and seemed to realize the importance of conservation. In addition, 76.5%, 73.2% and 84.0% of Types 1, 2 and 3 respondents, respectively, had the opinion that the abundance of mangrove forests in their communities would diminish in the next three years.

The majority of respondents thought that shrimp farming would increase in the next three years.

On the other hand, 70% of the Type 3 respondents believed that the price of shrimp would increase in the next three years, while 54.9% and 51.8% of Types 1 and 2 respondents, respectively, thought so. Around half (54.0%) of Type 3 respondents wanted to shift to shrimp farming to improve their incomes. Types 1 and 2 respondents rejected shrimp farming because of limited mangrove lands and high investment cost. It is surprising to learn, however, that no respondent rejected shrimp farming because of mangrove forest conservation.

Type 1 respondents, who had a well-developed shrimp farming business, and Type 3 respondents thought that fishcage culture would increase in the future. The opposite opinion was given by Type 2 respondents who were not sure that the prices of fish would increase in the coming years.

Most respondents thought that the productivity of fisheries would decrease and that the prices of aquatic animals would increase (Table 10).

Behavior toward mangrove forest destruction and uses

Table 11 gives the behavior of the local communities toward mangrove forest destruction and uses. Many respondents said that they used mangrove trees to construct houses, dikes, resting huts and water drainage gates. A majority said that they did not use the trees for fisheries practices. Use of mangrove trees for charcoal-making was not common except in the Type 3 community.

CONCLUSION: IMPLICATIONS FOR MANAGEMENT

The survey findings on the three types of communities in Ban Don Bay clearly indicate that the main causes of mangrove forest destruction in the bay are human activities: aquaculture, charcoal-making and house construction. If the destruction is allowed to continue, and if no serious effort is taken to conserve and replant the mangrove trees, they will not be there for long.

Unfortunately, respondents of the Types 1 and 2 communities did not realize the value of mangrove forests. Type 3 respondents may have this thinking, too, in the near future.

The findings show that the knowledge, attitudes and behavior of the respondents toward conservation and management are far from satisfactory. Public awareness, public participation and public relations need to be highlighted in the communities; tree planting should also be done. The government should also effectively implement the laws and regulations laid down by the Forestry Department. Support from both public and private sectors is also essential.

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Table 1. Sample sizes of the three target groups.

Types of communities	Villages	No. of respondents
1	Mu 7, Ban Pak Don Sak	51
2	Mu 2, Ban Bang Kung	56
	Mu 3, Ban Santisuk	
3	Mu 4, Ban Nua Nam	50
Total		157

Table 2. Existing mangrove forests, aquaculture and agriculture areas (in ha) in different districts at Ban Don Bay.

Districts	Existing mangrove forests	Aquaculture, shrimp ponds	Agriculture areas
Chaiya	1,784	103	566
Tha Chang	404	811	150
Phun Phin	411	-	206
Muang	508	-	390
Kanchanadit	836	2,213	768
Don Sak	217	2,204	643
Total	4,160	5,331	2,723

Source: Aksornkoae et al. 1988.

Table 3. Demography of the three communities.

Description	1	2	3
1. Nonimmigrants (%)	39.2	53.6	74.0
2. Immigrants (%)	60.8	46.4	26.0
3. Years of immigration	21.1	22.0	15.5
4. Nonimmigrants during the past year (%)	94.0	98.2	96.0
5. Nonmigrants during the past year (%)	88.2	94.6	98.0
6. Immigration due to job opportunity (%)	77.4	73.1	53.9

Table 4. Occupations of the three communities (%).

Description	1	2	3
Occupations after immigration			
Fisheries	54.8	84.6	69.2
Agriculture	3.2	-	-
Trading	16.1	7.7	-
Employee	19.4	7.7	7.7
Unemployed	6.5	-	-
Others	-	-	23.1
Current occupations			
Shrimp farms	5.9	7.1	-
Fishcage culture	7.8	-	-
Shellfish culture	-	73.2	-
Fisheries	58.8	-	72.0
Charcoal making	-	-	14.0
Crab peeling	7.8	-	2.0
Trading	5.9	8.9	2.0
Gill net repairing	13.7	8.9	8.0
Coconut plantations	-	1.8	2.0

Table 5. Landownership and land uses in the three communities (%).

Description	1	2	3
Average landownership (rai)	8.6	6.4	6.0
Thinking of changing land uses			
Change to shrimp farms	-	3.6	-
Change to agriculture	-	-	4.0
Building new houses	2.0	-	2.0
No idea	3.9	3.6	4.0
No change	94.1	92.9	90.0
Thinking of buying additional land (%)	21.6	25.0	26.0

Table 6. Income, expenditure and debt of the three communities. Figures are given in baht.[a]

Description	1	2	3
Average income per year	261,910	301,288	57,306
Average expenditure per year	169,331	121,144	21,105
Food	32,520	29,200	12,632
Drinking water	1,793	1,140	-
Domestic water	2,215	1,513	-
Investment in career	127,777	84,095	6,104
Health	1,709	1,314	1,069
Fuel	3,817	3,882	1,300
Average debt in 1987	85,018	63,920	17,982
Debt (in %)			
No debt	64.7	55.4	44.0
For additional occupational investment	35.3	44.6	50.0
Others	-	-	6.0

[a]March 1990: 25.83 baht = US$1.00

Table 7. Opinion on governmental services by the three communities (%).

Description	1	2	3
Health services			
Satisfied	90.2	78.6	78.0
Dissatisfied	5.9	8.9	14.0
Not sure	3.9	12.5	8.0
Police services and safety			
Satisfied	74.5	62.5	66.0
Dissatisfied	17.6	17.9	20.0
Not sure	7.8	19.6	14.0
Local administration			
Satisfied	82.4	85.7	100.0
Dissatisfied	7.8	8.9	-
Not sure	9.8	5.4	-
Schooling services			
Satisfied	98.0	98.2	100.0
Dissatisfied	2.0	1.8	-

Table 8. Expressed needs of the three communities (%).

Description	1	2	3
For government to provide training, information and to promote their occupations	11.8	8.9	44.0
For price control on goods	19.6	8.9	8.0
For water supplies	27.5	5.4	-
For roads	3.9	1.8	-
For electricity	-	33.9	-
For legal landownership	5.9	7.1	36.0
For equality	3.9	3.6	2.0
For loan	11.8	5.4	8.0
No answer	1.8	-	-
No need	13.8	25.0	2.0

Table 9. Knowledge possessed by the three communities on mangrove forest conservation and management (%).

Description	1	2	3
1. Ecosystem of mangrove forest	39.3	30.7	36.7
2. Names of 15 species of mangrove trees and their respective uses	52.0	42.7	59.3
3. Names of living aquatic animals in mangrove forest	90.0	83.3	81.7
4. Greenbelt or buffer zone of mangrove forest	49.0	44.6	62.0
5. Definition of conservation zone, economic zone A/B of mangrove forest	10.0	10.0	20.0
6. Correct identification of conservation zone, economic zone A/B of mangrove forest	2.0	5.4	20.0
7. Knowledge of extensive shrimp farming,	47.1	26.8	32.9
semiextensive shrimp farming,	39.2	26.8	36.0
intensive shrimp farming	23.5	17.9	32.0
8. Mangrove laws and regulations	23.5	19.6	38.0

Table 10. Attitudes possessed by the three communities toward mangrove resources (%).

Description	1	2	3
1. Positive attitude toward mangrove conservation	76.0	73.0	66.7
2. Opinion that the diversity of mangroves will diminish in the next three years	76.5	73.0	84.0
3. Opinion that shrimp farming will increase in the next three years	64.7	76.8	76.0
4. Opinion that the market price of shrimp will increase in the next three years	54.9	51.8	70.0
5. Reasons for accepting or rejecting shrimp farming			
- Accepting because of increased income	29.4	28.6	54.0
- Rejecting because of limited mangrove land available	23.5	16.1	6.0
- Rejecting because of no loan and high investment cost	25.5	16.1	4.0
6. Opinion on fishcage culture in the next three years			
- Will increase	70.6	30.4	50.0
- Not sure about the trend	23.5	57.1	30.0
7. Opinion on market price in the next three years			
- Will increase	60.8	28.6	62.0
- Not sure about the trend	37.2	66.0	32.0
8. Reasons for accepting or rejecting fishcage culture			
- Accepting because of increased income	19.6	7.1	8.0
- Accepting because natural living aquatic animals are decreasing		21.4	2.0
- Rejecting because lands are hard to acquire	15.7	8.9	4.0
- Rejecting because of no loan and high investment cost	21.6	19.9	22.0
- No opinion	31.4	28.7	30.0
9. Opinion that the fisheries productivity will decrease in the next three years	62.7	73.2	92.0
10. Opinion that the market price of living aquatic animals will increase	54.9	62.5	54.0
11. Accepting fisheries because they are their main occupation	47.1	50.0	46.0

Table 11. Behavior of the three communities toward mangrove forest destruction and uses (%).

Description	1	2	3
Uses			
1. In constructing their houses	33.3	19.6	38.0
2. In constructing dikes, huts and gates in shrimp farms			
Do not own a shrimp farm	94.1	91.1	100.0
Use some	4.1	5.3	-
Do not use	1.8	3.6	-
3. Fisheries-related business			
Not involved in such a business	35.3	19.6	28.0
Use some	2.0	5.4	24.0
Do not use	62.7	75.0	48.0
Destruction			
4. For charcoal-making	5.9	5.5	50.0
5. For cutting firewood	4.0	3.6	6.0

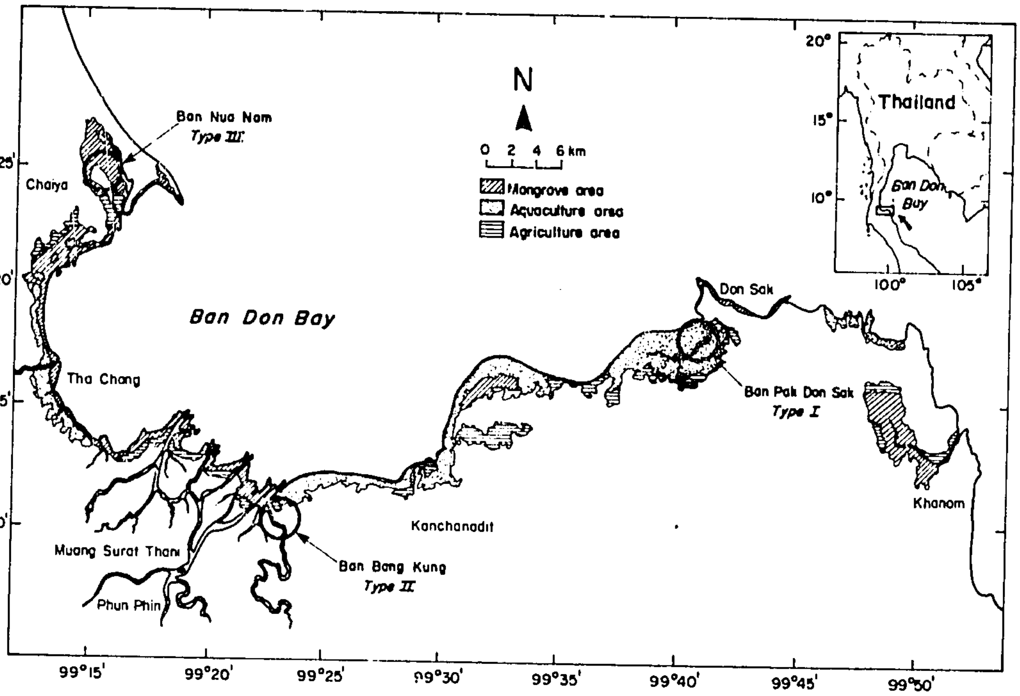

Fig. 1. Locations of the three selected communities and their existing land uses.

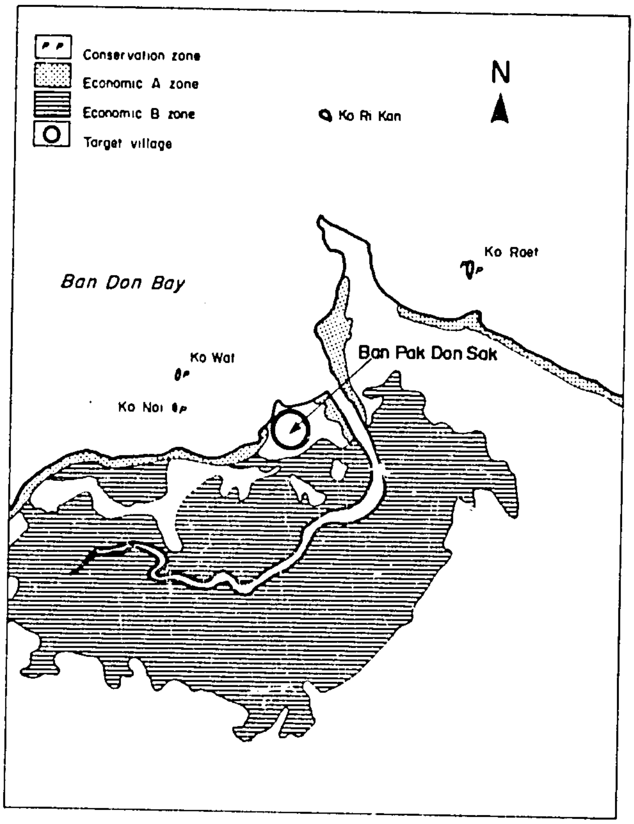

Fig. 2. Land uses at Ban Pak Don Sak, Amphoe Don Sak (Type 1 communities).

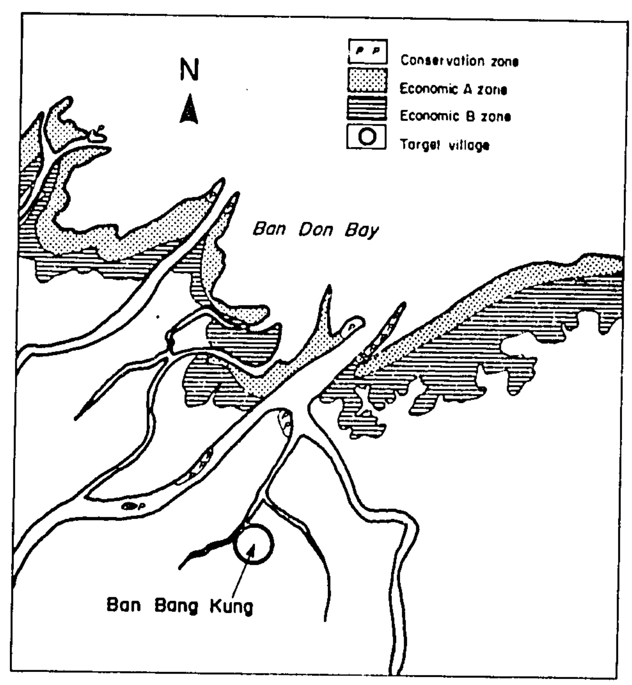

Fig. 3. Land uses at Ban Bang Kung, Amphoe Muang (Type 2 communities).

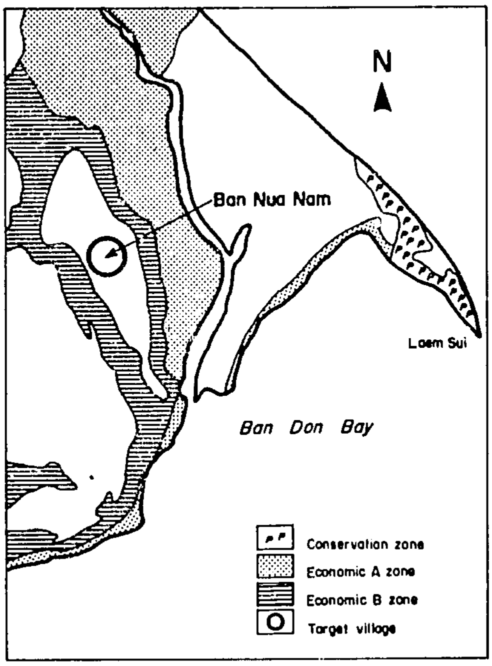

Fig. 4. Land uses at Ban Nua Nam, Amphoe Chaiya (Type 3 communities).

Session IIB
Socioeconomics of Coastal Resources and Communities

Municipal fishermen as research partners

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ABSTRACT

This paper documents the process of a one-year data collection for the daily recording of cost and return and weekly recording of household expenditures using participatory research. The participating 60 fishermen not only acted as data suppliers but also as actual partners in the research process. This paper also includes highlights of a workshop conducted with the fishermen and documents their full participation from the selection of topics, decisionmaking activities up to the formulation of action plans.

INTRODUCTION

In recent years, the majority of studies done in the fields of education and development followed traditional research methods like the survey. The questions posed appear to measure the poverty that people face and nothing else. Hence, the people's indifference to research.

The situation, posing a challenge to social scientists, led to the emergence of an action type of research that integrates theory and practice. Referred to as participatory research, it begins where research ceases to be a one-shot affair. Rather, it initiates a relationship that continues beyond the completion of a report. Data collection is not a hurried answer-oriented encounter. Rather, it follows a "question-answer-action-question" continuum that makes the research a learning process for the investigator and the people being studied. Collectively, the data are discussed and ultimately utilized for organized action.

The framework of participatory research guided the daily record-keeping of cost and return/weekly recording of household expenditures. Its primary concern was to establish an accurate income of the fishermen vis-à-vis their fishing expenditures. It investigated the seasonality of the fishing activities and the volumes and values of production. Likewise, it looked into the distribution of benefits from the major fishing activities, the earnings of the crew and owners, employees and employers, returns of investment of the owners and, estimates of pure profits.

Three major factors helped to obtain an accurate picture of the living conditions of the fishermen. First, the recording was done for one year because fishing is a year-round activity. This time frame sufficiently noted the lowest and highest incomes and expenses of the fishermen depending on the season. Second, the gear used by the different groups of fishermen greatly determined the volume and value of their catch. Third, the location of the fishing areas was also noted.

The significance of the data as input to the formulation of the proposed management plan led to the adoption of the participatory research framework. Using this type of approach, the fishermen were not mere subjects of development programs or management plans but active partners in the endeavor. The focus of this paper is the research process.

METHODS, PROCESS AND RESULTS

The study period was September 1986-August 1988. The first three months were devoted to the selection of the area and respondents. In November 1986, 60 fishermen in six communities in Pangasinan and La Union were selected.

The staff and the fishermen-cooperators consulted each other throughout the research process. This interaction was facilitated by the mutual acceptance and respect of each other's knowledge and experiences.

Personal relationships were thus developed between the staff and the fishermen. The integration entailed some difficult adjustments on the part of the researchers. In some cases, they slept on benches or shared a small one-room dwelling with the family. Constant communication with the community, in general, and the fishermen, in particular, created a dimension of involvement between the researchers and community members.

Dialogue and small group discussions with the fishermen led to "extra" tasks for the researchers. A case in point is when the cooperators initiated the formation of a fishermen's organization in their respective localities. Informal consultation was conducted every time the researchers were in the area. Organizational matters were the usual discussion. The assistance of the staff was requested particularly in giving out leadership and organizational trainings. In two research sites, local fishermen's organizations were formed as a direct result of such endeavors.

This type of involvement manifests the willingness of the people to participate. It became a step towards the realization of their capability for self-reliance and better living conditions. In Alaminos, for instance, the fishermen's organization (although formed even before the project) is conducting several socioeconomic and livelihood projects on artificial reef construction, basket weaving, shellcraft and crocheting.

For the most part, the fishermen religiously fulfilled their commitment to the project by recording daily. When problems arose, these were discussed openly and without hesitation. Suggestions flowed from the discussions. Inevitably, some cooperators resigned from the task due to economic difficulties (e.g., some left the community to become laborers), while others disengaged because of their doubts about the project. Fifty-one out of 60 cooperators continued until the project's end.

Three seminar-workshops were held during the project. The first, held after the final selection of research sites and cooperators, focused mainly on how to achieve efficient data collection. It was also a venue for orienting the fishermen about the project and the idea of formulating a coastal resources management (CRM) plan. A midterm workshop was held to share with them the initial findings of the research and to gather feedback. In both workshops, the ability to organize surfaced. This led to a resolution among the cooperators to form a fishermen's organization in their respective communities. A Lingayen Gulf-wide fishermen's alliance was formed during the first workshop.

The third workshop held in July 1988 served to discuss and interpret collectively the results of the one-year record-keeping activity. Representatives from institutions like the University of the Philippines Marine Science Institute and College of Fisheries were asked to share with the cooperators the findings of their groups. Likewise, the director of the National Economic Development Authority (NEDA)-Region I was invited to discuss the fishermen's involvement in the formulation and implementation of the proposed CRM plan. Having been consulted on topics to be discussed, the fishermen vigorously participated and willingly involved themselves in various tasks. Concrete plans and suggestions regarding the plan were discussed. Likewise, the director assured the fishermen of NEDA's direct participation and involvement in the formulation and implementation of the plan.

LESSONS AND RECOMMENDATIONS

For years, researchers from colleges and institutions have been conducting anthropological-cum-socioeconomic studies in the Lingayen Gulf and other areas. Various methods have been employed to provide a detailed description of the place and the community's way of life. Local people have come to accept researchers as outsiders who ask various questions. Researchers are often viewed as "experts" who have finally come to provide solutions to local problems. Eventually, however, the rural people became tired of them since they were not getting anything in return; thus, they lost interest in participating. As a result, people interviewed gave stereotyped answers and became experts at answering the same questions.

Given the inadequacies of conventional research approaches, the emergence of participatory research is an attempt to make research relevant to the present socioeconomic context as well as a learning process for those being "researched." In these authors' experience, participatory research did not merely entail being partners in data collection and interpretation. More importantly, the study, which claims to be participatory, should start from the investigator's basic trust in recognizing the capability of people to learn and take action to solve problems. Thus, research should attempt not only to provide solutions to problems but also to pave the way for participation in the study.

A researcher as an outsider comes to a rural community with a set of values and ideas. He/she is often faced with the dilemma of whether or not to conceal personal values and opinions, so as not to influence his/her respondent's view or way of thinking. The authors' experience showed that researchers should not enter a community with empty minds but open ones. They should engage in dialogues and make efforts for meaningful discussions.

Rural people are accustomed to not being heard. Often, they are quiet, especially when talking to persons of authority. Workshops and small group discussions are tools that can help them change this attitude. The fishermen who attended the first workshop became more confident in the succeeding workshops. Talking and being heard in groups such as these were valuable exercises at gaining self-confidence. They learned, if to a limited degree, to explain and clarify their condition.

A major limitation in the study method was that an action component of participatory research was missing. The methodology was participatory only to a limited extent because the fishermen became active research partners in data collection and interpretation. However, this experience would have been minimized if concrete actions were undertaken towards ultimately solving the problems they raised by implementing an actual project. The efforts made, for example, in forming fishermen's organizations were initiated by the cooperators. Such undertakings were not properly guided and sustained because the research staff were constrained to work within the boundaries of the workplan.

In summary, research endeavors in rural communities should begin with the assumption that the people concerned have the potential to solve their own problems and that a researcher's role is to assist those people in determining their situation and role in directing development. In this study, the identification of issues and problems in the community was not enough. The study should not have stopped at educating and raising awareness but should have continued to initiate concrete actions toward solving problems. In this light, research should go hand in hand with community organization. The success of any endeavor such as formulating a CRM plan lies in the process. The educative component of research should be linked with organizing efforts to socially prepare the community and equip it with the skills necessary for the implementation of the plan.

Women in fishing villages: roles and potential for coastal resources management

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ABSTRACT

This study focuses on women: their major contributions in sustaining fishing households, the extent of their involvement in economic-political activities in fishing communities, how they cope with the double pressure from their traditional gender roles and increasing economic activities, and the implications of these situations for a community-based coastal resources management scheme. Results of the study reveal that in spite of the women's expanded role, the economic-political life in the fishing villages continue to be male-dominated.

INTRODUCTION

The significant contribution of women in sustaining a community's socioeconomic life is often glossed over by statistical data. This neglect or ignorance results in an underestimation of women's potential and thus forces women to accept their abject conditions passively.

The Declaration of the International Decade of Women by the United Nations in 1975 has generated awareness of gender as an important variable in analyzing social issues and in formulating appropriate development schemes. This concern is manifested in the proliferation of research efforts and projects on women's role in development.

Many women researchers and activists argue that improving women's conditions does not merely imply integrating them with the current development mainstream but also reorienting the male bias of the dominant development concepts and strategies (Nelson 1979; Loutfi 1980). A crucial element in this reorientation is the deeper understanding of the changing roles of women.

In many parts of the Third World, including the Philippines, deteriorating economic conditions exert more pressure on women, especially in poor households. The women's domain is no longer confined to the household as mothers, daughters and sisters. Experiences reveal that in recent years, many women have contributed more working hours, ventured to varied productive activities and worked outside their homes, at the same time that they continue to perform their traditional gender roles in the family. In spite of these changes, however, their political involvement, particularly in decisionmaking and leadership roles, have been limited or even negligible.

Studies show that, in general, women in Philippine rural households actually work for as long as 15-16 hours daily (Illo 1983; Pagaduan et al. 1986), doing household chores, raising children, working in the fields either as unpaid family labor or as waged seasonal workers during peak seasons, and engaging in other income-generating or income-substituting activities. For Philippine fishing communities, there are very few accounts of how women actually contribute to the family sustenance. Acheson (1981) maintains that there remains a strong sexual division of labor in many fishing societies where the men fish while the women maintain the household. Field observations, however, tend to suggest that such roles have changed in recent years.

THE RESEARCH PROBLEM

The fishing industry contributes 5% to the Philippines' Gross National Product (GNP) and comprises 20% of the total agricultural output. It employs about 1 million people and is the source of survival for an estimated 6 million Filipinos.

The deteriorating condition of the Philippines' coastal resources calls for more efficient management strategies. Quite recently, Lingayen Gulf, located in northern Philippines and one of the traditional fishing grounds facing the gradual depletion of the fisheries resources, has been the focus of a comprehensive study on coastal resources management. To some 48,882 fishing families in the coastal towns surrounding the gulf and other households in neighboring towns, saving the gulf means saving their major income and food source.

Ferrer (1988) proposes a community-based coastal resources management scheme to protect fisheries resources and enforce laws. A community-based approach underscores the need to involve coastal people in decisionmaking and action programs to protect the environment. It is in this context that women's roles and potentials are analyzed in this study. Women, as a group, exert pressure on the coastal resources. Thus, the protection and proper use of these resources also demand the women's primary concern.

The present study focuses on:

- the major contributions of women in sustaining fishing households;
- the extent of women's involvement in economic-political activities in fishing communities;
- the ways in which women cope with the double pressure from their traditional gender roles and increasing economic activities; and
- the implications of these situations for a community-based coastal resources management scheme.

CONCEPTUAL FRAMEWORK AND REVIEW OF LITERATURE

Women in poor households

Poverty is the most basic problem in most rural areas of the Philippines. This is partly manifested by malnutrition, a high infant mortality rate, unsafe water, lack of health services, low wages and underemployment, and unstable peace and order situation. As Pagaduan et al. (1986) state:

> Under these conditions, women's problems are related to the question of survival, the drudgery of domestic and productive activities outside the home, and inequalities in the distribution of income and wealth, as in all class societies.

Empirical studies in Asian, African and Latin American countries suggest that women in poor households contribute immensely to the survival of their families (Boserup 1970; Heyzer 1986). Contrary to the notion that women's role is relegated to an auxiliary and subordinate position in industrializing societies, women in subsistence production tend to expand their role especially in the economic sphere (Heyzer 1986). Boserup (1970) contends that poor households have three main livelihood sources where women play a major role:

1. income in cash, earned through wages and sale of products and services;
2. income in kind, earned through work or barter of goods and services; and
3. goods produced and services provided for the family's own needs or sustenance.

Many rural women migrate to find employment in garments and textile industries, electronics corporations, plantations, and the domestic and service sectors, including prostitution. During the planting and harvest seasons in farming communities, the demand for female labor is likely to increase (Deere and De Leal 1981; Illo 1983). Some data also suggest that there is a wage differential between male and female farm workers.

In addition to being seasonal farm workers, women are also unpaid when involved with planting, weeding, harvesting and taking care of livestock and farm animals. Although women generally do not fish, they perform various fishing-related activities (Acheson 1981). Market trade and home industries also offer a wide range of livelihood opportunities. However, there is still widespread underemployment and low income. According to Heyzer (1986), the persistence of petty production and distribution ensures the existence of low-cost services and goods.

Women bear the burden of housework, which is nonmonetized whether they are married, unmarried, employed or unemployed (Miralao 1980). Many researchers emphasize the magnitude and significance of women's domestic tasks to the family's sustenance (Licuanan and Gonzales 1976; Illo 1977).

In a situation of constant poverty, the main concern is how best to generate additional income and allocate available resources. In the Philippines, where women generally control household finances, decreasing real incomes in the countryside means greater difficulty to make both ends meet. In times of cash shortages, the burden of finding supplementary income, food or sources of credit for the family's subsistence typically falls on the women (Bautista and Dungo 1986).

There is also a growing number of female-headed rural households due to separation, death or search for income opportunities. Boserup (1970) says wives of small farmers are becoming more burdened by agricultural work because their husbands take on nonagricultural work.

Gender issues: subordination and emancipation

Women are often trapped in the double burden of household tasks and economic pressures. In the countryside, the belief that "women do not work" or "women are secondary breadwinners" remains dominant. Men are considered the breadwinners, so even if they fail to earn sufficient income, the power of decisionmaking is with them in conflict situations (Heyzer 1986). Also, in the larger social sphere, men assume the role of contact point between the household and the outside community.

Agricultural improvement also tends to have a male bias. With the introduction of labor-saving techniques, particularly farm machineries, more women are displaced from paid labor (Illo 1983). At the same time, new technology has created marginalized tasks for women, e.g., picking left-over grains as the dried rice is being threshed (Bautista and Dungo 1986).

Membership and leadership in rural organizations are generally male-dominated, except for the traditional women's domain such as civic and religious groups. Women's noninvolvement is mainly due to the demands of household tasks and the necessity of contributing to the family's livelihood.

In spite of the long history of women's movements in the Philippines and the growing consciousness about gender issues (GABRIELA 1985; Maranan 1985; Camagay 1986), most rural women seem undisturbed by their secondary role in politics. To many, women's problems remain subordinate to, or worse, separate from national and class oppression (Pagaduan et al. 1986). There are efforts, however, toward education and organization of, for and by women, especially among the poorest sectors of society. These women's organizations aim to respond to specific gender issues as an integral and vital component of local and national development issues.

METHODOLOGY

The main source of the data was from the ethnographic studies of seven fishing villages in Pangasinan and La Union, namely:

- Binabalian, Bolinao, Pangasinan;
- Carot, Anda, Pangasinan;
- Telbang, Alaminos, Pangasinan;
- Capandanan, Lingayen, Pangasinan;
- Nibaliw West, San Fabian, Pangasinan;
- Balawarte, Agoo, La Union; and
- Alaska, Aringay, La Union.

The ethnographic data were gathered through integration, interviews, field observations and case studies in each community. The review of literature on women's studies provided the framework for analysis and synthesis of the data gathered.

Due to the qualitative nature of the research results, preliminary data validation was attempted through informal discussions with other researchers and community organizers who have worked with women in fishing villages. But the results should be discussed and further refined through group discussions/workshops with women in fishing villages and other groups concerned with women's issues.

SUMMARY OF FINDINGS

Women as mothers and wives

Household Responsibilities. The care of children, cooking, washing clothes, tidying of the house and sweeping the yard are responsibilities considered inherent in women. Fetching water, both for drinking and washing purposes, is most often done by women even when the source of water is quite far from their house.

With more women now sharing in economic activities, husbands see it fair that they assist in household tasks like watching over children and cooking. However, this cooperation rarely extends to washing clothes, the most time-consuming of household chores. This is usually done by the daughter or a close female relative. Men will only perform this when no female is able to do it. When one sees a man washing clothes, it indicates that his wife has just given birth. When a man is often seen doing women's tasks, he is labeled *Andres* (an allusion to "under the *saya*," meaning wife-dominated).

The household falls back on the support of relatives, especially the grandparents and other female relatives, when wives are unable to do household chores. Maiden aunts or single women relatives are automatically seen as caretakers of their siblings' offsprings. Older children also contribute to the household labor.

Childbearing and Rearing. A pregnant woman usually continues working until the day she senses the child will be born. Most people claim that it keeps the mother's body strong. A few days after childbirth, the mother is back at work. A mother working as a fish vendor comes home at lunchtime and in the afternoon just to feed the child who is being cared for by a female relative.

The average number of children is six. In some study sites, women have more than a dozen children. A factor that accounts for the high birth rate is the desire for children who are considered assets because they can assist in the household chores. A woman paradoxically wants to have more children so that her older ones can take care of her younger ones. Infant mortality rate is also quite high. Some informants feel harassed after having more than four children but, at the same time, their attitude is that once born, children should be accepted and cared for.

There is awareness of the different family planning methods but their use is limited. Birth control tends to be part of the women's responsibility. Women regularly drink a herbal concoction to hasten menstruation. Some make use of methods that are available for free (e.g., pills and tubal ligation). A few have experienced the ill effects of these methods. Natural birth control methods are also practised. Vasectomy is shunned because it is believed to weaken the man physically.

Children learn their sex roles early. Small girls accompany their mothers at the pump with their own basin and small clothing to wash. When the mother is busy at some other task or if both parents are away, the oldest daughter looks after the younger siblings. Children's games imitate their future roles, thus complementing the learning process. Seven-year-old girls in Alaska and Balawarte are already adept at bargaining and selling fish. They sometimes fill in for their mothers.

Family decisionmaking

Household finances are managed by the wife from the earnings that the husband is supposed to turn over to her. Sometimes, the money goes directly to the wife when she sells her husband's catch. In Telbang, a woman, usually the wife of the net owner, uses her discretion in dividing the catch between the crewmembers and the net owner. Some women meet their husbands returning from the sea and sort out the fish caught according to size and kind. For larger catches, the fisherman himself distributes them to market buyers. He is then expected to turn over the entire income to his wife when he gets home. There are complaints, though, about husbands who spend all their earnings on drinking. The norm, however, is for the husband to receive pocket money.

Aside from managing the household expenses, wives allocate expenditures for boat and gear maintenance, including investment in new fishing gear and the purchase of spare parts for the motor boat and gasoline. The wife thus takes an interest and participates to a certain extent in decision-making on fishing matters. However, ownership of the gear, boat and property is usually attributed to the man since he earned the money to purchase them.

Women must find ways for the family to survive when their husbands' income is insufficient. In small stores, women are the frequent borrowers of food and other daily household needs. Lean times call for women to help augment family income or even to become the main income-earners. When the alternative livelihood is done at home, women continue to attend to household responsibilities. When the livelihood is outside the home, household tasks are passed on to the husband, children and female relatives. If no mature female can be around to watch over the home, the wife often does not leave it. Instead, the teenage daughters are the ones who go out to work.

The husband tends to dominate in decision-making outside the home. During the baseline survey, when wives were asked to answer the first half of the survey when their husbands were away, they replied that they would do so only after they had told their husbands about it. They asked the researchers to come back when their husbands would be home. Exemplary was one fish vendors' association, composed mostly of women, which chose a woman separated from her husband to be president because "she had no husband who would restrict her from doing things."

Relationship with the husband

Women usually marry when 16 to 19 years old, with virginity literally "highly priced". The amount of dowry traditionally given by the groom's family to the bride's family (to be used in starting the household and to cover wedding expenses) goes down if the girl is widely suspected to be pregnant. Despite this social norm, premarital sex is common and pregnancy is often the reason for an early marriage. Once a girl gets pregnant, there is no choice but to wed her with the boy. Both their families then contribute to finance the wedding.

Wife-beating exists in the study areas. It stems from seemingly petty reasons: the wife nags; the husband is unable to cope with economic pressures; the husband wants to assert his dominance, drinks much or is having an extramarital affair.

Such "macho" actions are ingrained among some people in the fishing villages studied. Generally, men are not blamed for infidelity. Rather, both men and women rationalize that an affair happens because the woman flirts with the man and he, being weak, gives in. Extramarital affairs are usually tolerated. There are cases where the other woman is maintained by the man in a separate house along with his children by her. The economically independent woman who does not have to rely on her husband for financial support can opt for separation in such a situation.

WOMEN AS INCOME EARNERS

Fishing-related activities

Although men catch the fish, women contribute before and after the fishing activity in numerous ways. Women mend nets and attach bait to the hook and line, a major fishing gear; in Balawarte, Agoo, where blast fishing is rampant, they help prepare dynamite by pounding the gunpowder. When the men reach the shore after fishing, women sort and weigh the catch and deal with the buyer.

When large quantities of anchovies are caught in Nibaliw West, the women dry them under the sun. They are also primarily involved in making *bagoong* (shrimp paste). In Binabalian, where aquarium fishing thrives, wives clean the plastic packing bags and assist the men in packing the fish.

Women also have a hand in actual fishing in a limited way. Most of the fishing they do is considered "light work". In Nibaliw West, they pull with the men the beach haul seine. In Carot, women fish at night with the use of a beach seine that does not require great physical effort.

When male members of the fishing household get sick or are away, women harvest fish in a river or nearshore reef areas. One wife in an aquarium fishing group participates actively in packing marketable fish, keeping records of the expenses incurred in fishing, packaging and shipping to Manila, and giving wages to employees. In Carot and Binabalian, among owners of bag net *(basnig)* fishing vessels or managers of spearfishing groups, wives or adult daughters perform accounting tasks--they keep records of expenditures, loans of crew members, the catch share due them and the volume. Women sometimes decide on the amount of share that goes to the crew members.

Income-generating activities

To help sustain the needs of fishing households, women become compradors--they buy and sell fish--and engage in various income-generating activities.

In Balawarte, most of these compradors buy higher-priced fish (e.g., tuna and mackerel) and take them to a provincial market to be sold at wholesale prices. This work takes the most of one morning for which the woman can earn from ₱100-300[a].

Women also buy lower-priced fish and shrimp and sell them in the markets of Agoo, San Fernando and Dagupan, earning in the process about ₱50-100 a day.

Another home-based income-generating activity engaged in by women is shrimp pastemaking. They are also engaged in shell gathering on reef flats and in shellcraft. In Carot, when middlemen from Manila stopped placing orders for shellcraft, women gradually shifted to matmaking, which generates minimal earnings. The latter is done during summer when *buri* palm fronds can be dried easily. Women work on a single mat for five days to a week. They sell the mats during market days and earn from ₱40-60 for one mat.

During the start of the rainy season, some women in Carot hire themselves out as farmhands together with some of their fishermen-husbands.

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[a]April 1990: ₱22.03 = US$1.00.

A day's work provides them with ₱25 or its equivalent in kind, most often rice.

Another way of augmenting income is by sponsoring the game "ending," which is based on basketball game scores. It is like a small version of sweepstakes. The winner gets a pair of pants or a sack of rice. The sponsor automatically pockets about 30% of the collections or all the money if the winning combination was not bet upon.

Others engage in selling foodstuffs like rice-cakes, roasted bananas, cookies and candies. During the recent *barangay* festivities, stalls laden with goods mushroomed around the plaza where business activities are centered. Women attended to these ministores and those with enough capital put up larger stores.

Work outside the community

While women continually shift from one income-generating activity to another, it is during the lean fishing season that women's contributions become indispensable. Increasingly, women leave home and even the community to earn money.

In Nibaliw West, due to losses incurred during the lean season, fishermen opt to stay home, care for the children and do household chores while their wives continue to buy and sell fish.

In Alaska, women buy and sell tobacco. The children sort the leaves and roll them into sticks. These are sold to a dealer in the market. Losses are not uncommon. Income can range from ₱30-50 or ₱100-200 a day.

For lack of better community employment, many young and unmarried women leave their families to join the burgeoning number of domestic helpers in the cities of Dagupan, Baguio and Manila or in other communities, or to work as salesgirls in department stores.

Women in the community

Neglect of women's family responsibilities reflects badly on their image in the community. Men, on the other hand, are supposed to leave the home and struggle with the outside world to provide for the family's economic needs. This division of roles is reflected in the community's views regarding the acceptable behavior for women (i.e., they should be home at night and play bingo or cards for leisure but not the game of pool).

In political leadership, men are deemed more able to lead the *barangay* because of their physical superiority in handling disputes and stronger will. In all *barangay* studied, except one, the *barangay* captains were men. They also greatly outnumbered women as council members. If disputes within the *barangay* coincide with problems at home, the women are expected to attend to the home first.

However, Alaska's *barangay* captain is a woman. Although the people still favor a man, they acknowledged that she does a good job. The reason for her success in dispute settlements is the power of her word. A man cannot respond to a woman by hitting her because this would put him immediately in the wrong.

However, at the lower level of the *purok*, women are often elected. Also, women teachers play a large role in the *barangay*. They are also secondary hosts to visitors. In religious activities, women play an active role. More of them attend Mass on Sundays than men, and many are active in organizations such as the Catholic Women's League.

In fishermen organizations and cooperatives, women are usually chosen/elected to serve as treasurers and auditors. But there are only a few organizations with mostly women members.

In the context of community-based coastal resources management, women can play significant roles. Their ideas and perspectives need to be considered. As part of the women's nurturing role, information on environmental awareness can best be disseminated through the home and school. Although fishing remains to be their major source of income, other alternatives should be offered to develop their skills.

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Small-scale fishermen's participation in the salt industry: an alternative source of income?

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ABSTRACT

This study examines the feasibility of salt production and distribution as an alternative source of income for small-scale fishermen. The study was done in a fishing community along Lingayen Gulf through participant observation and unstructured interviews for seven field periods from January to August 1988. Salt production in the area was contextualized within the market scheme of the industry. This study focuses on people's participation, particularly of the small-scale fishermen, in the industry.

INTRODUCTION

The focus of fisheries research has shifted from the development of utilization methods to the management of fisheries resources. Several authorities in fisheries management suggest a reduction in the rate of exploitation in locations where resources are quickly deteriorating as well as alternative sources of livelihood (Smith 1979; Panayotou 1981).

With these considerations, an assessment of the salt industry was done. How feasible is it for the salt industry to absorb opportunities from the traditional fishing sector?

Salt is used for various purposes. About 65% of the demand for crude salt goes to human nutrition. The rest is used for the fish processing industry, livestock industry, refrigeration and tanning. The main users of industrial salt are the caustic soda-chlorine gas manufacturers. Other uses include food processing; soap, textile and pulp manufacturing; and the chemical and baking industries (Amio 1987).

The salt industry is also significant in generating employment. For instance, one 480-ha salt farm hired 60 permanent and 161 seasonal personnel (Hebron 1986).

There is an increasing trend in the production of crude and industrial salt but still local supply can not cope with the country's demand (Amio 1987). The local salt industry has supplied 33% of industrial salt and 93% of crude salt from 1971 to 1985. Pangasinan is the second largest producer of salt (11.86% of the country's total production).

METHODOLOGY

The study was undertaken in Barangay Telbang, Alaminos, Pangasinan, one of the coastal communities along Lingayen Gulf, using participant observation and unstructured interviews for seven field periods from January to August 1988.

A combination of the emic-etic approach was used in the analysis of the data sets. The views of the informants, those of the researcher and other authorities were presented for a more holistic perspective of the salt industry.

RESULTS AND DISCUSSION

Community profile

Telbang is one of the 38 barangays comprising the municipality of Alaminos. It is 11.5 km from the town proper, bounded on the north by Lingayen Gulf, on the south and east by Barangay Victoria and on the west by Barangay Panda; both *barangay* were once part of Telbang. There are six sitios in the *barangay*, namely: Bolo, Centro, Sidro, Paradise, Sigking and Cabulalaan.

As of 1984, the total population in Telbang was 2,041, comprising 356 households; 52% were males. It is the fifth most highly populated village in the municipality.

Telbang has a total land area of 869.8 ha. Of this, less than 1% comprises the residential areas. Some 40% is devoted to crop cultivation while the rest is composed of pasture and open ranges suitable for vegetables and root crops.

There were 171 houses being serviced by the Pangasinan Electric Cooperative (PANELCO) as of December 1983. Telbang had a total rate of 97 kwh, and the average consumption rate per household was ₱27.00[a] a month. The existing sources of water are the pitcher pump and shallow open well.

The major occupation in the village is farming. There are no big landlords and most families do not employ outside labor to till and plow their fields. There are, however, rich families who own ricemills and relatively big tracts of land.

Next to farming, fishing is an important source of income. Some 22% of the people in the area are municipal fishermen. Their gear are hook and line (*kitang*), which is labor-intensive, spear gun (*pana*) and cast net (*tabukol*). Most fishermen do not own motorized *banca*. Blast fishing is also a common activity.

Another significant economic activity in the area during the summer months is salt-making. There are a few people who operate on a large scale, but the majority are involved on a small scale.

Salt production

Banigan Method. This method utilizes water from the fishpond and produces salt by means of solar evaporation and the boiling method. From January to May, about 200 families temporarily migrate to *sitio* Bolo where a number of fishponds are located. During these dry months, most of the milkfish ponds are harvested and drained for salt production. The salt beds resemble miniature rice paddies and their spread-out appearance is perhaps how this method of production came to be known as the *banigan* (from the root word *banig*, a local term for "mat").

One way of producing salt using this method is by solar evaporation. This entails draining the fishpond and exposing its bottom to the sun's heat until a film of rock salt crystallizes on the tiled floor. When the unrefined salt is ready for collection, homemade baskets (*kaing*) are laid along the squares. The layer of salt is then raked with a wooden implement and stocked into the baskets. (One square fills one basket). The salt is piled into a mound before being packed into sacks for transport to the market.

Some owners do not line the fishpond bottom with clay tiles. The rock salt thus produced is more muddy and requires further processing by boiling. In this method, the ponds are gradually drained. The spillage is collected in canals for exposure to the sun's rays for several hours. The brine is transferred into cement tanks in nearby huts when it reaches the proper concentration. Brine concentration is simply tested with a rubber device attached to a bamboo pole. Should the rubber sink, it is an indication that the brine concentration is not saline enough to produce salt. If the device floats, then the solution is ready for cooking. Boiling is done over firewood for several hours until the brine evaporates. The salt produced has a fine powdery texture. It is stored in large baskets locally called *coribot*.

Scramble Method. This process produces salt by combining unrefined salt with seawater. The brine is evaporated using the boiling principle.

Salt trading

A typical salt trading crew consists of five to ten people, depending on the volume handled. The crew repacks the salt before transporting it. The profit margin is fixed at ₱5.00 per repacked sack.

The volume handled per team ranges from 50 to 500 sacks per trip. During the production season, approximately seven to ten trips are made weekly. The peak season is in April to May when most crews make daily trips. Otherwise, only weekly deliveries are made.

Dagupan and Lingayen are the market destinations. Large-scale middlemen would purchase the commodity during the peak season to be able to buy it at a low price. Occasionally, some crews trade their wares to the industrial factories of some Chinese businessmen in Jolo, Aparri or Cagayan. The usual term of payment is cash-on-delivery although there are also instances of credit arrangements.

RECOMMENDATIONS

One of the barriers to the marginalized fishermen's entry into the salt industry is capital. The

[a]1988: ₱21.34 = US$1.00.

cost of inputs should be reduced if returns are to be improved. For instance, since wood consumption comprises the bulk of expenditures, cheaper yet more efficient combustible materials like coconut husks or coal could be used.

A properly implemented credit scheme with socialized rates will alleviate the difficulty of starting a salt business. Increased production will also improve profits, considering that salt is an inelastic commodity and that the demand for it is not being met locally. Consider the case of the *banigan* producers who make three to four cavans daily as opposed to scramble producers who make four to five cavans daily. It is the brine concentration used in the scramble method that allows better production.

Based on the increasing demand for salt, the salt industry can very well absorb more fishermen. However, there should be a wide array of other such alternative sources of income so that the influx is spread out.

These recommendations will be realized only if the people are organized and cooperate with each other. Maximizing participation in the production and distribution process of an industry should be the goal of the community organization.

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Aquarium fish industry in the Philippines: toward development or destruction?

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ABSTRACT

Aquarium fish collection in the Philippines is a multimillion peso industry whose growth has been interrupted by major slumps over the last decade. These were attributed to the bad reputation of Philippine aquarium fish in the international market arising from the use of sodium cyanide in collecting them. This study gives an overview of the industry in Bolinao, a major source of aquarium fish. It also focuses on the different reasons for the persistent use of sodium cyanide. It reports that the efficiency of collection and economic incentive systems support the continued use of sodium cyanide in aquarium fishing. It points out that fishermen are able to befriend law enforcers and/or avoid them. It recommends that marketing arrangements be established that will encourage the sale of fish caught with nets and that community education facilitate the process of change. It also suggests cutting off the supply of sodium cyanide.

INTRODUCTION

Aquarium fish collection started out as a hobby and is currently a multimillion peso industry. A thorough assessment of its effects on the national economy and coastal environment is now in order.

Statistics show that the trade of these small colorful fish is big business. Over a span of 10 years, exports of these fish increased over twenty-fold (Albaladejo et al. 1984). The industry started with only three exporters and has 35 companies at present. In 1980, exporters shipped a total of 2 million kg of aquarium fish valued at ₱22.7 million. Today, aquarium fish ranks sixth in the category of major fisheries export products of the Philippines.

The export of aquarium fish from the Philippines was started by Earl Kennedy in 1957 (Rubec 1986). About 200 of the 2,177 marine fish species found in the country are commonly exported for the aquarium fish industry (Albaladejo et al. 1984). The industry's importance to the economy was first noticed 10 years later, when export volume reached 33,931 kg amounting to ₱153,329. Since then, exports increased steadily, suffering only occasional slumps during the period 1980-1982.

Over the last decade, Philippine aquarium fishes have been suffering from a bad reputation in the international market due to the use of sodium cyanide (NaCn) in collecting them. The use of NaCn to capture aquarium fish started in 1962 (Rubec 1986). A little-known fish collector named Gonzales began using it to stun coral reef fish to facilitate their capture. This practice spread until most collectors began using it. Fish exporters encouraged the practice by supplying NaCn to collectors. Today, some 80-90% of aquarium fish exported is captured using NaCn; this accounts for about 80% of the marine fish from the Philippines sold in the world market (Rubec 1988).

Bolinao, in addition to Cebu and Quezon, is a major source of aquarium fish. In one of its fishing villages, Binabalian, collection of aquarium fish was introduced in 1975 by two Visayans who learned the trade in Mauban, Quezon. These fishermen introduced fish collection with the use of a scoop net and a squirt bottle of NaCn. The use of NaCn was apparently known in the community even before its people learned of the aquarium fish trade. In the beginning, the fishermen operated in shallow waters. With the relatively large income from the trade, however, they were able to buy motorized *banca* and compressor machines.

The introduction of the compressor allowed them to operate in deeper waters and facilitated collection. Correspondingly, the number of aquarium fish gathered and fish gatherers increased.

With time, concern over the harmful effects of NaCn on man and his environment increased. In 1984, the International Marinelife Alliance (IMA) conducted a series of training programs in Binabalian on the use of different nets in aquarium fish collection. Despite IMA's vigorous efforts, it failed to convince the majority of the fishermen to stop using NaCn. Today, some 70% of the aquarium fish collectors in Binabalian still use NaCn (Robinson 1984).

THE PROCESS OF COLLECTING AQUARIUM FISH

A majority of the aquarium fish collectors use a 10- or 16-hp motorized *bunca*. Those operating in deepsea waters also have a compressor machine attached to the vessel's engine. This machine is connected to an air tank, which has two air tubes measuring 50 m each.

The following equipment are needed for a fishing trip:

1. an improvised basket *(sambirga)* attached to a floater *(pataw)* where gathered fish are placed while at sea;
2. 14-in diameter plastic bags;
3. oxygen tanks; and
4. a scoop net *(singapong)*.

Aquarium fishing is a year-round activity. Except on Sundays and stormy days, the fishermen collect aquarium fish from 8 A.M. to 4 P.M. Preparation of equipment and vessel, however, begins as early as 6 A.M. Hence, a fisherman spends 48 hours/week for collection and some 12 hours/week for preparation.

One way of classifying aquarium fish collectors is on the basis of their area of operation. There are shallow water aquarium fishermen who operate at depths of less than 10 fathoms and deepsea fish collectors, at depths of 10-30 fathoms.

For deepsea fish collectors, each fishing vessel or work group consists of three crew members. One acts as a lineman while the other two as divers. One of the divers is often the vessel owner. In cases when the owner of the vessel is not a crew member, he appoints a caretaker or a "captain" of the vessel from among the crew. The boat caretaker or "captain" acts as the *timonero* and decides where the crew will operate. He selects areas where he believes fish abound. He may also decide to fish at different depths, depending on the types of fish the group wants to collect. The lineman, on the other hand, is responsible for the compressor motor. He sees to it that the compressor's cooling system is always full of water to prevent overheating. He also checks the two sets of air tubes to see that they properly extend to the divers and do not get entangled. The lineman does not have a share in the fish catch. Rather, he is paid a daily wage of P20-P30. Fish catch is divided equally among the divers and the vessel owner.

Meanwhile, the shallow-water fish collectors have a different arrangement. In the absence of a compressor machine, gathering is basically an individual activity. A work group is composed of 8-12 collectors. The majority are young boys from 12 to 18 years old. The "captain," who is often the vessel owner, brings his crew to his selected fishing ground. Once the vessel is anchored, individual divers go to work. Almost all shallow-water collectors are NaCn users. Divers also bring a fish basket and an NaCn squirt bottle to the preferred diving spot. At the end of a fishing trip (which is financed by the vessel owner), the divers sell their catch to the vessel owner who, in turn, sells them to exporters in Manila.

THE USE OF SODIUM CYANIDE

Four aspects of the use of NaCn were assessed: (1) the user's and the people's perceptions of its harmful effects to man and his environment; (2) the role of institutions and social groups; (3) local practices to cope with law enforcement; and (4) the existing marketing arrangements.

Perceived dangers of the use of sodium cyanide

Cyanide users believe that their daily exposure to cyanide has no detrimental effect on them. They claim that, unless an individual actually swallows cyanide, there will be no toxic effects. This notion is reinforced by the fact that cases of cyanide poisoning while gathering fish are unknown. However, cyanide users take precautions while underwater. To avoid possible toxication, they refrain from swallowing or gulping water squirted with cyanide. Food fish caught with cyanide are thoroughly cleaned and their intestines and stomachs removed.

Users of cyanide contest other fishing groups' claims that exposure to cyanide results in skin rashes, lesions and bleached hair. No such instances of skin rashes or lesions due to cyanide have been observed nor cited by informants. The bleached hair of fish collectors has been attributed mainly to prolonged exposures to sunlight while at sea.

Fishermen are only apprehensive of the Constabulary Offshore Anti-Crime Unit (COSAC) officers who might arrest them while using cyanide. In spite of such a risk, the practice is tolerated and even justified by the fishermen's wives and the respected elders of the clans to which they belong.

Cyanide users and members of their families claim that they resort to using cyanide because of poverty. They also said that using cyanide for collecting fish is better than stealing. They prefer it to using fine-mesh nets because they believe that some fish, particularly the high-priced ones, are difficult to catch without cyanide. It also facilitates the job of fish collection since fish caught with fine-mesh nets, they said, are likely to be rejected by exporters because of the scratches and lesions acquired by the fish during the catch.

The role of institutions and social groups

Aquarium fish gatherers in Binabalian belong to a distinct group of fishermen. Most of the collectors who learned the skills from migrants belong to the poor sector of the community. They are either young teenagers who barely finished elementary education or landless migrants who remained in the community. Since then, they have formed clusters of houses in the eastern and western coastlines of the island and have erected their dwelling places on government-owned lands. The migrant Visayan aquarium fish gatherers occupy the eastern coastline, while the landless and the notorious cyanide users occupy the western coastline of the *barangay*.

The geographical isolation of cyanide users from the other members of the community has strengthened the ties among themselves, especially among those occupying the western coastline of Santiago Island. Apart from this, their relationship is further strengthened since they belong to one religious group; kinship ties also exist between collectors and managers. A majority of cyanide users in the area belong to one religious organization. While another religious group strongly forbids the use of illegal fishing methods, the said organization apparently tolerates the activities of its members. In fact, a religious leader (deacon), who is also a dominant member of a clan in this part of the island, is the supplier of NaCn in the area.

The use of cyanide is accepted in the community although users are often objects of antagonism. Together with the blast fishermen, they are blamed for the dwindling catch of a fisherman. The degree of antagonism toward cyanide users was intensified when IMA entered the community. Its members are former cyanide users who now look down on "unconvinced" fishermen because the latter refuse to resort to using nets. The antagonism between these groups has gone to the extent of name-calling. Cyanide users are branded as *tarantado* or *luku-luko* (fools). At times, they are called "sodium boys" or "cyanide addicts." They are seldom invited to participate in community activities and are rarely consulted in the decisionmaking process in the *barangay*. In one instance, the *barangay* celebrated its *fiesta* without their participation.

Local practices to cope with law enforcement

Cyanide users are aware that the use of cyanide for collecting fish is illegal and punishable by law. However, this does not deter them from continuing its use in their fishing activities. A number of practices have evolved to elude arrest, thus sustaining these illegal activities:

1. Establishing a lookout. Law enforcers usually intercept illegal fishing vessels leaving the *barangay* in the early morning. In response, some sort of a network has been established among illegal fishermen and their sympathizers. People in the networks forewarn one another of the presence of law enforcers; they often hide or are on the lookout for suspected illegal fishermen.
2. Bringing nets as bogus materials. Cyanide users never fail to bring nets during fishing expeditions. These are presented to law enforcers if they are apprehended. While at sea, cyanide users are on the lookout for any unfamiliar and suspicious-looking vessels, especially the COSAC patrol. When they see one, they immediately hide or discard any NaCn or squirt bottle in the *banca*. Cyanide balls are

often dropped and allowed to dissolve in the seawater. The bottle is either hidden in the crevices of corals or thrown into the sea to be swept by the waves. Illegal fishermen have learned from experience never to hide squirt bottles beneath the bamboo flooring of the vessel for this is often inspected by law enforcers. If no evidence is found on suspected vessels, the COSAC patrol can demand food fish from the fishermen.

3. *Padrino* system. There are 26 cyanide users among aquarium fish collectors in the community. Of these, 12 have been at one time or another apprehended for the possession and use of NaCn. However, it is common knowledge that only two fishermen have been imprisoned for the said offense. All other cases were settled amicably. An apprehension would cost the lawbreaker around ₱300-₱500 and a dog or a chicken for food of the COSAC officers.

During initial investigations after an arrest is made, the law enforcer may ask for the identity of the violator's manager and vessel owner. The real owner is seldom revealed. Instead, a person who has connections with the military or is a "friend" of the apprehending law enforcers is pinpointed as the violator's manager. The case is then settled immediately by the pseudo-manager.

In the study area, two groups of users have been assured of the continued use of cyanide because one of the COSAC men is a member of the religious organization mentioned earlier.

Establishing ties with law enforcers

The COSAC is generally perceived as corrupt by the fishermen. They acknowledge, however, that a few of its officers are sympathizers, in the sense that they tolerate their illegal activities. Hoping that having personal ties with COSAC will be to their advantage once apprehended, these fishermen go out of their way to establish good relations with them. A case in point was when the COSAC headquarters was constructed. A number of cyanide users offered to help in the construction, free of charge. They attended the headquarters' opening, brought food during the affair and consciously acquainted themselves with all members of the law-enforcing team.

Another way to develop friendly ties with COSAC men is to hold drinking sessions every time they visit the island. The cost of these drinking sprees is shouldered by the fishermen. Apart from this, cyanide users voluntarily give gifts to law enforcers in the form of food fish.

Establishing kinship ties with COSAC men is also a common practice. Such ties further bind the relationship of a COSAC man and a cyanide user. One often hears of a COSAC man being the godfather of a cyanide user's child.

Existing marketing arrangements

Some 70% of the tropical fish collected in the area are sold to different Chinese exporters based in Manila. All the fish so collected are caught through the use of NaCn. A minority group, collecting fish with nets, sells its catch to a Makati-based export company. These groups practice two distinct marketing arrangements. The former opts for the *bilihan* (buy-and-sell) system while the latter practices a set sharing system.

The rampant and extensive use of NaCn can be attributed to the kind of marketing arrangement that prevails in the area. The *bilihan* system, which is the dominant one, exists for several reasons:

1. Most aquarium fish collectors do not have fishing vessels and own only a scoop net and a squirt bottle. They inevitably become part of a work group led by a fishing vessel owner who acts as the local manager and trader. The manager selects and maintains 8-12 fish collectors who become his regular suppliers. These fishermen know how to use NaCn, which they have been doing for some time. The *bilihan* system works to their advantage because the responsibility for the fish caught ends after selling them to the local manager. Whether the fish dies is no concern of theirs. Furthermore, a collector who is part of a work group does not spend anything for a fishing trip. All expenses are shouldered by the local manager on the condition that all fish gathered will be sold to him.
2. Unlike in a set sharing system, where all expenses and income are divided among the crew (two divers and the *banca* owner), a local manager's role in the *bilihan* system is doubly difficult. He shoulders all the fees, taxes and permits necessary to collect and transport aquarium fish. He also shoulders the packaging cost.

Despite these, he is able to compensate for his efforts and recoup his investments by having a very high mark-up price. A local manager's mark-up price ranges from 140 to 400% which, according to him, is good enough, especially if high-priced fish species are caught. He augments his income by selling NaCn to his collectors.

3. *Amo* is the term used by local managers to address the exporters with whom they conduct business. These *amo* extend assistance to their suppliers in several ways. They are open to loans used for capital to buy gear and equipment. In some cases, some exporters loan money to enable gatherers to buy new fishing vessels. They also shoulder a portion of the transport expenses to Manila. Most of them have encouraged their suppliers to use NaCn in collecting aquarium fish. Most, if not all, sell cyanide to their suppliers. Apparently, these exporters are after the quantity of fish to be exported and the added income they can earn from selling NaCn.

CONCLUSION

This study shows that the use of NaCn is deeply embedded in the habits of the fishermen using it. Because of the relative efficiency of using NaCn to collect aquarium fish, fishermen are reluctant to give up the practice and will go to extreme measures to conceal its use. They also try to befriend law enforcers and are willing to forego friendships with some people who do not condone their activities. To change the fishermen's behavior patterns in the use of NaCn, several structural adjustments in the economic and social contexts should be made. These are:

1. Set up marketing incentives against the use of NaCn so that the exporter either buys only "netted" fish or pays more if the fishermen can prove that the fish were caught with nets.
2. Fishermen should see what benefits they can get if they use nets; otherwise, there is no incentive to change.
3. Checkpoints on fish quality would be more effective if these are placed away from the community where law enforcers are not involved with fishermen.
4. Local law enforcement should focus on education. Law enforcers should help explain new systems and benefits from using nets, etc. and still have the power to arrest.
5. Curtail supplies of NaCn so that its price would become too high.
6. Community education workers can provide a link in communicating with the fishermen, to facilitate more profitable market channels for netted fish.

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An economic analysis of brackishwater shrimp pond culture in Johore, Peninsular Malaysia

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ABSTRACT

Recent years have witnessed the impressive and rapid development of brackishwater shrimp pond culture in Johore, Peninsular Malaysia. According to official estimates, there were some 236 brackishwater ponds in operation, spanning an area of 336 ha in 1984. By 1987, the number of ponds had increased to 365 while the area developed was 490 ha. Some 2,500 ha of mangrove areas have been studied for aquaculture potential. Recognizing the tremendous potential for brackishwater pond culture in Johore, there has been an upsurge of interest by the private sector to invest in the aquaculture business, especially in tiger shrimp (*Penaeus monodon*) farming.

In the light of these current developments, this study seeks to determine the economic viability of brackishwater pond culture, with specific reference to tiger shrimp farming on a semi-intensive culture system. More specifically, the study aims to analyze the cost and earning structures of the shrimp farming enterprise; assess the economics of investment in shrimp farming using various profitability indicators; examine the farm's sensitivity to changes in production and price levels; and examine the impact of changes in production and price on the farm's net income. The data in this study were obtained from a cross-sectional survey of brackishwater pond operators in Johore during the 1987-1988 crop year.

INTRODUCTION

Brackishwater shrimp pond culture in the country has not been able to take off in a big way despite its tremendous potential for large-scale commercial development. Poor yields, lack of technical expertise, lack of seeds and broodstocks, inferior farm management, market constraints and other related problems have all contributed to the sluggish development of brackishwater shrimp farming in the country compared to neighboring countries like Thailand, the Philippines, Taiwan and Japan (Khor 1985; Tengku 1985; Kuperan 1988; Yahaya 1988). According to the latest estimates, there are 480 small- to medium-sized brackishwater ponds in Peninsular Malaysia covering a total of 473 ha mainly on intensive to semi-intensive culture systems for tiger shrimp (*Penaeus monodon*) and located mostly in Johore, Perak and Kedah (FD 1986). Total production from brackishwater pond culture in 1986 was 269 t valued at M$3.7 million[a] (wholesale) with shrimp accounting for 89% of the total production.

The potential area for shrimp culture in Malaysia is 98,334 ha, mainly in mangrove area (Anon. 1986). Commercial development of this potential is necessary if the international market, estimated at 600,000 t annually and valued at M$16.2 billion, is to be tapped (Anon. 1988). Shrimp is in great demand in Japan, followed by the United States and Europe.

Among the states in Peninsular Malaysia, Johore has about 23,875 ha of mangrove forests in South Johore with potentials for large-scale brackishwater pond development. Under the present economic conditions, all these areas are expected to be developed at the rate of about 1,000 ha per year at the cost of about M$16,000 per ha. Furthermore, a big boost awaits Johore's aquaculture industry, following a decision by a large United Kingdom multinational corporation, to invest M$106 million in a tiger shrimp project. The project will cover over 1,000 ha and will be located in the coastal area of Tanjung Sedili. Work on the project started sometime in 1988. It will be implemented over four phases. Phase I will involve an initial investment of M$5 million for the construction of 18 ponds with a production target of about 150 t of tiger shrimp for export by the end of 1988. It is envisaged that when all four

[a]29 December 1988: M$2.702 = US$1.00.

phases have been completed, there would be 150 ponds, providing job opportunities to 350 Malaysians (Anon. 1988).

The Johore State Economic Development Corporation (SEDC) has also gone into commercial shrimp farming. Currently, SEDC owns and operates one large tiger shrimp project in Sedili Kecil. The project is a joint venture between SEDC and Asian Marine Foods (Hong Kong) Ltd. At present, only half of the targeted 400-ha pond has been developed. Aside from the grow-out ponds, a hatchery and processing plant will also be part of the venture. Although the project's capital investment is not known, the 200 ha was developed at a cost of M$9 million, including land acquisition. The project is estimated to harvest about 130 t of shrimp in 1988 with a value of M$4 million, primarily for the export market.

The Johore Tenggara Regional Development Authority (KEJORA) has also earmarked some 10,000 ha, mostly in Johore River, for large-scale aquaculture development. The KEJORA's project will be implemented in stages under the privatization concept, in consonance with the State Government's effort to make Johore the leading aquaculture state in the country.

PROFILE OF COASTAL AQUACULTURE IN JOHORE

In the past, brackishwater pond and cage culture development in Johore always lagged behind that of freshwater aquaculture. However, accelerated development has come about very recently. In 1986, an estimated 302 ponds were in operation covering an area of 396 ha (FD 1986). Primarily employed for shrimp culture are intensive and semi-intensive culture systems, although the majority of the enterprises are small-scale in nature with minimal capital investment. A study by the Fisheries Department showed that about 68% of the total operators interviewed in the States of Johore, Perak and Kedah were operating farms less than 1.0 ha with the capital cost ranging from M$1,768 to M$39,067 (FD 1987).

However, in Johore, there are 17 large-scale commercial farms in operation. These are concentrated in the southwestern part of Johore within the Pontian District, the southern tip of the Johore Bahru District and in the Kota Tinggi/ Penggerang and Mersing Districts in East Johore (Fig. 1). A brief description of some of the farms listed is given in Table 1.

Despite the introduction of new farming techniques, the traditional trapping method of pond culture is still being practised by some farms in Johore although it is declining in importance. This method requires the construction of embankments with sluice gates to enclose large tracts of mangroves. During high tide, the sluice gates are opened to allow shrimp larvae to enter the embankment. The gates are then closed as the tide recedes, trapping the shrimp in the embankment. Harvesting is carried out two to four times a month with a yield averaging 500 kg/ha/year.

Brackishwater cage culture is another important coastal economic activity in South Johore. The two most important species cultured are the grouper *(Epinephelus salmoides)* and sea bass *(Lates calcarifer)*. The average yield for both species is about 75 to 125 kg/cage of 3m x 3m x 2m with a culture period of 10 to 12 months. Unlike pond culture, cage culture requires simple technology, management and less capital investment and is, therefore, associated more closely with fishermen or farmers seeking supplementary income. Its long-term development implications appear more favorable than brackishwater pond culture since it has a minimum ecological impact (i.e., no need to convert mangrove areas). Currently, 101 operators have permits by the Fisheries Department to undertake cage culture in Johore. Nearly half are found in the Kukup Laut area in the Pontian District. The number of cages in operation is estimated at 2,753 covering a total area of 27,204 m^2 (FD 1986). Total production from cage culture in Johore in 1986 was 245.3 t with a wholesale value of M$4.62 million (FD 1986).

Mussel *(Perna viridis)* culture using floating rafts is another coastal activity in Johore, especially in Selat Tebrau where a natural spat fall recurs. Culture period is from six to seven months when mussels attain the marketable size of about 7 cm. Each suspended rope can produce up to 30 kg of mussel per harvest. Mussel culture was initially operated as a part-time income supplementing activity by the local fishermen. However, with encouragement and support extended by the Fisheries Department, more and more fishermen are now undertaking mussel culture operations on a full-time commercial basis. To date, there are about 41 mussel operators in Johore, mostly in the Selat Tebrau area. Although the existing number of mussel farm operators is currently very insignificant, there is a tremendous potential for future expansion.

TECHNICAL ANALYSIS

Culture methods

There are three methods of shrimp culture commonly employed: extensive, semi-extensive and intensive systems (FD 1980; Liong et al. 1987). The extensive method is characterized by a low stocking rate, usually less than 5 shrimp/m², and relies mostly on tidal water exchange with minimal artificial feeding. Average pond size under this method usually ranges from 0.5 ha to 1.0 ha. The semi-intensive method is characterized by a higher stocking rate ranging from 5 to 15 shrimp/m². Water exchange is facilitated by the use of pumps. About 10-30% of pond water has to be changed daily to ensure good water quality.

The intensive method, which closely resembles the semi-intensive method, is characterized by a higher stocking rate (15 to 25 shrimp/m²), exclusive use of an artificial diet, aeration and frequent water exchange through pumping. Intensive tiger shrimp farming originated in Taiwan. Given the acute shortage of land and the high cost of construction in Taiwan, the average pond size is generally very small, usually not exceeding 1 ha. Stocking densities range from 25 to 50 shrimp/m², yielding as much as 4.5 t/ha/harvest (Liao 1981; Liao and Chao 1983; Kuo 1984).

Stocking of shrimp using any of the above culture methods consists of two types:

1. Batch system - Fry are stocked directly in grow-out ponds and allowed to grow until harvest; and
2. Progression pond system or cycling method - Fry are initially stocked in nursery ponds until the juvenile stage is reached and then transferred to grow-out ponds where these are eventually harvested. This type is more widely practised than the batch system because it is efficient in minimizing undue stress during the stock transfer.

Farm sites

A majority of shrimp farms in Johore are sited in or near mangrove areas. The choice of sites is influenced to a great extent by several factors such as (FD 1980; LKIM 1983; Cook et al. 1984):

1. availability, cost and extent of land area;
2. relationship between land elevation and tidal fluctuation;
3. water quality (dissolved oxygen, salinity, pH and temperature) at the site;
4. availability and quality of freshwater for salinity regulation;
5. extent of vegetation;
6. availability of infrastructure and amenities like roads, potable water and electricity; and
7. institutional support from the state government.

Pond design and management

Earthen dugout ponds constitute the principal design for most of the farms (FD 1980; Cook et al. 1984). Pond size varies from 0.25 ha to 1.0 ha, with separate water inlet/outlet gates. A pump is used for water exchange, especially during the low tide period. In most ponds, the inlet and outlet gates are so designed to allow at least 50% of water renewal within 24 hours. These inlet and outlet drainage canals are built parallel to the ponds (Fig. 2).

Most of the aquaculture farms sited in mangrove areas have experienced acid sulfate soil problems. Potential acid sulfate soils are generally found in mangrove areas where they become oxidized when exposed to the atmosphere, thus producing sulfuric acid and iron sulfate, especially during pond excavation and after a prolonged dry spell followed by a heavy rain. This results in the lowering of the pond water pH below 4.0. Studies have shown that acid sulfate soils have five adverse effects on the pond environment (FD 1980; Cook et al. 1984; Law 1988):

1. Sulfuric acid reduces pond water pH, causing stress and mortality in the cultured stocks.
2. Precipitation of fine ferric hydroxide particulates clogs the gills of cultured stocks, causing stress and mortality.
3. The low water pH reduces the pond productivity by inhibiting algae bloom.
4. The high concentration of iron and aluminum salts in the water is toxic to fish and shrimp.
5. Acid sulfate soils do not readily respond to fertilization, thus inhibiting primary production in the ponds.

To overcome the acid sulfate soils problem, lime is generally applied to neutralize the acidity. About 3.5 to 5.0 t/ha of lime are applied depending on the acidity of the soil. Another method of conditioning acid sulfate soils is through repeated leaching and flooding with saline water for several months. This method, however, is time-consuming. Hence, to reduce the acid sulfate problem, the pond should be constructed with minimum excavation, preferably by building bunds on the chosen sites and using pumps for water exchange. Such a type of pond construction has been adopted by East Asian Marine Farms and some other farms in Johore.

Feeding system

An effective feeding system in shrimp culture is essential to minimize feed wastage. Commercial feed accounts for 50 to 90% of the total feeds required for shrimp. This accounts for between 30 to 60% of the total production cost (Chuah and Yassin 1987; Liong et al. 1987; Ung 1988).

Shrimp are known to be slowfeeders and thus have to be fed at regular intervals throughout the day. The optimum number of feedings per day is about three to five times, usually between 0800 to 2200 hours at three to four hour intervals between each feeding (FD 1980; Ismail and Hanafi 1987). The amount of feeds given vary, depending on the stages of development of the shrimp. Postlarvae reared in nursery ponds are heavily dependent on the natural food from the pond. At postlarvae of 30-35 days, supplementary feed is given at 100% of their total body weight for one month and proportionately adjusted thereafter, usually at ten-day intervals.

There are two basic feeding techniques commonly adopted by shrimp farms: (1) dispersing feed manually with or without the use of boats and (2) dispersing feed using mechanical feeding devices. The former is practical for small ponds, while the latter, for large ponds exceeding 1.0 ha.

Food conversion ratio

Food conversion ratio (FCR) is a typical measurement for assessing the efficiency of the feeding regime. The lower the ratio, the more efficient the feeding is since this indicates less feed wastage. Field investigations and studies conducted in the past revealed that the FCR averaged at 1:2 (FD 1980; Chuah and Yassin 1987; Liong et al. 1987).

Survival rates

Survival rates are known to vary from farm to farm. But a survival rate of 60 to 70% is very typical for most farms.

Production

Production or average yield varies considerably from farm to farm. In general, however, the production averages at 5.28 t/ha/year and 4.33 t/ha/year for the intensive and semi-intensive systems, respectively (Table 2). The weight of shrimp at harvest is about 30-35 g per piece for both intensive and semi-intensive systems. In terms of the number of crops per year, it averages 2.7 crops and 2.5 crops in a year for intensive and semi-intensive systems, respectively. Culture period averages 3.6 months/crop for the intensive culture system and 3.5 months/crop for the semi-intensive system. This means that the production per crop is 1.95 t/ha and 1.73 t/ha for the intensive and semi-intensive farms, respectively.

The average yield of shrimp culture, compared to plantation crops like rubber, oil palm and cocoa, gave the following comparative figures for these crops: 4.5 t (value M$4,275)/ha/year for crude oil palm; 1.60 t (value M$4,480)/ha/year for rubber; and 0.74 t (value M$2,368)/ha/year for cocoa. Considering the high commercial value of prawns at M$1,800/t, the average yield estimated for the prawn enterprise (valued at M$9,500/ha/year and M$7,794/ha/year for intensive and semi-intensive farms, respectively) is slightly over that of the plantation crops.

FINANCIAL ANALYSIS

The following financial analysis applies to a semi-intensive system where the capital investment and operating costs are based on current market values.

Capital investment cost

The capital investment cost of a 10-ha semi-intensive shrimp farm are presented in Table 3. Total pond development (construction) cost amounted to M$80,000 or M$8,000 per ha and accounted for nearly 32% of the total investment cost. The next single largest capital item is equipment at M$50,000, accounting for almost 20% of the total investment cost. Other capital items include infrastructure and vehicles.

Capital investment cost in shrimp culture can be categorized into depreciable and nondepreciable capital items (Alplin and Casler 1968; De la Cruz 1987). Buildings, machinery, equipment and vehicles are generally considered depreciable capital items because they wear out, hence depreciating in value with use over time. The depreciation cost of these items was computed using the straightline method where the acquisition or initial cost was divided by the estimated lifespan of the items (Table 3). The salvage or residual value of the items is assumed to be zero. Depreciation cost is generally treated as a fixed noncash expense item spread over the lifespan of the capital items. The depreciation cost for the 10-ha semi-intensive farm was estimated to be M$12,000 ha/year. Not included in the depreciable investment cost are items related to pond development--infrastructure such as roads, fencing, water supply and electrical installation. The total investment cost for a 10-ha semi-intensive farm was M$251,000 or M$25,100/ha (Table 3).

Operating cost

The estimated annual operating cost per hectare of a semi-intensive culture system is given in Table 4. Preliminary estimates showed that the annual production cost per hectare for a 10-ha semi-intensive shrimp farm was M$59,090. Feeds constitute the single largest item, accounting for nearly 46% of the total operating cost. Shrimp stock cost ranked second, or 20.3% of the total cost. Other significant expenses for the operating cost include salaries and wages (16.2%), maintenance and repairs (7.6%) and electricity and fuel expenses (4.2%). In addition, expenses for the purchase of lime, fertilizer, teaseed cakes and others, and administration, marketing and transportation also contribute to the total operating cost. These expenses are generally classified as the variable cost since they vary according to production levels and are incurred only if production is carried out.

Another item customarily included in the operating cost is the fixed cost (i.e., that incurred whether or not production is carried out and includes depreciation cost and interest on cash operating expenses). The latter usually approximates the interest earnings the money would generate if deposited in a savings bank.

Production revenues

Table 5 shows the estimated annual production and value per hectare of a 10-ha semi-intensive shrimp farm. The production rate shows an increasing trend. During the first year of operation, most farms commonly achieve only 50% of their full output potential. By the fifth year, however, when farm operations have stabilized, the initial teething problems have been overcome and the workers have gained sufficient expertise and experience, the maximum productive capacity would have been achieved. After the fifth year of operation, the production rate is assumed to be constant. This means that at an average ex-farm price of M$18/kg, production revenues of M$45,000-M$99,000/ha could easily be achieved.

Income statement

The estimated income statement, derived by juxtaposing revenues (from the sales of shrimp) against the operating cost under the semi-intensive system, is shown in Table 6. The farm incurred a net loss of M$130,236 during its first year of operation because of a relatively low production. This is a very common phenomenon in the shrimp farming enterprise. However, by the second year of operation and onwards, net positive incomes were registered with increases in the production level. Net income from the farm was on an increasing trend after the second year of operation, reaching a high of M$362,964 by the fifth year, and stabilizing at this level onwards (Table 6).

From the income statement shown in Table 6, some inferences on the costs of production can be made. Under a semi-intensive system, there are expenses for commercial feeds. Shrimp fry and labor, which account for about 70-80% of the total cost, constitute the three largest cost items in the shrimp farming enterprise. Hence, commercial feeds and shrimp fry should be of good quality to enhance the viability of the farm enterprise. Likewise, farm workers should be qualified and experienced to make the enterprise succeed. Estimated total production cost of a semi-intensive farm (excluding depreciation and interest) is M$59,090/ha with a production rate (or yield) averaging at 5,500 kg/ha after the fifth year. Thus, the average production cost per kilogram of shrimp is about M$10.75. This estimate is close to what shrimp farm operators get (M$10.00 to M$11.00 per kg).

The average production cost of plantation crops --M$1.70/kg for rubber, M$0.50/kg for crude oil palm and M$2.50/kg for cocoa--shows that it is less compared to the production cost of shrimp culture, which is very high.

Based on the projected cost and return statement, the projected cash flow statement for the 10-ha semi-intensive shrimp farm was also calculated (Alplin and Casler 1968). Such a statement is useful for indicating the availability of cash for the continued operation of the farm. In any business enterprise, the initial cash inflow requirement during the first year of operation is usually provided by the investor's own capital. This is equivalent to the total project cost which is the sum of the total capital investment and total cash expense requirements for the first year of operation. Based on the projected cash flow statement, the project appears to be economically viable in the long run as it will not experience cash flow shortages after its first year of operation (Table 7).

Profitability

In any business enterprise, measuring the economic worth of investments is essential to determine its commercial profitability. Traditionally, the financial measures or indicators used for profitability include cash payback period, simple rate of return on investment (ROI), benefit-cost ratio (B/C ratio), net present value (NPV) and internal rate of return (IRR) (Squire and Van der Tak 1975; Gittinger 1982; Mishan 1982). One serious disadvantage of the cash payback period and ROI is that the timing of the capital outlays and benefits is not considered. Hence, both measures do not reflect that a dollar in hand today is more valuable than a dollar to be received sometime in the future. Thus, other financial measures like B/C ratio, NPV and IRR are more commonly used to assess the economic worth of investments. These three measures are sometimes referred to as "discounted indicators" because they incorporate the "time value of money".

Based on our preliminary estimates, the various profitability indicators such as B/C ratio, NPV and IRR were calculated (Table 8). The project enjoys a short cash payback period and a B/C ratio of 1.32. The NPV (at the ex-farm price of M$18.00/kg), which measures the present value of benefits forthcoming from the project, including the residual value of investment, is about M$1.19 million or M$119,000/ha. The higher the NPV, the more financially attractive the project is. Finally, the project enjoys an IRR of 85%. This is considered profitable since it is higher than the opportunity cost of capital (value).

CONCLUSION

A preliminary economic analysis of the brackishwater shrimp pond culture in Johore indicates that semi-intensive shrimp farming is viable. This supports the general notion that investment in the shrimp business is indeed worthwhile with the proper management and application of modern technology. Its economic viability notwithstanding, shrimp farming is undeniably a high-risk investment. Several reasons could explain some failures in the past: improper site selection and pond design, acid sulfate soil conditions, pollution, costly capital investment, high overhead cost, improper farm management and marketing inefficiencies, among others. These factors have kept away potential investors. Recently, however, large investors, particularly in Johore, have been showing an increased confidence in the shrimp business.

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Table 1. Commercial brackishwater shrimp culture farms in Johore.

Name of company	Farm location	Total pond area developed	Species cultured	Culture system	Stocking density (pieces/m²)	Size of fry at stocking	Average yield (t/ha/crop)	Remarks
Daiman Marine Products Sdn. Bhd.	Sg. Chokoh, Serkat	68.0	*Penaeus monodon*	Intensive to semi-intensive	25	1.5 cm	2.5	Integrated with hatchery farms
Malayan Commercial Enterprises Sdn. Bhd.	Gelang Patah	11.4	*P. monodon*	Semi-intensive	30-35	2.5-3.0 cm	3.0-5.0	Opening up eight new ponds covering about 6.4 ha
Kukup Marine Sdn. Bhd.	Serkat, Pontian	8.3	*P. monodon*	Semi-intensive	10	2.5-3.0 cm	1.8-2.0	Facing major high acid sulfate problems
Ternakkan Marine Sdn. Bhd.	Tg. Pelepas, Gelang Patah	74.9	*P. monodon*, *P. merguiensis*	Semi-intensive to extensive	5	1.5-2.0 cm	2.0	Integrated with hatchery farms
Syarika Penternakkan Udang Pelentong	Pelentong	Trapping - 12.1 Pond - 4.1	*P. monodon*, *P. merguiensis*	Semi-intensive	5	2.4-3.0 cm	2.0-2.5	Started as a natural trapping farm
Pertama Aquaculture Sdn. Bhd.	Sg. Melayu, Gelang Patah	15.0	*P. monodon*	Intensive to semi-intensive	20	1.5 cm	9.0	Rated as one of the most highly profitable farms; has its own hatchery farm in Sepang, Selangor
Sunong Sdn. Bhd.	Sg. Lebam	19.8	*P. monodon*, *P. merguiensis*				0.7	Trapping pond
Crustacea Enterprises Sdn. Bhd.	Sg. Penawar	20.3	*P. monodon*, *P. merguiensis*	Intensive	20-25	2.5-3.0 cm	2.0	Integrated with hatchery farms; one of the more successful farms in Johore
Temasik Marine Industries Sdn. Bhd.	Sg. Ambok/ Sg. Lebam	70.0	*P. monodon*	Intensive	25	2.0 cm	2.5	
Penggerang Farms Sdn. Bhd.	Sg. Ambok/ Sg. Lebam	12.5	*P. monodon*	Intensive	50	2.0 cm	1.0	
Aqua-Ace Sdn. Bhd.	Sg. Lebam	16.5	*P. monodon*	Semi-intensive	15	2.0 cm	0.8	

Continued

Table 1. (continued)

Name of company	Farm location	Total pond area developed	Species cultured	Culture system	Stocking density (pieces/m²)	Size of fry at stocking	Average yield (t/ha/crop)	Remarks
East Asian Marine Farm Sdn. Bhd.	Sedili Kecil	200	*P. monodon*	Semi-intensive	7.5	2.5-3.0 cm	1.35	A SEDC joint venture with Asian Marine Foods (Hong Kong) Ltd.
Kemajuan Pertanian dan Makanan Laut Sdn. Bhd.	Sg. Santi, Penggerang	21.3	NA	NA	NA	NA	NA	Formerly Agaliem Sdn. Bhd.
Projek Menternak Ikan Airpayan Udang Laut	Sg. Dangga	15.0	*P. monodon*	Semi-intensive	10	2.5-3.0 cm	8	LKIM project privatized to Kumpulan Guthrie; facing a severe pollution problem; closing down
Bungawang Sdn. Bhd.	Sedili	8.7	*P. monodon*	Intensive	30	2.0 cm	3.5	
Fugo Aquaculture Sdn. Bhd.	Kecil	8.1	*P. monodon, P. merguein-sis*	NA	NA	NA	NA	
Semenchu Fish	Sg. Lebam	40.4	*P. monodon*	NA	NA	NA	NA	

Notes: Sg. - Sungei (meaning "river").
Tg. - Tanjung (meaning "cape").
NA - Not available.

Table 2. Comparison of the production parameters of the intensive and semi-intensive culture systems.

Item	Intensive earthen pond	Semi-intensive earthen pond
Stocking density	15-25 pcs/m²	5-15 pcs/m²
Feed	Commercial	Commercial
Water management	Pump + aeration 50% replacement and frequency of 15-17 times/crop	Tidal + pump Daily exchange of 10-30%
Pond size	0.25 to 0.5 ha/unit	0.5 to 1.0 ha/unit
Culture period	3.6 mo./crop	3.5 mo./crop
Number of crops	2.71 crops/yr	2.5 crops/yr
Harvest size	30-35 g	30-35 g
Survival rate	60-70%	60-70%
Production/yr	5.28 t/ha/yr	4.33 t/ha/yr
Production/crop	1.95 t/ha	1.73 t/ha
Food conversion ratio	1:2	1:2

Table 3. Estimated capital investment costs (M$) of a 10-ha semi-intensive shrimp farm (pond size: 0.5 ha/pond).

Item	Total cost	% of total	Economic life (yr)	Annual depreciation[a]
Pond development[b]	80,000	31.9	-	-
Infrastructure[c]	26,000	10.4	-	-
Electrical installation	25,000	10.0	-	-
Buildings	30,000	11.9	15	2,000
Machineries/equipment[d]	50,000	19.8	10	5,000
Vehicles	25,000	10.0	10	2,500
Miscellaneous[e]	15,000	6.0	5	3,000
Total investment	251,000	100.0	-	-
Total depreciable investment	120,000	-	-	12,500
Investment/ha	25,100	-	-	-

[a]Computed using the straightline method with a zero residual value.
Formula used: (initial value - residual value)/economic life.
[b]Includes excavation, bunding, drainage and water gates.
[c]Includes roads, fencing and water supply.
[d]Includes pumps, engines, water paddles, filter plants, pump house and others.
[e]Includes buckets, nets, fish boxes and others.
Note: 29 December 1988: M2.702 = US$1.00

Table 4. Estimated operating cost (M$) per hectare of a 10-ha semi-intensive shrimp farm.

Input	Unit	Cost/unit	Quantity	Cost	% of total cost
Shrimp stock	pieces	0.04	300,000	12,000	20.3
Feed (FCR 1:2)	kg	3.00	9,000	27,000	45.7
Lime	kg	0.30	2,500	750	1.3
Teaseed cakes	kg	0.85	400	340	0.6
Electricity/fuel	-	-	-	2,500	4.2
Salaries/wages[a]	-	-	-	9,600	16.2
Repair/maintenance[b]	-	-	-	4,500	7.6
Miscellaneous[c]	-	-	-	2,400	4.1
Total				59,090	100.0

[a]For supervisor, technician, farm laborers and security guards.
[b]Usually incurred only two years after the farm had been in operation.
[c]Includes administration, marketing, transportation, etc.
Note: 29 December 1988: M$2.702 = US$1.00

Table 5. Estimated annual production (kg) and value (M$) per hectare of a 10-ha semi-intensive shrimp farm.

Year	Price/kg	Production: Quantity	Production: Value
1	18.00	2,500	45,000
2	18.00	3,250	58,500
3	18.00	4,000	72,000
4	18.00	4,750	85,500
5	18.00	5,500	99,000
6	18.00	5,500	99,000
7	18.00	5,500	99,000
8	18.00	5,500	99,000
9	18.00	5,500	99,000
10	18.00	5,500	99,000

Table 6. Projected income statement (M$) of a 10-ha semi-intensive shrimp farm at the ex-farm price of M$18.00/kg.

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Income: sales	450,000	585,000	720,000	855,000	990,000
Less: cost					
Variable:					
Shrimp stock	120,000	120,000	120,000	120,000	120,000
Feeds (FCR 1:2)	270,000	270,000	270,000	270,000	270,000
Electricity/fuel	25,000	25,000	25,000	25,000	25,000
Salaries/wages	96,000	96,000	96,000	96,000	96,000
Lime	7,500	7,500	7,500	7,500	7,500
Teaseed cakes	3,400	3,400	3,400	3,400	3,400
Repairs and maintenance	-	-	45,000	45,000	45,000
Miscellaneous	24,000	24,000	24,000	24,000	24,000
Fixed:					
Depreciation	12,500	12,500	12,500	12,500	12,500
Interest on operating cost (4%)	21,836	21,833	23,636	23,636	23,636
Total cost	580,236	580,236	627,036	627,036	627,036
Net income (Loss)	(-130,236)	4,764	92,964	227,964	362,964

Table 7. Projected cash flow statement of a 10-ha semi-intensive shrimp farm (M$).

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash inflow						
Equity[a]	797,000	-	-	-	-	-
Sales	-	450,000	585,000	720,000	855,000	990,000
Total cash inflow	797,000	450,000	585,000	720,000	855,000	990,000
Cash outflow						
Pond development cost	80,000	-	-	-	-	-
Other investment costs	171,000	-	-	-	-	-
Variable cost	-	545,900	545,900	590,900	590,900	590,900
Total cash outflow	251,000	545,900	545,900	590,900	590,900	590,900
Net cash inflow	546,000	-95,900	39,100	129,100	264,100	399,100
Plus:						
Cash balance, beginning	-	546,000	450,100	489,200	618,300	382,400
Cash balance, ending	546,000	450,100	489,200	618,300	882,400	1,281,500

[a]This corresponds to the total project cost calculated as the sum of the total capital investment and the total cash expense requirements for the year of operation.

Table 8. Profitability indicators of a 10-ha semi-intensive shrimp farm.

Year	Total income (M$)	Total cost[a] (M$)	Discount factor[b]	Discounted income (M$)	Discounted cost (M$)
1	450,000	796,900[c]	0.9091	409,095	724,462
2	585,000	545,900	0.8264	483,444	451,132
3	720,000	590,900	0.7513	540,936	443,943
4	855,000	590,900	0.6830	583,965	403,584
5	990,000	590,900	0.6209	614,691	366,890
6	990,000	590,900	0.5645	558,360	333,563
7	990,000	590,900	0.5132	507,870	303,250
8	990,000	590,900	0.4665	461,340	275,655
9	990,000	590,900	0.4241	419,760	250,601
10	1,105,000[d]	590,900	0.3855	426,530	227,792
Total				5,005,991	3,780,872

Year	Net income (M$)	Internal rate of return (IRR) Discount factor 15%	10%	Discounted net income 15%	10%
1	(130,236)	0.8696	0.9091	(113,253)	(118,398)
2	4,764	0.7561	0.8264	3,602	3,937
3	92,964	0.6575	0.7513	61,124	69,844
4	227,964	0.5718	0.6830	130,350	155,699
5	362,964	0.4972	0.6209	180,466	225,364
6	362,964	0.4323	0.5645	156,909	204,893
7	362,964	0.3759	0.5132	136,438	186,273
8	362,964	0.3269	0.4665	118,653	169,323
9	362,964	0.2843	0.4241	103,191	153,933
10	362,964	0.2472	0.3855	89,725	139,923
Total				867,205	1,190,791

NPV at 10% = M$1,190,791

[a]Excluding interest and depreciation.
[b]Based on the formula: $1/(1+0.10)^n$ where n = number of years.
[c]Including initial investment cost of M$251,000.
[d]Including residual values of pond development (M$80,000) and other investment items (M$35,000).
Notes: Benefit/cost (B/C) ratio = 1.32

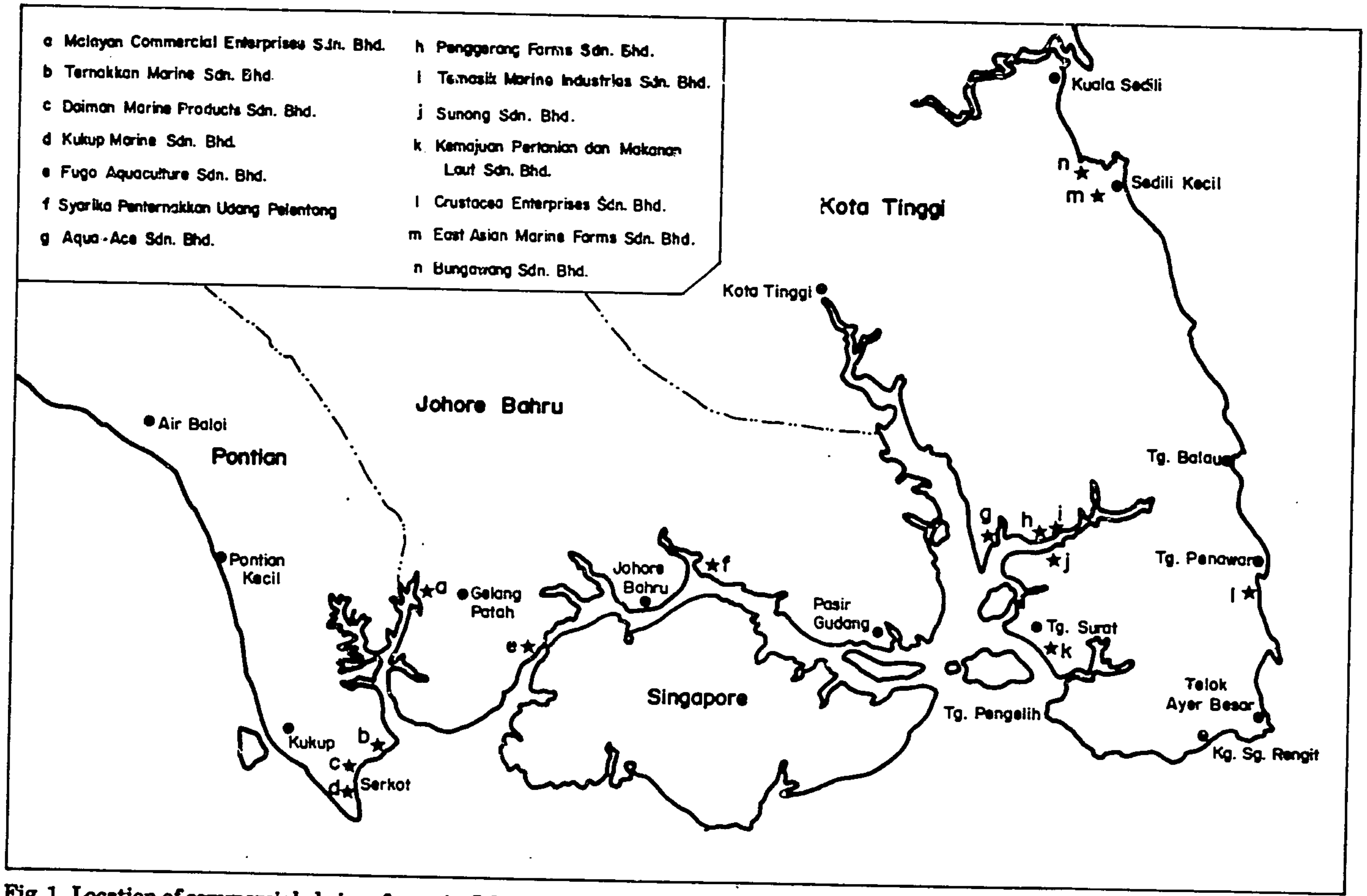

Fig. 1. Location of commercial shrimp farms in Johore, Peninsular Malaysia.

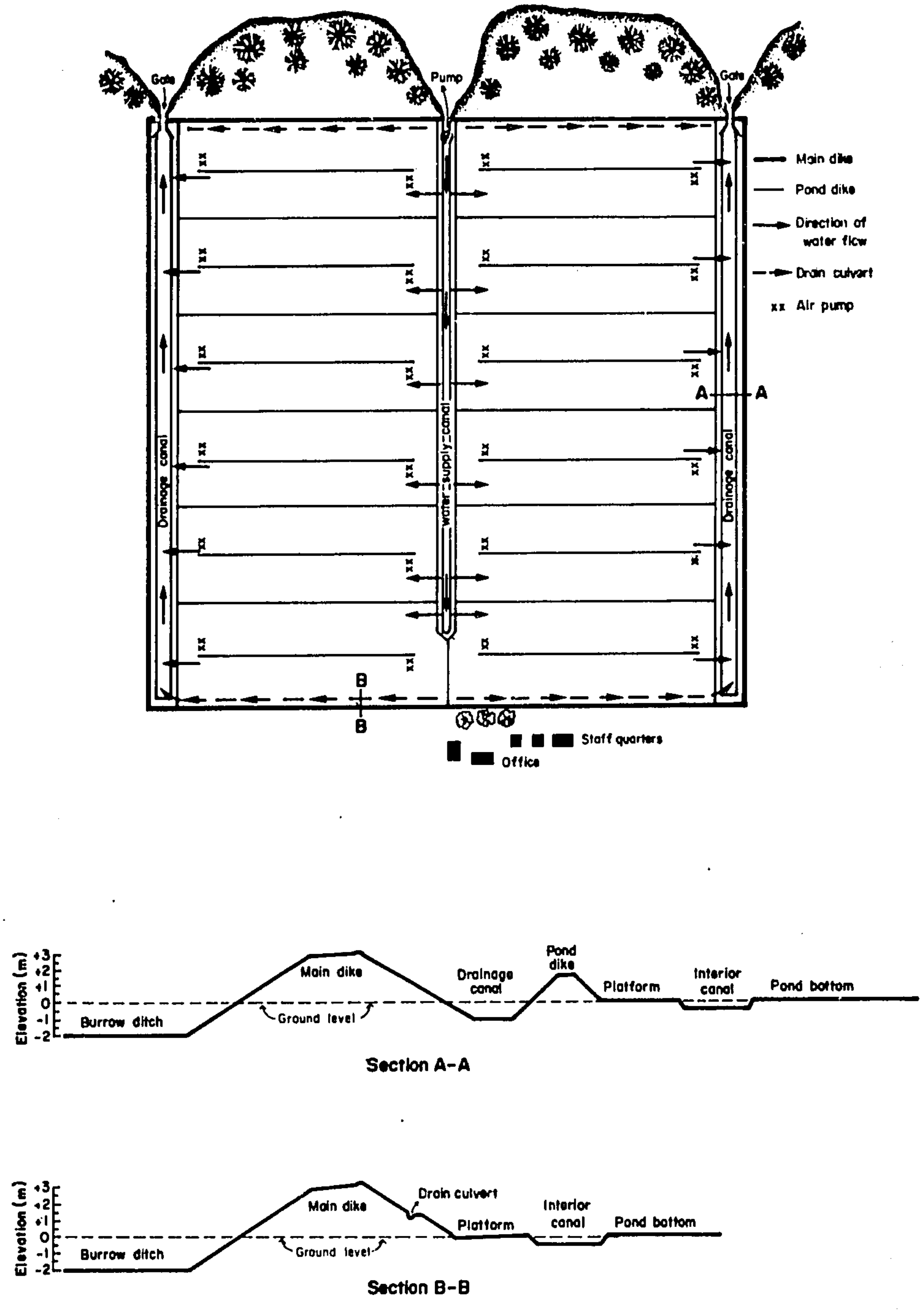

Fig. 2. Layout of the pond and its sections.

The economic impact of alternative investment and marketing decisions under varying conditions: a case of fish culture in the Philippines

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ABSTRACT

Decision theory and financial analysis were used to determine an investment and marketing strategy that would maximize returns for a grouper farm operating in the Philippines. Four strategies were considered: (1) full initial investment, export market; (2) full initial investment, domestic market; (3) staggered investment, export market; and (4) staggered investment, domestic market. Results show that all investment and marketing combinations yielded attractive returns, although it is the third strategy that should be espoused by industry planners because it favors small-scale entrepreneurs.

INTRODUCTION

Multiple uses of coastal resources such as fishing, recreation, tourism and aquaculture provide potential benefits and costs to society. Coastal resources management interventions seek to maximize the net benefits from these resources by promoting or influencing the processes involved in their use through policies, measures and regulations. For these interventions to be consistent with their proposed objectives, a clear understanding of the cause and effect relationships governing the various processes of coastal resources use is needed.

In the fisheries sector, these objectives include increasing fish supply, employment and exports (Pauly 1979) within a sustained framework. With these objectives in mind, management decisions are made at different levels of the public and private hierarchy (policymakers, businessmen, scientists, fishermen) and from different sectors of the economy (agriculture, industry, services). As management interventions are the consequences of decisions made by a heterogeneous group of decisionmakers, it is important to recognize that very frequently, decisions about coastal resources are based on noneconomic criteria such as ethical, political, religious, institutional, biological and a variety of other considerations (Emmerson 1980).

Today, decision theory and financial analysis provide the scientific bases for rational decisions that have likewise been done in the fields of engineering, business administration and economics (Cleland and King 1983). Their application to coastal resources management problems offers potentials for increased efficiency in the decision-making process and for understanding the behavior of various participants.

In this paper, the potential benefits of a particular type of coastal aquaculture activity are evaluated using financial analysis and decision theory. The aquaculture system analyzed is the cage culture of a live grouper, *Epinephelus malabaricus*[a]. Cost and revenue data and the operational regime of a grouper farm in Lingayen Gulf, Philippines were used in combination with biological parameters (Chua and Teng 1979) to generate financial and economic indicators of performance under different simulated scenarios.

These indicators include: (1) internal rate of return (IRR), which is a measure of the overall

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[a]The species *Epinephelus malabaricus* is synonymous with *E. salmoides* as identified by Katayama (Randall 1987). The former is generally misidentified as *E. tauvina*.

profitability of the project and which considers the opportunity cost of capital (through the discount rate) and the timing of the cash flow; (2) <discounted> break-even quantity (BEQ) level, which gives the level of production at which total cost equals the total revenue; (3) <discounted> average profit, which is estimated by subtracting from the average revenue all operating costs, including depreciation; and (4) <discounted> payback period, which estimates the number of culture periods required to recoup the initial investment.

These indicators are estimated and interpreted under two decisionmaking levels: one representing a set of controlled factors or variables, and the other representing the composite effect of exogenous factors (i.e., inflation rate, interest rate, foreign exchange rate) that impose constraints on internal decisionmaking.

The controlled factors are based on two of the more important issues a cage farmer (or any entrepreneur, for that matter) needs to contend with: investment (how much and when to invest) and marketing (where and when to sell).

The exogenous factors are reflected in four environmental scenarios: (1) the *base scenario*, which represents existing prices; (2) the *optimistic scenario*, which represents a simultaneous increase in the selling price of groupers and a drop in the price of feeds and seeds relative to existing price levels; (3) the *devaluation scenario*, which represents a 20% increase in the peso-dollar rate; and (4) the *price change scenario*, which represents a 10% increase in the price of feeds, seeds and groupers.

The choice of strategy ultimately depends on the type of decisionmaker who may opt to maximize returns (i.e., high profits) in a high-risk environment (maximax criterion) or a maximum level of returns with low risk (maximin criterion) (Halter and Dean 1971; Cleland and King 1983).

This decisionmaking process is relevant to the aquaculture entrepreneur because it provides an empirical and systematic approach for the estimation and interpretation of economic and financial indicators used to formulate and implement strategies that enhance profitability. The same process can also be used to predict the competitors' reaction to changes in the economic environment.

The decisionmaking process outlined in this paper was applied to the cage culture of live groupers for several reasons. First, there is an existing market niche with huge potentials for the expansion of live groupers both in the domestic and export markets. Live groupers are showcased as prime dishes in elite hotels and restaurants locally and abroad (e.g., Hong Kong and Singapore). Additionally, the Bureau of Fisheries and Aquatic Resources (BFAR 1984) reports that live (including fingerlings) and frozen groupers have also been exported to Europe and the USA. Exports of live and frozen groupers averaged 20,000 kg and 50,000 kg/year in 1983-1984, respectively.

Second, live groupers command a high price. The retail price of live groupers sold in tanks averaged ₱305/kg while the farmgate price ranged from ₱180-₱220/kg (De Guzman 1987). However, there is a sharp disparity in the price of live and fresh/frozen groupers (i.e., the retail price of frozen grouper is ₱130/kg.).

Third, the market supply of groupers comes from marine capture fisheries and aquaculture. Landings of groupers from the marine sector averaged 25,000 t from 1984 to 1987, of which 95% is accounted for by the municipal sector.[b] Groupers contribute an average of 3% and 0.3% to the total catch of the municipal and commercial sectors, respectively (BFAR 1986). The low production of groupers from the marine sector, especially the live ones, can be compensated by the aquaculture sector. No national production figures exist for farmed groupers given the fragmented and still developing nature of the industry. However, cage farms are known to operate in the provinces of Pangasinan, Palawan and Iloilo. Pond operations have likewise been noted in the provinces of Bulacan (De Guzman 1987) and Quezon. The cage culture of groupers in the Philippines is similar to the operation of cage farms in Thailand, Malaysia and Singapore (Chua and Teng 1978; Chen 1979).

Lastly, technological breakthroughs in the area of sex reversal (Chen et al. 1977), larval rearing (Hussain and Higuchi 1979) and stocking and feeding (Chen 1979; Chua and Teng 1979; Chua and Teng 1980) show a shift toward controlling the culture environment. Thus, this case study is a relevant application of the decisionmaking process.

[b]The municipal fishery sector is defined in the Philippines as that using gear with or without boats of tonnage equal to 3 t and below.

METHODOLOGY

The process of decisionmaking under uncertainty in an aquaculture system is based on a case study of the cost and revenue structure and operational system of a cage farm situated off the port of Sual in Pangasinan, Philippines. The cost and revenue structure is defined by the production strategy used.

Two broad strategies have been considered: investment and marketing. The investment strategy involves decisions on the timing and magnitude of purchases. Two investment options were considered. The first one involves making all investments on the first culture period, while the second one assumes that investment is staggered (i.e., distributed among several culture periods).[c]

The marketing strategy involves a choice between selling live groupers to the domestic market or selling them to the export market, implying a corresponding harvest strategy. The harvesting strategy is directly related to the marketing strategy because the choice of market determines the acceptable size.

Combinations of the given investment and marketing strategies result in the following:

Strategy 1	=	All investments in first month, export market
Strategy 2	=	All investments in first month, domestic market
Strategy 3	=	Staggered investment, export market
Strategy 4	=	Staggered investment, domestic market

The economic analysis is conducted over a period of 5 years or 60 months. Each culture period is taken as one cash flow period--strategies 1 and 3 (culture period is 8 months) are evaluated using 7 cash flow periods, whereas strategies 2 and 4 (culture period is 5 months) are evaluated using 11 cash flow periods.

[c]A culture period is the time necessary for a fry/fingerling to attain a marketable size. This size is 500 g for the domestic market and from 800 to 1,000 g for the export market. Assuming an initial stocking of 50 g, the culture period for a 500-g and 800-g grouper is five months and eight months, respectively. Initial stocking density and feeding rate is given in Table 1.

Purchase of materials and construction of the cage structure take a full month. Stocking is completed on the first day of the first month of the culture period. Harvesting is done on the last day of the last month. No major maintenance chores are necessary for restocking the next day after the harvest. Feeding, cleaning and repairing of nets take place simultaneously during the culture period.

Each strategy depicts a specific cost-revenue structure because each (strategy) is differentiated from the rest by the number of cages in operation, stocking density, feeding rate and harvesting.

For example, strategies 1 and 2 involve a full initial investment which is reflected in the first cash flow period. On the other hand, investment costs for strategies 3 and 4, which correspond to the number of cages constructed, are reflected in relevant culture periods. Monthly fixed costs such as sea rent, salaries, food allowance and maintenance costs remain constant for all strategy types.

Variable cost and revenue are based on the physical inflow and outflow of resources from the cage system (Fig. 1). The input-output relationship was based on parameters such as initial stocking density, growth and mortality rates, and food conversion ratios as studied by Chua and Teng (1980) (see Table 1).

Fig. 1 shows that at the start of the first month, 60 fingerlings are stocked, requiring 20 kg of trash fish. Variable cost per cage is based on the cost of fingerlings (base situation price is ₱15/fingerling) and the cost of feed (base situation is ₱4/kg) which is, in turn, dependent on the stage of growth of the fish. Feed and seed costs account for 80% of the total variable cost. Other costs include medicine and repairs. Total variable cost is computed as the sum of all variable costs of all cages in operation at various stages of fish growth.

Revenue is based on price and quantity harvested. Either 30 kg of 500-g groupers can be harvested every fifth month (as in strategies 2 and 4) or 45 kg of 800-g groupers every eighth month (as in strategies 1 and 3) (see Table 2 and Fig. 1). Total revenue per month is dependent on the number of cages ready for harvesting. Fixed revenues are generated from the ninth month onwards for strategy 1, assuming that all 30 cages have been stocked at the rate of 4 cages per month. For strategy 2, fixed revenues are generated from the sixth month onwards, assuming stocking to be at the rate of 6 cages/month over 5 months. Although revenues are also fixed for strategies 3 and 4, they are not earned successively because of the "stocking lags" between culture periods. Thus, the first culture period would register a revenue equivalent to one month, the second culture period would have two months, and so on. Table 2 depicts a comparison of the revenue schedules for all strategies.

From the monthly cash flow, a cash flow based on the length of the relevant culture period can be established from which the economic indicators can be derived. These include the IRR and the discounted values of the average profit, breakeven quantity level and payback period. The discount rate used is 12%, which is the average annual nominal loan rate (CRC 1988).

To incorporate the range of possible environmental conditions that may affect the outcome of a decision, the strategies are evaluated under four different states of nature (Table 3).

The approaches to decisionmaking under uncertainty are applied in this case study. These are the maximin and maximax criteria (Cleland and King 1983). The maximin approach is taken when the decisionmaker assumes a pessimistic view and decides to settle for the least attractive outcome for each strategy. The worst outcomes are then compared and then the best is chosen. Thus, the strategy chosen is that which provides the best outcome under the worst conditions. The maximax approach, on the other hand, is applied by an optimistic decisionmaker. He chooses the best outcomes and decides on the strategy which provides the "best among the best" outcomes.

RESULTS AND DISCUSSION

The cage farm used in the case study is located about 5 km from the shore near the port of Sual, Pangasinan. The system covers 1,200 m^2 and consists of 30 rectangular cages, each measuring 3 x 3 x .5 m. The cage structure includes the net, which is supported by wooden planks buoyed by fiberglass-coated styrofoam blocks. The support structure is also used as a working area. The anchors are cemented drums that are hinged to the main structure by nylon ropes, cables and chains. Initial investment cost is ₱145,000 (see Table 4).[d] Monthly fixed cost totalling ₱8,000 includes sea rent (₱25), salaries (₱7,200 for each of the four workers), food allowance (₱250) and maintenance for the boat (₱525); this remains constant for all strategy types. A typical cage culture system is shown in Figs. 2 and 3.

The four full-time workers man the farm 24 hours a day, taking charge of stocking, feed preparation, feeding, fish grading and sorting, cleaning of nets, harvesting, marketing and surveillance. Other costs include sea rent, salaries, food allowance and maintenance for the boat.

The indicators (IRR, BEQ, average profit and payback period) generated for each strategy under four different states of nature are presented in Table 5. The most desirable results for strategy 1 occur under the devaluation scenario. The IRR (362%) and average profit (₱87,240/culture period) are highest while the payback period (1.7) and BEQ (1,833 kg) are lowest. The same results are reflected in strategy 3 except for the IRR, which is slightly lower than that generated in the optimistic state (608%). The worst outcomes for strategies 1 and 3 occur under the price change scenario because the price of inputs (fingerling and feed) increased while the price of groupers remained constant. The best results for strategies 2 and 4 occur under the optimistic state. The outcomes under the base and devaluation scenarios are equal since the assumed devaluation does not affect domestic prices.

Results of the sensitivity analysis are shown in Table 5. In the short run, a devaluation is considered favorable for strategies 1 and 3. A higher rate of devaluation makes the outcome more attractive (i.e., higher IRR and average profit but lower BEQ and payback period). Strategy 3 registered a higher level of BEQ and lower average profit although the IRR is higher for all levels of devaluation. The same trend is reflected by the inflation scenario. Although all three indicators (BEQ, payback period and average profit) favor strategy 2 over strategy 4, the IRR of strategy 4 is higher.

Any of the four indicators may be used as a basis for final decisionmaking but the choice depends on what the entrepreneur considers to be most applicable. In this example, the IRR was used as a basis for applying the maximin and maximax approaches.

Table 6 summarizes the IRRs resulting from each strategy under the four different states of nature. To illustrate, the decisionmaker who uses the maximin approach chooses the lowest IRR for each strategy. It is 112% for strategies 1 and 2, 151% for strategy 3 and 116% for strategy 4. The

[d]The owner of the grouper farm pointed out that the initial investment cost can be scaled down to 25% of the original level.

best among the worst outcomes is 151%, and this results from applying strategy 3 if the price change scenario occurs. The more optimistic decisionmaker will choose the best among the best outcomes (highest IRR for every strategy), and this is 608%, which is registered also by strategy 3 under an optimistic scenario.

CONCLUSION AND IMPLICATIONS FOR MANAGEMENT

This paper has shown how financial analysis and decision theory can be applied as tools for systematic and rational decisionmaking in coastal aquaculture. While financial and economic analysis results in estimates of "project worth," decision theory permits the decisionmaker to decide on one among many options available, choosing that which is reflective of his perception and reaction to the prevailing risks.

The specific case of a cage farm shows the likely decisions adapted by the entrepreneur based on financial and economic indicators of four combinations of investment and marketing options. These decisions are likewise relevant to the government planner/industry analyst for the formulation of policies needed for the development of the industry. From the results earlier presented, the following conclusions can be derived:

First, that the cage farming of groupers is an extremely attractive business, a basic characteristic of infant industries. To illustrate, the lowest IRR registered is 112%, a rate that is almost ten times as much as the nominal loan rate of 12% (CRC 1988). This implies that a grouper farmer earns over and above what he could earn in alternative investments.

Second, although generally considered profitable, some strategies fare better than others. Strategies 1 and 3 (export marketing) resulted in relatively higher returns than strategies 2 and 4 (domestic marketing), which implies that the higher price obtained in the export market compensates for the additional time needed to obtain "export-quality" groupers. The role of the government and the coastal manager is to provide infrastructure support and marketing assistance, which is otherwise unavailable to small entrepreneurs.

Third, between strategies 1 and 3, which differ due to investment schedule, strategy 3 generated higher IRRs. This is because the piecemeal investment alleviates a heavy cost burden that is imposed by a lump sum investment (as in strategy 1) during the first period.

This implies that grouper farming can be profitable to small investors. Entry conditions (i.e., capital requirement) are not as rigid as intensive shrimp farming, which makes it possible for small investors to participate. Thus, coastal managers and industry planners should develop the potential of grouper farm operations to broaden the capabilities of the existing aquaculture sector and/or provide an alternative to traditional capture fisheries especially in overexploited areas.

Specific areas that need to be developed include marketing and financial assistance to suit the needs of small investors. Marketing support should also be provided to small farmers/investors for them to penetrate the export market.

The feasibility of a full-scale nationwide involvement in cage farming faces a number of constraints:

First is the number of suitable areas in the country. Only 8% of the total Philippine territory is relatively free from storms (Roces 1986), although the archipelago's irregular coastline, where protected bays and coves are common (e.g., the port of Sual), provides a number of appropriate sites. Water pollution can also be a constraint to cage farming as in the case of Lingayen Gulf (Maaliw et al. 1989).

Second are the economic risks brought about by fluctuations in the price of the produce and inputs. Results show that the price of groupers is the most important factor in determining profitability. However, profitability has a way of attracting investors that may, in the long run, result in oversupply and eventually, in depressed prices. The role of coastal managers is to regulate indiscriminate entry and to create a rational pricing policy to lessen fluctuations.

Abrupt changes in the availability/price of feeds and seeds (caused by seasonality in supply) also pose a threat to the viability of groupers farming.[e] The role of the coastal manager is to update and

[e]To check for seasonal fluctuations in supply, a multiplicative moving-average method was used to derive seasonal indices based on monthly data of the marine production of groupers in the Philippines from 1984 to 1987. The results show that, on the average, increases in production take place during the months of May to August, the country's wet season. Torres et al. (n.d.) observe that the supply of fish in Metro Manila is larger from March to June. The moving-average method was also used to detect seasonal fluctuations in prices (retail) of groupers. Results show that the retail price is highest from December to March, also the period when the supply is lowest.

disseminate technological information in larval rearing and feed preparations and provide the necessary infrastructure for a well-balanced industry.

Lastly, there are also noneconomic repercussions of unrestricted entry. These are social and environmental effects which are harder to quantify. The role of the coastal manager is to prioritize the uses of the coastal zone whether it be for recreation, aquaculture, navigation or capture fishing.

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Table 1. Biological parameters of grouper culture.

Initial stocking density	
fish/m³	**60**
weight, kg/m³	**3.35**
Initial size of fish	
mean length, cm	**15.7**
mean weight, g	**55.7**
Rearing period	
no. of months	**8**
Mean fish weight at harvest	
g/fish	**795.9**
Feed conversion rate (FCR)	
mean ratio	**3.7**
Mortality	**6%**
Average growth rate	
g/fish/day	**3.08**

Source: Chua and Teng (1980).

Table 2. Revenue schedules for all strategies.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
										(Month)										
Strategy 1									R	R	R	R	R	R	R	R	R	R	R	R
Strategy 2						R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Strategy 3									R								R	R		
Strategy 4						R					R	R				R	R	R		

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
										(Month)										
Strategy 1	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Strategy 2	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Strategy 3					R	R	R						R	R	R	R				
Strategy 4	R	R	R	R		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
										(Month)										
Strategy 1	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Strategy 2	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Strategy 3	R	R	R	R	R				R	R	R	R	R	R			R	R	R	R
Strategy 4	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

R: With revenue

Table 3. Four different states of nature (in Philippine peso).

Base	
Export price	200/kg
Domestic price	150/kg
Seed price	15/fingerling
Feed price	4/kg
Devaluation (P25:$1)	
Export price	300/kg
Domestic price	150/kg
Seed price	15/fingerling
Feed price	4/kg
Optimistic	
Export price	250/kg
Domestic price	200/kg
Seed price	12.5/fingerling
Feed price	3/kg
Inflation (10%)	
Export price	200/kg
Domestic price	165/kg
Seed price	16.5/fingerling
Feed price	4.4/kg

Table 4. Initial investment cost for a cage culture system (in Philippine peso, 1988 prices).

Nets[a]	18,000
Floats[b]	27,000
Anchor[c]	4,000
Platform	30,500
Chain/rope	3,000
Lamps	2,500
Land and water transport	30,000
Cottage/hut	30,000
Total	145,000

[a]For 30 cages; 20 m/cage at P30/m.
[b]90 floats (styrofore coated w/ fiberglass) at P300 each.
[c]15 anchors at P275 each.
Note: 29 December 1988: P21.35 = US$1.00

Table 5. Economic indicators resulting from four different states of nature (in Philippine peso).

	Base	Optimistic	Devaluation (P25:$1)	Inflation (10%)
	Export price = 200/kg Domestic price = 150/kg Seed price = 15/fingerling Feed price = 4/kg	Export price = 250/kg Domestic price = 200/kg Seed price = 12.5/fingerling Feed price = 3/kg	Export price = 300/kg Domestic price = 150/kg Seed price = 15/fingerling Feed price = 4/kg	Export price = 200/kg Domestic price = 165/kg Seed price = 16.5/fingerling Feed price = 4.4/kg
Strategy 1	IRR = 136% BEQ = 3,824/kg Ave. profit = 38,871 Payback period = 3.7 years	IRR = 348% BEQ = 2,110/kg Ave. profit = 74,960 Payback period = 1.9 years	IRR = 362% BEQ = 1,833/kg Ave. profit = 87,240 Payback period = 1.7 years	IRR = 112% BEQ = 4,332/kg Ave. profit = 33,699 Payback period = 4.3 years
Strategy 2	IRR = 112% BEQ = 5,540/kg Ave. profit = 37,289 Payback period = 3.9 years	IRR = 295% BEQ = 3,088/kg Ave. profit = 72,826 Payback period = 2 years	IRR = 112% BEQ = 5,540/kg Ave. profit = 37,289 Payback period = 3.9 years	IRR = 123% BEQ = 5,037/kg Ave. profit = 41,817 Payback period = 3.5 years
Strategy 3	IRR = 192% BEQ = 4,399/kg Ave. profit = 37,926 Payback period = 3.8 years	IRR = 608% BEQ = 2,427/kg Ave. profit = 74,016 Payback period = 1.9 years	IRR = 585% BEQ = 2,109/kg Ave. profit = 86,295 Payback period = 1.7 years	IRR = 151% BEQ = 4,984/kg Ave. profit = 32,755 Payback period = 4.43 years
Strategy 4	IRR = 116% BEQ = 6,945/kg Ave. profit = 27,883 Payback period = 5.2 years	IRR = 510% BEQ = 3,347/kg Ave. profit = 65,791 Payback period = 2.2 years	IRR = 116% BEQ = 6,945/kg Ave. profit = 27,883 Payback period = 5.2 years	IRR = 125% BEQ = 6,314/kg Ave. profit = 31,463 Payback period = 4.6 years

Table 6. Application of the maximin and maximax criteria in decisionmaking (in Philippine peso).

	Base	Optimistic	Devaluation (P25:$1)	Inflation (10%)
	Export price = 200/kg Domestic price = 150/kg Seed price = 15/fingerling Feed price = 4/kg	Export price = 250/kg Domestic price = 200/kg Seed price = 12.5/fingerling Feed price = 3/kg	Export price = 300/kg Domestic price = 150/kg Seed price = 15/fingerling Feed price = 4/kg	Export price = 200/kg Domestic price = 165/kg Seed price = 16.5/fingerling Feed price = 4.4/kg
Strategy 1	IRR = 136%	IRR = 348%	IRR = 362%	IRR = 112%
Strategy 2	IRR = 112%	IRR = 295%	IRR = 112%	IRR = 123%
Strategy 3	IRR = 192%	IRR = 608%[a]	IRR = 585%	IRR = 151%[b]
Strategy 4	IRR = 116%	IRR = 510%	IRR = 116%	IRR = 125%

[a]Decision rule using maximax criteria.
[b]Decision rule using maximin criteria.

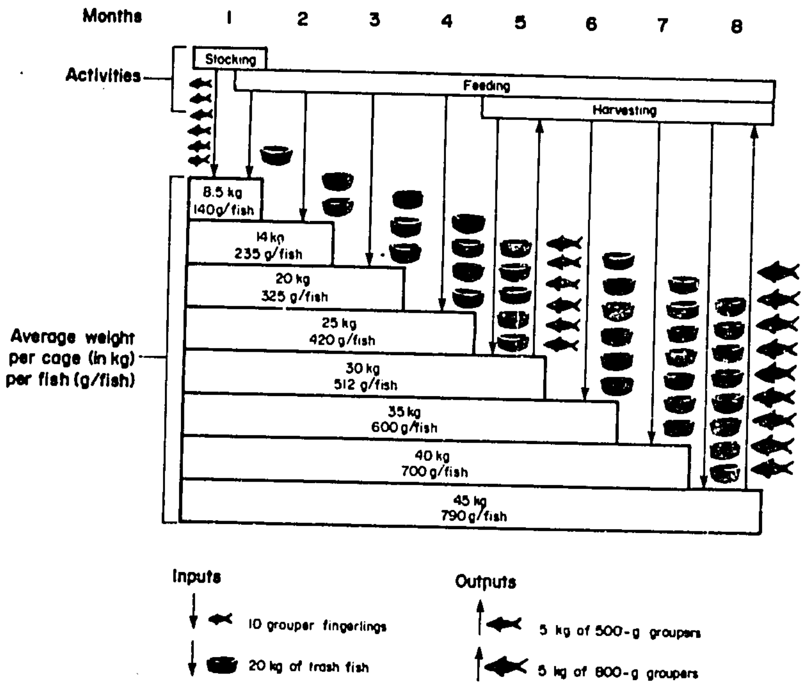

Fig. 1. Physical inflow and outflow of resources from the cage culture system.

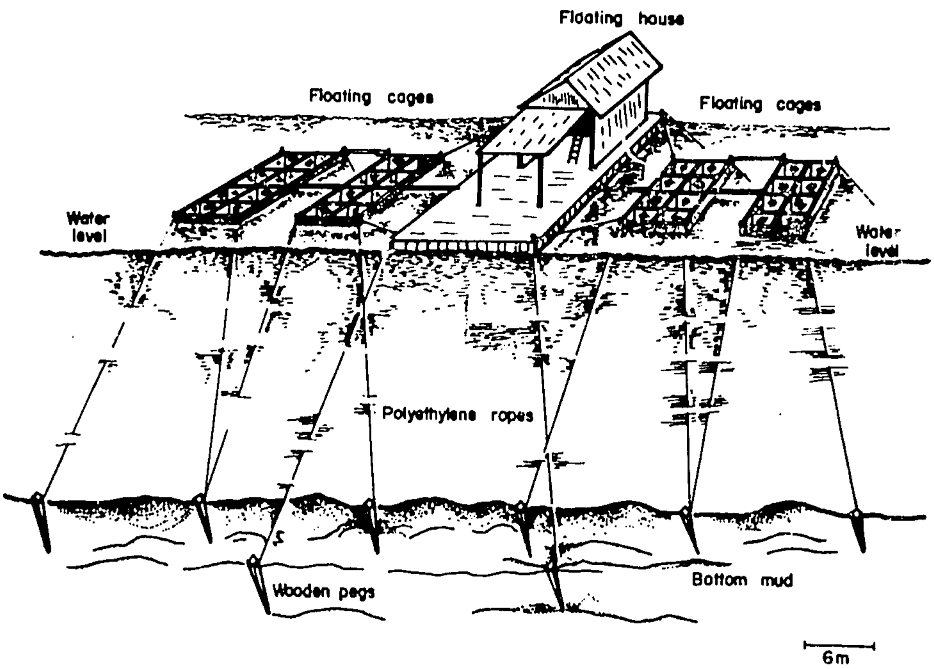

Fig. 2. Anchoring and arrangement of floating cages and floating house with wooden pegs (Chua and Teng 1978).

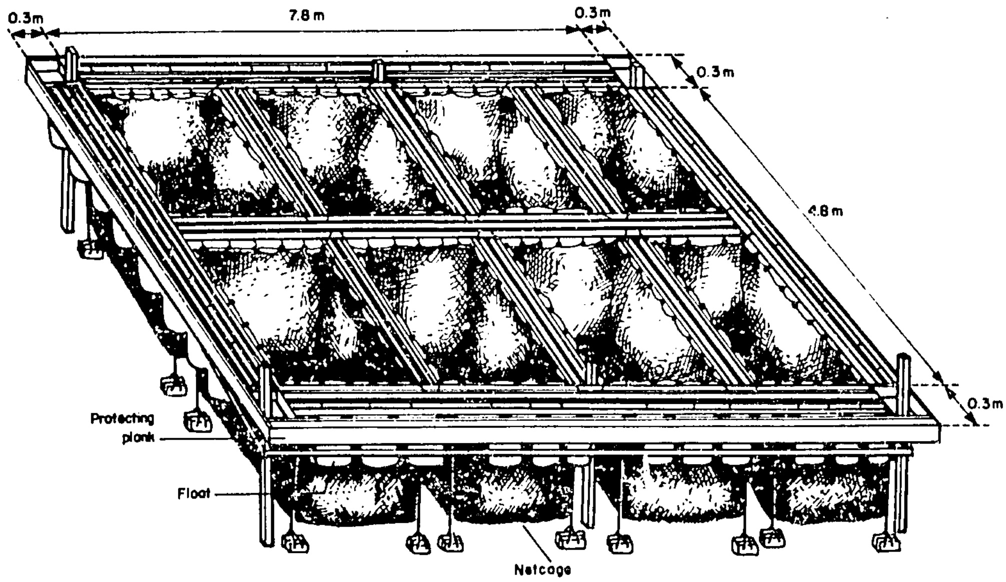

Fig. 3. A floating cage with eight netcages (Chua and Teng 1978).

Session IIIA
Legal and Institutional Arrangements in Coastal Area Management

Coastal area management in ASEAN: the transnational issues[a]

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ABSTRACT

The adjacency of ASEAN member-countries around a semi-enclosed sea and their extension of maritime jurisdiction dictate that some actual or potential coastal resources management issues will be transnational, as will their resolution. Such transnational issues include: (1) transboundary pollution effects from land-based sources, spills from oil wells and oil and hazardous cargo spills from vessels; sealane siting; (2) transboundary pollution control--harmonization of policies and regulations; (3) transboundary fisheries management of migratory species, shared stocks and illegal foreign fishing; (4) conservation--coordination of national and regional conservation schemes; (5) cooperation or harmonization of monitoring, surveillance and enforcement; and (6) management of islands and marine areas of uncertain jurisdiction. Examples of actual or potential transnational issues are elaborated and alternative solutions suggested.

INTRODUCTION

Nearshore waters and their biota are inextricably linked physically, chemically, biologically and ecologically with waters farther offshore. Indeed, the seaward boundary of the coastal area for research and management purposes is often defined as extending to encompass those waters harboring activities that can or do affect the coast. In Southeast Asia--with offshore oil exploitation affecting coastal infrastructural development, pollution from offshore tankers impacting the coast, and fish and fishermen migrating between offshore and inshore--the outward boundary of the coastal area for management and research purposes might well be considered coterminus with that of the Exclusive Economic Zone (EEZ). Most of the coastal countries in Southeast Asia have now extended their maritime jurisdictions to 200 nautical miles (nm) or more and, in many areas, their claims overlap (Fig. 1). This superimposition of a mosaic of national claims and policies on transnational resources and activities increases the possibilities for transnational marine resources management issues.

General areas where boundaries need to be drawn are in (see Fig. 1):

- Malaysia-Thailand: a quasitriangular-shaped area in the southwestern Gulf of Thailand resulting from a disagreement over the effect to be given to islands claimed by Thailand in drawing an equidistant line, although the two countries signed a memorandum of understanding on 21 February 1979 recognizing the overlapping claims and agreeing to establish a joint authority for the exploitation of seabed resources in the disputed area.
- Indonesia-Vietnam: a large trapezoid-shaped area north of the Natuna Islands where Vietnam claims the natural prolongation of its land territory to a depression just north of the Natuna Islands. Indonesia claims the equidistant line between Indonesia's archipelagic baseline and the Vietnamese territory.
- Malaysia-Philippines: a triangular-shaped area off northeast Sabah in the Celebes

[a]This paper is based on the following: Valencia (1983); Jaafar and Valencia (1985); Olson and Morgan (1985); Prescott (1985); Samson (1985); Valencia and Jaafar (1985); and White (1985).

Sea where Malaysia's continental shelf claim from a controversial baseline extends beyond lines of equidistance using various islands. There are also two small slivers of area here disputed by Malaysia and Indonesia because Malaysia's unilateral claim does not give effect to the Indonesian islands of Batuan Unarang and Pulau Maratua.

- Indonesia-Malaysia: a contorted triangular-shaped area extending northeast from the Sarawak-Kalimantan land boundary where the agreed continental shelf boundary is not coincident with an equidistant line.
- Brunei Darussalam-Malaysia: a triangular-shaped area where the United Kingdom, on Brunei Darussalam's behalf, claimed more shelf area than it was entitled to by an equidistant line.
- Indonesia-Australia: a rectangular-shaped area south of East Timor where Indonesia claims the equidistant line and Australia claims a direct line joining existing agreed boundary segments..
- Thailand-Kampuchea-Vietnam: a large part of the eastern Gulf of Thailand resulting from a disagreement on ownership of islands and the effect to be given to various islands in drawing equidistant lines, and on the azimuth of projections of land boundaries into the sea.
- Malaysia-Vietnam-Philippines-China: most of the central and northern South China Sea is claimed by China on historical grounds; all claim ownership of some of the Spratly Islands on various grounds.
- China (Taiwan)-Philippines: a large triangular-shaped area in the Bashi Channel resulting from Taiwan's declaration of an EEZ following the equidistant line and the Philippines' adherence to the treaty limits as territorial waters.
- Indonesia-Philippines: a small triangular-shaped area south of Mindanao where Philippine territorial waters extend beyond an equidistant line between the Philippine and Indonesian archipelagic baselines.
- Indonesia-Australia: a large area to the west of the Timor "gap" where Indonesia and Australia disagree on the effect to be given to the Australian Scott Reef and Ashmore, Cartier and Browse Islands.
- Indonesia-Australia: a large semicircular-shaped area between Christmas Island and Java where Indonesia argues that the island does not generate a right to a continental shelf because it is far closer (within 200 nm) to Indonesia than to Australia.
- Malaysia-Singapore-Indonesia: a small belt of disputed area generated by conflicting claims by Malaysia and Singapore to Horsburgh Lighthouse or, more accurately, to the feature on which it stands; the result could affect Singapore's boundary with Indonesia.

Besides these overlapping claims to the same waters, all ASEAN member-states share the waters of the semi-enclosed South China Sea and all have jurisdiction over waters that abut those of neighbors--both ASEAN and non-ASEAN members (e.g., Burma, Vietnam, Kampuchea and Papua New Guinea). ASEAN maritime neighbors include Thailand with Malaysia and Indonesia, Malaysia with all ASEAN members, Indonesia with all ASEAN members except Brunei Darussalam, Singapore with Malaysia and Indonesia, Brunei Darussalam with Malaysia and perhaps the Philippines, and the Philippines with Indonesia, Malaysia and possibly Brunei Darussalam. The foregoing means that the management of the national coastal area may not be purely a national affair. Indeed, coastal management is the basis for and blends with EEZ management.

TRANSNATIONAL COASTAL RESOURCES MANAGEMENT ISSUES

Marine environmental protection

ASEAN member-states have different strategies or specific regulations for the protection and preservation of the environment in shared or adjacent waters. For example, Malaysia, Indonesia and Singapore have adopted different strategies--Malaysia: mixed-uniform standards; Indonesia: multiple uniform standards; and Singapore: single uniform standards (with treatment options). The Philippines has taken the variable discharge standards approach by emphasizing the maintenance of the quality of its waters for various beneficial uses. Further, their specific standards are different for effluents discharged into watercourses other than those used for water supply (Table 1). In comprehensiveness and strictness, Singapore ranks generally higher than Malaysia, which ranks higher than Indonesia.

These policies and regulations reflect real differences in national priorities for environmental protection, in general, and for specific pollutants and pollutant sources, in particular. Yet a mosaic of different pollution policies and regulations could make environmental protection of shared and adjacent waters very difficult and possibly inhibit transnational activities such as oil shipping. Can and should standards be made uniform or be harmonized among, at least, the ASEAN member-countries with large adjacent jurisdictional areas? If so, which standards, where and on what common base?

Will differences be exploited?

A potential investor may look at the various pollution standards set by different countries as part of an economic assessment of project feasibility and siting. From an investment perspective, the Philippines might be projecting a more favorable regulatory climate by not explicitly expressing discharge standards in its pollution control laws. By specifying uniform discharge standards in their laws, Singapore, Malaysia, Thailand and perhaps Indonesia might discourage some polluting industries from investing in these countries. Should countries in the region standardize regulations to avoid offering incentives to polluting industries to locate in a particular country?

Transnational pollution

Fig. 2 shows hypothetical oil spill trajectories for five points of origin in the South China Sea. A spill from the hypothetical point of origin off the coast of Sabah would create an oil slick in Philippine-claimed waters and would cross waters claimed by Brunei Darussalam. A spill at the hypothetical point of origin east of Peninsular Malaysia could result in the pollution of Vietnamese and Indonesian archipelagic waters. Oil originating at Bach Ho off southern Vietnam could penetrate Indonesian and Malaysian waters.

Other more invisible but insidious pollutants such as dioxins can travel across national borders with the surface currents. Since the surface current pattern reverses itself twice each year, pollutants could be swept back and forth across jurisdictional boundaries. Moreover, where currents are generally weak such as in the Gulf of Thailand, the eastern South China Sea, the Arafura Sea and the Coral Sea, presumably so is the dispersion and dilution of pollutants. Airborne pollutants can be carried across national borders by winds and further distributed by surface currents. Another means of distribution of pollutants or their effects across national borders is through the organisms themselves. Some edible and commercial fish stocks are migratory or shared, and their patterns of movement indicate the potential for transnational distribution of accumulated pollutants.

ASEAN regional marine environmental policies

ASEAN has taken some regional initiatives to control pollution, e.g., the United Nations Environment Programme Regional Action Plan. But some of the marine areas claimed by ASEAN member-countries are also claimed by other countries not party to either the plan or ASEAN--Vietnam and Kampuchea in the eastern Gulf of Thailand, Vietnam in the Natuna area, and Vietnam and China in the "Dangerous Ground." Because pollution does not recognize jurisdictional boundaries, several different issues arise. Should these disputed areas be included in regional plans? Should and could the plans and international cooperation in marine environmental protection be expanded to encompass the entire South China Sea and adjacent bodies of water? Should extraregional users and polluters such as Japan and the United States participate in the plan or contribute to its implementation? To what degree should the plan be substantively weakened or its priorities changed to encourage more countries to participate?

Are there real differences in perception of pollution priorities among the countries? Does each ASEAN member-country wish to develop its own environmental impact assessment methodology and guidelines to fit its development objectives? How will any such perceptual differences affect the implementation of the regional plans? To what degree should politics influence the interpretation of scientific evidence in determining priorities?

A convention on the marine environment

Within ASEAN, there is a general disposition against the notion of a model statute or some regulations for environmental purposes, based partially on the diversity among ASEAN member-nations and the past success of the informal coordination of policies. But there is a wide range of intermediate steps between no cooperation and a formal convention. Should a series of less comprehensive interlocking agreements be established within the framework of a regional action plan? Should such arrangements be implemented even while progress is being made toward a convention? Should the regional action plans be expanded beyond the territorial sea limits of the participating countries to also include their EEZs?

International conventions

Many of the international conventions on the prevention and control of marine pollution have yet to be signed, ratified or acceded to by the ASEAN member-countries. They are generally skeptical of international conventions, particularly on the management of ship-generated pollution. Apparently, they feel that the cost imposed by the implementation and enforcement of the regulations outweigh the benefits to be derived. With increasing economic development and concomitant marine environment damage, however, it may now be considered timely for an individual or collective reexamination of the benefits and costs of those existing conventions.

Specially protected areas

The Convention on the Law of the Sea (Article 194) provides that environmental protection measures taken shall include those necessary to protect and preserve rare or fragile ecosystems as well as the habitats of depleted, threatened or endangered species. The region harbors many such ecosystems and species. Regulations for such areas could exclude, for example, ships carrying potential pollutants. Should proposals for the designation of such areas be discussed and approved on a multilateral basis among those countries affected? What criteria should be used, and what should the balance be between protection and use?

Conservation

As a result of the Convention on the Law of the Sea, coastal states are obliged to protect and preserve the marine environment and to cooperate in doing so directly or through international organizations. Further, a draft action plan for the conservation of nature in the ASEAN region has been formulated by the International Union for the Conservation of Nature and Natural Resources (IUCN). Priorities include the establishment of a network of ASEAN reserves and the institution of measures to protect endangered species. A marine reserve--ranging on a spectrum from functional, where resource utilization occurs, to preservational--is a crosscutting response to marine conservation needs. A network of reserves such as national parks, biosphere reserves, nature reserves and wildlife sanctuaries is regarded in the plan as one of the most effective ways to conserve ecosystems and their constituent wildlife. Stress is placed on finding common criteria to serve as bases for establishing an adequate reserve system. Should selection of these reserves be coordinated within ASEAN?

Sealane siting for tankers

In Southeast Asia, oil is a major pollutant and the tankers traversing the region are the major at-sea source. Eastbound tankers proceeding along the Malacca-Singapore Straits-South China Sea route are for the most part loaded with crude petroleum from the Arabian Gulf area and bound for East Asia, with some originating from Malaysian west coast ports or Indonesian ports on the northeastern coast of Sumatra. South- and west-bound traffic either carries refined products or is in ballast.

The physical restrictions imposed by channel depths of less than 23 m (75 ft) in the straits, and the safety limitation of a 3.5 m underkeel clearance added by the three coastal states, effectively preclude the use of this route by fully laden tankers of more than 200,000 dwt, which commonly have a draft of 19 m (62 ft) or more. The alternative route for these very large crude-oil carriers is through the deep (150 m) and wide (12.5 nm minimum) waters of the Lombok and Makassar Straits and the Celebes Sea south of Mindanao.

The Malacca-Singapore Straits, greatly preferred because of the shorter distance involved, is used by 72% of the east-bound, loaded tankers; the Lombok-Makassar Straits, by only 28% (Fig. 3). At any one time, there could be approximately 51 loaded or returning very large crude carriers (VLCCs) in the region. This creates a likelihood of 24.5 spills per year, averaging 1,000 MT within 50 mi of land and 5.6 spills per year, averaging 3,338 MT outside of 50 mi.

Between 0.35 and 0.50% of a tanker's cargo settles during long sea voyages, and unscrupulous operators discharge this residue into the sea. Approximately 1,000 or 300,000 gal could be discharged into the sea with tank washwater on a single voyage of a 200,000-t tanker. In Southeast Asia, this phenomenon results in major concentrations of ballast discharge at each end of the Strait of Malacca, in the western Java Sea, west of Madura, off Balikpapan, and off Brunei Darussalam and Sabah. Also, plumes of tank washings are generated along the two major tanker routes (Fig. 4). Furthermore, cargoes such as liquified natural gas, nuclear spent fuel and toxic chemicals transit the region, and some even originate from Southeast Asia.

Under the Convention on the Law of the Sea, the archipelagic states--Indonesia and the Philippines--may, with the approval of the International Maritime Organization (IMO), designate sealanes. These designations can influence the routing of some traffic, even diverting it into other countries' waters. Should designation of such sealanes be considered on a multilateral basis among those countries affected?

Environmental protection can be used as a rationale for siting or resiting sealanes. For example, Malaysia explained its denial of overflight off the Strait of Malacca to the British Airways' Concorde to prevent the sonic boom from disturbing spawning fish. Where vulnerable and valuable marine resources coincide with pollution or the threat of pollution, specially protected areas might be established and sealanes diverted. For example, in the Philippines, such areas could include the Palawan Passage route--which passes through islands containing pristine mangrove forests, major sea turtle nesting areas, endangered crocodile species and dugong--and the Sibutu Passage, which cuts directly through one of the world's major sea turtle nesting areas and mangrove forests, coral reefs and two marine reserves. In Indonesia, each of the major normal routes for tankers passes near valuable and vulnerable resources. For example, the Malacca-Singapore Straits route passes by areas of high (> 1,000 kg/km^3) fisheries catch, extensive mangroves and marine reserves; the Karimata Strait route passes by coral reefs and sea turtle nesting sites on Billiton and extensive mangrove forests on Kalimantan; and the Java Sea portion passes through areas of high fishing intensity.

FISHERIES ISSUES

Maritime jurisdiction, fish migrations and shared stocks

Fish that migrate across national maritime boundaries present problems of ownership, allocation and management since heavy fishing activities of one country can adversely affect the fishery of another country if both are fishing the same stock. Similar problems can occur with shared stocks, that is, nonmigratory stocks shared by two or more countries (Fig. 5).

Mackerel stocks, which move north and south along the western Malaysian, Thai and Burmese coasts, can be exposed to fishing pressure from all three countries. Yellowfin tuna migrate between northern Australia and southeastern Indonesia. The Philippines shares various tuna stocks with the Chinese province of Taiwan, northern Sabah, Malaysia and northern Indonesia. Shared demersal stocks of mackerels and other species occur between Thailand and Burma, Thailand and Malaysia, Malaysia and Sumatra (Indonesia), Sarawak (Malaysia) and Kalimantan (Indonesia), Vietnam and China, Hong Kong and China, Sabah and Kalimantan, and Indonesia, northern Australia and Papua New Guinea.

Maritime jurisdiction and total marine fisheries catch

Very heavily fished areas in the eastern Gulf of Thailand are claimed by Vietnam, Thailand and Kampuchea (Fig. 6). Heavily fished areas in dispute include parts of the outer Gulf of Thailand (Vietnam, Thailand, Kampuchea and, in the joint development area, Malaysia), western Natuna (Vietnam and Indonesia), the area north of Tanjong Datu (Indonesia and Malaysia), the Gulf of Tonkin (China and Vietnam), fringes of the central South China Sea (China, Vietnam and Malaysia), the eastern Mainland Shelf (China mainland and Taiwan) and the Miangas area (Indonesia and the Philippines).

Issues related to disadvantaged status and historical fishing rights

Distant-water fishing countries have suffered economic dislocations after being blocked from important fishing grounds, following the EEZ declarations of their neighbors and of countries outside the region. The ASEAN member-states adversely affected by the EEZ regime are Singapore and Thailand, although Singapore has shifted its interests to postharvest activities, including processing, transhipping and trading, with apparent success.

Article 62 of the Convention on the Law of the Sea enjoins the coastal state to recognize "the need to minimize economic dislocations in states whose nationals have habitually fished in the zone or which have made substantial efforts in research and identification of stocks." A related provision, Article 70, grants coastal states "whose geographical situation makes them dependent upon the exploitation of the living resources of the EEZs of other states . . . for adequate supplies of fish for the nutritional purposes of their population or parts thereof" the right to share "on an equitable basis" in the surplus resources of the coastal states.

Article 62, which deals with historical or traditional fishing rights, may apply to the distant-water fleets of Thailand and to the inshore fishing fleets of countries whose boundaries have dense fishing populations such as Indonesia-Malaysia, Thailand on the Strait of Malacca, Thailand-Burma on the Andaman Sea, Thailand-Kampuchea-Vietnam on the Gulf of Thailand and Brunei Darussalam-Malaysia in Brunei Bay.

The Convention on the Law of the Sea (Article 51) also says that "if a part of the archipelagic state lies between two parts of an immediately adjacent neighboring State, existing rights and all other legitimate interests which the latter State has traditionally exercised in such waters and all rights stipulated by agreement between those states shall continue and be respected." For Indonesia, this provision applies to the rights of fragmented Malaysia in the waters around Indonesia's Natuna Island. Consequently, Indonesia and Malaysia have a bilateral agreement that acknowledges Malaysia's traditional fishery rights in specified areas of the Indonesian archipelago and EEZ waters off the northern Anambas Islands.

Monitoring, surveillance and control

Illegal fishing by foreign vessels from neighboring or distant-water fishing nations is now a common complaint in the region. Due to weak surveillance and enforcement capabilities, most of the countries whose maritime zones are violated can respond only with token arrests, diplomatic *notes verbales,* loud denunciations in the press and a general feeling of frustration. Vessels from Taiwan and Thailand are the chief offenders (Fig. 7). The Tenasserim coast of Burma, the eastern and southern Gulf of Thailand, the Gulf of Tonkin and the Luzon Strait are the principal areas of vessel seizures, but there have been numerous incidents in Indonesian archipelagic waters as well.

Cooperation among countries in Southeast Asia to enforce their rights on the resources of the EEZs is permissible under the Convention on the Law of the Sea. Since surveillance and enforcement require ship and aircraft resources that can be expensive, all nations in the agreement would benefit if the necessary resources could be pooled.

But is it desirable or feasible? A subregional enforcement scheme might be considered although there are several reasons why it might not be feasible. Nations bordering the sea have very different interests in enforcement; Singapore, with its minuscule EEZ, and the Philippines, with its very large one, clearly do not have the same problems or interests. Some of the maritime territorial disputes in the region would make joint enforcement extremely difficult since it would be unclear who is entitled to be in the disputed region and who has sovereignty over the resources.

If cooperative enforcement is not feasible for the South China Sea, as a whole, would it be worth exploring for some of the smaller bodies of water in the Southeast Asian region? In the Malacca-Singapore Straits, Indonesia, Malaysia and Singapore already have a cooperative agreement concerning the regulation of navigation. The rules, which are recognized by the IMO and the shipping community at large, may have to be enforced. Joint enforcement seems particularly appropriate, since the straits are narrow and easily monitored. Other possible areas for cooperative enforcement might involve Indonesia, Malaysia and the Philippines in the Celebes Sea; and Malaysia and the Philippines in the Sulu Sea.

Some of the states in the region have already established cooperative surveillance schemes with their neighbors, and these could provide a framework for additional bilateral and multilateral surveillance and enforcement efforts. Indonesia and Malaysia have cooperated in joint surveillance of their common South China Sea border area for detecting Vietnamese refugees, and the Philippines and Indonesia have a bilateral agreement on joint surveillance in the Celebes Sea. In 1975, the ASEAN member-states joined in an Agreement for the Facilitation of Search for Ships in Distress and Rescue of Survivors of Ship Accidents. This multilateral pact could become a model for increased cooperative surveillance efforts among the ASEAN member-countries. But can the nations extend their cooperation beyond humanitarian concerns to activities with substantial economic and political connotations?

Perhaps subregional enforcement efforts are too much to expect, considering the differences among the ASEAN member-states. But nations in the region might harmonize their enforcement policies, since harmonization would not imply the sacrifice of any sovereignty over areas in dispute. If some coastal states were to agree to standard legal and judicial procedures, including levels of permissible punishment in the event of convictions, an important start could be made toward the effective management of resources for the benefit of all states in the region. Harmonization efforts could also extend to procedures for detecting and enforcing violations of environmental regulations and to programs for the conservation of living and nonliving resources.

As a first step, the ASEAN member-states could implement the pertinent articles of the Convention on the Law of the Sea, particularly Article 62, concerning access to surplus stocks, and Article 73, concerning enforcement procedures and permissible punishments. This might open the way for additional agreements designed to protect the marine environment by reducing the possibility of collisions and groundings. These activities might then be extended to include the establishment of agreed positions regarding other aspects of the Convention and its enforcement.

CONCLUSION

There are many issues in the ASEAN region that impart a transnational dimension to national coastal area management. There has been some progress in multilateral cooperation in the region for marine pollution prevention and control. However, more analysis and articulation of the benefits and costs to each country concerned are necessary before cooperative approaches to transnational issues can be fully supported. Although the UNEP Regional Action Plan is a first regional step toward responding to pollution in each country's coastal waters, formidable policy obstacles must be overcome to move toward a truly regional cooperative approach to marine environmental protection in ASEAN. The plan itself has created a new set of policy problems, this time intertwined with problems of international relations.

If full protection of the coastal and marine environments is desired, countries should first extend their environmental concern and control to their EEZs, including areas claimed by more than one country. Second, the countries should recognize and respond to the transnational nature of some pollutants and their impact, particularly oil from *all* sources. Third, the region for cooperation should be expanded to include the entire South China Sea, including its transnational oceanographic features and ecosystems. Fourth, the scope of the action plan should be extended to include environmental impact assessment and the management of pollutants from seabed exploration and exploitation and atmospheric emissions. Fifth, countries should consider standardizing their approaches to the management of pollution to facilitate the preparation of a regional convention for the protection and managed development of the South China Sea.

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Table 1. Effluent standards for point sources or discharges into rivers or open watercourses that eventually reach the ocean.

Type of waste	Item of analysis	Unit	Indonesia[a]	Malaysia[b]	Singapore[c]
Oil	Oil and grease	mg/l	100	10	10
Organic	BOD_5 at 20°C	mg/l	300	50	50
	Total suspended solids	mg/l	NS	100	50
Metals	Tin	mg/l	NS	1.0	10
	Barium	mg/l	NS	-	5
	Manganese	mg/l	NS	1.0	5
	Arsenic	mg/l	1	0.10	1
	Metals (total)	mg/l	NS	-	1
	Chromium (total)	mg/l	5*	0.05*	1
	Nickel	mg/l	NS	1.0	1
	Zinc	mg/l	10	1.0	1
	Beryllium	mg/l	NS	-	0.5
	Selenium	mg/l	NS	-	0.5
	Cadmium	mg/l	1	0.02	0.1
	Copper	mg/l	5	1.0	0.1
	Lead	mg/l	5	0.5	0.1
	Silver	mg/l	NS	-	0.1
	Mercury	mg/l	0.1	0.05	0.05
Thermal	Temperature	°C	45	40	45
Others	Total dissolved solids	mg/l	NS	NS	2,000
	Chloride	mg/l	NS	NS	600
	Sulfate	mg/l	NS	NS	500
	Chemical oxygen demand	mg/l	600	100	100
	Calcium	mg/l	NS	NS	200
	Magnesium	mg/l	NS	NS	200
	Iron	mg/l	10	5.0	20
	Detergents (as methylene blue)	mg/l	NS	NS	15
	pH value		5.5-10.0	5.5-9.0	6-9
	Color (LU)		NS	NS	7
	Boron	mg/l	NS	4.0	5
	Chlorine	mg/l	NS	2.0	1
	Sulfide	mg/l	2	0.50	0.2
	Phenolic compounds	mg/l	0.5	1.0	0.2
	Cyanide (as CN)	mg/l	NS	0.10	0.1
	Fluoride	mg/l	2	NS	NS
	Ammonia (free)	mg/l	2	NS	NS
	Nitrate	mg/l	NS	NS	NS
	Nitrite	mg/l	NS	NS	NS

Notes: NS = not specified.
* = Cr (VI)
[a]Mahbub (1979).
[b]Malaysia (1979).
[c]SCS (1980).

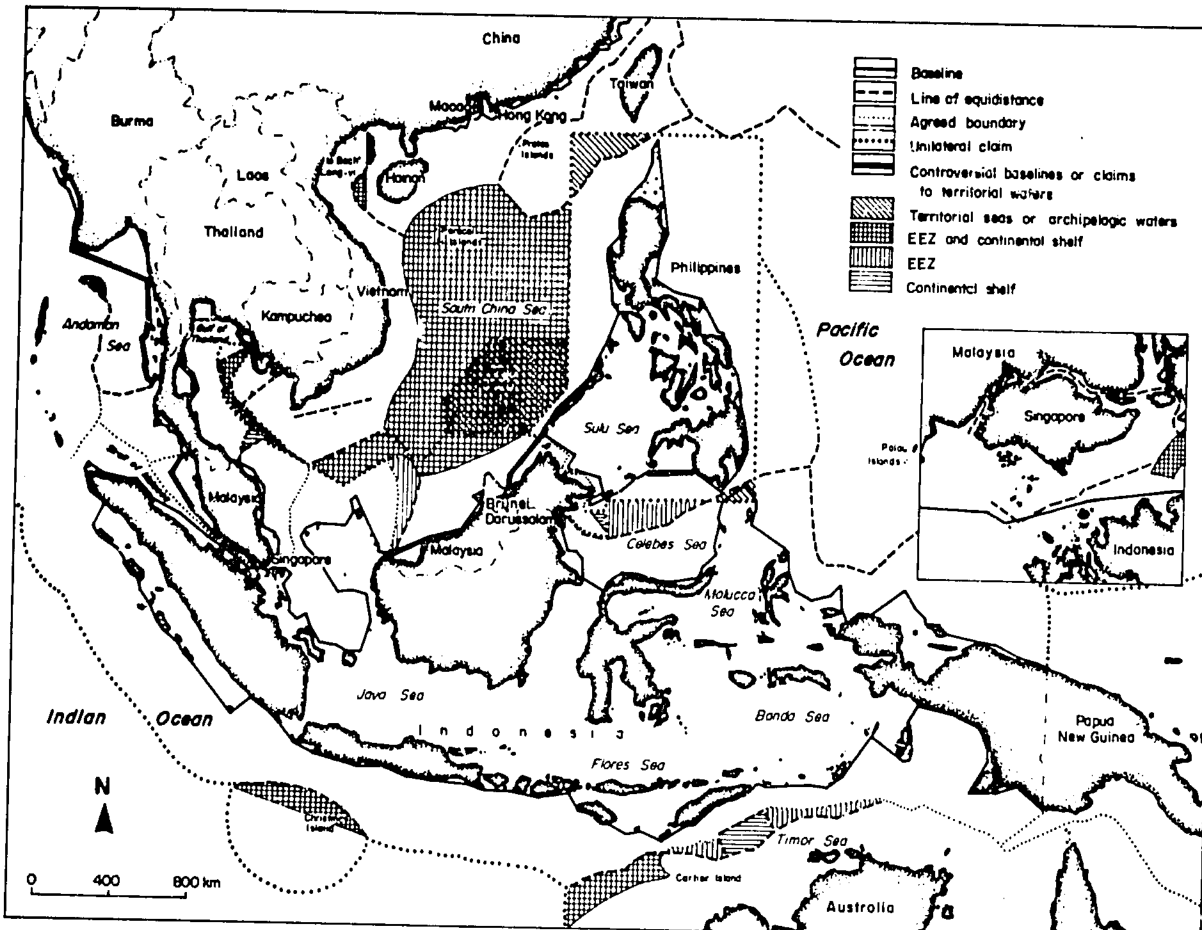

Fig. 1. Maritime jurisdiction in Southeast Asia: controversies (modified from Morgan and Valencia 1983).

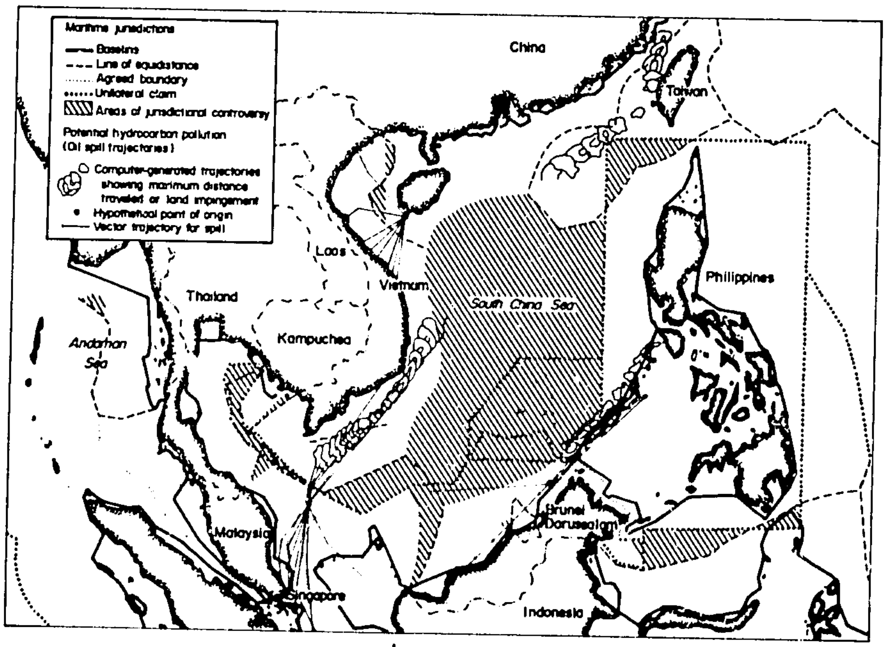

Fig. 2. Hypothetical oil spill trajectories and jurisdictional boundaries (modified from Morgan and Valencia 1983).

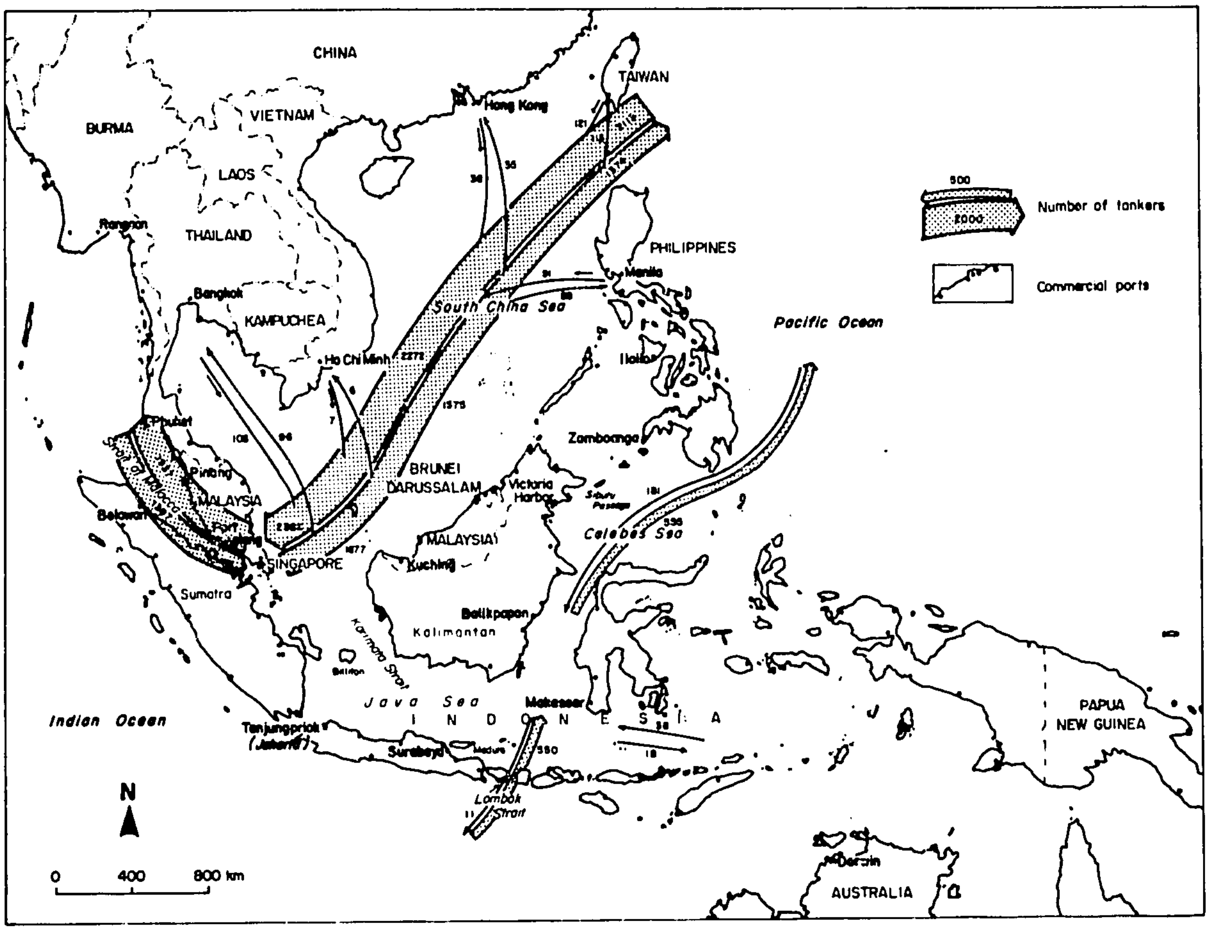

Fig. 3. Tanker traffic: ship movements, all sizes (1980) (modified from Morgan and Valencia 1983).

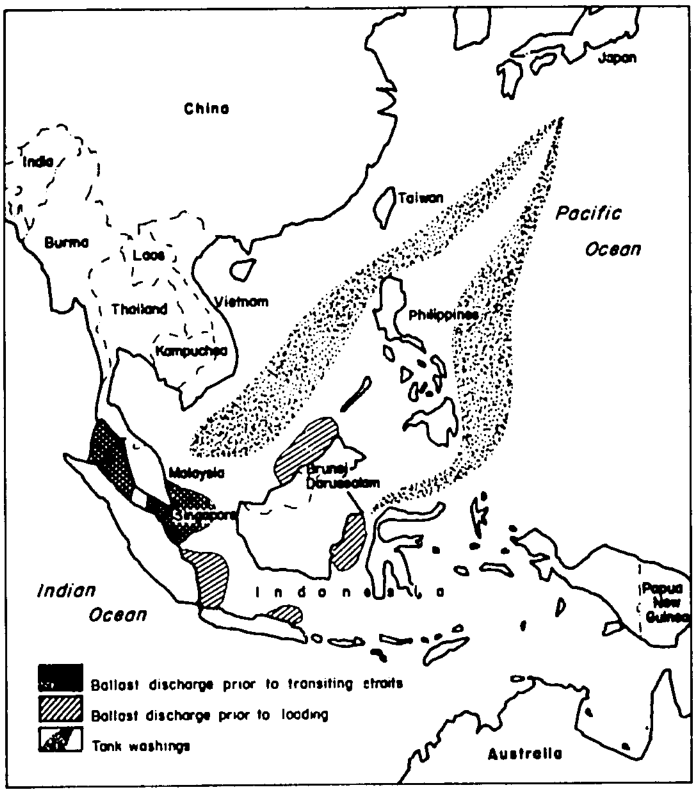

Fig. 4. Tank washings generated along two major tanker routes.

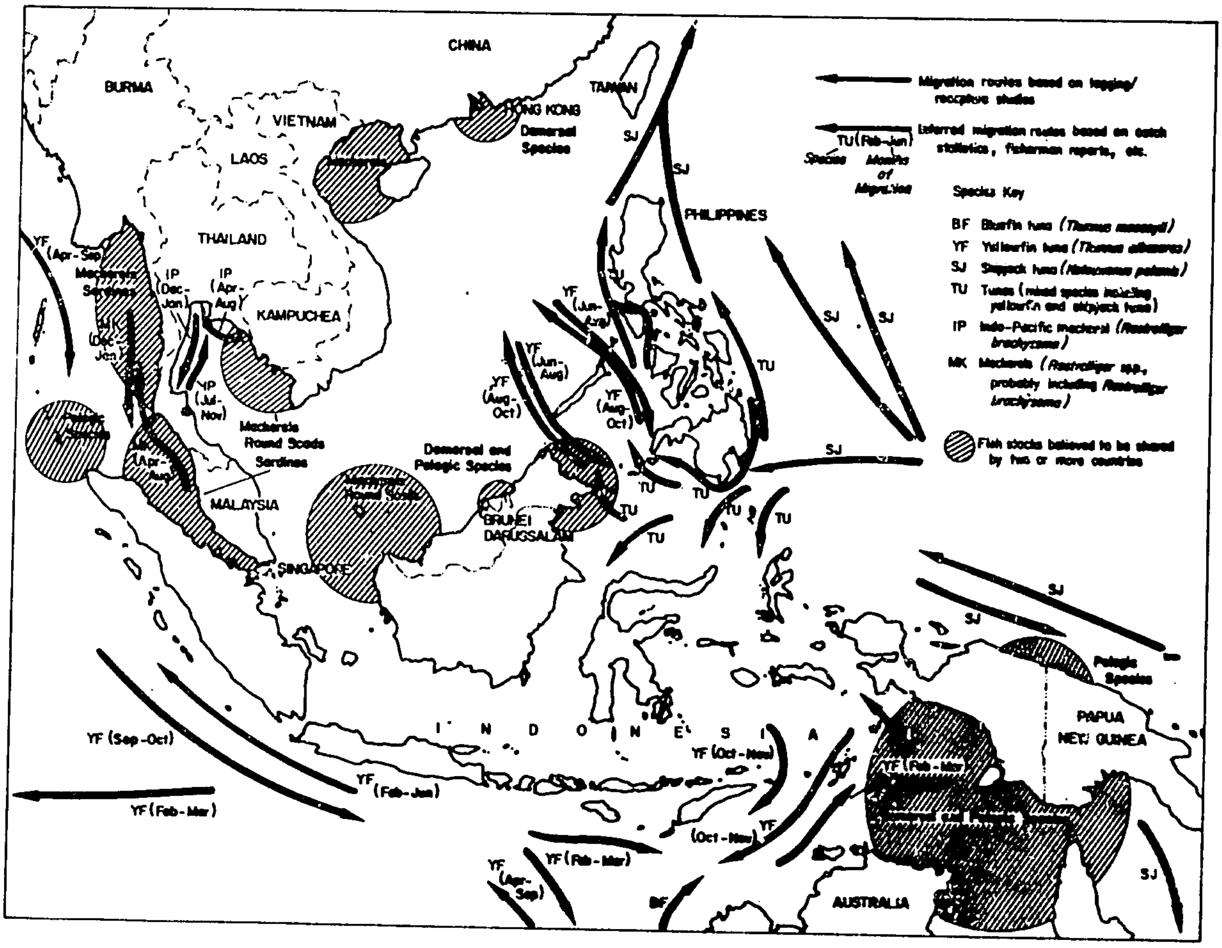

Fig. 5. Migration routes and shared stocks (Morgan and Valencia 1983).

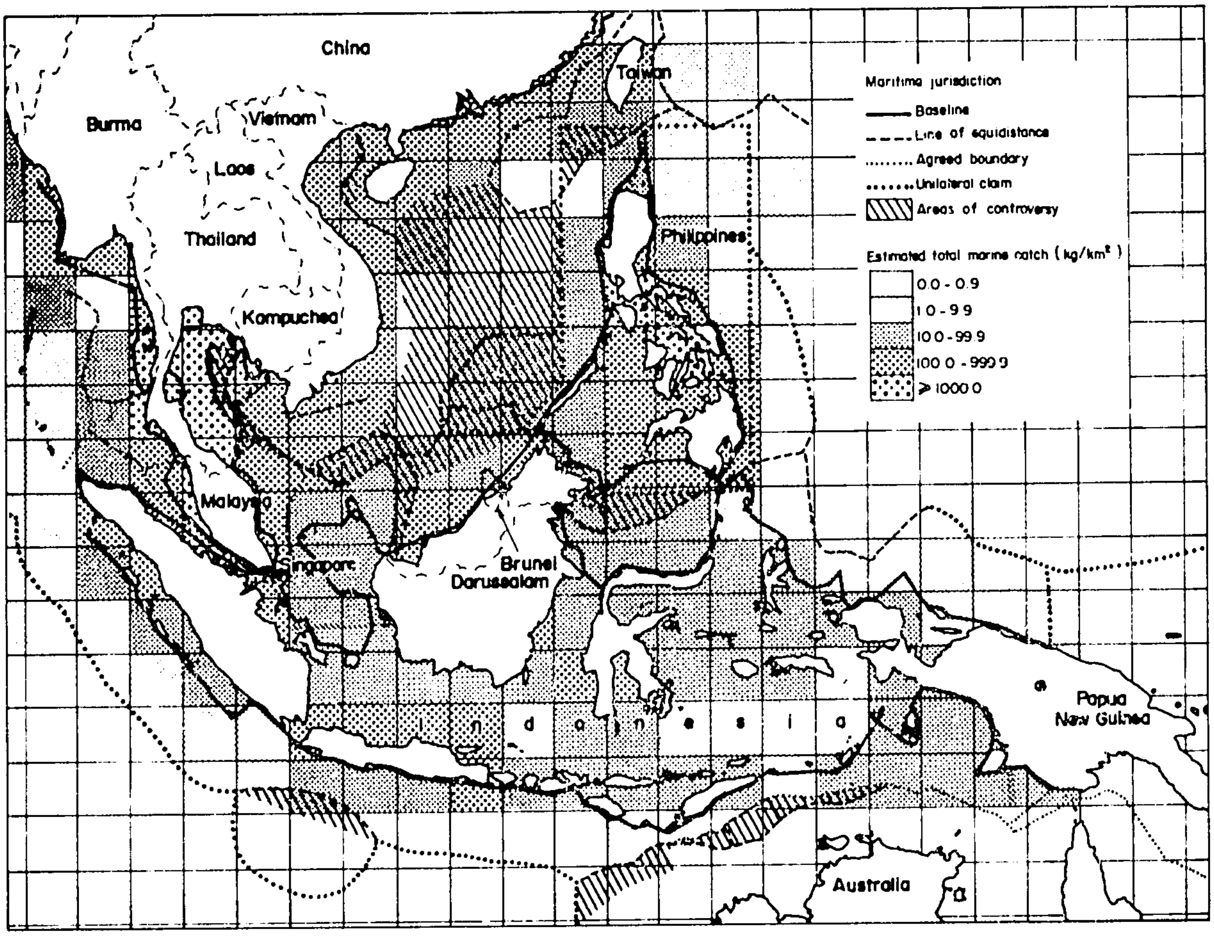

Fig. 6. Maritime jurisdictions and total marine catch (modified from Morgan and Valencia 1983).

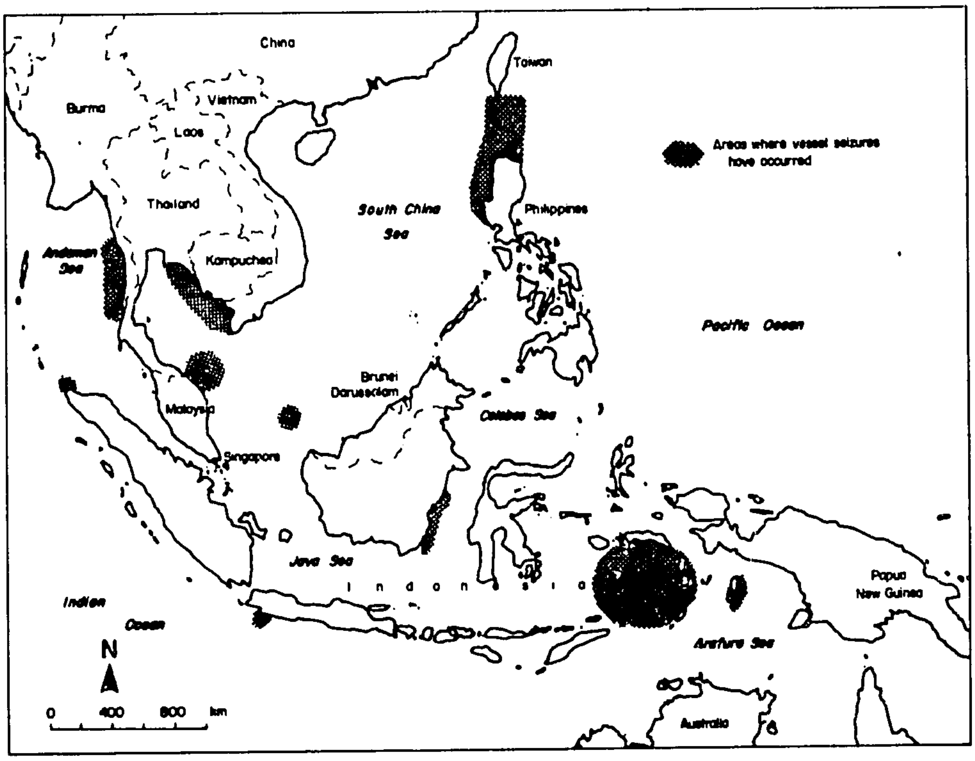

Fig. 7. Sites of vessel seizures (based primarily on *Foreign Information Service* reports).

Utilizing research for coastal zone management

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ABSTRACT

Inadequacy of the database is a common dilemma that faces resource managers all over the world. The nonavailability of information on the quantitative and qualitative changes in resources over a number of years makes it difficult for resource managers to draw correlations between causes and effects. Hence, it limits their ability to propose management policies and guidelines that impinge on established practices. This is further aggravated by the different approaches that managers and researchers use in acquiring information on coastal resources. Researchers generally want to acquire in-depth information on all elements of a resource and its linkages; managers focus on information that is relevant in addressing management issues. The researchers' approach results in the preparation of detailed inventories that the manager has neither the time nor the knowledge to convert to information that will be relevant for management purposes. The manager's inability to reach the researcher--to define clearly the issues that he wishes to address and the desired management objectives--often results in wasted effort.

In preparing the coastal zone management plan for Sri Lanka, the loss and degradation of natural coastal habitats should be addressed. Because there is a dearth of information on these habitats, management issues and objectives are difficult to identify. This paper attempts to document the approaches taken by the coastal zone managers in Sri Lanka to overcome this problem and to present how a productive relationship could be established with researchers to generate information that will be useful in formulating management strategies.

INTRODUCTION

The preparation of a coastal zone management plan for Sri Lanka was mandated by the Coast Conservation Act No. 57 of 1983. The statutory agency responsible for its preparation was the Coast Conservation Department (CCD). The Act defined the scope of the plan and set out the procedure for its preparation with a time frame of three years. The CCD decided to adopt an incremental, problem-oriented approach to prepare the plan. Three major issues would be addressed:

1. coastal erosion;
2. loss and degradation of natural coastal habitats; and
3. loss and degradation of recreational and scenic areas, and archaeological, historical and cultural monuments and sites.

The management framework with respect to the above-mentioned issues comprised defining the problem, analyzing it, stating the management objectives and enunciating policies to achieve these objectives. Implementing this planning method to the problem of the loss and degradation of coastal habitats presents the planner with a daunting task due to the paucity of information for management purposes. For instance, in preparing the coastal zone management plan for Sri Lanka, initial surveys indicated that available information sources ranged from articles in popular periodicals to unpublished documents and published scientific papers. Moreover, most of the information was descriptive and anecdotal. Qualitative changes in resources due to natural causes or human impact were rarely, if ever, presented.

Preparing detailed inventories before identifying management issues was impossible within the specified time frame. Although there are major resources use conflicts in the utilization of these habitats, management initiatives could not wait for the results of classical research methods of inventory and analysis, which the CCD staff did not have the capabilities to undertake. Furthermore, the available funds were very inadequate to sustain such research.

Defining management objectives, issues and priorities was difficult because the subjective perceptions of those interested in a particular habitat tended to cloud their rational judgment. Also, the nonavailability of spatial information on the location and extent of the various habitat types made it difficult to prioritize even the most apparent management issues. Hence, it was decided that the primary research tasks would be to prepare a preliminary habitat atlas and synthesize available information. Once these two tasks were completed, a close dialogue between the research community and the managers can be established.

HABITAT ATLAS

Available methods for the rapid mapping of the location and areal extent of selected habitat types were investigated. Because of limited time and funds, it was decided that to prepare the atlas, the following method be used that would indicate these features:

- coastal wetlands including mangroves, marshes, combined mangroves/marshes where they cannot be distinguished, fringing wetlands;
- lagoons;
- estuaries;
- sand dunes; and
- barrier beaches and sand spits.

The spatial information pertaining to the abovementioned features were obtained, thus:

1. Resource data were from available satellite images, aerial photographs and maps, which were updated from time to time. Interpretations were carried out in connection with land use and forest cover mapping by the Survey Department.
2. Base maps were compiled using topographic maps (1:50,000) through information transfer at the 1:150,000 scale. These base maps were compiled using one of the following methods:
   a. manual reduction with the help of a planvariograph mapmaker instrument;
   b. photographic reduction; and
   c. reduction using a Canon NP155 Zoom photocopier.

Where such maps were available, these reductions were transferred onto the greyline at the 1:50,000 scale topographical maps using light tables. Where such uncluttered maps were not available, overlays were prepared for use with the colored 1:50,000 scale maps. Thirty-eight sheets covering the entire coastline of Sri Lanka were prepared. On completion of the base maps, the data so collected were transferred onto a final map at the 1:250,000 scale.

SYNTHESIS OF AVAILABLE INFORMATION

Published information on coastal habitats is scarce. However, a considerable volume of information is found in unpublished reports and in the files of several agencies. Such information covers economics, management issues and research priorities for each habitat type, including a comprehensive bibliography. This information was then circulated to agencies and individual scientists involved in habitat management and environmental conservation. A workshop was organized with the following objectives:

1. to review and rank management objectives and issues for each coastal habitat type;
2. to identify research that will promote guidelines for better habitat management;
3. to identify ongoing management efforts and research; and
4. to identify management strategies for short- or long-term implementation.

The habitat atlas and the synthesis of available information were the primary documents used in the workshop. The workshop resulted in the adoption of a standard definition for each habitat type, a consensus in the definition of management objectives and issues, and a research agenda focusing on habitat types.

MANAGEMENT STRATEGIES

Based on the results of the workshop, a management strategy for coastal habitats was formulated and became part of the coastal zone management plan. The strategy comprised the following: the significance of the habitats, the nature of the problems faced, management issues and objectives and the policy on habitat mitigation. Regulatory initiatives, with respect to human activities that contribute to habitat degradation, could also be promulgated. There is also a need for a public education campaign on the values of coastal habitats and their management.

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Institutional arrangements for managing coastal tourism resources in Ban Don Bay: problems and issues

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ABSTRACT

Of the many tourist attractions in Ban Don Bay, Thailand, Ko (meaning "island") Samui is the most popular. Tourism has grown rapidly on the island. In 1980, it had only 14,868 visitors and a few bungalows; in 1987, it had about 210,000 visitors and 2,990 rooms. Tourists go to Ko Samui because of its attractive beaches, coral reefs and clear waters. However, these natural attractions are now under considerable pressure from tourism development. Existing institutional arrangements for the management of the island's coastal zone and marine resources are unsatisfactory and unable to halt their degradation since these are based on narrow sectoral interests and centralized policymaking. Thus, new cooperative arrangements among government agencies (both at the national and local levels) and the participation of its local people must be encouraged.

INTRODUCTION

The Thai Government is aware of the problems of natural resources degradation. The Sixth National Economic and Social Development (SNESD) Plan (1987-1991) reports that many of the country's natural resources have been rampantly exploited. Malpractices are prevalent in some areas, reducing the potential wealth from these natural resources (TDRI 1987). For example, forest areas have been depleted from 27.36 million ha, representing 53% of the total land area of the country in 1961 to 14.90 million ha or 29.05% in 1985. During this 24-year period, forest areas have decreased at an average annual rate of 512,000 ha. Mangrove forests, which cover 272,000 ha of land throughout the country, are expected to decrease at an average rate of 6,400 ha per year. Coral reefs are being destroyed with the use of explosives, offshore mining and other activities that deplete larval and fish fry grounds while the number of trawlers have increased five-fold from 1,872 in 1967 to 9,390 in 1983. Marine resources are then harvested faster than they can be replenished, and their natural habitat destroyed (Government of Thailand 1987).

There is a tendency toward increased conflicts in the use of natural resources. The country lacks effective operational plans for the sustainable use of these resources. If such plans do exist, implementation is difficult because of coordination problems within and without the organizations, especially at the local level.

Among the main objectives of the SNESD Plan are to increase efficiency in the wise use of natural resources and to conserve the environment for sustainable development. The plan also promotes tourism development in the Upper South subregion, which the Thai Government has selected as pilot site for the formulation of a comprehensive coastal resources management (CRM) plan. Ban Don Bay has been chosen as a study and planning area for which a management plan for tourism resources is being developed.

This paper aims to identify and analyze significant problems in managing coastal tourism resources, with special focus on local institutional arrangements.

METHODS

Both primary and secondary data pertaining to the development and management of tourism were collected by interviewing purposive samples of target groups in the study sites. Both structured and focused interviews were employed. Secondary data were gathered through the review of literature and national development plans.

The study site was Ko Samui, Thailand's third largest island, which covers about 230 km². Its location is 20 km northeast of Surat Thani Province. According to the Regional Administration Law, Samui is a district in Surat Thani Province, which is composed of 7 administrative units (*tambon*) and 39 villages. Ko Samui District (*amphoe*) has jurisdiction covering Ko Samui and its satellite islands. According to the Chief District Officer, the district's total population in March 1988 was 28,481; the income per head of the local agriculturists was about 4,000 baht (US$160) per month.

For this survey, three groups of people were interviewed to find out the problems related to institutional arrangements.

Group A comprised government officials both at the provincial and local levels and those working in the semipublic sector (e.g., *tambon* headmen, village headmen and members of the sanitary district committee) who were concerned with CRM. Thirty persons were interviewed by questionnaire and ten persons by discussion only (e.g., the governor of Surat Thani, the chief district officer of Ko Samui).

Group B comprised 100 businessmen and women who were owners or managers of hotels, bungalows and restaurants or were involved in other tourism activities on Ko Samui.

Group C comprised 325 local people from Ko Samui. Purposive and quota sampling techniques were employed. The sample group was classified into four community types (Fig. 1).

- Type A: 81 respondents from communities adjacent to the island ring road and along popular beaches.
- Type B: 81 respondents from communities adjacent to the ring road but not along popular beaches.
- Type C: 123 respondents from communities along isolated beaches where there were tourists and planned large-scale private development projects.
- Type D: 40 respondents from communities not adjacent to beaches or the ring road.

RESULTS

Administrative structure

Thailand is a unitary state with a highly centralized government. There are three levels of administration: central, regional and local.

At the central level, the Office of the Prime Minister and 13 ministries constitute the core of the national government. Each ministry is composed of departments, some of which have offices at regional and local levels. At the regional level, there are two sublevels: province *(changwat)* and district *(amphoe)*. Each district comprises a number of smaller administrative units called *tambon*, which is formed by a cluster of small villages. At the local level, four types of organizations form a system of local government, namely, *changwat* administrative organization, municipality, sanitary district *(sukhapiban)* and *tambon* council. Some political science academicians classify the Bangkok Metropolitan Administration and the City of Pattaya Administration as special authorities. Each level of local government has its own specific laws providing the legal basis for its organization and functions. Their power and functions vary but the limits of their territorial jurisdiction are demarcated.

The SNESD Plan pointed out that development plans for natural resources must consider the general state of affairs of the nation and the roles of central agencies that are the key bodies for decisionmaking. In other words, resources management is generally done in Bangkok by specific departments attached to the 13 ministries or the Office of the Prime Minister. Participation by agencies at the provincial and local levels has not been extensive (Government of Thailand 1987).

The government agencies involved directly or indirectly in managing coastal tourism resources are: the Office of the National Environment Board, the Tourism Authority of Thailand (TAT), the Royal Forestry Department, the Harbour Department, the Department of Fisheries, the Local Administration Department and the Royal Police Department (particularly its Marine Police Division). These agencies have their own specific functions. Unfortunately, the failure to coordinate has resulted in the deterioration of tourism resources.

The survey shows that about nine-tenths of Group A respondents thought that TAT should be the key agency in administering all aspects of planning, monitoring and evaluating for tourism development and management. In fact, TAT focuses on tourism promotion activities but conducts little research on tourism development planning. During fiscal year 1987, TAT spent 10,277,900 baht for surveys and data collection when it could have used it for planning.[a] Total expenditure of TAT in the same year amounted to 384,354,100 baht. Thus, only about 3% of the budget was spent for surveys and data collection.

Key ministries and agencies concerned with natural resources development have to be restructured to ensure the necessary integration between offices (TDRI 1987). This streamlining process needs to extend down to the local level, with the requisite authority and funding.

Table 1 shows the functional relationship among existing ministries and agencies and levels of government in CRM.

Participation in planning

More than half of Group A respondents disagreed with the statement that their respective organizations have appropriate vertical decentralization in the administration. Seven-tenths thought that their superiors had limited authority in making decisions regarding problems at the local level. Six-tenths of the respondents who are involved in CRM agreed that tourism resources have been used without considering the negative impact of tourism. More than one-third accepted that their organizations lacked qualified manpower with a good knowledge and understanding of CRM principles. About half of the respondents involved in CRM agreed that the problem of coordination prevails in the Upper South's provisions for tourism management, while six-tenths agreed that the exchange of tourism information among provinces has always been small. Six-tenths also believed that public agencies involved in tourism development were working independently without consulting or discussing the adoption of an integrated approach to tourism development and management (Table 2).

A provincial planning analyst said that since 1982, the provincial development plan has focused on rural development. But the policy guidelines formulated by the central government have not included tourism development in its rural development strategy. There is no plan for CRM, too. Therefore, the activities concerned with these endeavors have not been supported by the rural development budget. If any province or district would like to have such activities, its officials have to make a request to the central government agencies through their representatives working in the provincial or local offices.

Furthermore, most of the 18 interviewees, both at the local and provincial levels, said they had little if any participatory role in the tourism development planning process, because they were informed only after the plan had been approved for implementation. This lack of consultation resulted in the ineffective implementation of the plan.

Officials also indicated that problems of conflicting uses were common. For example, the maintenance of fish nursery grounds in the mangrove areas conflicts with wood and charcoal production, brackishwater aquaculture, tourism, mining, port development, road networks, housing and agricultural development. It is apparent that the importance of the mangrove estuarine system is poorly understood and that few realize that mangrove destruction will have adverse affects on the delicate nutrient balance over wide areas and the catches of mangrove-related commercial marine species.

Law enforcement

The culture of rural Thai society affects law enforcement. Law enforcement is still weak. Sixty percent of Group A thought that laws should be enforced seriously and that violations should receive immediate prosecution rather than delayed action.

However, some natural resources management laws have legal loopholes or are not up-to-date. For example, the Fisheries Act of 1947 does not actually stipulate coral reef protection. The protection of reefs at present is subject to legal interpretation. No law empowers the local people to protect their environment and natural resources as "common property resources." In this context, common property resources are basically accessible and freely available to any user in the country (Christy 1982).

The local government is a key agency in implementing a natural resources management policy. In this case study, an inappropriate local government for Ko Samui was noted as a problem. This island has been governed by a chief district officer appointed by the central government. He controls

[a]1987: 25 baht = US$1.00

and supervises the general operations in the district and is an ex-officio chairman of the sanitary district committee. This type of local government doesn't please the local people who do not want to cooperate with such an administration. This also affects the people's cooperation in implementing public policy.

According to the Municipality Act, a municipality is empowered to manage the coastal resources in the municipal areas without depending on the provincial and central administration. But in reality, many factors inhibit the upgrading of the sanitary district as part of the municipal government (Kongridhisuksakorn 1987).

Perspectives of the local people

The local residents at Ko Samui face the problem of access to the coastal areas since almost all land near the sea is privately owned. Most owners feel that land near their property belongs to them. After hotels, bungalows and restaurants were built, owners or managers tried to maintain the privacy of their guests by not allowing the local people to pass through the hotels, bungalows or restaurants on their way to the beach. When establishing a setback distance for construction in beach areas on Ko Samui, the businessmen tried to narrow the distance as much as possible. Comprehensive town planning is underway but problem-solving tends to be reactive rather than pre-active.

Another serious problem on Ko Samui is the shortage of water, especially during the peak season of tourist arrivals when some hotels buy water from the local people or rely on shallow groundwater. The demand for clean water continues to increase for the tourism business since the small-scale reservoir that was built for agricultural purposes was destroyed to maintain fishing in streams. The sanitary district is trying to transfer the responsibility for the water service to the Provincial Waterworks Authority (PWA). But there are conflicts because the PWA wants to get the land for construction without compensation and the chief district officer is reluctant to ask the people to donate land on the island because of its high market value.

Another problem is garbage disposal. People throw domestic waste into the sea at night, causing water pollution and affecting coral and fish. Because of the lack of resources (i.e., manpower, budget, land for dumping, equipment), the sanitary district cannot provide adequate services to address this problem.

The introduction of a bus-car ferry to Ko Samui brought rapid changes. Some residents have migrated to the mainland where the cost of living is lower. Many local people initially sold their land to outsiders because they could not compete with businessmen from outside. Now they tend to lease their properties, a practice that may become the trend on Ko Phangan.

The government tried to extend tourism development benefits to the local people by encouraging them to participate in tourism-related activities. However, this has not met with much success. For example, most of the owners of coconut plantations still prefer to stay with this crop. The Department of Agricultural Extension persuaded these people to grow new crops such as vegetables and fruits, which are in high demand by restaurants and hotels. However, the traditions of the farmers concerned inhibit the implementation of the department's plan.

Other issues

The study also shows that there is a problem of public relations. There is no mechanism to convey understanding and create public participation. For example, when the local people (Group C) were asked if they knew that the sanitary district had a project to solve the problem of water shortages on Ko Samui, only 57% of the sample knew about it.

Businessmen tend to have a better understanding of development projects than the local people, which probably reflects their education and access to media. Some owners or managers of tourism businesses feel that government agencies do not promote tourism development in certain areas (i.e., Mae Nam beach). The businessmen are thus forming a social group. Yet, most of the local residents who are agriculturists still work independently since the cooperatives supporting their occupations are weak.

Interviews show that 79% of the local people and only 55% of the businessmen (Group B) and women were satisfied with the development of Ko Samui at present. The private sector seems to want more development in areas where they have some investments.

PROPOSED SOLUTIONS

Training is needed to strengthen the local government's capabilities to cope with the problems in managing coastal tourism resources. It may be necessary to introduce a new type of local administration and a revised local tax system. The sanitary district should be allowed flexibility to impose higher taxes.

There is an urgent need to improve coordination, both vertically and horizontally, among and within the in-line agencies.

It is generally accepted that the greater the number of agencies responsible for natural systems management, the greater the possibility that the agencies will face conflicts, hence, the greater the need for interagency coordination and communication (Mayntz 1978).

Therefore, the guidelines contained in the SNESD Plan should be used; that is, they should resolve coordination problems among government agencies by implementing a program system that allows for more synchronization in operations and greater cooperation (Government of Thailand 1987).

Particularly in this case study, most of the respondents agreed that an Upper South coastal tourism resources management committee should be established. To some extent, it would solve the coordination problem and enhance information exchange. Some provincial and local officers concerned should be recognized and given a participatory role throughout the planning process.

Existing laws affecting coastal tourism resources (i.e., corals, beach encroachment, coastal water quality) should be reviewed.

Public relations at the local level should be improved. For example, meetings should be held, and *tambon* headmen, village headmen, informal village leaders and some businessmen should be invited to participate actively. This would help concerned authorities to understand the problems better and thus, find the solutions according to the expressed needs of the people.

CONCLUSION

There are many problems in institutional arrangements for managing coastal resources since this is a new area of development in Thailand. These problems can be solved only if concerned agencies sincerely wish to work as a team for the benefit of the people. Consensus is also needed among the local people that coastal resources are invaluable and should be used on a sustainable basis.

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Table 1. Government agencies managing coastal tourism resources in Ban Don Bay, classified by levels and functional relationship.

Functional relationship and level of government	Agencies
1. Central organizations managing through provincial authority with their provincial officers	Department of Lands, Department of Public Works, Royal Forestry Department, Department of Fisheries, Local Administration Department, Royal Police Department, Office of the Permanent Secretary of the Ministry of Interior
2. Central organizations managing through provincial authority with no provincial officers	Office of the National Environment Board of Thailand, National Research Council, Department of Town and Country Planning
3. Central organizations managing through their regional or local agencies with less provincial authority	National Economic and Social Development Board, Royal Forestry Department - National Parks Division - Wildlife Conservation Division Department of Fisheries - Marine Fisheries Division - Brackishwater Fisheries Division Harbour Department
4. Local organizations managing alone	Ko Samui Sanitary District, Muang Surat Thani Municipality

Note: The Tourism Authority of Thailand is a public enterprise that has its officers in some provinces.

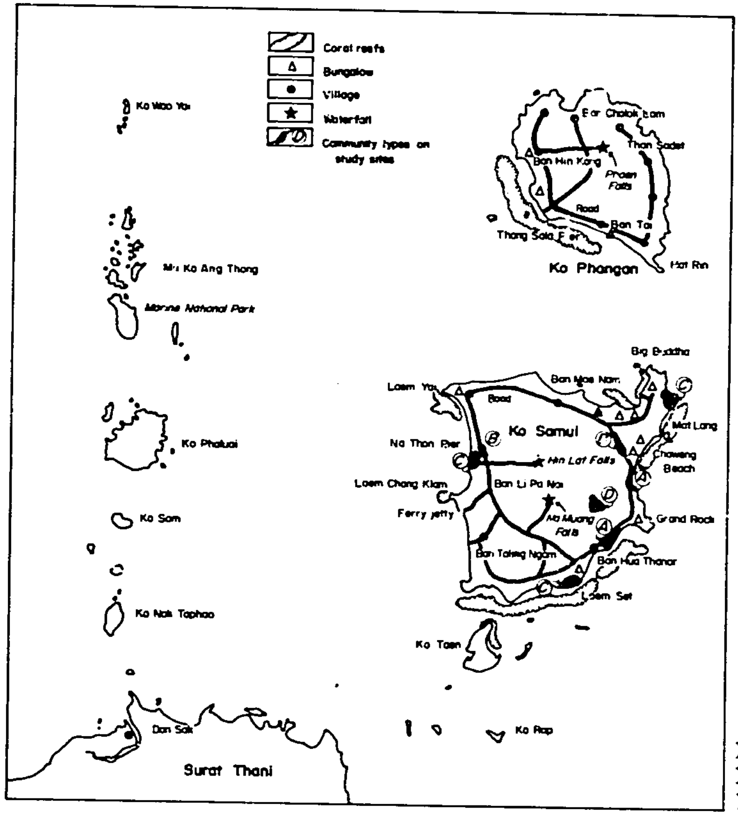

Fig. 1. Samui and Ang Thong Islands, Ban Don Bay, Thailand.

Table 2. Opinions of samples in Group A toward coastal tourism resources management.[a]

Opinions	No.	Percentage[a]
The organization in which you are working has appropriate vertical decentralization in the administration.		
agreed	14	47
not sure	-	-
disagreed	16	53
Your superiors have limited authority in making decisions to solve the problems encountered at the local level.		
agreed	22	73
not sure	2	7
disagreed	6	20
From the past until now, tourism resources have been used without taking into account their negative impact.		
agreed	17	61
not sure	2	7
disagreed	9	32
The organization in which you are working lacks qualified manpower who have a good knowledge and understanding of the principles of coastal resources management.		
agreed	11	37
not sure	-	-
disagreed	19	63
There is a coordination problem of tourism management in provinces located in the Upper South subregion.		
agreed	12	48
not sure	1	4
disagreed	12	48
Exchange of tourism information among provinces has always been small.		
agreed	14	61
not sure	1	4
disagreed	8	35
Public agencies involved in tourism are working independently without consulting or discussing with one another for an integrated approach to obtain appropriate benefits from coastal tourism development and management.		
agreed	18	64
not sure	3	11
disagreed	7	25

[a]Samples who did not give their answers were not included in the percentage computation.

Territorial use rights in fisheries and the management of artificial reefs in the Philippines

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ABSTRACT

Territorial use rights in fisheries (TURFs) is an alternative coastal resources management (CRM) scheme that aims to create the appropriate environment for self-management through the establishment of private or community ownership over common property resources. It can take the form of leasehold arrangements, franchises or allocations of ownership over an area or fish stock (e.g., award of a certificate of stewardship).

The experience of the Marine Conservation Development Program (MCDP) of Silliman University (Philippines) illustrates the potentials of TURFs as an alternative management scheme for artificial reefs, in particular, and for coastal resources, in general. The TURFs concept was used by the MCDP so that the "owners" of the resources would be interested in the current and future productivity and in the health of "their" coral reefs and thus be inclined to control fishing practices and efforts to improve net benefits from the resources.

INTRODUCTION

Competition for access to and use of coastal resources in Southeast Asia has noticeably increased in recent decades. Some major examples are the social conflicts on the use of fishpens in Laguna de Bay, Philippines; the industrial pollution in Kuala Juru, Malaysia; the tantalum incident in Phuket, Thailand; and the trawling ban in Indonesia.

In most of Asia, coastal resources, particularly fisheries, are generally regarded as open-access and common property. However, experience over the decades has shown that open-access management fails once the fishing effort has surpassed the natural rates of stock regeneration. Failing fisheries throughout the world have been characterized by declining total yields, sharp decreases in the yield per unit of fishing effort, disappearance of the more highly valued species, cut-throat competition among fishermen and, in some cases, the economic collapse of the fishing industry (Berkes 1986). Major fishing grounds in the Philippines are not exempted from these.

The aim of CRM is to ensure the wise use of the resources on a sustainable basis and to minimize resources use conflicts through a set of options. In most countries in the region, management alternatives have taken these forms: selective use of gear, gear restrictions, seasonal and area closures, catch quotas, fishing effort controls and economic controls.

CRM not only controls exploitation but also establishes ways to restore or rehabilitate destroyed or heavily depleted resources (Chua 1989). So, while past efforts emphasized conservation measures, technological advancement permits a complementary and parallel approach toward the restoration of essential coastal ecosystems. In the Philippines, the more common restoration efforts are mangrove reforestation, seagrass transplantation and artificial reef construction. However, these efforts are confronted by such property questions as who manages and who benefits from them.

The inability of policymakers and resource managers to understand fully the underlying causes of coastal environmental stresses apparently contributes to their ineffectivity in addressing these complex issues.

CRM schemes in the region have always been designed and implemented on the basis of the common property and open-access nature of coastal resources. However, an increasing number of scientists believe that the root cause of resources use conflicts lies in their common-property nature.

This paper focuses on the problem of common property and on the concept and practice of TURFs, which are explored as potential alternatives for the management of artificial reefs.

THE CONCEPT AND PRACTICE OF COMMON PROPERTY

Common property has characterized the use of most coastal resources, particularly fisheries, throughout the world for several centuries. Briefly, common property resources are those to which access is both free and open to a set of users or potential users.

No individual fisherman has an incentive to restrain his catch in the interest of future returns, for anything he leaves in the sea for tomorrow will be taken by others today. Thus, fisheries stocks tend to be used at, and frequently beyond, the point of maximum sustainable yield.

In the absence of controls on capital and labor, there will tend to be too much effort spent on too few fish. In overutilized fisheries, the same or even larger amounts of fish can be taken with fewer fishermen and vessels than are actually employed. This means that the same or greater total revenue could be produced with lower total costs.

The difference between the total revenue and the total cost that would occur if access to the fisheries was controlled, or if the common property condition was removed, is "economic rent." In common property fisheries, this rent is dissipated because whenever it occurs, it produces a surplus profit for the fishermen. Since access is free and open, the surplus profit will attract more fishermen. But the new fishermen will increase the total cost without increasing the total revenue. Only when the cost reaches the total revenue will the new entry stop. But at this point, the rent will be dissipated.

A related consequence is that the average income of small-scale fishermen will tend to be at or close to the bottom of the scale.

Conflict occurs in the form of congestion among fishermen using the same gear for the same resource; different gear for the same resource; or different gear for different fish stocks in the same space, as between mobile trawlers and fixed nets or pots.

In essence, the consequences of free and open access are generally quite damaging. Possibly, the only positive result is that the common fisheries may offer employment opportunities in situations where alternative opportunities are scarce or nonexistent. But this is a short-term benefit, which, in the long run, can be outweighed by the damage wrought.

TURFs

TURFs have been known to exist for centuries. Community fishing rights and other forms of proprietary rights have been the rule rather than the exception in many traditional coastal fisheries. They have emerged, and some are still maintained, where certain conditions permit relatively easy acquisition and defense of exclusive rights. Sedentary resources such as oysters, mussels and seaweeds have long been subject to use rights. Enclosed bodies of freshwater ponds, lakes and flood plains have also been subject to exclusive use rights for centuries (Christy 1982). TURFs have also emerged in areas or situations where ease of acquisition and defense of exclusive rights are not readily apparent. TURFs have developed in marine areas such as lagoons, along beaches and in relation to coral reefs, and, more recently, legally or illegally, in association with fish aggregation devices (FADs) and other new technologies.

TURFs are more pervasive. Fisheries and techniques using or permitting exclusive territorial use rights include: oyster and clam bottoms, seaweed beds, raft culture, FADs, beach seine rights, fishpens and cages, set net rights, bottom fish traps (e.g., lobster pots and octopus shelters), coral reefs, lagoon fisheries and fish traps/corrals (Christy 1982).

TURFs can remove, to a varying extent, the conditions of common property, thus reducing the negative consequences that tend to waste the resources. The owner(s) of a TURF can limit the inputs of capital and labor at the point where the greatest net benefits are produced. This could be where economic revenues and social objectives can be maximized (e.g., maximum employment at satisfactory levels of income).

Community-managed TURFs provide both the opportunity and the incentive for resources management within a territory. Since the owners of a TURF (group of individuals or a community) have the exclusive right to future products, it will be in their interest to ensure the flow of these future products. This would facilitate the imposition and enforcement of management measures whose most effective form occurs when it is in the self-interest of the user to comply with the rules.

In small-scale fisheries, where the community of users is relatively homogeneous and the group size is relatively small, reciprocal and mutually reinforcing relationships are feasible and thus facilitate self-regulation and minimize conflicts.

While community-managed TURFs provide community control over the resources and the benefits derived from them, the opposite can be damaging. Thus, if localized TURFs develop on their own, without effective community control, a class of sea lords that monopolizes resources may be formed. This has happened where wealthy fishpen owners have dominated the use of spaces.

PHILIPPINE EXPERIENCE WITH TURFs

Prior to Spanish colonization, the Philippines was inhabited by various ethnic groups organized into independent villages known as *barangay*. No comprehensive accounts exist of the manner in which these villages related to their environment, particularly the coastal resources. Yet, early Spanish documents (in Blair and Robertson 1903, as cited by Lopez 1983) mention that:

> *Barangay* in the vicinity of Manila claimed as much of the sea and nearby rivers as they could defend against neighboring *barangay* (Francisco Colin 1663); and
>
> Tagalogs established fishery limits and set aside sections of river for use as trading centers. Use of these areas by nonmembers of a settlement was contingent on the payment of fees (Juan de Plasencia 1589).

As Spanish rule prospered, the *barangay* were incorporated into the dominant sociopolitical system and with this, the territorial fishing rights claimed by each village broke down. Coastal and offshore waters became open to exploitation by all parties who had the means.

During the American occupation of the Philippines, exclusive use of the coastal waters, this time by individuals, was again established by the Fishery Act of 1932 for fish corrals, fishponds, oyster culture beds and for fry gathering. However, municipal fishing licenses issued under the Act still allowed subsistence fishermen to exploit all waters within the jurisdiction of a municipality.

According to Lopez (1983), "In at least one locality (Bolinao, Pangasinan), the Fishery Act was used to concentrate control of the municipal waters within a small circle of the affluent. Waters to a depth of 10 fathoms were divided into five or six lots and leased by auction. Concessionaires exacted fees from net fishermen and corral-builders who wished to operate within their lots, based on estimates of the potential catch. Hook-and-line fishermen were exempted from this levy because their catches were considered negligible. The concessionaire could then control the number of fishermen utilizing his lot and, in theory at least, make sure his stock would remain productive."

The exclusive use of coastal waters by individuals or corporations continues up to the present and remains the dominant arrangement for TURFs in Lingayen Gulf. For instance, Ordinance No. 8, Series 1976, of the municipality of Bolinao, known as the "Basic Fishery Ordinance" declares: "Operating fish corrals, oyster culture beds or catching of *bangus* fry or fry of other species for propagation shall be considered exclusive fishery privileges which shall be granted always to the highest bidder in public bidding held according to the provisions of this Ordinance."

In the municipality of Sual, TURFs for fish cages and stationary lift nets have been awarded to individuals or corporations. Similar arrangements exist for the oyster rafts and mussel stakes of Binmaley and San Fabian. Fish corrals all over the gulf are administered under individual or corporate franchises.

In the municipality of Agoo in La Union, a similar provision providing for the exclusive use of coastal waters in the operation of fish corrals, oyster culture beds and in the catching of fry exists in the ordinances pertaining to fisheries. However, there are no clear provisions on the operation of FADs or *payao* in La Union. Galvez (1988) notes the existence of a form of sea tenure system such that "anyone who has laid down an artificial reef in an area earns the sole right to fish around the reef. . . ." This may have developed in the practice of installing *payao* which follows a traditional use right system.

ARTIFICIAL REEFS AND TURFs

A recent development is the acquisition of TURFs by fishermen's organizations in several communities in connection with building artificial reefs. According to the management rules of these projects, the organizations' members should be given priority in sharing the benefits. Furthermore, anyone fishing within a 50-m radius of the artificial reef should share 5% of the catch either in cash or in kind. Only gill nets and multiple hooks and lines should be used. Blast fishing and cyanide poisoning near the artificial reefs are strictly prohibited.

This type of acquisition and maintenance of TURFs provides an alternative arrangement for the management of artificial reefs. It places community-based management over the dominant practice of individual and corporate management.

MARINE RESERVES AND TURFs

TURFs create the appropriate environment for self-management through the establishment of private or community ownership over common property resources. TURFs can take the form of leasehold arrangements, franchises or allocations of ownership over an area or fish stock (e.g., award of a certificate of stewardship).

The experience of the MCDP of Silliman University (Philippines) illustrates the potentials of TURFs as an alternative management scheme for artificial reefs, in particular, and for coastal resources, in general. White (1989) points out that reef resources can not be protected or enhanced unless those who exploit them are committed to this goal. Thus, the MCDP focused on education, community-building and potential TURFs as the means to marine resources management. The TURF concept was used by the MCDP so that the "owners" of the resources would be interested in their current and future productivity and in the health of "their" coral reefs, and thus be inclined to control fishing practices and efforts to improve the net benefits from the resources (White 1989).

The establishment of marine reserves and sanctuaries at the MCDP sites capitalized on the tendency of the local people to informally adhere to territorial rights. The MCDP has shown that TURFs, as applied to small islands, can remove the conditions of common property and thus reduce the negative consequences of open-access commons. The incentive to the community is that the flow of present and future products could be ensured if there is evidence for improved returns. The TURF arrangements in this case have reinforced self-regulations and minimized conflicts.

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Session IIIB
Environment/Habitat Enhancement and Production

Artificial reef program in Malaysia

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ABSTRACT

Rapid development and lack of understanding about the cause-and-effect relationships between development and adverse ecological impact on the coastal zone have resulted in the degradation of coral reef ecosystems in Peninsular Malaysia, specifically on the west coast. Malaysia has, however, responded in two ways--(1) it has declared the islands and the surrounding waters with intact coral reef ecosystems as protected areas as of 1984, with a view to creating marine parks; and (2) the country has embarked on an intensive artificial reef program.

The program began in the early 1970s and is currently being carried out by two departments within the Ministry of Agriculture: the Department of Fisheries (DOF) and the Fisheries Development Authority (FDA). The goal of both departments is to increase an already dwindling coastal fishery stock but for different reasons: that of the DOF is toward conservation and replenishment of stock while that of the FDA is toward increase of the fishing potential and, thereby, enhancement of the livelihood of the coastal fishermen.

The artificial reefs are made of tires and concrete and/or confiscated boats. Preliminary research indicates that there is an increase in catch directly over the artificial reefs. However, this raises the question of whether this is an indication of actual increase in fish stock in the coastal areas or aggregation of the dwindling fish stock in the artificial reefs. If the increase in catch is a sign of the latter, the establishment of artificial reefs to enhance fishing would lead to the rapid depletion of the fish stock in the inshore zone. On the other hand, if the increase in catch is a sign of the former, the establishment of artificial reefs for conservation and habitat enhancement could reinforce and improve a dwindling fish stock.

INTRODUCTION

Artificial reefs are generally considered to be any solid material (which is not already a part of the natural aquatic environment) placed at the bottom of the aquatic environment, aimed at improving the fish habitat and stock and enhancing colonization by marine organisms such as algae, barnacles and shellfish (Stone et al. 1979).

There are currently two artificial reef programs under the Malaysian Ministry of Agriculture: those of the DOF and the FDA. Both programs aim to increase fish stock but for different reasons. The DOF program is concerned with replenishing and conserving an already depleted inshore fishery stock. The FDA program is concerned with improving the livelihood of the coastal fishermen by increasing their catch through the provision of an artificial fishing habitat that attracts and aggregates the stock for easier fishing.

The DOF program began in an unassuming and ad hoc manner in 1975 as an experiment in habitat rehabilitation. The program did not obtain an official budget allocation until the formulation of the National Agricultural Policy (NAP) in 1984. This was because the total marine fish landings of Malaysia decreased rapidly (by 23.6%) from 757,000 t in 1981 to 578,000 t in 1985. Research conducted by the Fisheries Research Institute (FRI) also indicated that the average catch/hour of demersal resources off the west coast of Peninsular Malaysia dropped from 131.1 kg/hour in December 1970 to 58.9 kg/hour in December 1980 (i.e., a 55% decrease in the catch rate). The catch by trawlers decreased further to an average of 18.7 kg/hour in 1986 (DOF 1987). Under the NAP, the highest priority was accorded to the fisheries sector with special emphasis on the intensification of rehabilitation, conservation and protection.

Following the NAP, a comprehensive program was developed in 1985. With a budget allocation of M$8.24 million[a], a total of 65 artificial reefs were constructed as of December 1987. Each tire reef

[a]1985: M$2.43 = US$1.00.

module required an average of 28,000 tires. Some artificial reefs were also constructed out of confiscated boats and concrete pyramidal structures. The DOF program was complemented by seed restocking. The FRI produces fingerlings of selected commercial species from its two hatchery complexes in Kedah and Terengganu to increase fish population through seed restocking. In 1986, 7 million shrimp and 7 million sea bass fingerlings were released in the coastal waters near the artificial reef sites.

The FDA program was launched in 1983 to increase the catch per unit effort (CPUE) of the coastal fishermen. The artificial reefs were placed according to the requests of the fishermen or their associations and to the subsequent survey by FDA officers on the suitability of the site. The materials used in and the design of the artificial reefs were similar to those of the DOF program. However, no seed restocking was done.

The total number of artificial reefs constructed from 1975 to 1987 was 144 for the whole of Malaysia.

The distribution of artificial reefs by year of establishment and by state are shown in Tables 1 and 2, respectively, for both the DOF and FDA programs. The majority of the reefs were established from 1984 onwards and are primarily situated in Peninsular Malaysia (89.6%). Most of the reefs are along the east coast (64.6%) (Table 1). Mainly because of the FDA program, most of the artificial reefs are in the state of Terengganu (Table 2).

The target of the DOF program is to complete the construction of 65 artificial tire reefs, with a maximum of over 50,000 tires per reef, by the end of the Fifth Malaysian Plan (1986-1990). The FDA's policy is to build as many artificial reefs as required by the coastal fishermen.

EFFECTIVENESS OF ARTIFICIAL REEFS

As a conservation strategy

Although there are no quantitative data to evaluate the effectiveness of artificial reefs in providing an acceptable habitat, the qualitative data available, however, are supportive of the success of these reefs. These provide the appropriate environment necessary for shelter, feeding, spawning and orientation (Kojima 1956; Gooding and Magnuson 1967; Hunter and Mitchell 1967; Kakimoto 1982; Ogawa 1982a, 1982b; and Yoshimuda 1982).

The FRI's preliminary research (Wong 1988) indicates that artificial reefs develop a complex marine ecosystem very similar to that of coral reefs within the area.

Fish are seen schooling around and colonizing the artificial reefs rapidly (Russell et al. 1974; Russell 1975; Lim et al. 1976; Molles 1978; Bohnsack and Talbot 1980; and Wong 1988). In a few months, the artificial reefs are encrusted by a wide variety of typically coral reef organisms such as anemones, sponges, algae, sea fans, sea feathers, bivalves, mollusks and tunicates. The trend is for the resident fish population to increase to a maximum population size and then settle to an equilibrium community structure within one to five years (Turner et al. 1969; Stone et al. 1979; Bohnsack and Talbot 1980). Wong (1988) found that the fish population stabilized at a biomass of 68 t/km^2 inside artificial reef areas within a year. Various commercial fish were also identified such as snappers, sweetlips, parrotfishes, rabbitfishes, groupers, squids and cuttlefishes, among others. Corals start to appear about four years after the emplacement of the artificial reefs.

A number of researchers have suggested that in some areas, shelter is a limiting factor (assuming that all other physical, chemical and biological conditions for the establishment of a particular species are present) in the distribution and abundance of certain marine organisms like lobsters (Stewart 1970; Scarratt 1973; and Briggs and Zawacki 1974). Furthermore, the growth of encrusting organisms on artificial reefs also serves as a source of food and an attraction for marine fauna, as shown in the case of lobsters (Weiss 1970; Alfieri 1975; and Sheehy 1976).

Artificial reefs also help check trawling operations in the inshore area since trawl nets caught in them are destroyed, thus contributing to reef conservation efforts. Currently, all trawl fishing operations are prohibited within 5 nautical miles (nm) from the coast and only owner-operated trawlers less than 40 gross tons (GT) are permitted between 5 and 12 nm from the coast. These measures have been instituted because the trawlers, by dragging their nets along the seabed, destroy the spawning and breeding grounds; they also catch indiscriminately, thus aggravating the problem of a depleted inshore fishery stock. For Malaysia, which has an extensive coastline totalling 4,809 km (Peninsular Malaysia 1,972 km; Sabah 1,802 km; and Sarawak 1,035 km), enforcement of these regulations is an arduous task.

As a strategy to increase the biological productivity and carrying capacity of an area

Stone et al. (1974) found that artificial reefs increased the ability of an area to support fish. Mathews (1966) attributed the increased biological productivity of an area to the expansion of its firm surface area, thus allowing for the attachment of invertebrates and algae.

As a habitat enhancement strategy

Research done by the National Marine Fisheries Service (USA) has indicated that artificial reefs can be used for habitat enhancement because the artificial reef in the area of the natural reef it has studied doubled the carrying capacity and fish biomass there (Stone et al. 1979). This quantitative information was obtained from observations made on a small artificial reef and an adjacent natural coral patch reef in Biscayne National Monument, Florida, United States. Furthermore, this study questions the misconception that artificial reefs function only to concentrate fish. It has demonstrated the potential of these reefs for increasing stock sizes of fish.

As a rehabilitation strategy

The use of artificial reefs in rehabilitating marine and estuarine areas damaged entirely or impoverished by coastal development has been demonstrated in Biscayne Bay, Miami, Florida (Stone 1972). An artificial reef was constructed in an area dredged to a depth of approximately 30 ft from a normal depth of 8 to 10 ft. This dredging destroyed the natural bottom of the area (which was coral and limestone) and in its place left an unstable, semisolid mixture of particulate matter that could support only a few organisms. However, the construction of a high-profile artificial reef, which protruded above this soft bottom mixture, provided an alternate favorable substrate for encrusting organisms and a habitat for other marine fauna. The positive effects were evident within six months of emplacement of the artificial reef.

As recreational fishing areas

There is an upper limit to the amount of fish that can be harvested on a sustainable basis on an artificial reef. Monitoring by DOF showed that selective fishing can be carried out over the artificial reefs after a period of one year. Moreover, subject to certain constraints, primarily the intensity of fishing allowed, artificial reefs provide improved recreational fishing areas (Stone et al. 1974; Prince et al. 1975). Buchanan et al. (1974), who evaluated the potential of artificial reefs for recreational marine sport fishing off South Carolina, concluded that fishing success over these reefs was not as high compared to that done over a nearby live bottom habitat. This was so because of the high fishing intensity in the small area covered by the artificial reefs.

The success of artificial reefs for recreational fishing is also determined by their type of construction. Wickham et al. (1973) show that in the Gulf of Mexico, artificial reefs in the form of midwater structures have increased the CPUE for several pelagic recreational fish. The profile of fish found in the area and their habitat preferences are success factors, too. Pelagic and demersal species are attracted to high- and low-profile artificial reefs, respectively. Invertebrates such as shrimp, crabs and lobsters are attracted to small structures with small holes and crevices while large fish are attracted to large and high structures with numerous large crevices.

Another success factor is the presence of food resources. Randall (1963) found that the artificial reef off St. John contained a fish concentration 11 times higher than the two natural reef areas in St. John. He attributed these occurrences to additional food resources present in the surrounding seagrass beds.

As commercial fishing areas

Preliminary data on the benefits of FDA's artificial reefs to coastal fishermen show an increase in their earnings (LKIM 1987). The highest increase in earnings (99.7%) was from those who fished over artificial reefs that were made of confiscated boats, followed by those who fished over concrete structures (66%) and over tires (23%). This is to be expected as the reefs are known to aggregate fish, and this increase in earnings reflects a greater CPUE due to the presence of the artificial reefs. However, as in the case of recreational fishing areas, the success of artificial reefs as commercial fishing areas will also be determined by their types, the fishing intensity and the rate of fish stock replenishment.

More research is required to support the policy to use artificial reefs as commercial fishing areas.

Sheehy (1979) estimates that to expand existing fishing grounds, a minimum site area of 2,500 m^2 is required, while to create new ones, 20,000 m^2 is required. The current practice of allowing unlimited fishing over FDA's artificial reefs could cause the further depletion of fish stock in the inshore waters.

CONCLUSION

The potential for artificial reefs as a conservation strategy means to increase the biological productivity and carrying capacity of the area, habitat enhancement strategy, rehabilitative strategy and recreational fishing area is supported by the preliminary research results in Malaysia, USA, Japan and others. However, the use of artificial reefs as commercial fishing areas requires more investigation prior to adoption and implementation.

The potential of artificial reefs as a comprehensive mitigation/compensation method to enhance fish stocks will be determined by the type of management adopted in these areas. If these areas are to offset the disturbances/impact caused by coastal area development, then artificial reefs should be regarded as protected areas (until such time as when fish stock have been replenished and established) with prohibitions on fishing and any other activity that threatens them with destruction. Any management strategy that allows the exploitation of artificial reefs or their destruction prior to the replenishment of fish stock will negate the overall objective of their establishment.

The other factor determining the potential of artificial reefs is their actual structure. Currently, they are of a standard format in Malaysia. However, this is not so in Japan where there is a wide variety of structures and alterations that contribute to increasing coastal fisheries and aquaculture production. Examples of these structures are the moored and midwater surface fish attractors, shelters designed to increase specific seaweeds and invertebrates such as abalone and lobsters and to serve as nursery areas for hatchery-reared juveniles. There are also measures in Japan aimed at altering the substrate conditions (i.e., blasting, scraping. covering) and water flow (channels enlarged or constructed); at dampening the adverse effects of waves (floating or submerged breakwaters); and at altering species composition to eliminate predators, minimize competition or stock high-value species for culture-based fisheries.

More research is needed on the structure, impact, benefits and management of artificial reefs. The DOF, in response to this need, has initiated a four-year project from 1988 to 1992 under the Asian Development Bank. With a funding of US$1,739,000, the project will provide a detailed scientific assessment of the role of artificial reefs in the regeneration and enhancement of coastal fisheries resources.

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Table 1. Distribution of artificial reefs in Malaysia, by year of establishment.

Year	DOF Program			FDA Program		Total
	Peninsular Malaysia West Coast	Peninsular Malaysia East Coast	Sabah Sarawak	Peninsular Malaysia West Coast	Peninsular Malaysia East Coast	
1975	2	-	-	-	-	2
1976	1	-	-	-	-	1
1977	-	-	-	-	-	-
1978	2	-	-	-	-	2
1979	-	1	-	-	-	1
1980	-	-	-	-	-	-
1981	-	-	-	-	-	-
1982	1	-	4	-	-	5
1983	-	3	2	2	1	8
1984	1	7	4	4	24	40
1985	2	-	-	3	5	10
1986	10	29	2	4	8	53
1987	2	2	3	2	13	22
Total	21	42	15	15	51	144

Table 2. Distribution of artificial reefs in Malaysia, by state.

State	DOF Program	FDA Program	Total
Perlis	-	3	3
Kedah	8	5	13
Penang	5	-	5
Perak	4	2	6
Selangor	2	3	5
Negeri Sembilan	-	-	-
Malacca	1	2	3
Johore	11	6	17
Pahang	11	4	15
Terengganu	15	34	49
Kelantan	6	7	13
Sabah	6	-	6
Sarawak	9	-	9
Total	78	66	144

The need to develop a management scheme for mangrove forests in South Johore to ensure resource sustenance

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ABSTRACT

The mangrove forest reserves in South Johore, managed by the Forest Department for sustained timber production, form part of the permanent forest estate and stateland mangroves under the jurisdiction of the Johore State Government. These mangrove forests are becoming a dwindling resource because of their continued alienation for various land uses that are assumed to be of greater economic value. However, several strategies have been recommended to prevent further depletion of the resource.

THE RESOURCE

Mangrove forests in South Johore are located mainly along the sheltered west coast that borders the Strait of Malacca; at the estuaries of the Pulai and Johore Rivers on the sheltered south coast that borders Johore Strait; and at the estuary of the Sedili Besar River on the exposed east coast. These forests can be classified broadly into mangrove forest reserves managed by the Forest Department for sustained timber production. As such they form part of the permanent forest estate and stateland mangroves under the jurisdiction of the Johore State Government.

Mangrove forest reserves

In 1986, the total extent of these reserves in Peninsular Malaysia was reported to be about 98,300 ha (Table 1). Of this total, about 23,683 ha or 24% occurred in the State of Johore.

At present, there are ten mangrove forest reserves in Johore. These are found in the districts of Pontian, Johore Bahru and Kota Tinggi in the south. The extent of each of these reserves in 1960 (Edington 1963) and in 1986 is given in Table 2. For this period, about 4,900 ha involving 84 forest compartments were alienated out of a total of about 23,000 ha and 868 compartments. Conversion of mangrove forest reserves to agriculture, shrimp culture and also reversion to stateland mangroves have resulted in the the loss of about 2,240, 1,169 and 1,167 ha, respectively (Table 3). Other conversion activities include human encroachment (Johore River and Lebam River Forest Reserves), impoundment for freshwater supply (Johore River Forest Reserve) and mining for tin (Santi River Forest Reserve). Of these reserves, the Benut River Forest Reserve suffered the greatest loss. It was reduced from 2,661 ha in 1960 to a meager 300 ha in 1986 due to the conversion of its landward mangroves to agriculture and the reversion of its existing belt of seafront mangroves to protective stateland forests.

Stateland mangroves

Stateland mangroves, which occur outside forest reserves, are not managed for sustained timber production. Hence, they are often subject to great pressures of alienation. Their extent has dwindled from 8,752 ha in 1970 to 7,789 in 1986 (Table 4). Recent developments show that this resource has been further reduced. For example, another 48 ha (37%) of the Lunchu River stateland mangroves near Johore Bahru were converted for shrimp culture between 1986 and 1988.

In 1986, of the largest block of nipa *(Nypa fruticans)* forests in South Johore, the extent left was only 165 ha (Table 5). The upstream forests fringing the banks of the Benut River in Pontian District constitutes this block.

Forest accretion and erosion

Accreting mangrove shores, characterized by a raised mudflat and a low crop of *Avicennia* trees advancing seaward (Carter 1959), are found in Benut and Kukup on the west coast. In contrast, the process of erosion is characterized by a lowering of the nearshore profile, th formation of a retreating scarp, the collapse of mangrove trees and the presence of a beach of shell fragments or *chenier* (Salleh and Chan 1988).

Erosion is presently occurring at the estuary of the Pulai River and in Tanjong (it means "cape") Piai. At the former, the Ternakan Marine Sdn. Bhd. shrimp farm is located about 300 m from the coast. The farm will be faced with the problem of erosion since the protective mangrove vegetation at the seafront was reduced to a mere 50-m wide strip. Pulau Kukup is experiencing both accretion and erosion. From 1970 to 1986, there was a net gain of about 360 ha of mangroves in South Johore (Table 6).

Value

Mangrove forests in South Johore are an important source of fuelwood for the production of charcoal and poles for piling, scaffolding and fishing stake. Commercial species are *Rhizopora apiculata, R. mucronata, Bruguiera cylindrica, B. gymnorrhiza, B. parviflora* and *Ceriops tagal.* Common noncommercial species are *Xylocarpus granatum, Scyphiphora hydrophyllacea, Avicennia marina, A. lanata, A. alba, A. officinalis* and *Lumnitzera littorea.* These noncommercial species are used mainly as fuelwood for firing kilns. At present, there are 24 charcoal licensees operating 81 kilns in South Johore.

In 1987, the revenue collected by the Forest Department from the mangroves, in the form of royalty and premium, amounted to about US$68,000.00. This amount is meager compared to the expected annual worth of mangrove forest produce--about US$1.13 million for the Pulai River Forest Reserve and US$0.35 million for the Johore River Forest Reserve (Tables 7 and 8), based on annual coupes (areas allocated for felling or harvesting) of 415 ha and 92 ha, respectively.

FOREST MANAGEMENT

Previous working plans

A working plan was prepared by A.C.F. Walker in 1941 for the forest reserves of Pulai, Benut, Kukup, Pendas, Johore River and Belungkor. Due to the Japanese Occupation (1941 to 1945), the plan was not enforced until 1947 by which time, conditions had rendered many of its prescriptions inapplicable. P.F. Burgess (1950) prepared another working plan implemented for the period 1950 to 1954. His plan was revised by I.P. Tamsworth in 1955 and by P.W.J. Edington in 1963 for the periods 1955 to 1959 and 1960 to 1964, respectively. Edington's (1953) working plan for the South Johore mangroves has not been revised. The present management procedures are derived from it.

Present management system

The rotation or cutting cycle is fixed at 20 years, while the prescribed harvesting system is clear-felling. At the Pulai River Forest Reserve, felling is selective and restricted to forest areas fringing rivers and creeks. The use of small rowing draft boats *(pok chai)* by individual loggers who operate independently to enter the forest and to transport logs out of it may contribute to the selective nature of tree-felling, which is highly dependent on the tides. On the other hand, trees from inland areas can be felled only during spring tides. Moreover, at the Johore River Forest Reserve, loggers operate in teams and logs are shoulder-carried to the riverbanks where large transport boats can come alongside. Thus, logging is more intensive there.

No replanting of logged-over forest areas is presently carried out. Stocking then for the next cut is dependent solely on natural regeneration. Only the following silvicultural regulations are prescribed:

1. Retain a 5-m buffer belt of vegetation along rivers navigable during low tide.
2. Fell or girdle all noncommercial trees such as *Xylocarpus, Avicennia, Scyphiphora* and *Lumnitzera.*
3. Only trees with a 5-cm diameter at breast height (dbh) and above can be felled.

A forest inventory carried out in Benut, Pendas, Pulai and Johore Rivers showed that *Rhizophora* is losing its dominance and that mangrove forests in South Johore are very mixed in species composition (Table 9). Compared to the managed Matang Mangrove Forest Reserve in Perak, these reserves are considered poor in terms of the density of their commercial trees and in their timber production per hectare.

Natural regeneration of commercial species up to two years following logging appears to be adequate in the Johore River Forest Reserve, which has all its forest compartments fringing the river. Sufficient seedlings and saplings of *Rhizophora* regenerate naturally up to 200 m from the river. The observed high tidal range in South Johore is an important attribute in ensuring successful regeneration through the dispersal of water-borne propagules produced by seed trees that survive the logging operations.

However, inland compartments in the forest reserves of the Pulai, Belungkor and Santi Rivers were reported by Burgess (1950) and Edington (1963) to be stocked inadequately due to the infrequent tidal inundation, the presence of numerous mud lobster mounds and dense thickets of *Acrostichum* ferns. Planting of *Rhizophora* should inevitably be undertaken to enrich such logged-over areas. Transplanting seedlings (wildings) of Rhizophora from adjacent riverine compartments where regeneration is adequate is recommended.

DISCUSSION

Mangrove forests in South Johore are a dwindling resource because of their continued alienation for various land uses that are assumed to be of greater economic value. Such an approach to resource utilization is due mainly to an inadequate appreciation and understanding of the importance of the mangrove ecosystem. If allowed to continue, alienation will inevitably lead to environmental transformations that conflict directly with the multiple-use traditional management system of the coastal communities. This is by far the most important management issue that should be addressed since such land uses have even encroached on the mangrove forest reserves that are part of the country's Permanent Forest Estate for sustained management.

Mangroves are used in producing a variety of goods and services that form the resource base for sustaining mangrove-dependent economic activities of many coastal communities. These economic activities include the harvesting of timber from the forests for fuelwood and construction, nipa for *atap* and cigarette wrappermaking and *nibong* poles for marine piling. In addition, the coastal waters, estuaries and waterways of the ecosystem are rich in fisheries resources. Of greater importance is the ecological role of mangroves in protecting and stabilizing the coastline and as spawning and nursery grounds for marine fisheries. Mangroves are therefore an extremely important coastal ecosystem when all the economic, ecological and environmental benefits are considered holistically.

Large-scale reclamation of mangrove forests for agriculture is being implemented in the west coast of South Johore. The cost of reclamation is high for there is a prerequisite need to ameliorate the acid sulfate saline mangrove soils prior to cultivation. Some areas under intensive management can yield an average of 28 t of fresh fruit bunch of oil palm and 1.8 t of copra/ha while in other areas the reclaimed land is barren of any crops (Law 1984). Mangrove soils are therefore unsuitable for crop cultivation unless properly managed.

There is a need to promote brackishwater aquaculture in coastal mangrove areas to supplement the declining marine food production. Thus, ongoing culture methods such as cockle and cage culture, which utilize mangrove estuaries and waterways should be intensified. Such culture methods have been projected to have a very high profitability. They also integrate very well into the traditional forestry-capture fisheries mangrove system.

Of concern is the recent upsurge of mangrove forest conversion in South Johore for shrimp pond culture since this has resulted in the substantial loss of forests. Existing large shrimp culture farms are located at former coconut plantations (e.g., the Daiman Marine Products Sdn. Bhd. and the Kukup Marine Sdn. Bhd.) and in sandy coastal areas (e.g., the Crustacea Enterprise Sdn. Bhd.). To conserve the mangrove ecosystem for traditional forestry and capture fisheries purposes, the Malaysia Working Group on Mangroves has drawn up some guidelines on the use of the ecosystem for brackishwater pond culture. The recommended strategy is to avoid the use of mangrove forest reserves and instead to use mangrove areas already reclaimed, followed by dryland and stateland mangroves that are often unproductive for forestry use.

Another important management issue is the gradual degradation of managed mangrove forest reserves. Compared to the managed Matang Mangrove Forest Reserve, the commercial timber productivity of the forest reserves in South Johore is low due to the preponderance of noncommercial tree stocking and regeneration. Thus, the present silvicultural regulations aimed at encouraging natural regeneration should be reexamined. The recommended management strategy is to eliminate the noncommercial trees and to regenerate artificially with commercial species those logged-over forest areas that are devoid of natural regeneration. Silvicultural procedures developed in the Matang Mangrove Forest Reserve, such as weed eradication, girdling of unwanted trees, retention of seed trees and enrichment planting, can be adapted and applied in South Johore.

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Table 1. Extent (ha) of mangrove forest reserves in the various states of Peninsular Malaysia in 1986 (Anon. 1986).

State	Extent
Kedah	8,825
Penang	345
Perak	40,869
Selangor	17,674
N. Sembilan	1,135
Malacca	338
Johore	23,683
Pahang	2,483
Terengganu	2,982
Total	98,334

Table 2. Loss of area (ha) and forest compartments in the various mangrove forest reserves in South Johore from 1960 to 1986.

Forest reserves	1960		1986		Loss	
	Extent	Compartments	Extent	Compartments	Extent	Compartments
Pulai	9,148.6	500	7,633.2	443	1,515.4	57
Johore River	3,800.3	173	3,215.8	155	584.5	18
Kemudi and Bahan Rivers	155.6	22	155.6	22	0.0	0
Pulau Kukup	650.0	17	650.0	17	0.0	0
Lebam River	1,473.0	19	1,354.0	18	119.0	1
Belungkor	1,261.8	38	1,261.8	38	0.0	0
Santi River	2,502.1	43	2,453.5	42	48.6	1
Pendas	815.6	56	545.8	49	269.8	7
Benut	2,661.0	0	300.0	0	2,361.0	0
Kuala Sedili	433.0	0	433.0	0	0.0	0

Table 3. Alienation of mangrove forest reserves in South Johore from 1960 to 1986.

Forest reserves	Shrimp culture	Agriculture	Human encroachment	Impoundment	Mining	Stateland	Total
Pulai	739.5	775.9	-	-	-	-	1,515.4
Johore River	318.2	-	214.1	52.2	-	-	584.5
Kemudi and Bahan Rivers	-	-	-	-	-	-	-
Pulau Kukup	-	-	-	-	-	-	-
Lebam River	111.3	-	7.7	-	-	-	119.0
Belungkor	-	-	-	-	-	-	-
Santi River	-	-	-	-	48.6	-	48.6
Pendas	-	269.8	-	-	-	-	269.8
Benut	-	1,194.0	-	-	-	1,167.0	2,361.0
Kuala Sedili	-	-	-	-	-	-	-
Total	1,169.0	2,239.7	221.8	52.2	48.6	1,167.0	4,898.3

Table 4. Extent (ha) of stateland mangroves in South Johore.

Stateland mangroves	Extent 1970	1986
Johore Bahru	1,228	1,214
Kukup	833	801
Pontian Kecil	1,556	1,556
Kota Tinggi	3,626	2,871
Kuala Sedili	592	570
Tanjong Surat	917	777
Total	8,752	7,789

Table 5. Extent (ha) of nipa forests in South Johore in 1986.

Location	Nipa forests
Benut	89
Kuala Sedili Besar	28
Pontian Kecil	24
Pontian Besar	24
Total	165

Table 6. Extent (ha) of accretion and erosion of mangrove areas in South Johore from 1970 to 1986.

Location	Accretion	Erosion
Pulau Kukup	22	36
Kuala Pulai River	-	49
Tanjong Piai	-	69
Kukup	113	10
Benut	389	-
Total	524	164

Table 7. Estimated annual value of mangrove forest produce from the Pulai Forest Reserve.

Poles	Annual coupe = 415 ha Average expected yield = 400 pieces/ha Present market value = US$1.20/piece Present value per ha = US$480.00 Expected annual value = US$199,200.00
Charcoal	Annual coupe = 415 ha Average expected yield of greenwood = 60 t/ha Average expected yield of charcoal = 15 t/ha Present market value of charcoal = US$150.00/t Present value per ha = US$2,250.00 Expected annual value = US$933,750.00
Total annual worth of forest produce = US$1,132,950.00	

Table 8. Estimated annual value of mangrove forest produce from the Johore River Forest Reserve.

Charcoal	Annual coupe = 92 ha Average expected yield of greenwood = 99 t/ha Average expected yield of charcoal = 25 t/ha Present market value of charcoal = US$150.00/t Present value per ha = US$3,750.00 Expected annual value = US$345,000.00
Total annual worth of forest produce = US$345,000.00	

Table 9. Species composition and timber productivity per hectare of some forest reserves in South Johore.

Forest reserves	*Rhizophora* Trees	Volume	*Bruguiera* and *Ceriops* Trees	Volume	Noncommercial species[a] Trees	Volume	Total Trees	Volume
Benut								
?	270.2	15.[illegible]	256.3	3.6	720.1	27.0	1,246.6	46.0
Pendas								
1-10	441.4	16.9	325.6	5.6	136.4	4.9	903.4	27.4
21+	788.5	67.7	697.6	29.8	481.4	15.9	1,967.5	113.4
Pulai								
1-10	839.1	50.9	418.9	12.4	165.7	10.1	1,423.7	73.4
11-20	1,346.7	64.1	813.8	27.1	260.3	14.6	2,420.8	105.8
21+	1,599.0	73.0	714.2	21.3	510.8	14.8	2,830.0	109.1
Johore River								
1-10	297.5	10.4	68.9	2.5	163.1	12.4	529.5	25.3
11-20	602.0	40.3	340.3	13.2	249.4	21.4	1,191.7	74.9
Matang								
21+	1,207.4	173.0	144.4	23.5	7.4	0.3	1,359.2	196.8

[a]Noncommercial: *Xylocarpus, Avicennia, Scyphiphora* and *Lumnitzera*.

A study of some fish fauna in Boat Quay, Singapore, and observations on the effects of stocking

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ABSTRACT

In 1977, the Singapore Government embarked on a 10-year program to clean up Singapore River and its surrounding bodies of water. The Primary Production Department (PPD) initiated a program to enrich aquatic life in 1986 by stocking fish and shrimp fry in the river. The stocked species were seabass *(Lates calcarifer)*, cherry snapper *(Oreochromis niloticus* hybrid) and banana shrimp *(Penaeus merguiensis)*. The water quality of the Boat Quay area was found to be suitable for sustaining life in the river.

A study of the fish fauna of Boat Quay, a section of the Singapore River, was made during the period 1986-1988 by surveying the catches of amateur fishermen and through capture attempts using various fishing gear like fish trap, trammel and gill nets, cast net and beach seine. Around 80,000 seabass, 8,500 cherry snapper and 630,000 banana shrimp fry were stocked in the Boat Quay area during the period April 1986-October 1988.

Recently, a seabass and some banana shrimp were caught by beach seine and trammel net, suggesting that these animals may have established their ecological niche in the Singapore River, with the seabass probably preferring the upper reaches where the water is more brackish; and that numbers stocked to date could be approaching the detectable level by capture efforts.

INTRODUCTION

Singapore River is 2.95 km long and its widest part is at the mouth of Boat Quay, which reaches 160 m. The deepest part of the river is at the mouth, being 3.2 m at low water spring tide. Boat Quay occupies 6 ha or 40% of the Singapore River (Fig. 1). The river can be subdivided into three reaches: (1) the upper reach, the area between Kim Seng Bridge and Ord Bridge; (2) the middle reach, the area between Ord Bridge and Elgin Bridge; and (3) the lower portion, the area from Elgin Bridge to the river mouth.

The Singapore River was the hub of trading activities in the past because it was a main waterway for boat traffic. As a result, it became progressively silted and polluted. The neglect and eventual loss of much of its fish fauna and other life-forms followed.

In 1977, the government launched the River Clean-up Program to improve water quality for life-forms to be reestablished. Lighters, which had been using the river for years as a waterway for unloading cargo, were relocated to Pasir Panjang, southwest of Singapore. Other sources of pollution in the river basin--duck and pig farms and unsewered premises and hawker sites--were also cleared.

PPD conducted several surveys on hydrology and water quality along Singapore River from 1985 to 1986 (unpublished). Fish and shrimp stocking was initiated in 1986 together with surveys on fish fauna.

MATERIALS AND METHODS

Area selection

Water quality and hydrological surveys were conducted in various parts of the river at different tidal conditions to assess its overall condition.

Various water quality and physicochemical parameters--water temperature, dissolved oxygen, salinity, pH, turbidity, chemical oxygen demand, phosphate-phosphorus (PO_4-P), ammonia-nitrogen (NH_4-N) and chlorophyll a (Chl. a) and permanganate value--were determined using the methods for seawater analysis described in Lim and Sugahara (1984).

Plankton samples were collected by the horizontal towing of a 40 μm mesh plankton net (net opening area = 0.096 m^2). Benthos samples were taken with a bottom sampler of the Marukawa type, which has a sampling area of 6 cm x 4 cm or 0.0024 m^2.

Interviews with amateur fishermen

Surveys of fishermen (mainly anglers and operators of fish traps and barrier nets) were carried out on 16 occasions, for the period April 1986-May 1987, and on four occasions, for the period August 1987-October 1988. In between these periods, new legislation that allows angling only in rivers and waters was implemented on 5 June 1987. Amateur fishermen were interviewed at Boat Quay and at the mouth of the Singapore River (Fig. 2). Fish species reportedly caught and those actually observed to have been caught were recorded.

Fish/shrimp stocking

Stocking was initiated in April 1986 but only with banana shrimp *(Penaeus merguiensis)* fry. From 1987, stocking was scheduled on a quarterly basis with 100,000 shrimp postlarvae and 5,000-10,000 finfish (seabass, *Lates calcarifer*, and cherry snapper, *Oreochromis niloticus* hybrid) targeted for each quarter. Banana shrimp fry postlarvae were of an age ranging from 5 days to adult, while seabass fry were of a mean total length (TL) of 2.5 cm and a mean weight of 0.2-0.4 g (Table 1). In total, 6,084 tagged adult shrimp were also released between August 1986 and January 1988. The survival of tagged shrimp was simultaneously monitored under tank conditions. Shrimp were tagged using streamer tags (Floy Tag, FTSL 73) and India ink, according to the methods described by Jones (1979).

Recapture efforts

Attempts at recapturing stocked species were initiated in January 1987. This was to see if they were establishing populations that were large enough for sampling. Most of the recapture was done at Boat Quay, but from August 1988, recapture was also carried out in the upper reaches of the river at the Ord Bridge area.

Types of fishing gear used were fish traps (with mesh sizes of 1.2 cm and 2.4 cm and these dimensions: 85 cm in length, 62 cm in width and 31 cm in height); trammel nets, which consist of two panels (outer mesh sizes of 3.5 cm and 5 cm, inner mesh sizes of 0.9 cm and 1 cm and 33 m in length each); gill nets, which also consist of two panels (mesh sizes of 3.5 cm and 5 cm and 33 m in length each); cast nets (mesh size of 2 cm and 2.7 m^2 in area); and more recently, beach seines (mesh size, which ranges from 1.5 to 3.5 cm and 40 m in length).

For each operation, six fish traps were set covering a total area of 3.16 m^2 in Boat Quay, a 66-m trammel net and a 66-m gill net traversed Boat Quay, while 80-100 casts per operation were also made at the edge of Boat Quay (Fig. 1) at the same time. Seining was done in Boat Quay and the Ord Bridge area. This replaced trammel and gill netting from July 1988, since it appeared to be more efficient at trapping seabass. With the exception of fish trap operations, which took two to three days per operation, the other fishing methods were one-day operations. Recapture efforts were made two to three weeks after stocking until March 1988, when these were rescheduled to twice a month to fit better with tidal conditions. All fish and crustaceans caught were identified and recorded.

In 1987, four cast net operations and five trammel and gill net operations were conducted. In 1988, 12 cast net operations, 8 trammel and gill net operations, 2 seine operations and 10 fish trap operations were carried out (Table 2).

In conducting recapture operations, data on the fish and crustacean fauna of Boat Quay continued to be obtained and recorded from February 1987 to October 1988.

Fish stomach content examination

Stomach content examination was initiated in January 1988 to ascertain if the stocked species were being cannibalized by existing carnivorous species, especially soon after stocking. Ten percent of the fish caught with the gear, as described, were sampled for stomach content examination (see Table 3). Freshly caught fish were killed, their stomach portion dissected and their contents examined in situ.

RESULTS

Area selection

From various surveys (unpublished), it was found that Boat Quay was most suitable for the rehabilitation of marine and brackishwater fish and crustacean species. Physicochemical factors are best for water in the Boat Quay area and are most similar to that of the Marina Bay (unpublished) (Fig. 2). Levels are comparable to acceptable standards for river and coastal waters for fisheries use in Japan (Yokokawa 1982). A survey of plankton at Boat Quay (unpublished) confirmed that food is available for fish and shrimp at densities comparable with the Changi area in East Johore Strait (unpublished).

Fish fauna surveys

Interview with Amateur Fishermen. Table 4 shows fish and crustaceans caught and the type of gear used by amateur fishermen at Boat Quay for the period April 1986-September 1988.

A total of 24 families of fish and 2 families of crustaceans, consisting of 29 and 4 species, respectively, were recorded. The common families of fish are Clupeidae, Leiognathidae, Lutjanidae; the common species are the gizzard shad *(Anodontostoma chacunda)*, pony fish *(Leiognathus* sp.*)*, and snapper *(Lutjanus* sp.*)*. The common families of crustaceans are the Portunidae; the common species are the flower crab *(Portunus pelagicus)*, and mangrove crab *(Scylla serrata)*.

Capture by Fishing Gear. Table 5 shows fish and crustaceans caught by PPD with the various fishing gear mentioned.

A total of 36 families of fish and 4 families of crustaceans were caught, involving 82 and 9 species, respectively. The commonly caught families of fish are Clupeidae, Leiognathidae, Lutjanidae, Gerreidae, Engraulidae; the common species are gizzard shad *(Anodontostoma chacunda)*, pony fish *(Leiognathus equulus, L. fasciatus)*, silver biddies *(Gerres abbreviatus, G. filamentosus)*, herring *(Sardinella fimbriata)*, anchovy *(Stolephorus indicus)*, and snapper *(Lutjanus monostigma)*. The common families of crustaceans are Portunidae and Metapeneidae; the common species are the flower crab *(Portunus pelagicus)*, mangrove crab *(Scylla serrata)* and sand shrimp *(Metapeneus ensis)*.

Fish and shrimp stocking

Table 1 summarizes the data on finfish and shrimp stocked by PPD for the period April 1986-October 1988. A total of 627,789 banana shrimp, 79,171 seabass and 8,540 cherry snapper were stocked in Boat Quay from April 1986 to October 1988, involving 28 stockings.

Capture of target species

Until September 1988, no seabass was captured. However, a few banana shrimp were caught from Boat Quay since March 1987 by cast and gill/trammel nets. In August and October 1988, banana shrimp of a TL of 6.3 cm and an estimated mean weight of 1.8 g were caught by seine. Large seabass were also sighted in the Ord Bridge area where salinity is less than Boat Quay.

Fish stomach content examination

Table 3 summarizes the fish species examined for their gut contents. Partially digested shrimp of indeterminate species were found generally in the carnivorous species of >15 cm TL.

DISCUSSION

Fish fauna surveys

The combined results of survey interviews and actual capture efforts confirm the presence of life in the river. The numbers and species caught may be modest because the various fishing gear employed were limited and the catches do not entirely represent the Boat Quay fauna. Some of the fish caught are probably migratory species, with their presence depending on tidal condition.

A total of 26 species of animals was recorded by the National University of Singapore (Yip et al. 1987), which did a survey on the Singapore River. These included five families of finfish that were also found in the surveys done by PPD for this study.

Shrimp and fish stocking

Fish and shrimp were released in the Boat Quay area, mostly from the riverbank. It was observed that they were grouped together for some time. This made them more susceptible to predators and poachers. The release of stocks in the center of Boat Quay would subject them to churning waters and boat traffic from river cruises.

Recapture of stocked species

The survival of tagged shrimp in tank condition was 35-76% after two weeks. Mortality was likely due to handling trauma. Their mortality in the river, therefore, may be higher because of the additional stress during transportation and their transfer to a new environment. Tagging studies were conducted only with adult banana shrimp that were captured from the population in the test area and released at the same area after being tagged, according to the methods described by Frusher et al. (1985) who conducted tagging studies with captured shrimp.

There were only two tagged banana shrimp caught in Boat Quay and Ord Bridge, probably due to the high mortality from tagging stress and predation by endemic species.

Seabass that were stocked have not been recaptured from Boat Quay. However, one seabass of a TL of 18.7 cm was caught in the Ord Bridge area. It is likely that the seabass came from the stock. This may be due to the different fishing gear used, or that the fish stocked in Boat Quay, being a euryhaline species, have made their way to the upper reaches of the river where they prefer less saline conditions. Of these two explanations, the latter is likely as seabass are commonly caught by line, gill and trammel nets elsewhere. Also, seabass may have been stocked in numbers (79,171 from April 1986 to October 1988, Table 1; and 1 retrieved, Table 5) that may have established a population, but it is still not possible to estimate the population size because the movement of the seabass has not been determined and some may not have stayed in the sampled area.

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Table 1. Fish and shrimp stocking at Boat Quay, Singapore River for the period 1986-1988.

Date	Fish (Seabass and cherry snapper) Species	Mean weight (g)	No. stocked	Shrimp (Banana shrimp) Age	Mean weight (g)	No. stocked	Total fish and shrimp
1986							
Apr-Jun	-	-	-	PL24-36	0.02-0.1	208,400	208,400
Jul-Sep	-	-	-	Adult	1.4	4,000	.
						977*	4,977
1987							
Jan-Mar	Seabass	0.2-2.4	8,000	Adult	2.5	1,000	11,477
	Cherry snapper	0.4-1.20	800	Adult	3.8-5.8	1,677*	
Apr-Jun	Seabass	0.2-0.4	1,600	PL5-45	0.0007-0.2	30,500	32,100
Jul-Sep	Seabass	0.4-14	7,271	PL24-67	0.03-0.3	186,500	198,101
	Cherry snapper	0.7	3,000	Adult	9.1	1,330*	
Oct	-	-	-	Adult	3.6	2,100*	2,100
1988							
Jan-Mar	Seabass	0.1-0.3	17,000	PL17-45	0.007-0.2	122,000	145,305
	Cherry snapper	3.8-9.3	4,000	Adult	3.9-4.8	2,305	
Apr-Jun	Seabass	0.3	9,500	PL85	3.2	1,000	11,240
	Cherry snapper	11-21	740				
Jul-Sep	Seabass	0.8-120	15,800	PL22	0.02	66,000	81,800
Oct-Dec	Seabass	0.1	20,000				20,000
Total			87,711			627,789	715,500
Seabass			79,171				
Cherry snapper			8,540				

*Tagged shrimp.

Table 2. Schedule for capcure and recapture studies at Boat Quay, Singapore River for the period 1987-1988.

Year	Type of gear used	Dates	Area	Tide condition
1987	Trammel and gill net	10.2.87	Boat Quay	Set at high tide and hauled at low tide.
		26.2.87	"	
		11.3.87	"	
		18.3.87	"	
		9.9.87	"	
	Cast net	10.2.87	Boat Quay	
		11.3.87	"	Low tide
		18.3.87	"	
		9.9.87	"	
1988	Trammel and gill net	4.1.88	Boat Quay	Set at high tide and hauled at low tide
		16.3.88	"	
		30.3.88	"	
		14.4.88	"	
		28.4.88	"	
		31.5.88	"	
		14.6.88	"	
		13.7.88	"	
	Cast net	4.1.88	Boat Quay	
		25.1.88	"	
		16.3.88	"	
		30.3.88	"	
		14.4.88	"	
		31.5.88	"	Low tide
		14.6.88	"	
		26.6.88	"	
		13.7.88	"	
		28.7.88	"	
		8.9.88	"	
		11.10.88	"	
	Seine	25.8.88	Boat Quay	
		5.10.88	Boat Quay/Road and Ord Bridge/ Ord and Clemenceau Bridge/beyond Clemenceau Bridge	Low tide
	Fish traps	16.3.88	Boat Quay	Not entirely dependent on tidal condition because the traps were left for a minimum of 2 days.
		26.3.88	"	
		14.4.88	"	
		28.4.88	"	
		31.1.88	"	
		28.7.88	"	
		23.8.88	"	
		25.8.88	"	
		14.10.88	Boat Quay/Ord Bridge	
		19.10.88	Boat Quay	

Table 3. Gut content examination of the captured fish from Singapore River.

Family	Species	Description of gut content
Ambassidae	Unidentified sp. 1	Indeterminate
Apogonidae	*Apogon hyalosoma*	"
	Unidentified sp. 1	"
Batrachoididae	*Batrachomoeus* sp.	Shrimp head, partially digested
Carangidae	*Alepes* sp.	Indeterminate
	Atropus sp.	Shrimp head, partially digested
	Carangoides malabaricus	Indeterminate
	Scomberoides commersonnianus	Shrimp, partially digested
	Scomberoides tol	Indeterminate
	Unidentified sp. 1	"
Chaetodontidae	*Parachaetodon ocellatus*	"
Clupeidae	*Anodontostoma chacunda*	"
	Sardinella fimbriata	"
Eleotridae	*Butis* sp.	"
Elopidae	*Elops machnata*	Shrimp tail, partially digested
Engraulidae	*Stolephorus heterolobus*	Indeterminate
	Stolephorus indicus	"
Epinephelidae	*Promicrops lanceolatus*	"
Gerreidae	*Gerres abbreviatus*	"
	Gerres filamentosus	"
Gobiidae	*Exyrias puntang*	"
	Unidentified sp.	"
Leiognathidae	*Leiognathus equulus*	"
	Leiognathus fasciatus	"
Lutjanidae	*Lutjanus fulviflammc*	"
	Lutjanus monostigma	Shrimp body, partially digested
	Lutjanus russelli	"
Mugilidae	*Mugil ceramensis*	Indeterminate
Mullidae	*Upeneus tragula*	"
Platycephalidae	*Platycephalus indicus*	Fish head
	Platycephalus macracanthus	Indeterminate
	Platycephalus scaba	"
	Platycephalus sculptus	"
Plotosidae	*Plotosus anguillaris*	"
	Plotosus canius	"
Pomadasyidae	*Pomadasys opercularis*	"
	Pomadasys sp.	"
Scatophagidae	*Scatophagus argus*	"
Serranidae	*Epinephelus tauvina*	Crab and fish, partially digested
Siganidae	*Siganus guttatus*	Indeterminate
	Siganus javus	"
Sillaginidae	*Sillago sihama*	"
Sphyraenidae	*Sphyraena jello*	"
Tetraodontidae	Unidentified sp.	"

Table 4. Record of fish and crustaceans caught in Singapore River by amateur fishermen according to fishing gear for the period 1986-1988.

Type of fish and crustaceans caught	1986							1987							1988		
	Apr-Jun			Jul-Aug				Jan-Mar				Apr-Jun		Jul-Sep	Jan-Mar	Jul-Sep	
	Pole fishing	Crab trap	Pole fishing	Gill net	Cast net	Crab trap	Pole fishing	Gill net	Cast net	Crab trap	Pole fishing	Cast net	Crab trap	Pole fishing	Pole fishing	Pole fishing	Crab net
Ambassidae *Ambasis* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Apogonidae *Apogon* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Balistidae *Monacanthus* sp.	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Carangidae (Trevallies)	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
(Scad)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Centropomidae *Lates calcarifer*	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Clupeidae *Anodontosoma chacunda*	+	-	-	+	+	-	-	-	-	-	+	-	-	+	-	-	-
Dussumieria hasselti	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Sardinella sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Drepanidae *Drepane* sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-
Engraulidae *Stolephorus* sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Gerreidae *Gerres filamentosus*	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
Gerres sp.	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Leiognathidae *Leiognathus* sp.	+	-	+	-	-	-	+	-	-	-	+	-	-	+	-	+	-
Lutjanidae *Lutjanus* sp.	+	-	+	-	-	-	-	-	-	-	+	-	-	+	+	+	-
Mugilidae *Mugil* sp.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Mullidae *Upeneus* sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemipteridae *Nemipterus* sp.	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-

Continued

Table 4 (continued)

Type of fish and crustaceans caught	1986							1987							1988		
	Apr-Jun			Jul-Aug				Jan-Mar				Apr-Jun		Jul-Sep	Jan-Mar	Jul-Sep	
	Pole fishing	Crab trap	Pole fishing	Gill net	Cast net	Crab trap	Pole fishing	Gill net	Cast net	Crab trap	Pole fishing	Cast net	Crab trap	Pole fishing	Pole fishing	Pole fishing	Crab net
Pentapodidae																	
Gymnocranius sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Platycephalidae																	
Platycephalus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Plotosidae																	
Plotosus anguillaris	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plotosus sp.	+	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-
Scatophagidae																	
Scatophagus argus	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
Sciaenidae																	
(Croaker/Jew fish)	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-
Serranidae																	
Epinephelus sp.	+	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-
Sillaginidae																	
Sillago sihama	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraenidae																	
Sphyraena jello	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Synodontidae																	
Saurida sp.	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triacanthidae																	
(Tripod fish)	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Portunidae																	
Portunus pelagicus	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Scylla serrata	-	+	-	-	-	+	-	-	-	-	-	-	+	-	-	-	+
Unidentified	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Shrimp, unidentified	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-

+ = Fish and crustaceans caught.
- = Fish and crustaceans not caught.

Table 5. Catch and abundance of specimen by different fishing methods in Singapore River for the period 1987-1988.

		1987			1988					
		Gill/trammel net	Cast net	Total no.	Gill/trammel net	Cast net	Seine	Fish trap	Total no.	Grand total
Ambassidae	*Ambasis urotaenia*	-	-	-	-	1	-	-	1	1
	Unidentified sp. 1	-	-	-	-	7	-	-	7	7
Apogonidae	*Apogon fraenatus*	20	-	20	-	1	6	-	7	27
	Apogon hyalosoma	-	-	-	-	1	-	-	1	1
	Unidentified sp.	-	2	2	-	43	7	-	50	52
Batrachoididae	*Batrachamoeus occidentalis*	-	-	-	-	-	2	-	2	2
	Batrachamoeus sp.	-	-	-	-	-	-	4	4	4
	Batrachamoeus trispinosus	-	-	-	-	-	2	2	4	4
Bothidae	*Pseudorhambus* sp.	-	-	-	1	3	-	-	4	4
Carangidae	*Alectis indicus*	-	-	-	-	-	1	-	1	1
	Alepes milanoptera	-	1	1	-	1	-	-	1	2
	Alepes sp.	-	-	-	-	1	-	-	1	1
	Atropus sp.	-	-	-	-	4	-	-	4	4
	Carangoides armatus	-	-	-	1	-	-	-	1	1
	Carangoides chrysophyrs	1	-	1	-	-	-	-	-	1
	Carangoides malabaricus	2	-	2	-	1	-	-	1	3
	Scamberoides cammersonnianus	-	-	-	-	6	8	-	14	14
	Scamberoides sp.	-	-	-	-	1	-	-	1	1
	Scamberoides tol	-	-	-	-	12	-	-	12	12
	Selaroides leptolepis	-	1	1	-	-	-	-	-	1
	Unidentified sp. 1	-	3	3	-	1	-	2	3	6
Centropomidae	*Lates calcarifer*	-	-	-	-	-	1	-	1	1
Chaetodontidae	*Parachaetodon ocellatus*	-	1	1	-	3	-	-	3	4
Clupeidae	*Anodontostoma chacunda*	112	218	330	258	1,624	806	-	2,688	3,018
	Dussumieria hasseltii	2	-	2	-	-	-	-	-	2
	Opisthopterus tardoore	-	-	-	1	-	-	-	1	1
	Sardinella fimbriata	-	2	2	420	68	84	-	572	574
	Sardinella gibbosa	-	-	-	-	1	-	-	1	1
Eleotridae	*Butis* sp.	-	-	-	-	-	-	1	1	1
Elopidae	*Elops machnata*	-	-	-	-	2	-	-	2	2
Engraulidae	*Stolephorus heterolobus*	-	-	-	7	-	5	-	12	12
	Stolephorus indicus	62	1	63	15	6	2	-	23	86
	Thryssa mystax	2	-	2	-	-	-	-	-	2
	Unidentified sp. 1	-	-	-	2	-	-	-	2	2
Epinephelidae	*Pramicrops lanceolatus*	-	-	-	-	4	-	5	9	9
Gerreidae	*Gerres abbreviatus*	1	11	12	1	139	13	1	154	166
	Gerres filamentosus	2	5	7	2	56	3	-	61	68
	Gerres oyena	-	-	-	-	46	-	-	46	46
Gobiidae	*Acentrogobius criniger*	-	-	-	-	2	-	-	2	2
	Eleotris sp.	-	-	-	-	1	2	-	3	3
	Exyrias puntang	-	-	-	-	1	-	-	1	1
	Unidentified sp. 1	-	6	6	-	35	13	12	60	66
Haemulidae	*Plectorhinchus gibbosus*	-	-	-	-	1	-	-	1	1
Hemiramphidae	*Hemiramphus* sp.	-	-	-	-	2	-	-	2	2
Labridae	Unidentified sp. 1	-	-	-	-	1	-	-	1	1
Lactariidae	*Lactarius lactarius*	1	-	1	-	-	-	-	-	1
Leiognathidae	*Leiognathus brevirostris*	-	-	-	-	9	12	-	21	21
	Leiognathus equulus	105	23	128	22	301	188	-	511	639
	Leiognathus fasciatus	-	36	36	-	66	4	-	70	106
	Leiognathus leuciscus	-	-	-	3	7	-	-	10	10
Lutjanidae	*Lutjanus fulviflamma*	-	-	-	-	4	-	-	4	4
	Lutjanus malabaricus	-	-	-	-	-	1	-	1	1
	Lutjanus monostigma	-	4	4	-	22	-	-	22	26
	Lutjanus russelli	-	-	-	-	6	-	2	8	8
	Lutjanus johni	-	-	-	-	-	-	1	1	1
Mugilidae	*Mugil ceramensis*	-	4	4	-	15	-	-	15	19
	Mugil iade	-	-	-	-	9	11	-	20	20
Mullidae	*Upeneus tragula*	-	-	-	3	2	-	1	6	6
Parapercidae	*Parapercis filamentosa*	-	1	1	-	-	-	-	-	1
Platycephalidae	*Platycephalus indicus*	-	-	-	4	5	1	-	10	10
	Platycephalus macracanthus	-	-	-	-	2	-	-	2	2
	Platycephalus scaba	-	1	1	1	8	-	-	9	10
	Platycephalus sculptus	-	-	-	-	1	-	-	1	1
Plectorhynchidae	*Pseudopristipoma nigra*	-	-	-	-	1	-	-	1	1
Plotosidae	*Plotosus anguillaris*	9	-	9	5	-	-	9	14	23
	Plotosus canius	-	-	-	3	-	-	1	4	4
Poeciliidae	*Lebistes reticulatus*	-	-	-	-	-	67	-	67	67
Pomadasyidae	*Pomadasys opercularis*	7	4	11	-	8	-	-	8	19
	Pomadasys sp.	-	-	-	-	3	-	-	3	3
Scatophagidae	*Scatophagus argus*	-	7	7	-	40	6	2	48	55
Serranidae	*Epinephelus malabaricus*	-	-	-	-	-	-	1	1	1
	Epinephelus tauvinar	1	4	5	-	24	1	13	38	43
Siganidae	*Siganus guttatus*	-	-	-	-	5	1	-	6	6
	Siganus javus	-	-	-	-	53	-	2	55	55

Continued

Table 5 (continued)

		1987			1988					
		Gill/trammel net	Cast net	Total no.	Gill/trammel net	Cast net	Seine	Fish trap	Total no.	Grand total
Sillaginidae	*Silligo sihama*	-	-	-	-	52	1	.	53	53
Sphyraenidae	*Sphyraena jello*	2	8	10	-	11	3	-	14	24
Synodontidae	*Saurida undosquamis*	1	-	1	-	-	-	-	.	1
Tetraodontidae	*Amblyrhynchotes* sp.	-	-	-	-	-	-	6	6	6
	Arothron reticularis	-	-	-	-	1	-	2	3	3
	Arothron sp.	-	-	-	-	.	-	1	1	1
	Unidentified sp. 1	-	-	-	-	1	-	4	5	5
Theraponidae	*Therapon theraps*	1	2	3	-	1	-	-	1	4
	Total no of species	17	22	30	17	57	27	20	75	82
	Total no. of specimen	331	345	676	749	2,732	1,251	72	4,804	5,480
<u>Shellfish</u>										
Menippidae	*Myomenippe hardwicki*	-	-	-	-	-	-	7	7	7
Metapenaeus	*Metapenaeus ensis*	-	-	-	-	13	196	2	211	211
	Metapenaeus sp.	-	-	-	1	-	2	-	3	3
Penaeus	*Penaeus indicus*	-	-	-	-	1	-	. -	1	1
	Penaeus merguiensis (tagged)	1	1	2	-	-	-	-	-	2
	Penaeus merguiensis (untagged)	-	5	5	-	5	2	-	7	12
	Penaeus semisculatus	-	-	-	-	5	-	3	8	8
Portunidae	*Portunus pelagicus*	15	-	15	71	30	26	8	135	150
	Scylla serrata	-	2	2	23	3	2	15	43	45
	Total no. of species	2	3	4	3	6	5	5	8	9
	Total no. of specimen	16	8	24	95	57	228	35	415	439

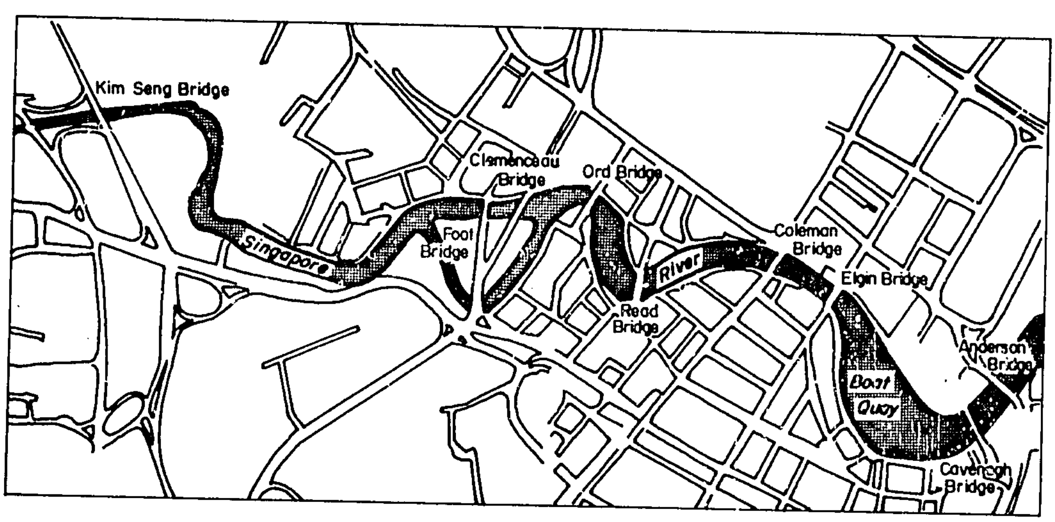

Fig. 1. Map of Singapore River.

Assessment of reef resources at sites identified for artificial reef establishment in Singapore

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ABSTRACT

High sedimentation levels accompanying large-scale land reclamation and heavy shipping activity in the Singapore seas over the past 20 years have reduced the abundance, but not the diversity, of coral reef life-forms. Since artificial reefs have shown in many parts of the world that they can enhance living marine resources, they were considered part of a habitat restoration effort. Site selection surveys for possible artificial reef establishment were carried out at seven sites between February 1987 and June 1988. Results showed that Terumbu Bemban has the highest percentage of live coral cover ([illegible].88%) and the largest average size of coral colonies. Cyrene Reefs has the highest diversity, with 28 genera covering 48.06% of the transect. Pulau Semakau has the lowest average coral cover and diversity, as well as the lowest average coral colony size. Although Terumbu Jarat and Pulau Semakau have poor community structure and low recruitment potential, reef enhancement using artificial reefs will be more significant.

INTRODUCTION

Singapore has one of the highest population densities in the world with 2.6 million people and a land area of just over 600 km². This shortage of land has resulted in a heavily utilized and highly modified coastline. Much of the original coastal resources have been reduced by the country's effort to use all available space. Massive land reclamation, which was started in the 1960s, was intended to reach its target of increasing the land area of Singapore by 10%. However, in doing so, living marine resources have been affected by the reclamation (Chou 1987). The fringing reefs along the southern coast have long been destroyed and fish catches over the past 20 years have declined (Tham 1986).

Artificial reefs have been used in many parts of the world to enhance and restore living marine resources in disturbed environments. Sunken structures on the seafloor have been known to attract fish and serve as substrates for encrusting organisms. These human-made reefs have been shown to provide habitats for many reef organisms and to enhance living marine resources (Higo and Notonakano 1984; Munro and Polovina 1984). Under the ASEAN/US Coastal Resources Management Project, seven potential sites were surveyed for the establishment of artificial reefs in Singapore between February 1987 and June 1988 (Figs. 1 and 2).

As the diversity and abundance of organisms of nearby reefs will affect the final composition of the artificial reef, the reef life-forms of site-adjacent reefs were surveyed. Results of physico-chemical parameters and seafloor characteristics of selected sites have been earlier documented (Chou and Hsu 1988). Summarized results of adjacent reef characteristics of seven sites were reported (Chou and Hsu 1987). This paper focuses on the reef community of the natural reefs adjacent to the sites.

METHODOLOGY

The natural reefs next to the seven sites examined were Cyrene Reefs (1°15'N, 103°45'E), Terumbu Jarat (1°12'N, 103°47'E), Terumbu Pempang Tengah West (1°12'N, 103°44'E), Terumbu Bemban (1°12'N, 103°45'E), Kukor Beacon (1°14'N, 103°45'E), and Terumbu Pempang Tengah North (1°14'N, 103°44'E). The reefs were surveyed using a 100-m line-intercept life-forms transect set on the reef slope at a depth of 3 m from the reef crest (Dartnall and Jones 1986). The data were analyzed in terms of the percentage cover of the live coral, dead coral, algae, other fauna and abiotic components with respect to the 100-m transect at each site. The community structure of the hard corals at each reef was then examined.

RESULTS

Summarized results of the line-intercept life-forms transect on the site-adjacent reefs with reference to their biotic and abiotic components are shown in Table 1. The analyses of hard coral community at the generic level and the Shannon and Weaver diversity indices of all the transects are shown in Table 2.

The transect at Terumbu Bemban had the highest live coral cover of 65.88% and the highest number of colonies. Pulau Semakau had the lowest number of colonies on its transect. From the diversity indices in Table 2, Cyrene Reefs had the most diverse hard coral community (2.96) and the highest total number of genera. Terumbu Pempang Tengah West had the second highest diversity index of 2.44 and the second highest total number of genera. Terumbu Jarat had the lowest coral diversity of only 1.99. The average size of the colonies of each transect (Table 2) was calculated by dividing the total percentage cover by the number of colonies on each transect. The average size of coral colonies was highest at Terumbu Pempang Tengah North (0.66 m), followed by Terumbu Bemban (0.44 m). Pulau Semakau had the smallest average coral colony size.

The most common corals found on the transect at Cyrene Reefs were mainly the massive and the foliose types. The dominant genera were *Merulina, Pectinia* and *Favites*, each covering over 5% of the transect. The genus *Acropora* was absent. Three colonies of the nonscleractinian *Heliopora* were encountered at this site only. Dead corals comprised mainly those with algal coating and none were recently dead. The algae observed on the transect were filamentous ones in the form of algal assemblages. The other types of reef fauna observed included sponges, soft coral and hydroids but these were predominated by zoanthids. The abiotic components were mainly rubble and silt.

The transect at Terumbu Jarat had only 22.54% live corals (Table 1), of which the genera *Physogyra* and *Pavona* were dominant. Although the transect there had the lowest coral cover, there were two occurrences of *Acropora* taking up 0.1% of the 100-m transect (Table 2). The common growth forms were the encrusting, massive and foliose types. The dead corals were predominantly those with algal covering. Coralline algae and algal assemblages were also observed along the transect. Other reef fauna were mainly sponges and hydroids. At this transect, the highest percentage of abiotic components (62.38%), like rubble and water fissures, were recorded.

The second highest live hard coral cover was encountered at Terumbu Pempang Tengah West with the genera *Pachyseris, Favia, Merulina, Porites* and *Pectinia* among the more abundant. The transect had two colonies of *Acropora* with a percentage cover of 0.4%. The dominant growth forms were the encrusting type (*Pachyseris* and *Merulina*). The submassive and branching growth forms each had only one representative on this transect. Like the previous two sites, dead corals had algal covering and the algae encountered were either coralline algae or in the form of algal assemblages. Sponges were observed covering 0.94%. Among all the transects, this site had the lowest abiotic components (19.01%), comprised mainly of rubble. The site north of this patch reef, however, did not have the high live coral cover encountered in the west. But the dominant genera were common for the two sites minus the genus *Merulina*. The transect on the north site did not have any algae although filamentous algae were plentiful in other parts of the reef. Patches of sand were found interspersed between the living part of the reef.

The dominant corals at Terumbu Bemban were the foliose forms of *Montipora* (43 colonies, 21.70%) and *Pavona* (21 colonies, 14.35%). One colony of *Acropora* was observed on the transect. The dominant growth form was the foliose type, comprising mainly of *Pavona* and *Pectinia*. It is interesting to note that on this transect, and even more so on the reef flat, there was an abundance of the branching form of *Porites*, which is not very common in other Singapore reefs. Apart from the usual occurrences of algal assemblages, the macroalgae *Sargassum* was present. Other reef fauna included sponges, sea urchins and sea anemones. There were 58 occurrences of abiotic components like sand, rubble and water fissures, but these occupied only 26.47% of the transect.

Pulau Semakau had the lowest percentage cover of live corals (15.61%) and the highest percentage cover of dead corals (49.81%). The genus *Acropora* was absent. The predominant coral was the encrusting form of *Montipora*. The algae that occurred were in the form of filamentous assemblages. Zoanthids formed the highest percentage cover of noncoral life-forms. There was a total of 12 occurrences of zoanthids covering 2.35% of the transect. Other fauna included sponges, hydroids and soft corals. The majority of the abiotic components was made of rubble, although other components like silt, sand, water fissures and rocks were present on the transect.

DISCUSSION

The high percentage cover of life-forms on the transects at Terumbu Bemban, Terumbu Pempang Tengah (North and West) and Cyrene Reefs offers good recruitment potential for the artificial reefs (Chou and Hsu 1987). The low percentage cover of live corals at Terumbu Jarat and Pulau Semakau offers lower recruitment potential compared to the other sites, but reef enhancement using artificial reefs will be more significant there. It is interesting to note that the life-forms transect carried out very near the site at Pulau Semakau a year ago had 42.09% live corals and 9.82% dead corals. This is a good reef cover, especially when compared to the transect carried in June 1988, which had 15.61% live corals and 49.81% dead corals. Although the abundance of hard corals was reduced significantly, the reef remains diverse, with a Shannon and Weaver index of 2.25. This drastic drop in coral abundance can be attributed to the dumping of earth spoils southeast of this site. The increase in the level of sediment in the water and the subsequent reduction of water visibility have resulted in the death of many corals and other life-forms. If this dumping at Pulau Semakau is contained, the construction of artificial reefs may be a possible solution to the enhancement and restoration of the natural reef. The rich and diverse reef that existed here before the dumping shows this area to be ideal for rapid reef recolonization.

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Table 1. Life-forms cover at 3-m depth on the reef slope of the surveyed sites (based on a 100-m line transect).

Surveyed site	Percentage cover				
	Live coral	Dead coral	Algae	Other fauna	Abiotic components
Cyrene Reefs	48.06	2.00	1.58	1.66	46.70
Terumbu Jarat	22.54	12.73	0.00	2.35	62.38
Terumbu Pempang Tengah West	54.42	19.16	5.22	2.19	19.01
Terumbu Bemban	65.88	3.91	1.53	2.21	26.47
Kukor Beacon	-	-	-	-	-
Terumbu Pempang Tengah North	38.05	25.90	0.00	1.85	34.20
Pulau Semakau	15.61	49.81	1.60	4.35	28.63

Table 2. Hard coral community analyzed at generic level (figures indicate percentage cover with colony number in parentheses).

Genera	Reef Site					
	Cyrene Reefs	Terumbu Jarat	Terumbu Pempang Tengah (W)	Terumbu Bemban	Terumbu Pempang Tengah (N)	Pulau Semakau
Acroporidae						
Acropora	-	0.10(1)	0.40(2)	-	-	-
Montipora	0.98(3)	0.30(1)	1.16(4)	21.7(43)	-	4.70(15)
Agariciidae						
Leptoseris	0.60(1)	-	-	-	0.85(1)	-
Pachyseris	1.94(4)	0.10(1)	13.07(26)	4.40(9)	10.75(12)	0.40(3)
Pavona	0.20(1)	4.13(9)	2.35(6)	14.85(21)	3.70(2)	0.43(2)
Fungiidae						
Fungia	0.30(2)	0.55(4)	0.75(7)	1.79(12)	1.70(4)	0.10(1)
Heliofungia	-	-	-	-	-	0.20(1)
Lithophyllop	-	-	-	0.50(1)	-	-
Podobacia	1.24(3)	0.50(1)	1.50(5)	-	2.10(7)	-
Poritidae						
Goniopora	1.19(3)	-	1.14(5)	0.30(1)	-	-
Porites	2.15(5)	0.40(1)	2.50(8)	4.63(7)	2.65(9)	1.94(7)
Siderastreidae						
Psammocora	-	-	-	-	0.20(1)	-
Faviidae						
Cyphastrea	0.08(1)	-	-	-	0.70(3)	1.96(4)
Diploastrea	-	-	-	-	-	1.40(2)
Echinopora	2.25(5)	1.35(3)	2.38(6)	0.90(2)	-	-
Favia	2.59(10)	0.45(3)	5.55(7)	-	7.00(4)	1.23(3)
Favites	5.28(10)	0.90(2)	1.40(5)	1.10(4)	0.30(1)	0.50(1)
Goniastrea	2.19(6)	0.50(3)	0.70(3)	-	1.70(2)	-
Hydnophora	1.31(2)	0.50(2)	1.90(4)	1.95(6)	-	-
Leptastrea	-	-	-	-	0.10(1)	-
Montastrea	3.46(6)	-	-	-	-	0.20(1)
Platygyra	2.93(10)	-	0.34(2)	0.75(4)	-	-
Trachyphylliidae						
Trachyphyllia	-	-	-		-	0.20(1)
Oculinidae						
Galaxea	1.46(6)	-	0.50(3)	0.14(1)	-	-
Merulinidae						
Merulina	5.87(13)	0.85(4)	8.15(18)	4.18(10)	-	-
Mussidae						
Lobophyllia	0.68(2)	-	-	0.90(1)	-	-
Symphyllia	1.00(3)	0.50(2)	0.50(4)	-	-	-
Pectiniidae						
Echinophyllia	2.50(3)	-	0.72(1)	-	-	-
Mycedium	-	-	-	-	5.15(5)	0.80(3)
Oxypora	1.08(2)	-	-	0.60(2)	0.40(2)	-
Pectinia	5.34(15)	1.65(6)	8.51(27)	4.99(21)	0.15(2)	1.20(3)
Caryophylliidae						
Euphyllia	1.10(2)	-	0.50(2)	-	-	-
Physogyra	0.10(1)	9.76(11)	0.40(1)	2.35(3)	-	-
Plerogyra	0.30(1)	-	-	-	0.10(1)	-
Dendrophylliidae						
Tubastraea	-	-	-	-	-	0.05(2)
Turbinaria	0.09(1)	-	-	-	-	0.30(1)
Helioporidae						
Heliopora	0.85(3)	-	-	-	-	-
Total percentage cover	48.06	22.54	54.42	65.88	38.05	15.61
(Number of colonies)	(126)	(56)	(146)	(148)	(58)	(50)
Total number of genera	28	16	21	17	17	16
Shannon and Weaver diversity index[a]	2.96	1.99	2.44	2.12	2.12	2.24
Average colony size (m)	0.38	0.40	0.37	0.44	0.66	0.31

[a]Odum (1971).

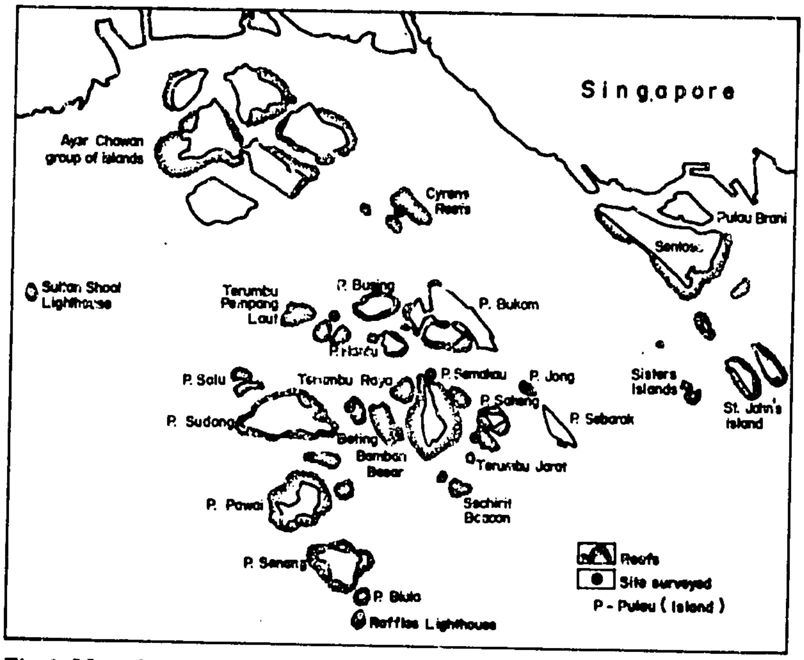


Fig. 1. Map of coral reefs in Singapore showing sites surveyed.

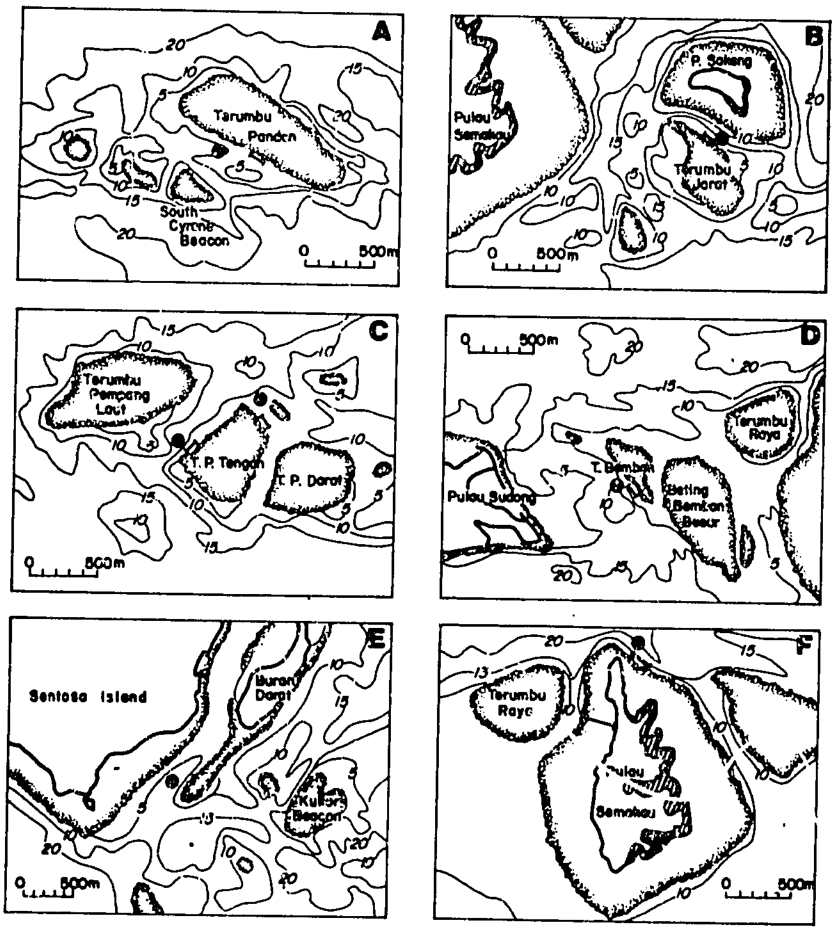
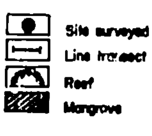


Fig. 2. Map showing location of sites investigated: A - Cyrene Reefs; B - Terumbu Jarat; C - Terumbu Pempang Tengah; D - Terumbu Bemban; E - Kukor Beacon; F - Pulau Semakau. (Isobath depths indicated are in meters.)



The fish fauna around proposed reef sites in Singapore

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ABSTRACT

Five sites were identified as possible areas for the establishment of artificial reefs. These were Terumbu Bemban, Terumbu Jarat, Terumbu Pandan, Terumbu Pempang Tengah and Pulau Semakau. The fish fauna at these sites was surveyed and a preliminary list of reef species observed at the sites is given. Only three species of indicator butterflyfishes (Chaetodontidae) were recorded during the surveys. Generally, there were few target species (families Caesionidae, Carangidae, Haemulidae, Lethrinidae, Lutjanidae and Serranidae). The most abundant fishes were the pomacentrids and the labrids. The fish fauna was abundant at 3 m depth and generally poor at 10 m depth.

INTRODUCTION

The Artificial Reefs in Living Resources Enrichment in the Singapore component of the ASEAN/US Coastal Resources Management Project is the first project of its kind in Singapore. It aims to increase fish habitats and restore critical habitats for the purpose of increasing fish production, enhancing recreational fishing and preserving genetic diversity in Singapore waters. Studies on Singapore reefs have shown that artificial substrates may prove significant in coral recruitment and growth (Chong 1985; Chou and Lim 1986). Artificial reefs can also serve as fish aggregating devices. The initial activities of the project entailed a site-selection survey for possible artificial reef sites and a documentation of reef substrate. This paper gives a list of visually conspicuous reef fishes surveyed and an estimate of their abundance in each site.

METHODOLOGY

Five reefs south of the Singapore mainland were chosen as potential artificial reef sites (Fig. 1). They are Terumbu Bemban, Terumbu Jarat, Terumbu Pandan, Terumbu Pempang Tengah and Pulau Semakau. The reefs at the first four sites are patch ones, while that at Pulau Semakau is fringing.

The fish surveys were made by visual census, modified from that described by Dartnall and Jones (1986). At each site, a 150-m transect line was laid along the reef slope, parallel to the reef crest, at two depths (3 and 10 m). Two observers swam along the line and recorded the fish observed within 3 m to the left, right and above. The total area covered using this method was 900 m^2.

Actual counts were made for the indicator species (family Chaetodontidae) and the target species (important food families such as Haemulidae, Lethrinidae, Lutjanidae and Serranidae). The abundance of all other families of fishes was estimated according to log 4 abundance categories (Table 1). The abundance of scads (Carangidae) and fusiliers (Caesionidae), although considered target species, have been estimated according to log 4 categories because of their schooling habit.

All surveys were carried out between 11 A.M. and 3 P.M. within a three-month period from June to August 1988. No data were collected for the 10-m transect at Terumbu Jarat since the reef slope was not beyond 6 m deep.

RESULTS

A total of 57 species of fishes from 17 families was recorded. The results are summarized in Table 1.

Indicator fish (Chaetodontidae)

The butterflyfishes recorded were *Chaetodon octofasciatus, Chelmon rostratus* and *Coradion chrysozonus. C. rostratus* and *C. octofasciatus* were ubiquitous at all the sites surveyed. However, while *C. rostratus* was observed at both depths, *C. octofasciatus* was observed only at the 3-m depth transect. *C. chrysozonus* was not recorded in any of the transects but was sighted at Terumbu Bemban at 10 m depth.

Target species

The nine species recorded under this category were two species of sweetlips (Haemulidae), two species of groupers (Serranidae), two species of scad/trevallies (Carangidae), two species of fusiliers (Caesionidae) and one species of snappers (Lutjanidae). No emperor bream (Lethrinidae) was observed. The schooling fusiliers *(Caesio teres* and *C. caerulaurea)* were most abundant and occurred in schools of 10 to 40. Their sizes ranged from 10 to 18 cm. Among the solitary target species, the snapper *(Lutjanus carponotatus)* and the small grouper *(Cephalopholis pachycentron)* were more common. Single large individuals (approximately 30 cm in length) of groupers *(Plectropomus areolatus)* and sweetlips *(Plectorhynchus pictus)* were recorded at Terumbu Jarat and Terumbu Bemban, respectively. The small scad *(Selaroides leptolepis)* was also present in the reefs but was not recorded in the transects.

Major families

In terms of the number of species and abundance, the dominant families recorded were Pomacentridae and Labridae. A total of 17 species of pomacentrids and 11 species of labrids were recorded during the fish surveys. The smaller pomacentrids of genera *Neopomacentrus* and *Pomacentrus* were most common. *Pomacentrus* was distributed throughout the reef and was abundant at the 10-m depth, while *Neopomacentrus* was confined to shallower depths (3 m). Among the labrids, the most common were *Halichoeres dussumieri* and *H. melanurus*. The soapfish (Grammistidae, *Diploprion bifasciatus*) was also relatively abundant at all sites.

Other families of fishes observed at the sites were Apogonidae, Blenniidae, Gobiidae, Mullidae, Nemipteridae, Ostraciidae, Pomacanthidae and Scaridae.

Eleven species were common at lower depths (10 m). Five of these were pomacentrids: *Pomacentrus alexanderae, P. brachialis, Chrysiptera unimaculata, Hemiglyphidodon plagiometapon* and *Neopomacentrus* sp. 1. The rest were: one chaetodontid (*Chelmon rostratus*); one pomacanthid or angelfish (*Chaetodontoplus mesoleucus*); one labrid *(Halichoeres dussumieri)*; one Caesionidae *(Caesio caerulaurea)*; one lutjanid *(Lutjanus carponotatus)*; and one Grammistidae or soapfish (*D. bifasciatus*).

Fish species recorded at the sites were generally small. Only a few large species were sighted: *P. areolatus, P. pictus, P. chaetodontoides, Scarus ghobban* and *Chelinus fasciatus*. With the exception of the more pelagic fusiliers *(Caesio teres, C. caerulaurea)* and scad/trevallies *(Selyroides leptolepis, Caranx* spp.*)*, all other fishes were observed to be closely associated with the reef.

DISCUSSION

Randall noted that the number of species of reef fish in Singapore was low (Tay and Khoo 1984). Tay and Khoo (1984) recorded 99 species from 28 families. It should be noted that the 57 species recorded in this survey can not be directly compared with the number of species they reported as the methods and time of recording differed greatly. While Tay and Khoo used comprehensive but time-consuming methods, the method used for this study yielded quick but only semiquantitative data. However, this method allowed the identification of the visually conspicuous species of reef fishes and an estimation of their abundance for the assessment of the fish populations (GBRMPA 1978).

The pomacentrids and labrids were the dominant reef fishes at all the sites surveyed. The chaetodontids, with only three species, can be considered poor in terms of variety. This trend was also observed for the target species.

The reef fishes were generally of greater variety and more abundant at the 3-m depth than at the 10-m depth. This can be attributed to the greater live coral cover at the 3-m depth compared to the 10-m depth (Hsu and Chou, this vol.). At greater depths (10 m), the percentage of rubble was greater; this implies a lower availability of food and shelter. Eleven species, however, seem to have adapted to these conditions. Most of these species were generally small; the larger species observed were only a few.

The proposed artificial reefs may enhance the fish population at these sites. Once established, these reefs will be evaluated for their effectiveness.

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Table 1. The distribution and abundance of reef fishes at proposed artificial reef sites.

		Survey site/depth								
		Terumbu Pandan		Terumbu Pempang Tengah		Terumbu Bemban		Terumbu Jarat	Pulau Semakau	
Family	Species	3 m	10 m	3 m	10 m	3 m	10 m	3 m	3 m	10 m
		Actual counts								
Chaetodontidae	*Coradion chrysozonus*						+			
	Chaetodon octofasciatus	1		11		5		5	4	
	Chelmon rostratus	14	1	5	5	5	11	6	11	2
		Log 4 abundance								
Apogonidae	*Apogon compressus*			1			1			
	A. sealei		3							
	Cheilodipterus macrodon	+		+					+	
Blenniidae	*Meiacanthus grammistes*								1	
	Blenny sp.									2
Caesionidae	*Caesio teres*	2		3		4	4	2		
	*C. coerulaurea**									
Carangidae	*Selaroides leptolepis*			+	+	+		+		
	Caranx sp.							1		
Grammistidae	*Diploprion bifasciatus*	4	+	3	3	4	4	4	4	3
Gobiidae	*Goby* sp. 1			1				1	2	
Haemulidae	*Plectorhynchus pictus*					1				
	P. chaetodontoides							+		+
Labridae	*Choerodon anchorago*	1	1	1	1	2		1	3	
	Cheilinus fasciatus				1				1	
	Halichoeres chloropterus	1		1		2				
	H. melanurus	3	1	1		3				
	H. melanochir	1								
	H. scapularis			1						
	H. dussumieri	4	3	4	4	4	3	+	4	4
	H. hartzfeldii				3					
	Hemigymnus melapterus						1			
	Labroides dimidiatus					1				
	Thalassoma lunare					2				
Lutjanidae	*Lutjanus carponotatus*			3		1	3	1		
Mullidae	*Upeneus tragula*							1		
Nemipteridae	*Pentapus caninus*		1							
	Scolopsis bilineatus									
	S. trilineatus		1			1				
	S. vosmeri						1			

Continued

Table 1 (continued)

Family	Species	Terumbu Pandan 3 m	Terumbu Pandan 10 m	Terumbu Pempang Tengah 3 m	Terumbu Pempang Tengah 10 m	Terumbu Bemban 3 m	Terumbu Bemban 10 m	Terumbu Jarat 3 m	Pulau Semakau 3 m	Pulau Semakau 10 m
Ostraciidae	*Ostracion* sp.	1								
Pomacanthidae	*Pomacanthus sexstriatus*	1			1	1		1	1	
	Chaetodontoplus mesoleucus	3	1	3	3	4	2	3	3	2
Pomacentridae	*Abudefduf bengalensis*							1		
	A. coelestinus							1		
	A. saxatilis		1							
	A. vaigiensis		1							
	Amblyglyphidodon leucogaster			1		1	3			
	Amphiprion frenatus			1						
	A. ocellaris	+			*				+	1
	Chrysiptera unimaculata	1			3				3	
	Hemiglyphidodon plagiometapon		3		2	3		4		
	Neopomacentrus taeniurus	4				2				
	Neopomacentrus sp. 1	4	2	4	2	4	3		4	2
	Neopomacentrus sp. 2						1			
	Paraglyphidodon nigrosis		1	4		3		3		
	Pomacentrus alexanderae	4	3	4	3	5	5	1	4	4
	P. brachialis	4	2	3		4	2	3	4	1
	P. moluccensis			2						
	Pomachromis richardsoni			4		4		4	2	
Scaridae	*Scarus ghobban*			1						
	Scarus sp.								4	
Serranidae	*Cephalopholis pachycentron*		1	2						
	Plectropomus areolatus							1		

Log 4 Categories	No. of individuals
1	1
2	2 - 4
3	5 - 16
4	17 - 64
5	65 - 256
6	257 - 1,024

+ indicates presence

*No data on distribution and abundance but present at 10-m depth.

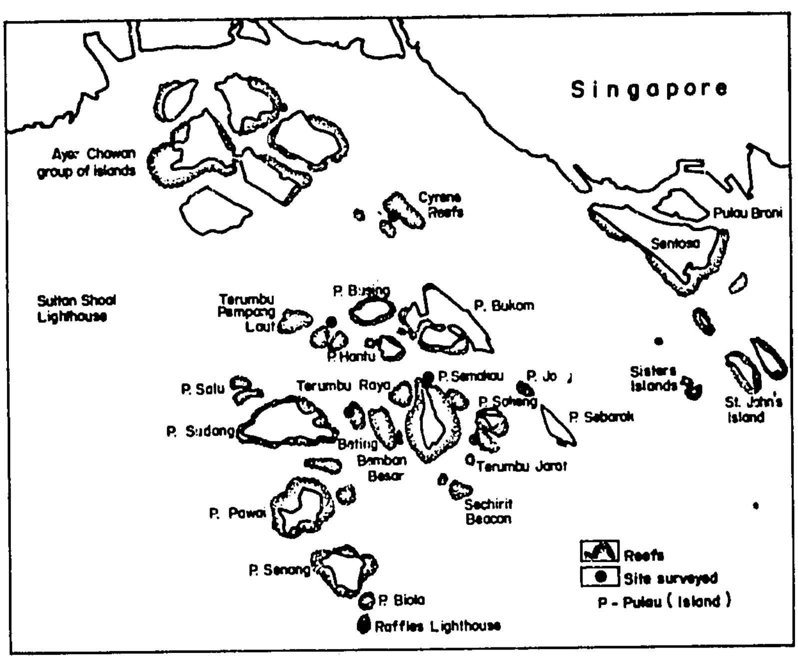

Fig. 1. Map of coral reefs in Singapore showing sites surveyed.

Enhancement of the natural stock of *Macrobrachium rosenbergii* (de Man) in Brunei Darussalam

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ABSTRACT

Macrobrachium rosenbergii is widely distributed in Southeast Asia, including Brunei Darussalam. The local marketed production of *Macrobrachium* from 1980 to 1987 ranged from 16.9 to 54 t with a very negligible contribution from aquaculture. In line with the program of the Fisheries Department (FD) to develop the culture of *Macrobrachium*, a pilot-scale hatchery was constructed in 1982. Since then, the annual hatchery production has increased remarkably from 12,200 to 297,500 postlarvae. All of the postlarvae produced until 1986 were stocked in grow-out ponds. By 1987, restocking of the postlarvae in the major waterways of the country began and 77.4% of the year's hatchery production was utilized for this purpose. Guidelines on restocking activities will be formulated and their impact on fisheries will be assessed.

INTRODUCTION

Udang galah (Macrobrachium rosenbergii), commonly called giant freshwater prawn, is widely distributed in Southeast Asia, including Brunei Darussalam. It is one of the most important commercial freshwater species. Although at present the natural population of the giant prawn has not been assessed, restocking of the natural waterways is assumed to be of great value in enhancing the natural stock. In 1987, 56.4 t of prawn were marketed in the country of which only 37.8 t were produced locally. The local production of prawn comes mainly from capture fisheries while that from aquaculture is very minimal (less than 100 kg).

The number of fishermen involved in prawn fishing is not precisely known, but the majority of them are part-time fishermen involved in other inshore fishing activities.

In view of the potentials of prawn for aquaculture, FD set up a pilot-scale hatchery in 1982 to supply the fry requirement of the department's demonstration farm and private grow-out ponds. When fry supply exceeded the targeted requirement, restocking in the natural waterways of the State was done. In 1987, the hatchery produced 297,500 postlarvae of which only 67,200 were absorbed by the limited grow-out ponds and the rest (230,300) were restocked in the major waterways.

At present, there is no specific restocking program in the country. The number of fry to be stocked per area, frequency of stocking, monitoring and assessment scheme need to be formulated.

Freshwater prawn hatchery

The pilot-scale hatchery at the FD's station in Muara has minimal facilities--twelve 0.8 t circular fiber tanks, three 8 t circular fiberglass tanks, two 2 t conical fiberglass tanks, one 32 t rectangular fiberglass tank, four 50 l *Artemia* hatching tanks, twelve 120 l glass aquaria and an algal room for the maintenance of natural foods (*Chlorella* and *Tetraselmis*).

The aeration system is supplied by a 3 horsepower (hp) vortex blower. Seawater is drawn from the coast through a 1.5 hp submersible pump. Pumped seawater is stored in the 32 t reservoir and filtered, using a rapid sand filter pump. The freshwater source comes from the tap and stored into an elevated 3 t storage tank. The desired salinity (12-15 ppt) is attained by mixing the sea- and freshwater in the 8 t circular tanks.

The annual production of the pilot-scale hatchery is summarized in Tables 1 and 2. Dramatic increases in the annual production (1982-1987: 12,200 to 297,500 postlarvae) and survival rate (1986-1988: 16.5% to 50.0%) have been achieved since 1982. This is the result of continued refinements in the production scheme as well as the development of the hatchery staff's technical skill.

Restocking activities

Restocking of prawn postlarvae in natural waterways started in 1987. For restocking purposes, four major areas were identified (Fig. 1): Sungai (Sg. throughout this text; means "river") Brunei, Sg. Temburong, Sg. Tutong and Jerudong Park Reservoir.

Sg. Brunei has a relatively small catchment area (around 360 km^2) (WHA 1987) and discharges into the inner Brunei Bay. The estuary is heavily used for water transport, recreation and artisanal fishing.

Sg. Temburong discharges into the head of Brunei Bay from a total catchment area of some 1,100 km^2, mostly jungle and largely uninhabited. There are two major tributaries that drain into Sg. Temburong--the Sg. Labu and Sg. Batu Apoi. The riverbanks abound with mangrove and nipa *(Nypa fruticans)*.

The Sg. Tutong basin drains a total catchment area of about 1,300 km^2 (WHA 1987). It is contiguous with Sg. Belait in the west but that part of the basin drains directly into Sg. Telisay. On the other hand, Sg. Tutong discharges into the China Sea between two sandpits that form an elaborate estuarine system. Its riverbanks are covered with nipa up to 12 km upstream and tidal influence extends up to 46 km upstream.

The Jerudong Park Reservoir, on the other hand, has an area of 28.3 ha. Water supply comes mainly from the water runoff of the surrounding hilly areas. It has a water-holding capacity of 170 million gal. The reservoir has a water depth range of 1 to 15 m.

Local prawn production

The amount of prawn marketed in the country from 1980 to 1987 is summarized in Table 3. Of the total prawns marketed, only 26 to 49% were produced locally and mainly from capture fisheries.

Most of those involved in prawn fishing are part-time fishermen and their exact number at present is not known. In 1986, there were 1,566 registered part-time fishermen, 71.3% of them were from the Brunei-Muara District, 11.4% from Tutong District and 7.9% from Temburong District (Khoo et al. 1987). Although Temburong District had the least number of registered fishermen, it was the major local source of prawn.

The gear used in prawn fishing are *kilong*, *bubu* and *rambat*. *Kilong* (Fig. 2) is similar to the fish corral used in coastal areas. It has two to three guide walls of 4 to 6 m long, leading to the catching chamber. It is usually installed perpendicular to the riverbank or against the flow of the receding tide. Collection of the prawn in the catching chamber is done at two to three days' interval. A single collection can produce more than 1.5 kg (Amzah, pers. comm.).

Bubu (Fig. 3) is the local term for trap or pot. The *bubu* used for prawn is different from that used in the open sea for catching fish. The fish *bubu* is made from chicken wire mesh and is usually rectangular in shape, while the prawn *bubu* is made from woven bamboo with its mouth facing the incoming flow of water. The mouth is conically shaped and will allow only the entrance of prawn. The body is further covered with nipa leaves or the bark of tree for camouflage. The *bubu* is usually 0.75 to 1.2 m long and the mouth diameter is about 0.3 to 0.5 m. One *bubu* can catch about 0.3 to 0.5 kg of prawns in three to four days' time. Most fishermen experience a better catch if the *bubu* are installed in areas affected by salinity fluctuations (5 to 15 ppt).

The third type of gear used is the *rambat* or cast net. Usually operated during low tide, this type is not as commonly used as the *kilong* and *bubu* for catching prawn.

DISCUSSION

The magnitude of prawn fishery in Brunei Darussalam has not been fully assessed. Local production of prawn did not show any fixed trend from 1980 to 1985 (Table 3). However, there was a sharp decrease in production of nearly 50% from 1986 to 1987. The explanation for this decline in the natural fishery was not well established, but the long drought period experienced in the country (from December 1986 to May 1987) may be one of the major factors. If such a trend continues, restocking the country's natural waterways will be necessary to enhance the natural prawn stock. An increase in the natural stock could boost local production and subsequently reduce, if not totally eliminate, the importation of this species. Furthermore, such a thrust will augment the income of the local fishermen.

The initial results from the 1987 restocking are promising. In the Jerudong Park Reservoir, the prawn grew (80 to 120 g) after eight to 12 months of stocking. Reservoir stocking may not be as effective as stocking in rivers, where the prawn can complete their life cycle. However, stocking in the reservoir would produce large prawn that can be use as broodstock for the hatchery.

In Thailand, Pawaputanon (1986) similarly observed good growth and recovery rates in their 1982 stocking at the Ubolratana Reservoir. Out of the 300,000 *Macrobrachium rosenbergii* fry stocked, over 2 t of market-size prawn (300 to 500 g) were recaptured after one year of stocking.

CONCLUSION

Restocking of Brunei Darussalam's natural waters could well increase the local production of *Macrobrachium rosenbergii*, which could substantially reduce imports in the future. At present, about 60% of the total prawn marketed in the country are imported. Compared to other countries in the region, the river systems of Brunei Darussalam have low pollution levels as the watershed areas are relatively undeveloped, especially for agriculture. Such conditions would be ideal for a prawn stocking program, ensuring good survival and sustained production as well as enhancing the natural stock.

There is a need to formulate guidelines and policies that will ensure the success of the restocking program, including monitoring and impact assessment. Baseline studies on the characteristics of bodies of water targeted for restocking should be made to determine proper stocking procedures and enhancement activities. Impact on the biota must also be assessed to minimize interspecific competitions and/or displacement of local species arising from the restocking program.

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Table 3. *Macrobrachium rosenbergii* marketed (kg) in Brunei Darussalam.

Year	Local	Import	Total	
1980	16,996 (40%)	25,487 (60%)	42,483	
1981	31,205 (44%)	39,791 (56%)	70,996	
1982	29,047 (49%)	30,436 (51%)	59,483	
1983	19,701 (31%)	44,697 (69%)	64,398	
1984	44,016 (26%)	123,894 (74%)	167,910	
1985	54,023 (38%)	89,354 (62%)	143,377	
1986	39,253 (38%)	63,294 (62%)	102,547	
1987	18,561 (33%)	37,845 (67%)	56,406	
Total	252,802 (36%)	454,798 (64%)	707,600	(100%)

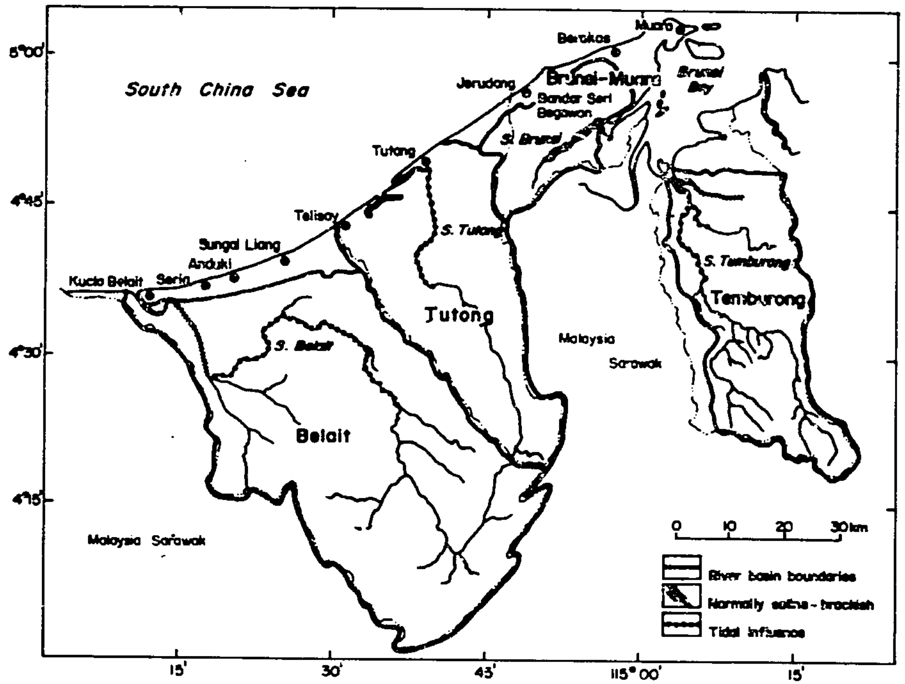

Fig 1. Rivers of Brunei Darussalam (adapted from Grant 1984 and Loo et al. 1987).

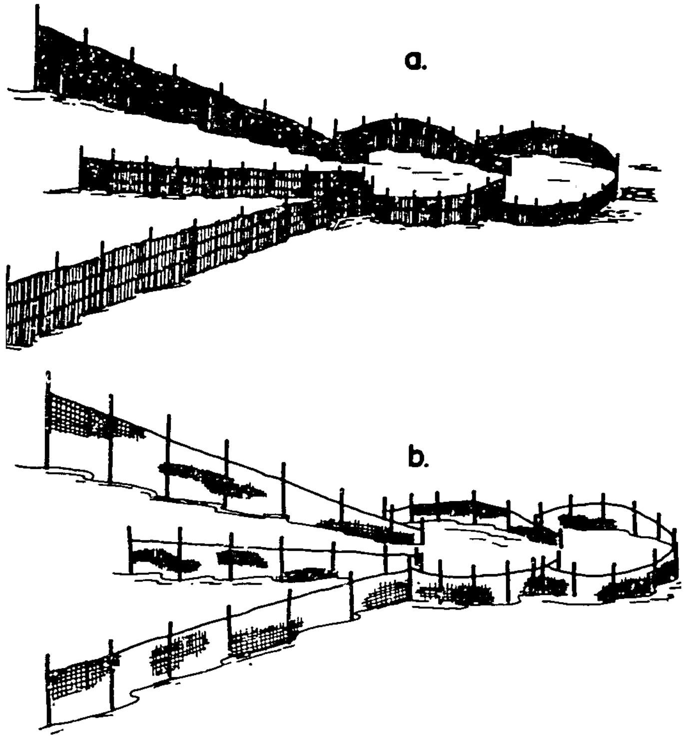

Fig. 2. *Kilong* (fish corral) using (a) woven bamboo splits and (b) polyethylene nets as guide walls and catching chambers.

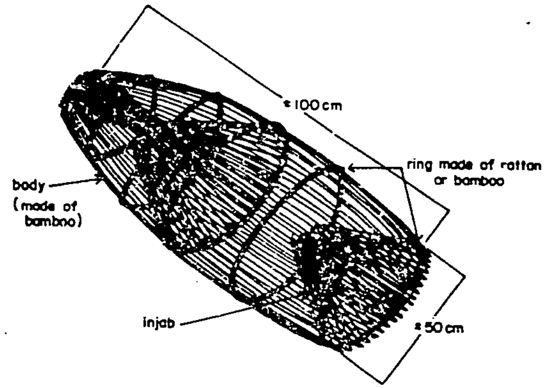

Fig. 3. *Bubu* (pot) used in prawn fishing.

Session IV
Resource Planning and Management

Coral reef management in the ASEAN/US Coastal Resources Management Project

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ABSTRACT

This paper discusses and summarizes the various approaches to coral reef management being attempted in the project sites of the ASEAN/US Coastal Resources Management Project (CRMP). Except in Indonesia, the coastal pilot sites of the other five ASEAN member-countries include coral reef areas and resources.

The specific sites of interest are Pelong Rocks and several patch reef areas in Brunei Darussalam; Pulau Rawa Archipelago and Pulau Sibu Archipelago Marine Parks, Johore, Malaysia; Santiago Island and several adjacent islands, Bolinao, Philippines; several offshore islands of Singapore; and Mu Ko Ang Thong and Ko Phi Phi National Marine Parks, Ko Samui and Ko Phangan, Upper South, Thailand.

The approaches to the management of coralline and adjacent areas by means of marine reserves and parks are site- and country-specific. Brunei Darussalam intends to declare marine parks that limit use to recreation and research only in specific small areas. The Malaysian marine parks include most, if not all, coral reefs in the vicinity and will designate a zonation scheme for multiple use management. The Philippine project is considering a municipal marine park that will involve the community for effective management. Singapore's efforts are directed toward habitat enhancement through artificial reefs and raising awareness to support the preservation of some coral reef areas. The two marine parks in Thailand under the Royal Thai Departments of Forestry and of National Parks are broadening their management to include community interests and multiple uses with a focus on tourism.

Since the various well-known destructive impacts of coastal populations on adjacent coral reef areas are continually increasing at these sites, there is an urgency to complete a management program for implementation. Each proposed management regime, although not large in scale, is practical and has a good chance of success if given the necessary support.

INTRODUCTION

The coral reef ecosystems of Southeast Asia and their associated resources have been overused and damaged in recent years (Yap and Gomez 1985). The primary causes of degradation are: (1) intense and destructive fishing methods such as blasting, use of cyanide, muro-ami, trawling, gleaning and spearing; (2) sedimentation from deforestation and poor land use practices; (3) boat anchorages of all kinds; (4) pollution from urban and industrial areas; and (5) tourism in some heavily frequented areas. The rate and causes of disturbance to coral reefs are well documented by, among others, White and Wells (1982); Yap and Gomez (1985); Salvat (1987); and White (1984 and 1987).

In response to this deterioration of coral reef resources and coastal areas in general. each ASEAN member-country has been experimenting with site-specific management in the form of marine parks and reserves (White 1988b). Most examples of this form of management are focused on protecting and sustaining coral reefs in a manner that is practical and feasible for implementation on tropical coastlines with high population densities of people who depend on fishing for their livelihood. The inherent problems of implementing marine parks and reserves for coral reef and coastal management have been the topic of recent studies and fieldwork by Kenchington and Salvat (1984); Salm (1984); White and Savina (1987); and Alcala (in press). It is often indicated that the management of coral reef areas must involve the users, the local community and the government in the process for any prospects of long-term success. This reasoning is rooted in the communality of the resource and use patterns that are often based on traditional rights and territories. However, resource users are not always conscious of such patterns, but these become important when external management regimes, which do not consider these underlying rules and customs, are imposed.

The ASEAN/US Cooperative Program on Marine Sciences includes the Coastal Resources Management Project (CRMP), which intends to formulate coastal resources management (CRM) plans for the pilot sites in the six ASEAN member-countries (Fig. 1). Each country's pilot site has a variety of coastal resources such as mangroves, coral reefs, seagrass beds, beaches, small islands, inshore and offshore fisheries, coastal landforms, minerals, etc. The variety and range of economic sectors that depend on and use these resources are extensive.

One of the best represented and most utilized resources are coral reefs, which, in turn, influence the condition of adjacent ecosystems like seagrasses, beaches, mangroves and fisheries. Within each pilot site (except in Indonesia), coral reefs are present and are receiving some form of management attention. In the cases of Malaysia, the Philippines, Singapore and Thailand, coral reef areas will play a major role in the overall management strategies evolving for the pilot areas.

The purpose of this paper is to elucidate the approaches being considered for coral reef and adjacent area management in each CRMP pilot site. A discussion of the planning and management approaches will also relate other management examples that can contribute to the solutions of particular management problems in each site.

ASEAN/US CRMP PILOT AREAS

Brunei Darussalam has included its entire coastline and offshore waters in the management area. The coralline areas shown in Fig. 2 will be included in a special area management scheme (Chou et al. 1987).

Indonesia has chosen Cilacap-Segara Anakan on the southern coast of Java as its pilot area. The only coral reef resources in the vicinity are at Pangandaran Beach on the coast facing the Indian Ocean. This reef area, although important for tourism and local fishing, is not within the project boundaries. It is worth noting that this area has been recommended as a special management area under national parks because of its importance to tourism.

Malaysia selected the State of Johore as its pilot site. The offshore islands of Pulau Rawa and Pulau Sibu Archipelago already have been declared as marine parks and will be the focus of management plans for coral reefs in the Johore site (Fig. 3).

The Philippines is concentrating on the whole of Lingayen Gulf in Northern Luzon (Fig. 4). Since coral reefs support extensive inshore small-scale fisheries in the western side of the gulf near Bolinao and the islands offshore, a principal ingredient in the overall planning for the area will be a management strategy for the coral resources and related fisheries bordering the small islands.

One aspect of the project in Singapore is the development of management plans for all remaining coastal areas that have not been altered by development (Fig. 5). This includes the coral reefs that, although few, are intact and border several small offshore islands. The Singapore CRMP also focuses on habitat enhancement through artificial reefs for those areas where coral reefs are no longer viable as a habitat.

Thailand chose the Upper South Region of Ban Don Bay in the Gulf of Thailand and Phangnga Bay on the Andaman Sea (Fig. 6). These areas have a multitude of resources, including significant coral reef areas. Ban Don Bay has Mu Ko Ang Thong National Park, a group of small islands fringed by coral reefs. Ko Samui and Ko Phangan, also bordered by coral reef areas, are both important for tourism. In Phangnga Bay, Mu Ko Phi Phi National Park has extensive fringing coral reefs used by tourists and local fishermen.

APPROACHES TO CRM AND CORAL REEF MANAGEMENT PLANNING

The CRMP adopts the following process for formulating general CRM plans for each country pilot site.

The general steps are: (1) compilation of all secondary data; (2) formulation of management goals/issues; (3) primary data collection; (4) synthesis of research data for management purposes; (5) development of policy and specific management recommendations; and (6) implementation of plans. The most notable outputs of this process are: (1) planning policies; (2) protected area management plans; and (3) issue-oriented action plans for sectoral conflicts (Chua and Agulto 1987; White 1988a).

Planning for the management of coral reefs in each country, except in Singapore, has entailed field research work in order to: (1) map the extent of the coralline areas; (2) document the condition and quality of the reefs by measuring substrate cover, coral and fish diversity and abundance, water quality and visibility, and fish productivity; (3) document the extent and patterns of coral resources use by the local people and assess the impact of these uses by analyzing various fishing methods and the number of contacts these people had with the reef areas; (4) document the socioeconomic status of local communities dependent on the resource; (5) determine the resource management problems and potential solutions; (6) determine what organizations (government or nongovernment) at the community, municipal, provincial and national levels could affect a management regime; and (7) analyze the existing and potential legal framework and law enforcement in the area.

All the information from the fieldwork provides a baseline for the formulation of the management plan and solutions for the physical environment and the human community in the area. The process then becomes very site-specific because the solutions to management vary from site to site. Also, the process of deciding on the final plans is country- and site-specific depending on: (1) local and national politics; (2) extent of the problem; (3) population density; (4) current legal status of the areas; (5) socioeconomic condition of the immediate community; and (6) local culture and traditional practices (Salm 1984; White 1988a). The plan, once developed, will be implemented for pilot areas under Phase II of the project.

Management plans for the coralline areas will fall under the label of protected area management (marine parks and reserves) and/or issue-oriented action plans. The latter is appropriate when the resource is under severe pressure over wide areas and is of primary concern as in the Philippine and Thailand sites.

SITE MANAGEMENT PROBLEMS AND PROPOSED SOLUTIONS

Brunei Darussalam

A 1987 survey of coralline resources showed that because of turbid offshore waters, coral reef formations are not extensive (Chou et al. 1987).

Areas known to have coral growth, estimated at 4,500 ha, are indicated in Fig. 2. Field surveys that document the generally mediocre quality of reefs in Brunei Darussalam focused on Pelong Rocks, Two Fathom Rock and Pulau Punyit. Patch reefs farther offshore are probably of higher quality than the nearshore reefs but are not yet well documented.

Even though the coral reefs are from moderate to low natural quality, they are considered a scarce resource and all will be included in the CRM plan. Pelong Rocks is the focus of management efforts, at least initially, because this area is accessible and the most frequented for fishing and recreation. The coral growth surrounding Pelong Rocks shows signs of stress from physical damage (blast fishing and anchors) and from sedimentation. The fish population is not very abundant but is also not intensively fished as suggested by the large size and tameness of the fish (Chou et al. 1987).

The issues for coral reef management in Brunei Darussalam are:

1. prevention of destructive fishing and other damaging activities (e.g., blast fishing and anchoring);
2. restoration of the damaged areas so that the coral cover can improve; and
3. implementation of a management regime that will prevent destructive activities, allow for undisturbed spawning and breeding grounds and provide for education, research and recreation.

A solution being considered is to legislate a marine park with provisions for the above issues and with two different zones for use. Such a marine park with a "traditional use zone" and a "sanctuary zone" marked by buoys could be implemented by the Department of Fisheries (DOF) with the cooperation of user groups such as fishermen and recreational groups (e.g., Brunei Sub-Aqua Diving Club and Brunei Nature Society). The implementation of a marine park at Pelong Rocks need not be a burden if DOF would make periodic visits. Nongovernmental organizations (NGOs) could be involved informally for education and monitoring of the site.

Malaysia

As in Brunei Darussalam, the turbid waters along the eastern coast of Malaysia do not support lush coral growth. The offshore islands all have fringing coral reefs of medium quality. Nevertheless, these islands support a tourist industry partially dependent on the attraction of the coral reefs. The islands of Pulau Rawa and Pulau Sibu Archipelagos are no exception (Fig. 3). They were surveyed environmentally in 1987 for reef and marine resources by Operation Raleigh and by the

Fisheries Research Institute. The islands have been declared as marine parks under the Fisheries Research Act of 1985 but have not received actual field management (Chua et al., in press).

The management issues in these islands are [researchers from the National University of Singapore and Department of Fisheries (DOF), Malaysia, pers. comm.]:

1. improper shoreline development for small tourist resorts that does not consider setbacks, resulting in landform degradation and sedimentation;
2. unregulated sewage dumping by resorts and shoreline residents, resulting in inshore water pollution;
3. blast fishing in some areas;
4. anchoring of fishing and tourist boats in reef areas;
5. use of spearguns by scuba divers and collection of shells, corals and other marine life; and
6. lack of an effective institutional framework at the local level to deal with the problems as indicated by the ad hoc manner of shoreline development without building permits or guidelines for reef resources use.

Although the islands and marine areas shown in Fig. 3 are legally protected, no management plans have yet been formulated. These plans would require:

1. an assessment of the current use patterns of coral reef resources;
2. prioritization of the primary negative factors affecting reef areas;
3. a socioeconomic evaluation of the island communities;
4. an assessment of attitudes and customs of the local community regarding management issues and their ideas for potential solutions; and
5. the identification of marine zones based on the quality of the environment and current use patterns such that the following uses and zones are accommodated:
   - scuba diving and snorkeling;
   - traditional, nondestructive fishing;
   - beach-related recreation;
   - sanctuary areas with no anchoring or fishing;
   - intense use zones with controlled anchoring, recreation and traditional fishing; and
   - restoration areas.

These management zones could include provision for boat anchoring sites and the use of buoys as described by Rahman and Mohamad (1986) for Pulau Redang Marine Park, Malaysia. Implementation, in general, would require management committees at the local level representing tourist operators, residents and fishermen. The marine park officials under DOF would need to work closely with the island users of the resource and provide guidance in the plan's implementation.

Philippines

Lingayen Gulf has numerous coralline islands on the western side (Fig. 4). The islands are bordered by extensive reef flats dominated by seagrass beds and fringing coral reefs (McManus et al. 1988). Fishing families are heavily dependent on the coral reef fisheries for their livelihood, but because of overfishing and habitat degradation, the catch per unit effort is low and declining (Calud et al. 1989). The coral reef management issues in the area are complex because of the deteriorating socioeconomic status of many people. This condition progressively encourages the use of efficient but destructive fishing methods without regard for their long- or medium-term consequences (Galvez and Sadorra 1988). Major issues of concern are:

1. destructive fishing methods (e.g., blasting, cyanide, gleaning, inshore trawling and use of fine-mesh nets);
2. overfishing because of a dwindling resource;
3. low income of local people and lack of an alternative livelihood;
4. declining strength of the social/cultural fiber, which condones illegal/destructive fishing activities;
5. poor law enforcement; and
6. lack of institutional arrangements to implement community development and coral reef management programs.

A coral reef management strategy for the islands on the western side of Lingayen Gulf will necessarily involve a comprehensive approach to community-based management. A two-pronged approach could:

1. outline a general coral reef management strategy for the entire area that would include:
   - education programs on marine ecology;
   - community livelihood programs;

- training programs for law enforcers and local government officials;
- organization by live-in fieldworkers of community groups for CRM and policy;
- media campaigns; and
- building local institutions.

2. develop detailed and specific area management plans for municipal marine parks/reserves that would zone areas for traditional use and sanctuaries by:
   - encouraging a process of community decisionmaking and action through nonformal education and community organization;
   - providing extensive education and training for the concerned communities;
   - promoting the involvement of local institutions to facilitate the implementation and involvement of the local people; and
   - passing municipal laws which can be supported by national enforcement agencies.

Such a municipal marine park plan will inherently evolve from the needs of the community in relation to the scientific information available about the environment (White 1988b). The decisionmaking process can be one of give-and-take between the "outside" planners and the local resource users. A model to consider is the one used by the Marine Conservation and Development Program of Silliman University, Philippines, where a community-based approach has proven to be successful on three islands (White and Savina 1987).

Singapore

The coral reefs of Singapore occur mostly as fringing or patch reefs associated with the Southern Islands (Fig. 5). High levels of suspended sediment dominate the water surrounding these islands resulting from extensive land reclamation projects and dredging activities since the 1960s (Chou 1988). The present average water visibility of 2 m, compared to 8 m prior to 1960, severely limits the growth and health of Singapore's reefs. Many coral reef areas have been smothered by sediment, and growth on reef slopes below 5 m is minimal because of low light penetration (Chou 1988). Some reef areas have also been the direct victims of land reclamation as some islands have been enlarged for development, or of dredging as channels have been deepened and widened for shipping. Nevertheless, some shallow reefs are stable and healthy, mostly in more of the Southern Islands where disturbance is less.

Management issues regarding coral reefs in Singapore involve pressure from the economic development and literal expansion of the Singapore mainland and islands. These issues are:

1. high levels of sedimentation;
2. continued reclamation, which covers living reefs;
3. dredging activities, which suspend sediment;
4. anchoring by recreation, fishing and research boats;
5. collecting and spearing by local scuba divers;
6. general lack of public awareness about coral reefs; and
7. low priority given by the government in protecting and managing the remaining coral reef areas.

The Singapore CRMP is formulating a comprehensive management/zonation plan for all coastal resources and areas, including coral reefs (Chia et al. 1988). There are existing documents on the status and uses of the resources with recommendations for priority and protected areas through use zones. In this regard, it is suggested that the plan include:

1. zonation for "sanctuaries" with no extraction allowed; "general use areas" for fishing and recreation; and "restoration" areas;
2. a design for a mooring buoy system;
3. the encouragement to stop reclamation and dredging activities near the better quality reefs;
4. recommendations for legislation to protect and manage certain priority areas and to change the status of some areas now within military jurisdiction or planned for reclamation or other development uses; and
5. a design for a public and government education program that provides accurate information on the values of coral reef resources as a living ecosystem.

The design and implementation of a coral reef management program in Singapore will be directly linked with present government policy decisions about land and marine space use. Since all marine space in Singapore is already allocated, reef management will require changes in the present policy. This will inherently require approval from high-level government agencies and require adequate justification, which is being provided by the current research program.

Thailand

The islands of Ban Don Bay are the focus of the Thailand CRMP. The extensive tourism in Ban Don Bay relies heavily on the quality of the environment in the offshore islands. About 65% of the tourists to Surat Thani Province are attracted to Ko Samui's beaches, clean waters and healthy coral reefs. Ko Phangan attracts an additional 10% of the over 300,000 provincial visitors to the two islands (Dobias and White 1988; Paw et al. 1988).

Ko Samui (247 km^2), Ko Phangan (150 km^2) and the adjacent islands are high and of relatively steep topography with dense natural forest cover, except where agriculture is practised. Freshwater is available because of the natural watersheds of Ko Samui and Ko Phangan but is still a limiting resource for tourist development. Coastlines are interspersed with steep cliffs and white sand beaches. Coral reefs occur along many shorelines and, although not lush by international standards, are some of the better reef areas in Thailand (Fig. 6). Water clarity, which affects reef quality directly, tends to be better in the outlying areas of the eastern coast, Ko Tao in the north and other offshore islands (Dobias 1988; Suraphol, pers. comm.; Bunpapong and Ngernvijit, this vol.).

Mu Ko Ang Thong National Park, established in 1980, is 10,200 ha, of which 8,400 ha is marine. Thirty-seven islands lie within the park's boundary and are known for their forests, beaches and some good reef areas on the northern tip. Fishing in the archipelago's waters is good and has attracted many fishermen, some of whom live on isolated beaches in the park (Dobias 1988).

The CRM issues of immediate importance for the islands of Ban Don Bay involve the rapid development of tourism and the resulting impact on the environment, particularly on coral reefs. The issues concerning reef management can not be separated entirely from the broader development and environmental degradation problems. Nevertheless, those directly pertaining to reefs as identified by Dobias and White (1988) are:

1. blast fishing by local inhabitants and outsiders;
2. boat anchorage by fishing and tourist vessels;
3. coral and shell collection by local residents and tourists;
4. pounding corals while fishing;
5. use of poisons in fishing;
6. sedimentation from shoreline construction, deforestation and boating;
7. pollution from improper waste disposal;
8. poor implementation of current laws affecting reefs;
9. poor implementation of Mu Ko Ang Thong National Park rules;
10. low level of public awareness about the resources; and
11. lack of planning and cooperation among implementing and local government and private resource users.

The planning team for coral reef resources management in the islands of Ban Don Bay is focusing on several approaches to the above problems with the theme of involving local tour operators and communities in the implementation process. The goals for management being discussed are:

1. formation of conservation zones that broadly follow "sanctuary" and "traditional use" areas, which include all the coral reef resources of Ban Don Bay, for implementation by the local authorities, the national park and the community's cooperation;
2. provision of mooring buoys in strategic locations;
3. enforcement of legislation affecting coral reef resources;
4. revision of the law to prohibit the sale of all coral reef-derived products;
5. prohibition of construction activities adjacent to sanctuary areas;
6. "environmental impact assessment" and/or permits for all construction in traditional use areas that will affect setbacks, soil/land management and proper waste disposal;
7. formation of an environmental task force to oversee management;
8. involvement of local leaders and authorities in the planning and implementation process; and
9. education, public awareness and training programs for appropriate target groups.

These management targets are being formulated into specific projects and prioritized for immediate implementation. One proposed pilot project for Ko Phangan is designed to integrate appropriate tourism development, resource conservation and community development (Dobias 1988). Such a program could involve the community in the process of managing its beach and reef resources in a sustainable manner for its own benefit. If successful, such a pilot program could provide an example for neighboring communities and other island sites.

CONCLUSION

The five country sites discussed with regard to coral reef management concerns all have similar but differing degrees of problems. Thus, strategies to deal with the management issues will vary more than the apparent problems because the means for implementation will be quite different in each country. Table 1 summarizes the management issues by country. Probably the most wide-reaching issues affecting large areas of coral reefs are the impact of siltation from various upland and coastal activities, destructive fishing, in general, and blast fishing, in particular, and the incidence of boats and anchors at populated, tourist and fishing sites.

Table 2 highlights potential management strategies appropriate for the sites. Singapore and Brunei Darussalam are at the end of the strategy spectrum, almost totally dependent on government authorization and approval to be successful. This is because traditional and/or destructive uses by coastal residents is not such an important influence compared to government programs for land reclamation and resource zoning which can be relatively easy to enforce in these two countries.

In contrast, the Philippines' strategy is almost totally dependent on community support, education and an alternative livelihood to be successful. This situation is evidenced by the problem in the Philippine site, which is essentially one of too few resources for too many people. This is not to say that the government is not important in the Philippine example but only that the factors determining success lie more with the local residents and community leaders than government agencies for policy support and law enforcement.

Thailand and Malaysia fall in the middle of the policy/management spectrum. They will require mixed programs with good community-based participation and education and strong government approval and support. These two countries have adequate infrastructure and government organizations supportive of good management solutions. Nevertheless, the coral reef areas in question are populated and heavily used so that the practices of these people need to be altered. Effective management will also require the cooperation of the immediate coastal resource users.

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Table 1. Comparison of coral reef management issues among the five ASEAN/US CRMP sites.

	B	M	P	S	T
Fishing					
Blasting	x	x	x		x
Poison			x		
Overfishing			x		x
Anchors	x				x
Shoreline or upland development					
Land reclamation/sedimentation				x	
Deforestation/sedimentation		x	x		x
Mining/sedimentation			x		
Unregulated building		x			x
Waste disposal		x			x
Recreation					
Anchors	x	x		x	x
Collecting/spearing		x	x	x	x
Information/institutional					
Low public awareness	x		x	x	x
Poor law enforcement			x		x
Cultural erosion			x		
Low priority in policy	x			x	
Economic					
Low income			x		
Lack of alternatives			x		

B = Brunei Darussalam
M = Malaysia
P = Philippines
S = Singapore
T = Thailand

Table 2. Comparison of coral reef management strategies among the five ASEAN/US CRMP sites.

	B	M	P	S	T
Area management					
Zonation schemes		x		x	x
National marine park	x	x		x	x
Municipal marine park			x		x
Mooring buoys/signs	x	x	x	x	x
Issue-based management					
Public education			x	x	x
Training for officials	x	x	x		x
Upland management		x	x		x
Community livelihood			x		
Community development			x		x
Legal/institutional/implementation					
Revise laws	x				x
Improve law enforcement			x		x
Build local institutions		x	x		x
National government control	x	x		x	
Community-based management			x		x
NGO participation	x		x		x
Regulate shoreline construction/EIA		x		x	x
Create a local task force		x	x		x
Require EIA/permits for building		x			x
Policy changes					
Increase national priority	x		x	x	
Slow coastal development				x	x

B = Brunei Darussalam
M = Malaysia
P = Philippines
S = Singapore
T = Thailand

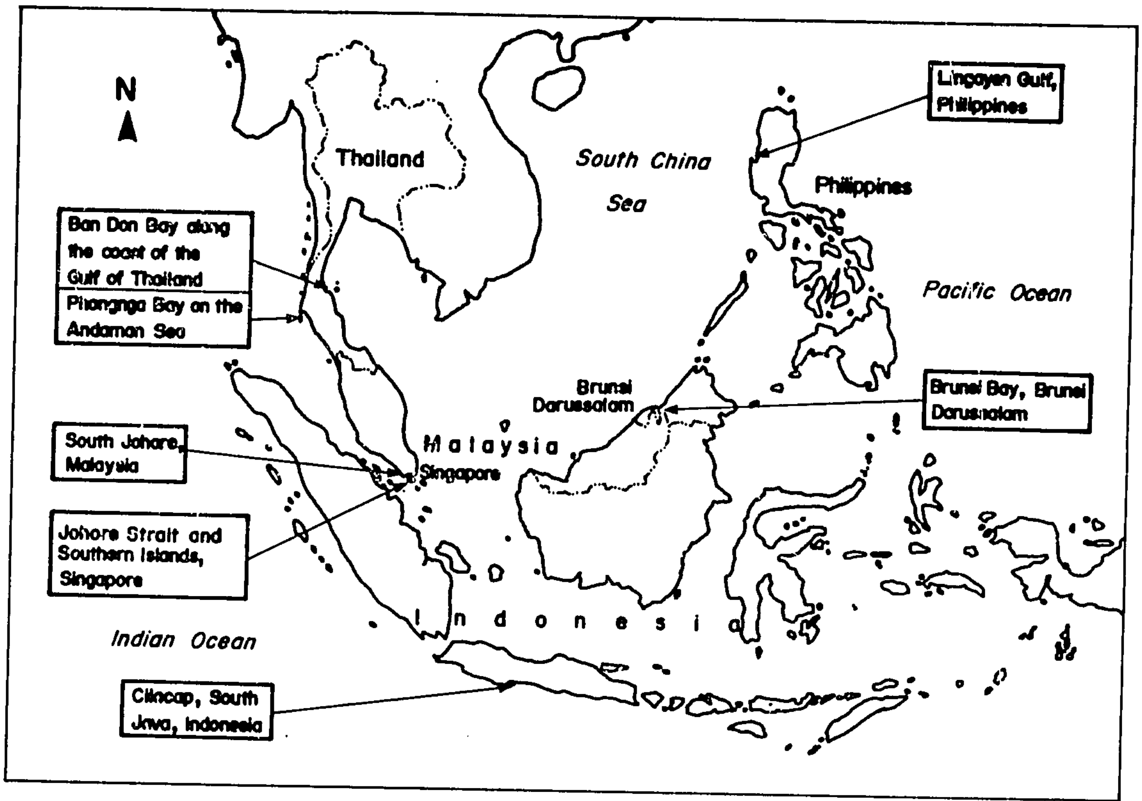

Fig. 1. Project sites in the six ASEAN member-countries (Chua and Agulto 1987).

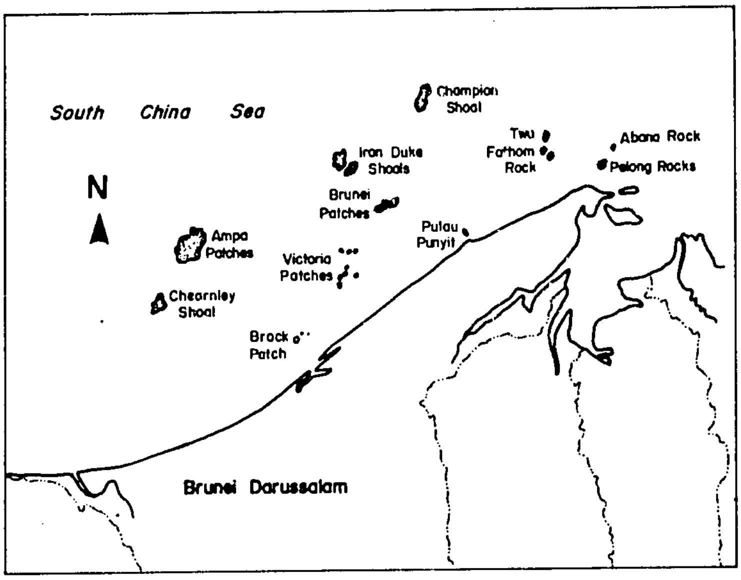

Fig. 2. Known coral reef areas in the offshore areas of Brunei Darussalam (Chou et al. 1987).

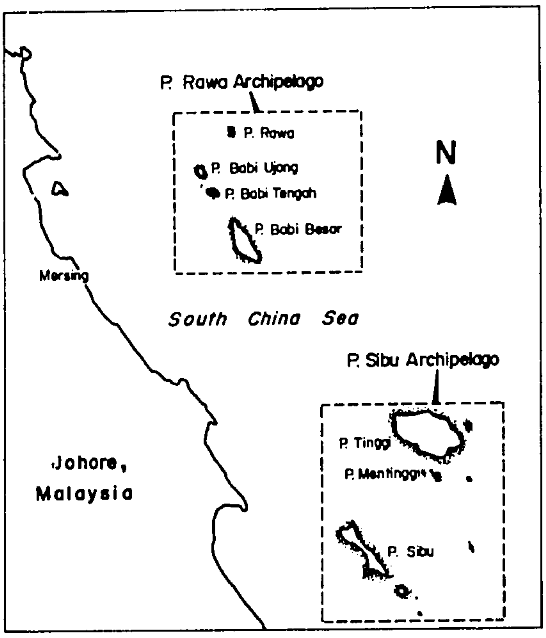

Fig. 3. Pulau Sibu and Pulau Rawa Archipelagos Marine Parks, Johore, Malaysia. (Chua et al., in press).

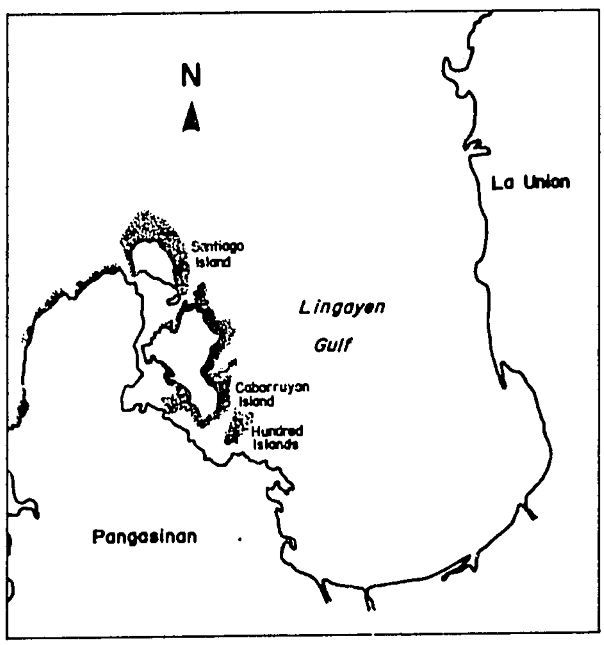

Fig. 4. Western islands and fringing coral reefs of Lingayen Gulf, Philippines (McManus et al. 1988).

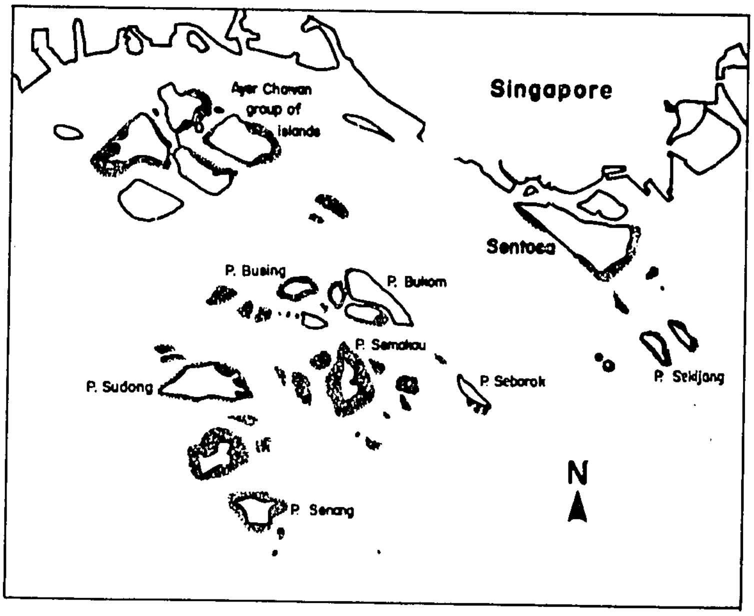

Fig. 5. Singapore's Southern Islands with fringing and patch reefs (Chia et al. 1988).

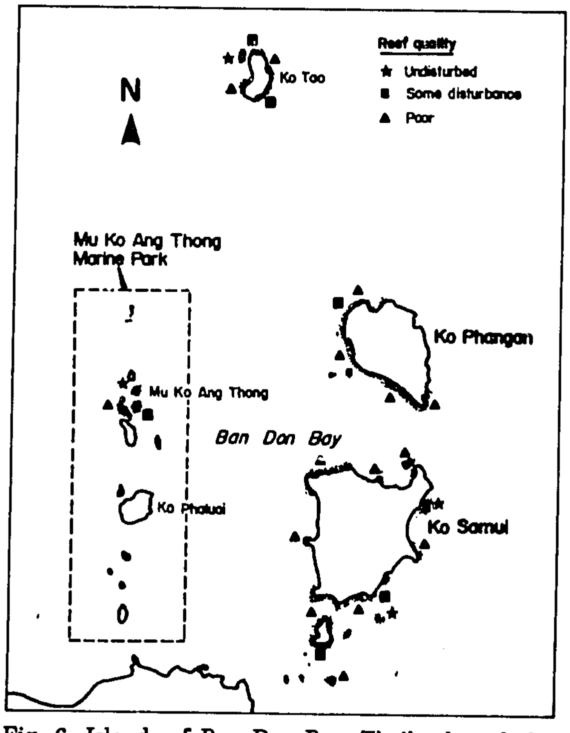

Fig. 6. Islands of Ban Don Bay, Thailand, and their fringing coral reefs (Paw et al. 1988).

Guidelines for coastal resources management for tourism and recreation in South Johore, Malaysia

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ABSTRACT

This paper reports the findings of the tourism study group of the Malaysian Coastal Resources Management Project of the ASEAN/US CRMP. It briefly reviews the policies, plans and proposals of the various tourism sectors--government and private agencies, and individuals--and identifies the existing supply, demand, uses and impact of coastal tourism resources. The study formulates management guidelines for tourism resource zones and regulations for development in each zone.

INTRODUCTION

South Johore is the southern gateway to Peninsular Malaysia by way of Singapore. Singapore is visited by about 3 million tourists annually (JICA 1988), even with its limited supply of coastal tourism resources. The South Johore coast, on the other hand, is well-endowed with natural resources, which are quickly becoming tourist attractions but are inappropriately managed.

This study aims to identify the existing and potential supply and demand for facilities and activities of coastal tourism in South Johore; to assess the contribution of tourism to the coastal economy; and to review the perceptions of the various tourism sectors--government and private agencies, tour operators, resort managers, foreign and domestic visitors, etc. Recommendations and guidelines for the management of tourism and recreation are proposed.

SCOPE AND METHODS

The study area covered the West (south of Benut), the South and the Southeast Johore coasts [south of Tandjung (Tg. throughout the text; it means "cape") Logok] and the offshore islands (Fig. 1).

The study had various components (Fig. 2); it included a literature search and a review of the current government's plans and policies for the tourism industry. Secondary data or interviews provided most of the information. A series of site visits and surveys by land and/or sea were undertaken to assess existing and potential tourism resources.

The results of the surveys were summarized through a checklist-cum-matrix technique where the quality and quantity, or interaction between elements were noted, and where appropriate, were classified and coded into symbols (Fig. 3).

COASTAL TOURISM POTENTIAL

The coastal resources that have significant potential for tourism and recreation were classified into five major categories: beaches, offshore islands, estuaries, mangroves and coastal waters (Fig. 4). Existing policies, plans and proposals for the development of these resources for tourism by various federal and state government agencies as well as the private sector are shown in Fig. 3.

Beaches

Most of the beaches in the study area lie within the jurisdiction of the Southeast Johore Regional Development Authority (KEJORA) and, therefore, are covered by comprehensive policies, plans and proposals in the form of the Desaru Tourism Master Plan (i.e., Tg. Siang, Tg. Lompat, Tg. Balau, Tg. Penawar, Tg. Punggai and Desaru). The master plan, which covers the overall development of the other beaches in the KEJORA region together with the Desaru Tourist Complex, aims to provide a framework for guiding and approving proposals from private developers (KEJORA 1986). The master plan shows that the scale and intensity of development in this area is expected to be great but as yet neither KEJORA nor the other state agencies have any form of development control policies.

The Japan International Cooperation Agency (JICA) is helping the Johore Government in formulating a tourism development plan for the southeastern coast of Johore. JICA has recommended the expansion of the Desaru Tourist Complex to include the neighboring beaches in the KEJORA region, in the form of resort development. Activities planned for this area include beach, recreation, water and inland sports and amusement parks.

This development is expected to attract 73% of the total tourist arrivals to the southeastern coast of Malaysia by 1995--around 0.8 million guests and 21 million day-trippers (JICA 1988). With the increase in tourist arrivals, the projected total number of hotel rooms needed by 1995 is 2,116, taking up around 56% of the total land area in the expanded complex (Table 1).

Tourist accommodation facilities (huts, chalets, longhouses) are also provided by private individuals and the local people. At present, there are about 30 rooms at Teluk Mahkota and 40 rooms at Tg. Punggai.

The study team surmised that although tourism is well promoted by the state agencies, implementation depends a lot on the private developers. Their present proposals are large in scale and intensity but duplicate each other in types of activities planned and do not consider appropriateness to local conditions.

Islands

Tourism development on the islands is on a small scale, in the form of low-budget accommodations and facilities.

The Fisheries Department exercises control over the islands in the marine park, i.e., Pulau (P. throughout this text; it means "island") Rawa, P. Hujung, P. Tengah, P. Besar, P. Tinggi, P. Mentiggi and P. Sibu.

The State Economic Planning Unit (UPEN) recommends that development on these islands be restricted and medium-type lodgings such as chalets be encouraged (UPEN 1987). In 1987, around 10% of the total number of tourists visited the islands; by 1995, the number is projected to increase to 24,400 visitors or 14% of the total tourist arrivals (JICA 1988). Tourists are projected to spend 81,400 nights/year on the islands.

Accommodations are provided on most of the islands either by the local population or by private developers from the mainland (Table 2). Development is more intense on the islands closer to the mainland (e.g., P. Besar, P. Sibu and P. Rawa), than on the islands farther offshore (e.g., P. Aur and P. Pemanggil). For economic reasons, tourism development on the nearby islands is being managed by private developers from the mainland either by renting, leasing or purchasing land from the local community.

Estuaries

Policies on estuarine areas focus on control and conservation. The Drainage and Irrigation Department restricts the development of river reserves to prevent erosion and siltation, but in large parts of the estuarine areas these reserves are occupied by squatters, illegal workshops and waste disposal sites.

There are also existing and proposed seafood restaurants owned by private individuals like those in Teluk Sengat and Kong Kong, in the Johore River estuary. The visitors are mainly day-trippers; no accommodation facilities are available in the area, except at Kong Kong, which has 14 hotel rooms classified as "domestic standard". However, river cruise service is available.

Mangroves

Similar to those for the estuarine areas, policies on mangrove areas have to do with control and conservation. The Forest Department looks after these areas to maintain them as mangrove reserves.

Possible attractions to these areas are activities such as river cruises, bird watching and dining in seafood restaurants.

Coastal waters

The policies over the coastal areas, mainly over passage near them and pollution control, come directly under the Johore Harbor Master Plan. Thus, the sea-based lodging houses that have sprung up in places like Teluk Sengat to cater to anglers/fishing enthusiasts are one of its many concerns.

TOURISM DEMAND SURVEY

Tourists

About 75% of those surveyed were foreign tourists from the United Kingdom, West Germany, United States, Australia/New Zealand, Japan, Korea and Hong Kong. Compared to the JICA study, the samples were more representative (Table 3). About 84% were holiday tourists (Table 4). Their popular activities were swimming (27%), sightseeing (22%) and eating seafoods (17%), activities included in most package tours (Table 5).

Beaches were perceived to have the most potential for tourism, followed by the islands (Table 6). According to DURP (1988), the most popular tourism development is resort development (23%), followed by recreation/sports (14%) (Table 7). These show that future tourism development could be concentrated on the coastal areas.

Tour and business operators

All the tour operators surveyed by DURP (1988) render service to tourist attractions both on the mainland and on the offshore islands. When asked which has the most potential for tourism development, 37.5% of the samples said it was the beaches and 34.4% said it was the islands, although facilities there need to be improved (Table 8).

Local community

Among the local community, 37% felt that tourism has the most potential for development, followed by fishing (19%) and agriculture (17%) (Table 9). The responses indicate that conflicts are likely to occur in trying to accommodate tourism within the traditional sources of employment and income of the local community (DURP 1988).

The establishment of shops was considered the facility most needed to attract more tourists as well as to benefit the local population (Table 10).

IMPACT OF TOURISM ON COASTAL RESOURCES

The interaction between the coastal resources and their alternative uses, such as fishing, agriculture, forestry and urban development, is summarized in Fig. 5.

Beaches

The Desaru Tourist Complex will reduce the natural environment and the aesthetic quality of the beaches due to congestion, especially during peak tourist seasons.

There is a proposed treatment plant in the Desaru Tourist Master Plan. However, the problem of sewage and solid waste disposal is likely to occur in populated villages due to the increase in the number of chalets and longhouses constructed by the local community (i.e., Tg. Punggai).

The beaches in the KEJORA region are managed and planned by a resourceful federal government agency, and this facilitates coastal resources management.

Islands

The islands are slowly beginning to attract tourists. However, poor accessibility and lack of promotion have resulted in the slow growth of the islands as tourist attractions. Despite being small in scale and low in density, the impact of tourism on the natural resources of the islands is considerable, as there is no effective control or management of their development.

Sewage and solid waste disposal is a major problem as chalet-type accommodations are constructed in an ad hoc manner. The problem is most serious at P. Besar, where tourist development has taken the whole area along the beach.

Water supply is limited in all the islands, especially at P. Sibu. Because of this, tourism on the islands will create a conflict between the demand for freshwater for tourism and the demand for freshwater by the local people.

The development of tourism has also resulted in some displacement of the local population. Property along the beaches has been sold to new owners from the mainland, thus limiting the opportunities for local community participation in tourism. The problem is more acute on the islands close to the mainland such as P. Besar and P. Sibu.

At P. Aur, P. Besar and P. Sibu, the lack of grazing space for cattle and goats has conflict with the expanding tourism facilities. Also, many coral reef areas around the inhabited islands have been depleted.

Tourism development has benefited the local population by creating employment opportunities, especially in the transportation sector. Many islanders operate boats plying between the islands and the mainland (Mersing); they also operate boats for fishing trips. However, the boat operators are not efficiently organized into a proper association and do not have a professional code of ethics. Thus, their livelihood could be affected if an organized sea transport system is introduced in the future.

Mangroves

Tourist activities in mangrove areas generally do not cause an adverse impact on the environment. Bird watching and river cruises, for example, are passive activities with little impact. However, conflicting uses of mangrove areas will upset the natural ecosystem and reduce the variety and diversity of animal life there. Special areas for activities are necessary to promote tourism.

Estuaries

Seafood restaurants at places like Telok Sengat and Kong Kong in the Johore River estuary cause sewage and waste disposal problems and add to the pollution along Johore Strait, leading to the causeway.

Coastal waters

Sea-based lodging houses and *kelong* have been erected in places like Tg. Sengat and are rented to fishing enthusiasts. These houses create sewage and solid waste disposal problems and cause over-exploitation.

Urbanization

Urban development creates sewage and solid waste disposal problems in the coastal waters along Johore Strait. Solid waste disposals along the beach are being implemented by private developers in an ad hoc manner.

CONCLUSION

Tourism resource zones are proposed as a means of guiding the management of coastal resources affected by tourism in South Johore (Fig. 6). The management guidelines include the following:

1. Any development for tourism and recreation must blend with the natural environment; conserve areas of outstanding natural beauty;
2. Sensitive coastal and marine habitats and those of significant scientific interest must be conserved;
3. The local community must participate in the development and management of coastal tourism resources; and
4. Appropriate legal and institutional arrangements must be established to administer the offshore islands.

Technical guidelines for physical planning, which take into account the impact of the physical structures on the environments, must be made. Appropriate physical planning criteria (design or performance standards) can be applied to protect the coastal area from inappropriate development. Other specific management guidelines proposed (Table 11) cover three issues: the environmental impact of tourism development; the appropriate institutional and legal framework to regulate and monitor tourism development, especially on the islands; and the extent of local community participation.

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Table 1. Distribution of classified accommodation facilities at Desaru and the neighboring beaches.

Type of room	Existing (1988) No.	Existing (1988) %	Projected (1995) No.	Projected (1995) %
International deluxe	0	0	790	37
International	0	0	850	40
Regional	234	69	349	16
Domestic	105	31	127	6
Total	339	100	2,116	99
(% Land area)	19%		56%	

Source: JICA (1988).

Table 2. Estimated number of accommodation facilities (rooms) on the offshore islands.

Island	Accommodation
P. Rawa	64
P. Sibu	32
P. Tinggi	18
P. Besar	68
P. Pemanggil	43
P. Aur	12
Total	237

Source: DURP (1988).

Table 3. Origin of foreign visitors to South Johore.

Residence	Johore Bahru No.	Johore Bahru %	Kukup No.	Kukup %	Desaru No.	Desaru %	Total No.	Total %
United Kingdom	1	25.0	9	50.0	1	5.6	11	27.5
West Germany	-	-	-	-	2	11.1	2	5.0
France	1	25.0	-	-	-	-	1	2.5
Europe	1	25.0	1	5.6	4	22.2	6	15.0
USA/Canada	-	-	1	5.6	3	16.7	4	10.0
Australia/New Zealand	-	-	6	33.3	2	11.1	8	20.0
Japan	-	-	-	-	2	11.1	2	5.0
Korea	-	-	-	-	1	5.6	1	2.5
Singapore	1	25.0	-	-	-	-	1	2.5
Others	-	-	1	5.6	3	16.7	4	10.0
Total	4	100.0	18	100.1	18	100.1	40	100.0

Source: DURP (1988).

Table 4. Purpose of visit, in percentage.

	Johore Bahru	Kukup	Desaru	Total
Holiday	6.0	44.0	34.0	84.0
Transit	2.0	0	0	2.0
Food	4.0	0	0	4.0
Others	8.0	-	2.0	10.0
Total	20.0	44.0	36.0	100.0

Source: DURP (1988).

Table 5. Visitor's activity, in percentage.

Activity	Johore Bahru	Kukup	Desaru	Total
Fishing	-	1.8	-	1.8
Swimming	8.3	-	18.3	26.6
Sailing	-	-	3.4	3.4
Windsurfing	-	-	1.7	1.7
Snorkeling	-	-	4.1	4.1
Diving	1.7	-	1.9	3.6
Hiking	-	-	3.4	3.4
Cruising/ sightseeing	6.7	11.7	3.6	22.0
Eating seafoods	-	13.3	3.4	16.7
Others	3.4	5.0	8.3	16.7
Total	20.1	31.8	48.1	100.0

Source: DURP (1988).

Table 6. Resource development potential in South Johore (tourist perception study), in percentage.

Resource	Johore Bahru	Kukup	Desaru	Total
Beaches	5.3	28.7	8.5	42.5
Islands	5.3	16.0	13.8	35.1
Mangroves	-	2.1	6.4	8.5
Estuaries	-	1.1	-	1.1
Coastal waters	2.1	4.3	6.4	12.8
Total	12.7	52.2	35.1	100.0

Source: DURP (1988).

Table 7. Potential type of tourism development in South Johore (tourist and tour operator/agency perception study), in percentage.

Activity	Tourist	Tour operator
Resort development	23.1	25.0
Recreation/sports	14.3	15.0
Swimming	8.4	12.5
Fishing	6.9	7.5
Snorkeling	5.4	2.5
Diving	5.7	
Boating	11.8	2.5
Cruise	9.5	5.0
Hunting	1.8	2.5
Hiking	1.8	
Wildlife	1.8	2.5
Culture	5.4	7.5
Craft	4.1	5.0
Others		12.5
Total	100.0	100.0

Source: DURP (1988).

Table 8. Resource development potential in South Johore (tourist and tour operator/agency perception study), in percentage.

Resource	Tourist	Tour Operator
Beaches	40.0	37.5
Islands	40.0	34.4
Mangroves	3.4	9.4
Estuaries	10.3	12.5
Coastal waters	6.3	6.2
Total	100.0	100.0

Source: DURP (1988).

Table 9. Resource development potential in South Johore (local community perception study).

Activity	%
Industry	5.3
Agriculture	16.8
Forest	6.2
Mining	0.9
Fishing	18.5
Craft	6.2
Tourism	37.2
Recreation/sports	8.9
Total	100.0

Source: DURP (1988).

Table 10. Facilities improvement for tourism development (local community perception study), in percentage.

Facility	Islands	Kukup	K. Tinggi	Penawar	Desaru	Total
Hotels	-	17.6	5.0	18.1	31.1	13.2
Communication	23.0	11.8	5.0	18.1	12.5	15.1
Public amenities	-	26.5	20.0	9.1	12.5	15.1
Shops	40.0	26.5	50.0	36.4	18.8	40.0
Entertainment	-	14.7	5.0	18.3	18.8	10.4
Others	32.0	2.9	15.0	-	6.1	6.2
Total	100.0	100.0	100.0	100.0	99.8	100.0

Source: DURP (1988).

Table 11. Guidelines for tourism/recreation development in coastal resource zones.

Tourism resource zone	Guidelines
1. Southern gateway	• Control development along the coast. • Establish regulations to control the impact of any existing urban development on coastal resources (e.g., sewage at Lido and Stulang beaches). • Establish and enforce water quality standards for recreation and tourism use (e.g., Johore Strait, Skudai River estuary). • Restrict and monitor large-scale and high-intensity tourism and recreation development along mangroves (e.g., Skudai River estuary, coastal resources between Stulang and Pasir Gudang).
2. Mangrove estuaries	• Establish a mangrove buffer zone to control erosion. • Designate selected mangroves for wildlife sanctuary and observation (e.g., Tg. Piai, Kukup Island, Benut). • Promote and regulate mangroves as a tourism and recreation resource (e.g., for birdwatching, river cruises, fishing). • Integrate local economic activity with tourism (e.g., cage culture, aquaculture, orchard tours). • Control the discharge of waste from seafood restaurants, local communities, etc.
3. Historical estuaries	• Control the discharge of waste from seafood restaurants, local communities, etc. • Designate and promote areas of historical interest along Johore River estuary (e.g., Johore Lama, Panchor). • Permit and regulate sea-based lodging houses (for angling, fishing), including controls for their waste disposal. • Monitor the mangrove harvesting activity. • Integrate and regulate aquaculture for tourism development. • Provide for local community participation in the development of tourism and recreation. • Institute appropriate measures to reduce the pollution and siltation of the river estuary.

Continued

Table 11. (continued)

Tourism resource zone	Guidelines
4. Beaches	• Prohibit development (e.g., hotels, motels, shops) on beaches. • Establish density control along coasts populated with people (e.g., Tg. Penawar, Tg. Punggai). • Institute a setback requirement from the shoreline for buildings and construction to avoid erosion and protect beaches. • Designate buffer zones within and between development areas. • Protect the tropical rainforest areas and wildlife and bird habitats. • Protect and maintain natural environments, especially those of significant scientific interest and outstanding natural beauty. • Zone areas to protect natural watersheds (e.g., mangrove forests). • Prohibit sand mining and logging activities. • New development should incorporate measures for waste and sewage disposal (e.g., local community/non-KEJORA projects).
5. Coastal waters	• Regulate coastal fishing and shipping lanes to conserve significant coastal and marine habitats. • Enforce restriction on the open spillage of discharges from coastal fishing and shipping.
6. Islands	• Monitor and control resort development on the islands. • Institute appropriate control and enforcement measures over coral reefs, shell and other aquatic life of significant and scientific interest. • Establish setback requirements for development to preserve beaches, shorelines and landscapes. • Tourism development should be sensitive to the local culture and its values. • There should be controls and regulations in acquiring land for tourism development. • Development for tourism/recreation should not displace the local population. • There should be zoned areas for local community use and tourism-related activities (e.g., pasture land, motels). • Tourism development should consider the availability of water supply and the local community's water requirements. • Improve provisions for the islands' infrastructure and amenities consonant with tourism development. • There should be appropriate standards for the development and construction of tourism facilities and activities to be applied and enforced by the relevant local authority. • Any proposal for tourism development should be channeled to the appropriate local authority (e.g., district office). • Establish, promote and regulate a sea transport system to and from the islands to improve efficiency. • Establish an alternative staging point from Sedili or Desaru to the islands to improve their accessibility.

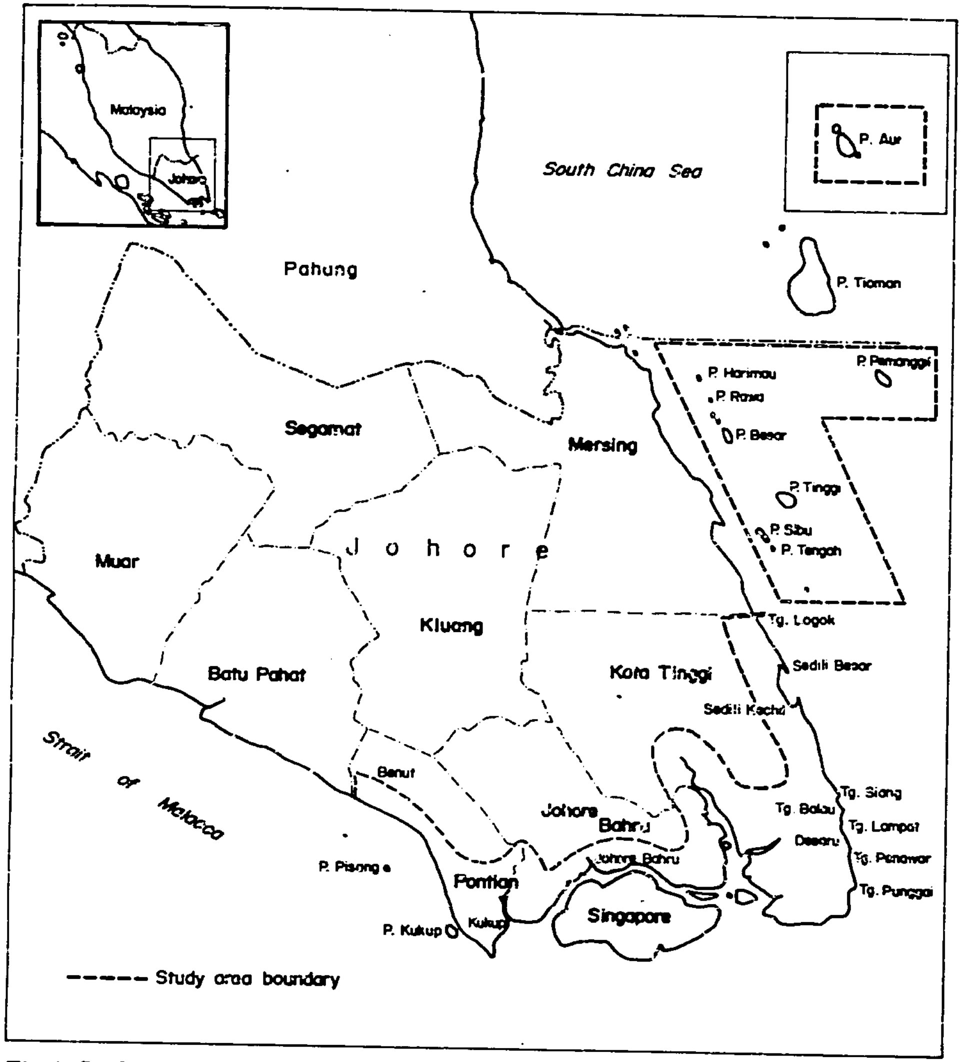

Fig. 1. Study area of the coastal resources management for tourism and recreation.

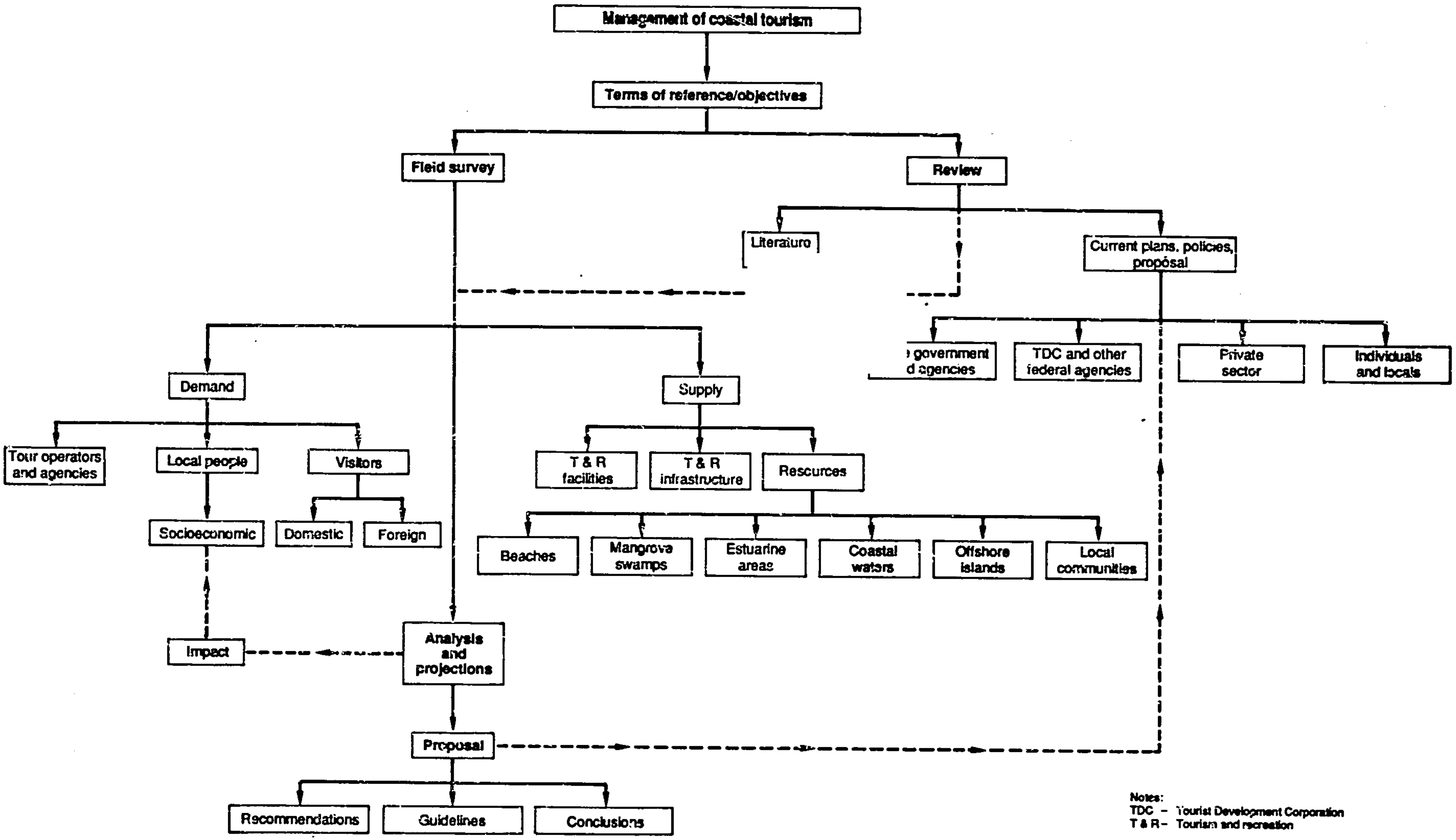

Fig. 2. The study flowchart.

Resources \ Agencies	State																		Federal				Others	
	State Social Development Tourism Committee	State Economic Planning Unit	State Tourism Office	State Economic Development Corporation	State Town and Country Planning Department	Southeast Johore Regional Development Authority (KEJORA)	Johore Tourist Association	Johore Bahru Municipal Council	Pontian District Office	Kota Tinggi District Office	Mersing District Office	Johore Forestry Department	Harbour Master	Agriculture Department	Land and Mines Department	Drainage and Irrigation Department	Community Progress Section	Public Works Department	Tourism Development Corporation	MARA	Department of Environment	Fisheries Department	Private Sector	Individuals
Beaches (Desaru area)	○	○	○	●		○ ⊘ ●	⊘					○		○	○	○	●		○			○ ⊘ ●	⊘ ●	●
Beaches (Outside Desaru)	○	○ ⊘ ●	○ ⊘ ●		⊘	○	⊘			○		○		○					○				●	●
Estuaries						○ ⊘ ●	⊘ ●	○				○	○			○		○			○	○	●	●
Mangroves						○ ⊘ ●			○			○			○	○						○	●	●
Coastal waters													○								○	○	●	●
Offshore islands	○	○					⊘ ●			○	○		○							●		○ ⊘ ●	●	●

○ Policies ⊘ Plans ● Proposals

Fig. 3. Checklist of policies, plans and proposals for the development of resources for tourism.

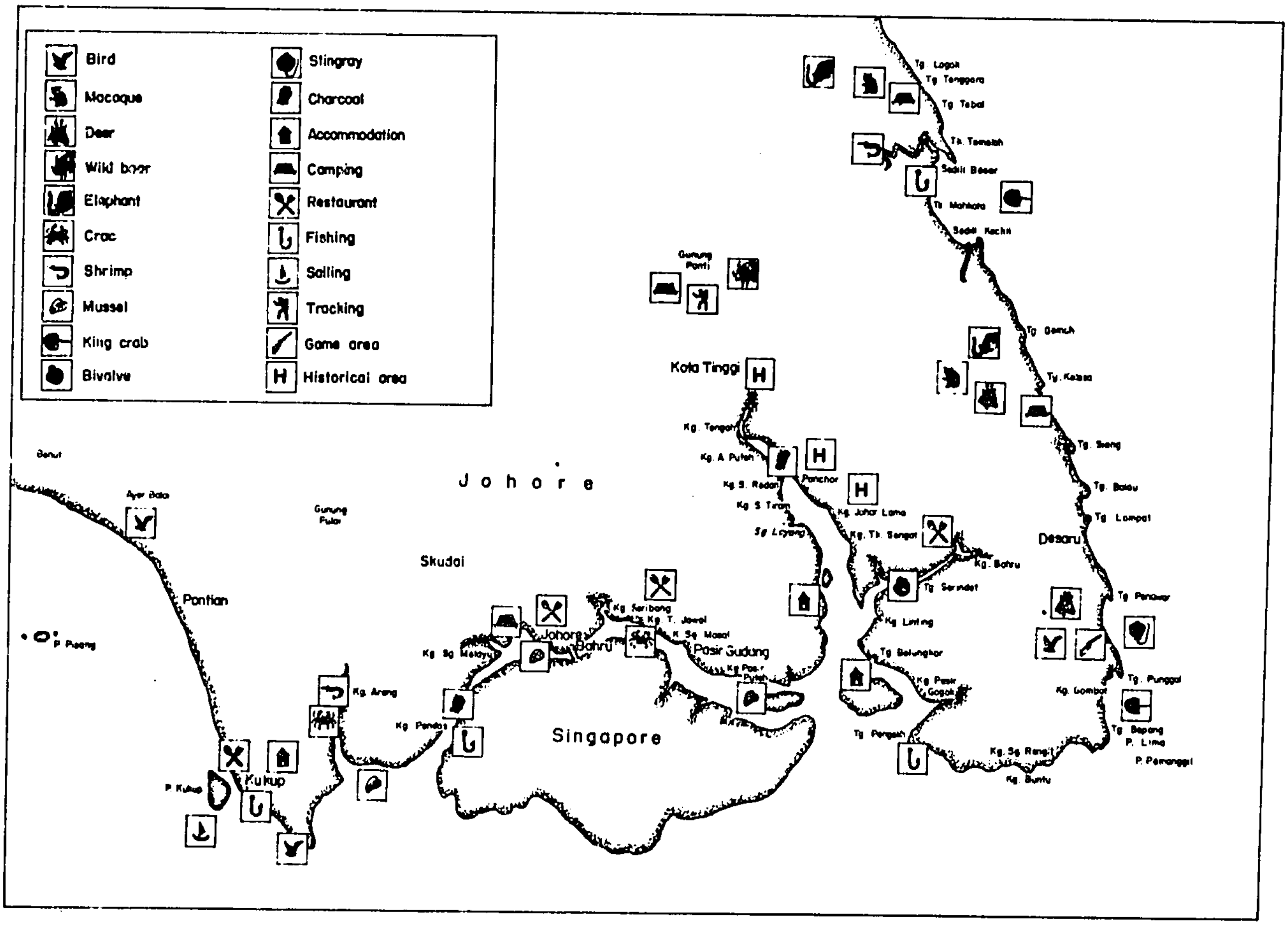

Fig. 4. Tourism resources in the study area.

Impact / Resources	Mining		Fishing			Agriculture	Forestry		Sea Transport	Urban				Social			Economic		Tourism
	Sand	Mineral	Fishing	Aquaculture	Deep sea	Oil palm	Logging	Mangrove	Pollution	Land clearing	Settlement	Resort development	Industry	Yellow culture	Displacement	Values	Income	Employment	Tourism
Beaches (Desaru area)	O		O			O	O			O		O			O		O	O	O
Beaches (Outside Desaru)			O			O	O			O							O	O	O
Estuaries		O	O	O				O	O	O			O		O		O	O	O
Mangroves			O	O				O			O						O	O	O
Coastal waters			O						O								O	O	O
Islands			O													O	O	O	O

Fig. 5. Checklist of possible impact of tourism development activities on coastal resources.

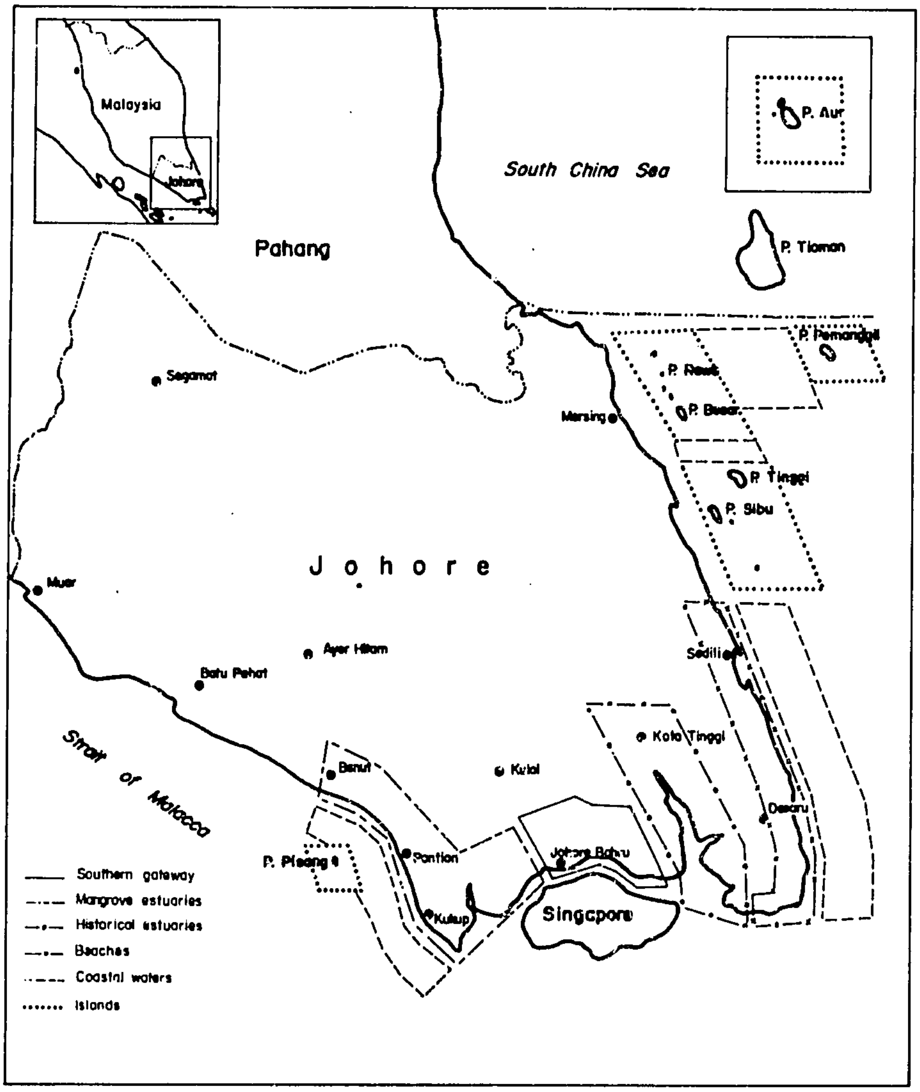

Fig. 6. Tourism resource zones.

Proposed management guidelines for offshore sand mining activities in South Johore, Malaysia

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ZAMALI, B.M. and S.C. LEE. 1991. Proposed management guidelines for offshore sand mining activities in South Johore, Malaysia, p. 365-373. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

Sand deposits in the form of beach ridges, alluvium and, more recently, subaqueous accumulations, found along the eastern coast of Johore Strait have been extensively extracted for use in construction and, to a lesser extent, for glass manufacturing. Often, the conditions imposed on the approval for offshore sand mining activities are expressed in administrative terms, without technical consideration of their potential impact on the stability of the affected coastline.

The removal of offshore sand can reduce the amount of sediment available to replenish the beach. If the sand deposits occur as subaqueous sandbars/banks, thereby protecting the coast from direct wave action, their removal could also lead to shoreline instability. Offshore dredging not only destroys marine habitats; it also imposes stresses on marine communities. By considering the physiographic adjustments and biological impact of offshore dredging, this paper proposes a management plan for offshore sand mining that allows the harmony between economic resources use and the maintenance of environmental quality.

INTRODUCTION

The projected economic recovery and the attendant buoyant construction market in the local scene will increase the demand for sand aggregates. There is also a huge demand for sand as fill material for reclamation work in Singapore since it is near Johore. Thus, local entrepreneurs view sand mining as a viable venture. With the availability of these ready markets for sand, both locally and in Singapore, applications for sand mining concessions will increase.

According to one sand mining application, the southern coast and the eastern section of Johore Strait have 100 million m^3 of sand deposits that can be extracted for export. This lucrative venture is further borne out by the numerous overlapping applications received by the Land Offices. To illustrate, the projected revenue accruing to the State Government, which levies royalties ranging from M$0.70[a] (seabed) to M$1.20[a] (river sand) per m^3 on export sand can be substantial.

Applications for concession areas are concentrated along the Johore River estuary, the Johore Strait and the seabed off the southeastern corner of Johore (Fig. 1). Along these coasts are many fishing villages and a major tourism and recreational center. At present, the only road link to the Customs Complex and the Ferry Service Centre at Tg. Pengelih also skirts along the coast. Some stretches of the coast have been identified as Category 1: erosion areas (EPU-PMDM 1985). Therefore, sand mining in the aforementioned coastal/offshore areas, if not carefully planned and controlled, can initiate new erosion and/or aggravate existing erosion (Fig. 2).

Often, the conditions imposed on the approval for offshore sand mining activities are expressed in administrative terms, without technical consideration of their impact on the biological environment and the physical stability of the affected coastline. To arrive at a harmony between economic pursuits and environmental quality in the case of offshore sand mining, the likely impact of dredging activities should be considered.

This paper gives an overview of the different dredging operations and their relative ability to generate adverse environmental impact. It also discusses the various potential environmental stresses that can result from offshore dredging, with emphasis on the physical and biological environments. The paper then outlines the prevailing

[a]28 December 1988: M$2.70 = US$1.00

management practices in other countries to minimize the adverse impact of offshore sand mining. Based on the proven management strategy employed in these countries and in light of the peculiarities of local conditions, the paper then presents a set of tentative management guidelines as a first step toward formulating a comprehensive management plan for offshore sand mining that balances economic development and environmental quality off the southeastern coast of Johore.

DREDGING TECHNOLOGY

Despite its technically demanding process and the associated risks in operating under potentially adverse weather conditions, dredging is the most popular method employed for offshore sand extraction. Two types of dredging systems are commonly used: the hydraulic and the mechanical types (Fig. 3).

Hydraulic dredges

The two most frequently used hydraulic dredges in coastal waters are the cutter suction and the trailing suction hopper dredges. The former uses a rotating spiral-shaped cutterhead to break the consolidated materials and then pumps the slurry to the disposal point via a flexible floating pipeline or into a transporting barge. The dredging operation is restricted to moderate sea conditions, especially if a floating pipeline to a shore spoil area is adopted. In contrast, the trailing suction hopper dredge is a self-propelled seagoing vessel fitted with a suction pipe dragged across the bottom. Materials collected in the form of slurry are pumped into a hopper, which is also located on the same vessel, and periodically transported to and dumped at the designated disposal point. Not only does it dispense with the need for a transporting barge, the dredge can also operate in more exposed and heavier sea conditions due to the flexible linkage between the trailing suction pipe and the vessel.

Mechanical dredges

The most common mechanical dredges are the dipper and bucket types. The former is basically a barge-mounted power shovel that is equipped with a scooplike bucket attached to a power-driven ladder structure. The bucket is forcibly thrust into the seabed for material extraction. This type of dredge can work in water depths of up to 15 m. In contrast, the bucket dredge consists of a barge-mounted crane. A drop bucket fitted to the end of the wire is used to excavate bottom materials. The clamshell and the dragline types are the most common dredges under this category. The material excavated by these mechanical dredges is placed in hopper barges, which are then towed to the disposal area. The effective working depth for a bucket dredge is limited to about 30 m.

The dredge to be used in offshore sand mining should be selected properly. Different dredges employ different working systems; thus, they have differing degrees of environmental impact. Mechanical dredges, such as the clamshell, bucket or dipper types, cause a resuspension of material at the bottom of the water column and also spew the fine sediment from the bucket during the hoisting operation. To a lesser degree, hydraulic dredges also release, under wave action, some sediment from the leaking joints of the floating discharge pipeline while they are pumping the slurry ashore.

ENVIRONMENTAL IMPACT OF OFFSHORE DREDGING

Biological environment

The environmental impact due to offshore dredging stem from the suspension of sediment themselves and the release of pollutants from the disturbed sediment. Thus, dredging-induced suspensions can perturb water quality and affect local biota (Dubois and Towle 1985). Dubois and Towle cite operational design, scale and duration of activity as significant factors since each material handling phase--extraction, transport and emplacement--can generate undesirable effects. While the direct environmental impacts associated with offshore dredging are due to the massive displacement of the substrate and the subsequent destruction of nonmotile benthic communities, the resulting indirect impacts are more subtle and can escape recognition by an untrained person. They include (Price et al. 1978):

a. restriction of feeding and respiratory efficiencies and induced mortalities in bottom-dwelling biota, such as bivalve mollusks, as a result of the smothering effect of sedimentation;
b. reduction of the primary productivity (photosynthesis) due to turbidity in the water column;

c. introduction of abnormal volumes of organic material and nutrients, thus increasing the biological oxygen demand (BOD), which in turn reduces oxygen levels and productivity;
d. reintroduction of toxic substances uncovered by mining activities;
e. inadvertent destruction of the adjacent habitat critical to the life cycles of certain organisms; and
f. disruption of migratory routes of motile marine organisms.

A concentration of resuspended sediments and their subsequent distribution and deposition are the primary agents causing the biological stresses mentioned above. Survival under these stressful conditions depends largely on the specific requirements of the marine communities affected and a host of extraneous factors such as depth of sediment, length of time under burial, time of year, sediment grain size and sediment quality.

Another consequence of concern is the physical reduction in habitat area, which is a function of the rate of repopulation of the dredged area. Sea bottom borrow pits remain intact for long periods of time unless infilling occurs from current-induced sediment movement. If the sediments are organic-laden, the subsequent decomposition can lead to anaerobic conditions and the deterioration of the quality of the ambient water. Hence, the reestablishment of marine habitats at the dredged area is again dependent on the magnitude of the dredging operation, new sediment interface and water quality.

Physical environment

Offshore mining activity normally incurs a risk of altering the beach dynamics, wave and swell pattern, and coastal current circulation, which can invoke an undesirable morphological response from the coastline such as erosion or sedimentation. Dredging can influence the coastal physical processes through:

a. beach drawdown due to infilling of the dredged pit during calm periods;
b. interception of sediment movement by the dredged pit, which results in sand depletion onshore/downdrift;
c. removal of protection afforded by offshore banks, which leads to bigger waves impinging on the coast; and
d. changes in the wave refraction pattern, which concentrates wave energy at a particular place.

All the above modifications in the coastal response lead to coastal erosion. It will be seen in later sections that the concerns enumerated above also constitute the primary criteria applied to offshore dredging in other countries.

OVERSEAS PRACTICE

In the United Kingdom, the licensing system for offshore dredging has evolved to a stage where a license is granted only after comprehensive consultations with many authorities. Whereas the Crown Estate Commissioners are entrusted with the issuance of sand mining licenses on a first-come, first-served basis, the governmental review on applications for sand mining is coordinated by the Department of Environment.

The Hydraulics Research Limited (HRL) plays a central role in vetting the application for an offshore sand mining license. Its opinion is often the first to be sought by the Crown Estate Commissioners, who are empowered to issue licenses for gravel extraction. If HRL's opinion on the application is unfavorable from the standpoint of the stability of the adjacent coastline, the license application is unlikely to proceed further (Price et al. 1978).

The following factors must be addressed when processing dredging applications for sand mining in the United Kingdom (Brampton 1987):

a. whether beach slumping or drawdown into the deepened area will occur;
b. whether dredging will affect the natural movement of seabed material by intercepting onshore sediment movement, thereby interrupting sediment supply to the shore;
c. whether the dredging areas include bars and sand banks that might provide protection to the coast from wave action; and
d. whether wave refraction over the dredged area will cause significant changes in the pattern of waves at the coast, such as wave energy concentration or the alongshore transport of bed material.

Based on HRL's detailed investigation of material movement and comprehensive research, which are premised on the answers to the factors addressed above, the following guidelines have been adopted in assessing the effects of dredging on the coastline:

1. *Beach drawdown.* There are two criteria based on the seasonal sequence of beach

recession during storms and beach building during calmer weather: (a) a minimum water depth of 10 m and (b) a minimum offshore distance of 600 m. It will be seen that these are seldom invoked as they are overridden by stringent requirements under other considerations, except for small scale or short-term operations for beach nourishment or land reclamation purposes.

2. *Interception of sediment*. This criterion is based on field investigation of the incipient motion of waves and tidal currents with the 18-m water depth limit at present. More recent studies have revealed that induced shingle movement occurs at depths as great as 22 m. This has been attributed to the stronger tidal current experienced at the test site. Further studies are still ongoing.
3. *Protection by offshore banks*. The ability of offshore banks to dissipate incident waves through premature breaking, bottom friction and reflection, hence, providing protection to the coast, is well acknowledged. At present, however, uncertainty inherent in modeling the wave transmission characteristics of these submarine features still exists. Therefore, the dredging of sandbanks adjacent to the coastline is generally not permitted, unless the rate of sand accretion there is very high and well documented. Even under the latter circumstances, dredging is only for the short term and strictly controlled.
4. *Change in wave refraction*. Waves refract when they enter shallow water since those waves in deeper water travel faster than those in shallow water. Thus, the wave crest tends to wheel around in an effort to parallel the bottom contours/coastline. Thus, waves traversing through a dredged pit can change direction and consequently, concentrate on certain parts of the coastline previously unaffected. In general, the effects of wave refraction are insignificant in water depths greater than 14 m.

The above criteria indicate that the controlling factor is the water depth over the area to be dredged. Hence, in British coastal waters, dredging is not allowed shoreward of the 18-m bottom contours on sediment supply consideration. Although the wave climates and textural properties of sand between the United Kingdom and Malaysia differ, the criteria adopted in the former do serve as a good starting point for formulating a sand mining management plan for the South Johore area, which will be dealt with in later sections.

On the other hand, the potentially deleterious impact of offshore dredging on fisheries and coastal ecology are obviated through the implementation of a Code of Practice for the extraction of marine aggregates. This is usually attained by conducting a baseline study to delineate sensitive resource areas that are to be avoided. Often, site precautionary measures such as erecting a screen around sensitive benthic and other nonmotile communities are specified. Thus, the requirements are very site specific and are seldom depth-dependent as in the case of evaluating the impact of offshore dredging on the physical environment.

OFFSHORE SAND MINING IN SOUTHEAST JOHORE

Present practice on sand mining control

Applications for offshore sand mining concessions are concentrated in the offshore areas between Tg. Siang to Tg. Sepang and off the southeast coast in the South China Sea, along the eastern side of Johore Strait and the Johore-Lebam estuarine system (Fig. 1). However, there are also applications for offshore sand mining off Kukup Island on the western coast of Johore, which is fronted by mangrove-fringed mudflats. There the mechanics of sediment transport are likely to be different since sand is evidently not the primary littoral material for shore building. Nevertheless, the considerations relating to the potential effects of offshore dredging on wave refraction and attenuation by offshore sandbanks, as enumerated in the earlier sections, are still valid.

Having conducted a prospecting survey, a prospective company applies for the mining concession area with the District Land Office, which in turn will consult the various concerned agencies. If there is no objection from any government agency, the application is approved contingent upon adherence to the technical comments, which are listed as preconditions, received from the respective government agencies.

In the past, if the area of interest to the company is within the jurisdiction of the State Government, which is within 3 nautical miles (nm) from the coastline, the State Authority will not have to consult the Federal Government. However, with the implementation of the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment Order 1987) and General Circular No. 5/1987, which is described in the following section, it becomes mandatory for the State Authority to inform the Department of Environment and the Coastal Engineering Technical Centre of the Drainage and Irrigation Department of any application for offshore sand mining and seek their technical comments.

The present legal/administrative machinery

The Environmental Quality (Prescribed Activities) (Environmental Impact Assessment Order 1987) was gazetted pursuant to the Environmental Quality Act of 1974 and enforced in April 1988. Under this order, anybody who intends to engage in any of the prescribed activities is required to carry out an Environmental Impact Assessment (EIA). Under the subject of mining, the order requires an EIA study to be conducted for sand mining that involves an area of 50 ha or more.

In an effort to reduce the need for future coastal protection work, the Federal Government has issued General Circular No. 5/1987 pertaining to the approval of development plans in the coastal area. Under this circular, any development activity, including sand mining, in coastal areas has to be referred to the Coastal Engineering Technical Centre of the Drainage and Irrigation Department for comment.

While the EIA study under EIA Order 1987 covers both the biological and physical environments, the circular is concerned only with the physical environment. For mining activities involving areas larger than 50 ha, the order precedes Circular 5/1987, and the Coastal Engineering Technical Centre then functions as a member of the panel that will evaluate the EIA report collectively.

Coastal Engineering Technical Centre's criteria

At present, the Coastal Engineering Technical Centre bases its recommendation for approving sand mining applications on the seaward limit of sediment movement within which it significantly influences shoreline change. This seaward limit is related fundamentally to sediment and wave characteristics and is site-specific. For most Malaysian conditions, this depth is taken to be the 10-m depth. For a typical east coast offshore profile, it is located about 2 km offshore. Sand mining seaward of the seaward limit of effective sediment transport should not have a significant impact on the shoreline insofar as erosion and accretion are concerned.

This criterion will be examined in greater detail under the ongoing South Johore Coastal Resources Management Project by subjecting it to more rigorous analyses such as refraction using radioactive tracers techniques as has been employed in the United Kingdom. As a comparison, the recommended water depths seaward where dredging is permitted are 18 m, in the case of the United Kingdom (Price et al. 1978), as mentioned earlier, and 35 m, in the case of Genkai Sea, Kyushu, Japan (Kojima et al. 1986). On the other hand, the Shore Protection Manual (US ACEWES 1984) cites a depth limit between 5 and 20 m for offshore sand mining, depending on site conditions, while Dubois and Towle (1985) recommend that "any nearshore marine mining adjacent to a beach should take place outside the 10 meter depth contour. . . ."

Although the depth limit for offshore dredging recommended for the case of Southeast Johore is much less stringent than for those in the United Kingdom and Japan, one must consider that the wave climate in Malaysian waters is much less energetic than those experienced in the countries mentioned above. Another additional consideration is the difference in shoreline geometry, which will be explained below.

Physically, the eastern seaboard of Johore consists of a series of crenulate (or hook-shaped) bays, which can be mathematically analyzed using the log-spiral. Under the constant beating of waves emanating from a predominant direction, the bay will tend toward an equilibrium. Once the equilibrium is attained, the bay can be considered as a closed system with a minimal exchange of sediment with the outside environment. Unfortunately, this stage is almost never reached due to human interference. Sharifah Mastura (1987) has analyzed the physical stability of these hook-shaped bays and found them still in the process of adjusting toward the equilibrium platform. Such a shoreline geometry is less likely to be influenced by the onshore-offshore sediment movement compared to that in British waters, which has more linear features. The direct transposition of the guideline in this case will be untenable.

Therefore, the concept of active profile closure depth and its methods of determination as outlined in the Shore Protection Manual (US ACEWES 1984) are employed to determine the depth limit for dredging operations.

As for the seabed off the western coast of Johore, the prospect of economic offshore sand mining is still uncertain. Nevertheless, the same depth limit has been imposed in the interim.

MANAGEMENT OBJECTIVES AND GUIDELINES

A review of the potential impact of dredging operations on the biological and physical environments and the prevailing dredging practice in other countries elicited these elements for an effective management plan for offshore sand mining:

1. proper inventory of the available resources through a sand resources survey;
2. identification of alternative sources such as land-based river sand;
3. zoning of areas where dredging is permitted;
4. a predredging baseline survey and dredging and postdredging monitoring;
5. precise positioning of dredge to avoid sensitive areas;
6. use of dredging equipment that minimize sedimentation and turbidity; and
7. public education on the adverse impact of offshore sand mining.

To date, the Geological Survey Department of Malaysia has conducted a field geophysical survey with its German counterpart in the South China Sea. Although the spatial coverage is large and sand resources may not have featured strongly in the survey, useful information on the thickness of sand deposits off the southeastern coast of Johore can be gleaned from the report. In addition, a private dredging company has commissioned a sand resources study off the eastern coast of Johore but, unfortunately, the information it obtained is deemed proprietary.

Guided by the above-mentioned elements toward an effective management plan, the proposed management guidelines follow:

1. Offshore sand mining will not be allowed shoreward of the 10-m bottom contours measured from the Lowest Astronomical Tide.
2. Suction dredges are preferred over mechanical dredges and, if feasible, plain suction dredges are preferred over cutter suction dredges.
3. An Environmental Impact Assessment (EIA), which includes a preproject baseline survey of marine biota at the proposed sand mining area, should identify and delineate the natural resources (i.e., corals, commercial clam beds, sea turtle-nesting beaches, fish-spawning areas and seagrass beds) to avoid potential damage to these resources.
4. If dredging is to be carried out near sensitive resource areas, a barrier should be erected to separate them from the dredging site.
5. The dredge should be positioned accurately in the designated area and the anchors/cables/discharge pipes should be placed in the sand or other nonsensitive habitats.
6. Shallow dredging over a large area is preferred over deep dredging to avoid the formation of a stagnant borrow pit that requires a long time to recover. Additionally, dredging should proceed from layer to layer.
7. All leaking joints in delivery pipelines should be repaired immediately to prevent the release of sediment in large quantities to the water column.
8. Dragging of anchors/cables on the seabed is prohibited.
9. Dredging is to be conducted during periods of lowest biological activity.
10. A monitoring program should conduct periodic seabed and marine biota surveys during and after the dredging operation.

These guidelines imply that the removal of sand from the beach itself is to be prohibited. Beach sand mining is not only a direct attack on the very resources to be protected; it also leaves behind a visually cogent evidence of the deleterious impact of such an activity in the form of gaping holes or run-down dunes with resulting wave overwash. The erosion that follows is also likely to be imminent. Available published literature is replete with examples of such human oversight/indiscretion, which invariably lead to disastrous implications. Thus, mobilizing public support for such a prohibition is easy. Only under very rare circumstances, such as a well-documented shoreward accreting beach at the terminus of a littoral cell or landward dunes of a relict beach ridge system, should the above prohibition be relaxed but still strictly controlled in terms of the rate of extraction.

On the other hand, the physiographic adjustment that results after offshore dredging is a gradual process--its main bulk is likely to be subaqueous initially--and may not be apparent within a few years. The associated hazards can surface long after the cessation of sand mining activities. Hence, close and documented monitoring is imperative to reveal early signs of unanticipated stressful conditions and to provide enough information to fully understand this complex coastal phenomenon.

Other potential issues relate to the impact of offshore dredging on navigation and the socioeconomic aspects of the local residents. These impacts are of secondary importance as far as the southeastern coast of Johore is concerned since a major shipping route lies to the south (except within Johore Strait), and dredging operations are highly capital- and equipment-intensive; hence, the local population's involvement in offshore sand mining is likely to be minimal.

The above guidelines represent, at best, a preliminary attempt to enumerate the salient features of a proposed management plan for offshore sand mining. Only the coastal engineering aspects have been dealt with in detail; the biological aspects, which are just as important, have been skimmed over. The cursory treatment of the latter is explained by the professional limitations of the writers, thus underscoring the need for a multidisciplinary approach in formulating a comprehensive management plan for offshore sand mining.

CONCLUSION

Sand mining physically removes sand and alters bathymetry. It also disturbs marine habitats and exerts stresses on marine communities. The physical effect manifests itself in shoreline change as a result of the imbalance in sediment transport while the biological impact transforms into lower productivity and even direct loss of living aquatic resources. Thus, the need to regulate offshore mining activities is obvious.

Prevailing practice in other countries indicates that the physical impact on the shoreline can be obviated by disallowing dredging shoreward of a specified or agreed-upon water depth limit. Various methods are available to ascertain this depth limit as outlined in the Shore Protection Manual (US ACEWES 1984) and employed by Hydraulics Research Limited of the United Kingdom. None of these has been conclusively proven or is universally applicable. Nevertheless, on the basis of wave statistics prevailing along the southeastern coast of Johore and on the practice in other countries, it is recommended that 10 m be considered the minimum depth for the shoreward limit, where offshore dredging should be prohibited. Future work through the use of radioactive tracers techniques or other suitable field methods to study the incipient motion of seabed sediment under various depths is strongly recommended. Such work will strengthen further the practical basis for the depth limit adopted vis-à-vis the anticipated mounting pressure for its relaxation because land-based alternatives for sand resources are depleted.

On the other hand, the impact of offshore dredging on the biological environment is best evaluated through preproject biotic and postproject recovery surveys. These surveys should be included as standard features in the mandatory EIA. Administratively, the complementary Environmental Quality (Prescribed Activities) (Environmental Impact Assessment Order 1987) and General Circular No. 5/1987 are adequate regulatory controls to effect the harmony between economic resources use and the maintenance of environmental quality in the case of offshore sand mining.

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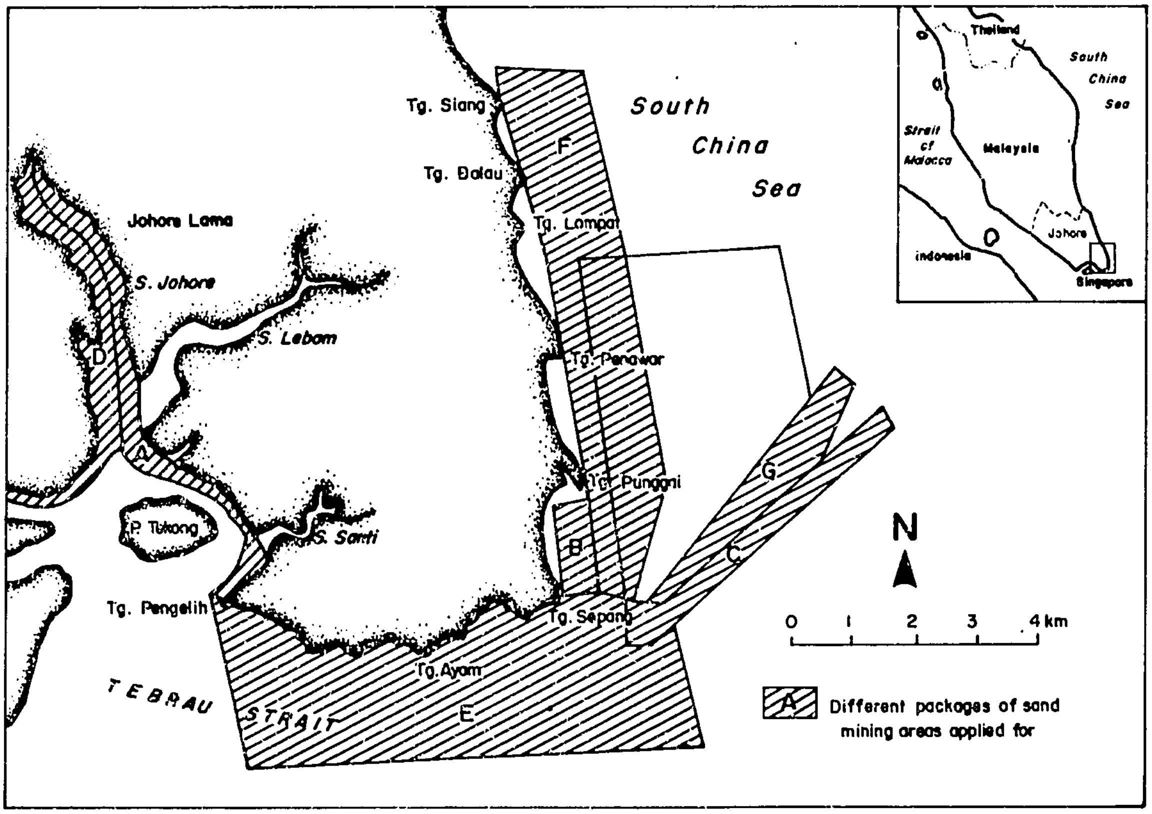

Fig. 1. Applications for sand mining in the rivers and off the coast of Southeast Johore.

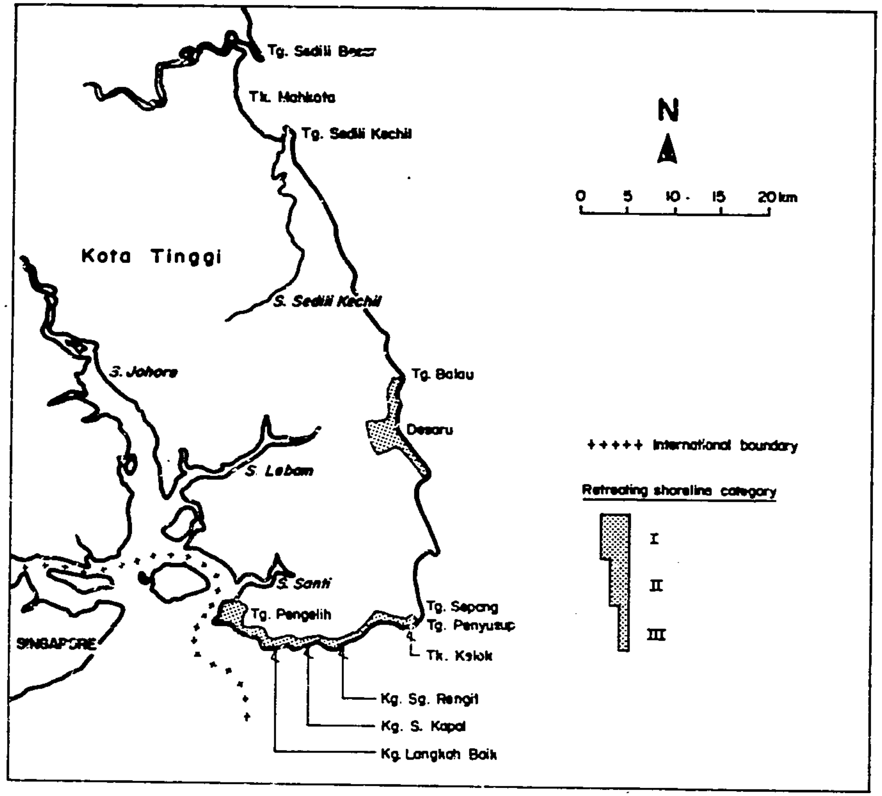

Fig. 2. Coastal erosion areas along the coast of Southeast Johore.

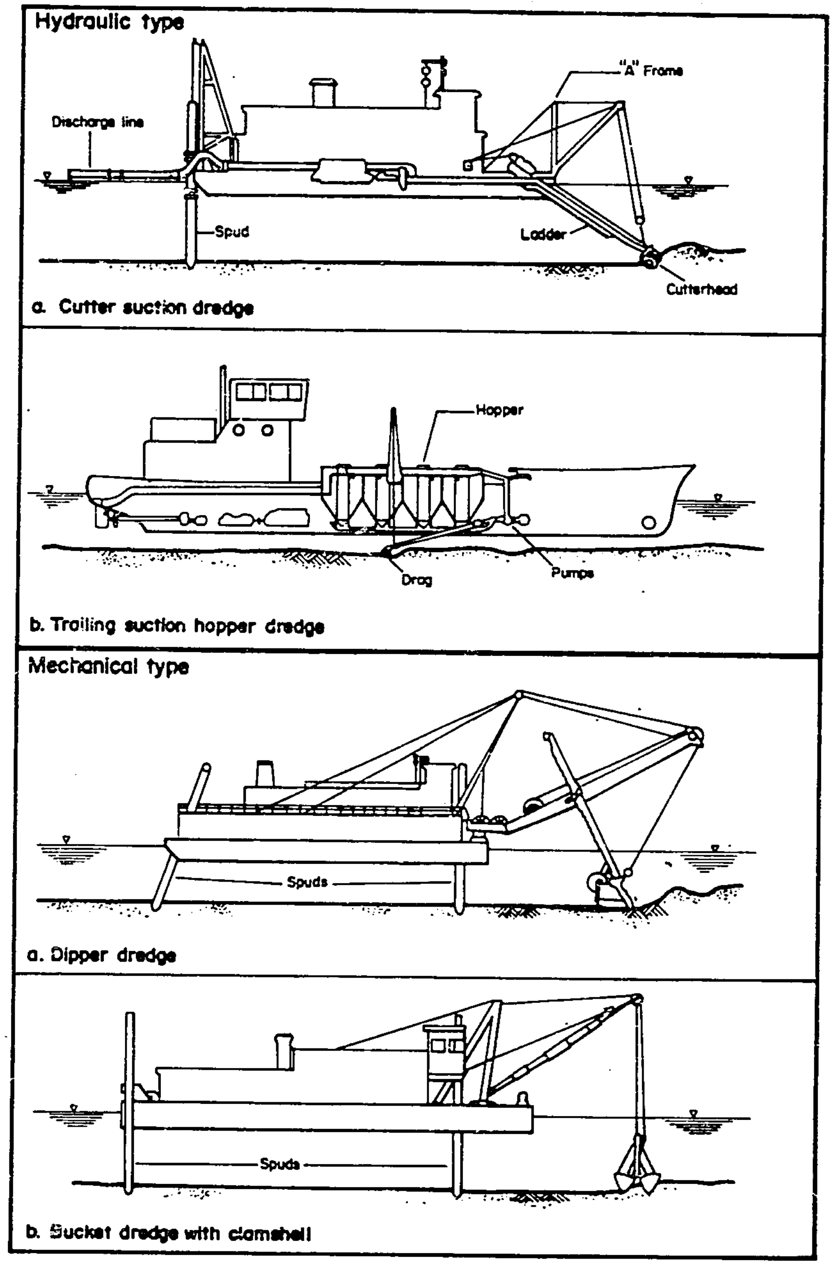

Fig. 3. Common types of dredges.

Some considerations in the development and management of the coastal fisheries resources of Brunei Darussalam

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ABSTRACT

Although fisheries are relatively insignificant in terms of contribution to GNP compared to the oil industry, they are close to the hearts of the Bruneians. In Brunei Darussalam, the fisheries are largely artisanal; trawls and purse seines are recent introductions. The fisheries resources as opposed to fish requirements, the conflicts between artisanal and industrial fishermen, the control of fishing effort, the problems in enforcement and obtaining scientific data and the effects of the oil industry's structures on fisheries are discussed in this paper.

The fisheries resources are being developed in line with the policy of diversifying the economy, but such a development should be based on scientifically obtained data. Also, management should be geared toward ensuring that the fisheries resources are in a healthy state and do not suffer from overexploitation.

INTRODUCTION

Brunei Darussalam has a long history of fishing. Recently, there has been a movement away from the sea due to the large number of secure land-based jobs but even so, fishing has not been completely ignored. Rather, it is carried out on a part-time basis. Fish consumption is high at 40 kg per capita per year. The reported local annual fisheries production in 1986 was 2,268 t. This figure does not include the fish landings contributed by part-time fishermen who numbered as many as 1,566 in 1986. The number of people engaged in full-time fishing is relatively small. In 1987, there were 1,948 part-time fishermen compared to 523 full-time fishermen (Table 1). Fifty-two percent of the country's fish consumption in 1986 was imported.

A variety of fishing gear are used in Brunei Darussalam. Most of these are artisanal gear; the rest are industrial gear, which include trawls and purse seines. Table 2 gives the total number of gear used in 1987.

Most artisanal fishing is carried out in nearshore waters and in the Brunei estuarine system. Some operators, especially those using traps and long lines, have wider ranging operations, close to the oil industry's structures and shoals. The trawlers and purse seiners operate farther out to sea and, by legislation, are prohibited from fishing within 3 miles from the coast.

Brunei Darussalam is heavily dependent on its oil industry as is evident from the latter's contribution to the gross national product (GNP). Although the GNP contribution from fisheries (e.g., 0.26% in 1986) is small, fisheries resources represent a potential that can be developed to assist in diversifying the economy (EPU 1986).

MANAGEMENT CONSIDERATIONS

The country imports about 50% of its fish requirements. Given the fisheries resources potentially available in Brunei Darussalam, it should be possible to satisfy local demand, in terms of biomass at least, by enhanced exploitation of the fish stocks. It has been estimated that fresh fish demand in 2001 will be 9,334 t and the fish stocks have been estimated to have a potential yield that far exceeds this requirement.

However, one has to consider consumer preferences. It is possible that certain types of fish desired may not be available in sufficient quantities to meet the local demand. It may also be that to exploit the stocks fully is more costly than to exploit them partially and import the rest of the fish requirement.

It is thus necessary to obtain data on such matters as local demand and availability for particular fish types and cost of exploiting against cost of importing. These data can then be used in making decisions on the level of exploitation, level of exports and imports, and in accomplishing a comprehensive development and management plan for the fisheries resources.

It is also envisaged that a healthy trade relation will be established by Brunei Darussalam with other countries in importing fish types in short supply and exporting those in excess.

ARTISANAL AND INDUSTRIAL FISHERIES

Brunei Darussalam's fisheries have long been and are still artisanal in nature. Lately, however, they have been undergoing "industrialization" with the introduction of the trawl and purse seine.

Four wooden stern trawlers are in operation at present, each fitted with a mechanical split drum trawl winch of 1.5 to 2.0 t barrel pull, compass, radar, echosounder and VHF transceiver as required by the Fisheries Department. The five purse seiners in operation have the same navigational instruments. There is a plan to increase this fleet.

The introduction of the trawl and purse seine has brought a certain amount of unease and numerous complaints from some artisanal fishermen. The most persistent complaints come from trap fishermen who accuse trawlers of sweeping away and destroying their traps. However, the Fisheries Department demonstrated to them that a properly marked trap would not be swept by a trawl net as the mark would assist the skipper of the trawler to take evasive action. It was also shown that extensive damage results when a trap is entangled in a trawl net, something that trawler fishermen do not want to happen at all. These demonstrations have helped pacify the trap fishermen, but complaints about loss of traps still remain.

The Fisheries Department is aware that artisanal fisheries would not be capable of exploiting sufficiently available fisheries resources and that it is necessary to have industrial fisheries as well. But the plight of the artisanal fishermen who, although relatively less productive, have legitimate claims to improving their lot must also be taken into account.

Among the steps taken toward this goal is the closure of an area of the sea 3 miles from the coast. This area is reserved for artisanal fisheries. The Fisheries Department has also started building artificial reefs. Moreover, enforcement and surveillance activities have been increased to prevent the encroachment of trawlers and purse seines into the fishing grounds of the artisanal fishermen.

Despite these steps, it is envisaged that there would still be complaints from artisanal fishermen. So, a continuous and patient education process would be necessary. The conflict between artisanal and industrial fishermen is not as serious as it is in neighboring countries. This is because the Fisheries Department has imposed strict control over the development of the fisheries and, in general, the fisheries are still lightly exploited.

OIL INDUSTRY

The oil industry is the mainstay of Brunei Darussalam's economy. This industry has several structures at sea (i.e., pipelines on the seabed), which frequently are in the way of certain fishing operations (i.e., trawling). To avoid damage to the structures, a regulation has been imposed prohibiting trawling and purse seining within an area of 1 nautical mile from any such structure. However, at the moment, this is not a serious impediment as most of the pipelines are concentrated at one end of the country, and there are still large areas where fishing can be carried out far from the oil structures.

In the future, when more oil wells will be struck at sea and more trawls and purse seines will be in operation, the constraints could become more pressing. Thus, the expansion of capture fisheries would have to consider the possible reduction in fishing grounds. This would necessitate a more conservative approach to the development of the fisheries or, alternatively, a review of the abovementioned regulation.

The oil structures serve as sanctuaries for fish and other marine life exploited by artisanal gear such as traps and lines. In this case, the expansion of these structures at sea would lead to increased fishing grounds for artisanal fishermen.

CONTROL OF FISHING EFFORT

Methods generally employed to control fishing effort include closed areas, closed seasons, limited entry and control on fishing gear. In Brunei Darussalam, the methods used would probably be closed areas and limited entry. The former are already employed in trawls and purse seines, which are prohibited from fishing within 3 miles from the coastline and near oil structures. But these areas can not strictly be called closed as they are open to exploitation by artisanal fishermen. With respect to limited entry, there is no strict control on entry to artisanal fisheries other than the licensing requirement. Up to the present, any person who applies for an artisanal fishing gear is invariably given one. This has been partly because there have been no dramatic increases in requests for licenses for artisanal gear and the bulk of the fishermen are operating on a part-time basis. But the Fisheries Department is mindful of the undesirability of allowing entry to the fisheries without sufficient data on stock size and optimum level of fishing effort, etc. To this end, a study is soon to be initiated to assess the stocks available to the artisanal fisheries and the appropriate effort levels. Upon completion of this study, the artisanal fisheries will also come under proper control, a step toward their management.

It is mainly within the trawl fisheries that fishing effort control has been enforced strictly. Trawling, after all, is known to be an unselective fishing method. This includes entry, which is strictly regulated by means of a licensing system based on phased entry to a permissible level of fishing effort. There is also control on the horsepower of the trawler engine based on a permissible level of horsepower units as suggested by Beales (1982).

The control of fishing effort in Brunei Darussalam takes on an important dimension when one considers that most of the fisheries resources are in a very early stage of development, so there is good potential for expansion. Effective control at this stage will ensure the continued viability of the fisheries. Otherwise, there is the definite possibility that they would go in the direction of many other fisheries in the region--overexploitation. This is what the Fisheries Department is determined to avoid, and limited entry is expected to be the major means of controlling fishing effort.

ENFORCEMENT ACTIVITIES

In tandem with the control of fishing effort are the activities undertaken to enforce the various Fisheries Regulations. At present, the number of staff available in the Fisheries Department to carry out enforcement work is limited and so is the number of vessels for sea-going work. It must be realized that the quality of management would depend to a certain extent on the enforcement facilities available.

The present development and management strategies have been formulated without taking into account losses due to illegal fishing, which are difficult to quantify. This is not considered to be a serious deficiency as illegal fishing is not perceived to be widespread. Nevertheless, the Fisheries Department plans to expand the enforcement staff's strength and to procure more vessels.

SCIENTIFIC ADVICE AND STATISTICS

The need to assess the fish stocks and obtain other related data before making decisions on fisheries development and management is widely recognized by concerned scientists. In many countries, however, the decisionmakers do not consult with fisheries scientists regarding biological and economic realities but rather make decisions based on political expediency. This practice inevitably results in disastrous consequences.

Brunei Darussalam has taken a very pragmatic approach in this respect. The development of artisanal fisheries has not strictly been based on survey results, although Khoo et al. (1987) have estimated the maximum sustainable yield based on statistics. Artisanal fisheries have been found not to have increased dramatically with most of the exploitation done by part-time fishermen. Also, the prawn and fish resources are being surveyed so that appropriate development and management could be made.

The collection and use of fisheries statistics are hampered by the lack of staff, which, in turn, results in insufficient coverage of the fishermen, late processing of data and inability to present data in a form suitable for management purposes. At the moment, data are collected only from full-time fishermen and not from part-time fishermen who greatly outnumber the former.

AQUATIC ENVIRONMENT

Fisheries depend on the aquatic environment. Pollution problems and the reduction of mangrove ecosystems adversely affect fisheries.

Pollution is at a very low level at the moment but could rise with increased industrialization and urbanization. Chua et al. (1987) state that at present, pollution from industrial sources other than the petroleum industry appears to be negligible.

It would be particularly worrisome if the offending discharges were to be released into the Brunei River Estuary System as this is a very important fishing ground. In this regard, the government has commissioned a study to propose National Water Quality Standards. Brunei Shell Petroleum has a contingency plan for oil spills. Therefore, pollution is not a major threat to the fisheries resources, at least for the present, but the necessity for vigilance can not be overemphasized.

A possible threat to the fish and shrimp stocks in the Brunei Bay region is the reduction of the mangrove areas by conversion into human settlement. Also, there has been increasing interest recently to convert mangrove areas into brackish-water shrimp ponds. Studies have not been conducted in Brunei Darussalam to establish a link between the mangrove swamps and the shrimp fisheries, but it is widely held that the rich belt of mangroves fringing the Brunei Bay area is the basis for the highly productive shrimp fisheries in that area. Mock (1966) observes that an altered shrimp nursery area had over 2.5 times fewer *Penaeus aztecus* and 14 times fewer *P. setiferus* than the natural habitat and Gedney et al. (1982) show reduced landings in Peninsular Malaysia. Zamora (1987) also reports that shrimp and fish fry were seen in great quantities among the tangled rifts of *Rhizophora* plants.

Since the conversion of mangroves into shrimp ponds or other uses can have a negative effect on the shrimp fisheries, the Fisheries Department has plans to study the shrimp stocks and the mangrove ecosystem in the near future to estimate the amount of mangrove area that can be released for brackishwater shrimp farming without markedly affecting the fisheries.

Of concern also is the destruction of mangroves for logging and human settlement. Since the relevant government departments (e.g., Forestry, Housing Development, Town and Country Planning) are all under the Ministry of Development as is the Fisheries Department[a], the latter can be a moderating influence in reducing the impact of mangrove conversion on the fish and shrimp stocks.

DISCUSSION

Various issues introduced above are related to the development and management of the fisheries resources in Brunei Darussalam. Providing a sound scientific basis is the concern of the Fisheries Department.

The basic approach used is one of obtaining data on fisheries resource levels, catch rates of suitable fishing gear, appropriate fishing effort levels, marketing data and others, before embarking on development or expansion. The development of the fisheries is not carried out in one instance, with fishing licenses corresponding with the total number of possible fishing gear being issued once and for all. Rather, the development is done in stages with monitoring and reviews in between. This is because the Fisheries Department is aware of the need to be cautious when using the results of initial resource surveys and of the tendency of catch rates to drop after initial exploitation. Thus, the development and expansion in fishing effort have been programmed to increase in phases.

In the case of trawl fisheries, as based on the resource survey done from 1979 to 1980, a level of fishing effort was calculated by Beales (1982). The total number of fishing licenses commensurate with this fishing effort was not issued in one instance. At first, only five licenses were offered. This was followed by a period of monitoring before the next batch of licenses was issued. In this way, the problems of overexpansion and overcapitalization were avoided.

The two problems associated with the monitoring and review processes are in conducting repeated resource surveys and obtaining reliable catch and effort data from the trawler fishermen. The former is a constraint due

[a]Editor's note: On 1 January 1989, the Fisheries Department was transferred to a newly created Ministry of Industry and Primary Resources.

to staff limitation and is already being addressed. The latter is the general reluctance of the trawler fishermen to fill the logbooks with their catch and effort data, which is a more serious problem as it affects the monitoring of the fish being removed from the stock. This matter is currently being attended to by the Enforcement Section of the Fisheries Department to ensure that the trawler fishermen will hand in their duly completed logbooks to the department every month.

The monitoring of demersal stocks has also been conducted through monthly catch samplings in three selected areas since 1980. Halidi (1987) analyzes these results and finds a declining trend in the demersal stocks. Khoo et al. (1987) proposed various reasons to explain this apparent decline.

Halidi's (1987) findings have made it necessary to review the further expansion of the trawl fisheries. Thus, a comprehensive trawl survey will soon be conducted to rationalize the further development and management of the trawl fisheries.

Brunei Darussalam is more fortunate than other countries as the state of its fish stocks and other resources, such as the mangroves, are still lightly exploited. The environment is also in a healthy state, given the low level of industrial activities. The fishermen have a relatively high standard of living and have access to sufficient fisheries resources, unlike in other countries where fishermen are usually poor and are faced with overexploited fish stocks. The country is also not dependent on fisheries as a major source of revenue.

Thus, Brunei Darussalam has a good opportunity to develop its fisheries resources in a progressive manner, taking into account the magnitude of the stocks so as to prevent overexploitation. This is something that many other countries cannot afford.

However, the government, mindful of the non-renewable nature of its oil and gas resources, has started to increase emphasis on the diversification of the economy.

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Table 1. Number of fishermen by district in Brunei Darussalam, 1987.

District	Full-time	Part-time	Total
Brunei Muara	337	1,542	1,879
Belait	66	178	244
Tutong	120	157	277
Temburong	Nil	71	71
Total	523	1,948	2,471

Table 2. Fishing gear in Brunei Darussalam, by district, 1987.

Gear type	Brunei Muara	Belait	Tutong	Temburong	Total
Pukat tunda (trawl)	4	-	-	-	4
Pukat lingkong (purse seine)	5	1	-	-	6
Pusau (encircling net for *Formio niger*)	2	18	-	-	20
Paguyut (beach seine with cod-end)	-	-	-	-	-
Pukat (small hauling net)	39	-	-	-	39
Andang (gill net)					
Karan (trammel net)	918	33	109	32	1,092
Rantau (drift net for night operation)	23	2	25	-	50
Anoaz (encircling net)	9	11	8	-	28
Katam (set bottom net for crabs)	-	-	-	-	-
Jarang (net with large mesh size of > 2")	7	6	-	2	15
Tangsi (net with large mesh size of 1-2")	-	62	23	-	85
Pukat kikis (beach seine)	-	7	4	1	12
Pukat kurau (bottom set net for shads)	-	-	-	1	1
Pancing (hook and line)					
Jaul (hand lines)	588	111	42	1	742
Rawai (bottom long line)	500	-	-	1	501
Tunda (troll)	-	-	-	1	1
Perangkap (trap)					
Tugu (intertidal funnel-shaped net)	436	-	-	-	436
Lintau (small corral)	30	-	-	-	30
Kilong (large corral)	4	-	-	-	4
Kabat (tidal weir)	15	-	1	-	16
Selambau (lift net)	-	-	-	-	-
Bubu (pot)	174	498	311	-	983
Rambat (cast net)	57	13	7	24	101
Total	2,806	767	535	63	4,161

A red tide action plan for Brunei Darussalam

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ABSTRACT

Red tides occurred in Brunei Darussalam in 1976, 1980 and twice in 1988. No unusual water discolorations were observed during the latter incidences. However, high levels of paralytic shellfish poisoning (PSP) toxins (up to 5,354 µg/100 g of flesh) were recorded in the green mussel *Perna viridis*, which was used as a test species. There was an increase in number but not to "bloom proportions" of *Pyrodinium bahamense* var. *compressa*, which was identified as the causative agent of toxic red tides in the country.

Regular monitoring for the presence of *P. bahamense* var. *compressa* in selected stations in the coastal waters and PSP toxin levels in *Perna viridis* is conducted by the Department of Fisheries. Public health safety during red tide occurrences could be assured through the operation of a red tide action plan, involving primarily the Department of Fisheries (DOF), Ministry of Development; Department of Medical and Health Services (DMHS), Ministry of Health; Radio and Television Brunei, Ministry of Communications, and other news media. The details of the operation of the action plan are discussed.

INTRODUCTION

Brunei Darussalam is located on the northwestern coast of the island of Borneo, between latitudes 4°N and 5°5'N and longitudes 114°23'E and 115°22'E. It lies between the East Malaysian States of Sarawak to the southwest and Sabah to the northeast.

Brunei Darussalam has been particularly interested in red tides since their first reported occurrence in the country's waters on 11 March 1976 (Beales 1976). The causative agent was initially thought to be a *Gonyaulax* species but was later identified as a toxic variety (var. *bahamense*) of *Pyrodinium bahamense* Plate, 1906. Matdanan and Selvanathan (1984) have dealt in detail with the two occurrences in 1976 and 1980 and the methods used in monitoring and surveillance.

The DOF has been monitoring the levels of *P. bahamense* var. *compressa* in selected sampling sites in the coastal waters likely to be affected by red tides based on previous experiences. Between the occurrence in 1980 and the end of 1987, no blooms or excessive number of the organism were recorded. Further, no PSP toxins were recorded during this period, although several shellfish species were tested using the Standard Mouse Bioassay for PSP toxins. However, Brunei Darussalam was placed on a state of alertness for red tide blooms and possible PSP in July 1983, December 1985 and December 1986 due to the occurrence of either red tides or paralytic shellfish poisoning in neighboring Sabah, East Malaysia.

On 2 December 1987, the DOF received a report from the Animal Health Unit of the Agriculture Department, Brunei Darussalam, which indicated that the Veterinary Clinic at Berakas had treated 40 cats over a period of 2 days for suspected food poisoning after being fed fresh sardines (*Sardinella* sp.). Seven of the cats had succumbed to the illness while many were reported in serious condition. An examination of the stomach content of the *Sardinella* sp. given to some of the sick cats indicated that over 80% of it were made up of cells of *P. bahamense* var. *compressa*. Subsequent paralytic fish poisoning (PFP) toxin tests carried out on the suspected *Sardinella* sp. indicated a toxin level of 196 µg/100 g of flesh. This reconfirmed the cause of the food poisoning in the cats as the toxic dinoflagellate, *P. bahamense* var. *compressa*. The contaminated *Sardinella* sp. were imported from Sabah, East Malaysia. Quick action was taken to confiscate and destroy all planktivorous fish. The warnings issued to the public, based on the findings of the stomach content analysis of the sardines, prevented any PSP/PFP-related public health problems in Brunei Darussalam. A red tide alert was imposed. A ban on imports of planktivorous fish and mollusks was also enforced. In Brunei Darussalam, no abnormal levels of *P. bahamense* var. *compressa* or PSP toxins in green mussels *(Perna viridis)*, which are routinely used as test organisms, were observed during this period (December 1987). However, very high levels of both PSP and PFP were recorded at the beginning of February and again at the end of April 1988. Table 1 gives the PSP/PFP toxin levels recorded for the first eight months of 1988. The maximum PSP toxin levels recorded in the green mussels from Serasa during these two periods (5,354 µg/100 g of flesh for February and 1,119 µg/100 g of flesh for April) were very much higher than the maximum level recorded for Brunei Darussalam during the 1980 red tide occurrence (200 µg/100 g of flesh for green mussels from Serasa) by Matdanan and Selvanathan (1984).

In addition to the regular monitoring and surveillance program carried out in Brunei Darussalam, there is a need to formalize the field-tested procedures adopted during red tide occurrences into a red tide action plan.

THE RED TIDE ACTION PLAN

Objective

The objective of the red tide action plan is to provide timely and adequate response to safeguard public health during toxic red tide occurrences in Brunei Darussalam or in the neighboring East Malaysian States of Sabah and Sarawak. The plan establishes the procedures and responsibilities so that the response time can be reduced to a minimum. The details of the procedures are to be made available to the departments and units concerned. Priority is given to human life.

Organization

Fig. 1 summarizes the proposed organizational structure of the red tide action plan. The National Red Tide Response Team (NRTRT) is to be made up of senior officers of the DOF, DMHS and the Municipal Board (MB). The DOF is responsible for executing the Red Tide Monitoring and Surveillance Program through the Environment Unit (EU) of its Marine Fisheries Section. Although the DMHS is directly involved in the safety of the public, the DOF and the MB play major roles in red tide-related public health problems as the former has overall jurisdiction over fish and fishing, and the latter, over markets and marketing. The Department of Broadcasting and Information plays a role in the dissemination of information on red tides, e.g., through government publications like the *Pelita Brunei*.

Procedures

The procedures are summarized in Fig. 2. In addition to the routine monitoring and surveillance carried out by the EU of the Marine Fisheries Section of the DOF, any information on actual or suspected red tides should be immediately conveyed to the Chairman/Deputy Chairman of the NRTRT who will then alert all other members. The following actions will then be carried out:

Phase I - Confirmation of a red tide occurrence

1. The EU will immediately confirm the report and provide a feedback to the NRTRT.
2. Reports of water discoloration in the coastal waters outside the range of small boats will be investigated by helicopter.
3. Unusual numbers of *Pyrodinium bahamense* var. *compressa* in vertical plankton haul samples or in the gut contents of planktivorous fish will be detected and analyzed, to be followed by immediate PSP toxin assays of cultured *Perna viridis*.
4. In the case of suspected PSP/PFP poisoning, samples of cooked/uncooked food and, if traceable, samples from market outlets of suspected fish/shellfish should be tested.
5. Although a PSP toxin level of 80 µg/100 g of flesh is generally accepted as hazardous to human health, the presence of

detectable levels of PFP/PSP toxins in fish/shellfish will be taken as sufficient evidence of the occurrence of a red tide.

6. The DMHS will put all hospitals and clinics on the alert for patients with possible symptoms of PSP/PFP (refer to Appendix 1).
7. The airwing of the Armed Forces, the Royal Brunei Airlines, the Marine Department and Brunei Shell Petroleum Company Sendirian Berhad (BSP) will be requested to report any unusual water discolorations in the coastal waters.

Phase II - Steps to be taken on confirmation of a red tide occurrence

Procedures will depend on the extent and severity of the red tide incident and whether it is in Brunei Darussalam or other parts of Borneo. However, the following general steps are to be taken:

1. Issue warnings on prevailing red tides and public safeguards (e.g., do not consume affected fish and shellfish) through radio, television, newspapers, posters, etc.
2. The Enforcement Section of the DOF will ban the harvesting/import of mollusks and, if necessary, planktivorous fish and other affected organisms.
3. The DMHS, DOF and MB will inspect markets and other sales outlets so that no banned fish/shellfish are sold.
4. The EU will:
   a. reduce the interval of monitoring red tide organisms in the coastal waters to once-a-week, instead of the usual once-a-fortnight procedure, and PSP toxins to once-a-fortnight instead of the usual once-a-month procedure;
   b. increase monitoring stations to cover Temburong, Tutong and Belait Districts; and
   c. maintain close contact with the Fisheries Department of the East Malaysian States of Sabah and Sarawak with respect to the red tide situation.

Phase III - End of a red tide occurrence

The recurrent negative results of PSP toxins in test shellfish for one month together with only an occasional occurrence of a few cells of *P. bahamense* var. *compressa* in plankton haul samples over the same period of time can be taken to signal the end of a red tide. The following actions need to be taken:

1. The NRTRT should make a public announcement that the red tide alert is lifted.
2. All posters and boards put up to warn the public should be removed unless they can still serve the purpose of public education on or awareness of red tides. Particular attention should be given to boards banning the harvesting of shellfish from specific locations.
3. The EU will resume its normal monitoring and surveillance procedures.

Phase IV - Review of the red tide action plan

The red tide action plan should be reviewed after the occurrence of a red tide incident to strengthen it. Further, at least an annual review should be made to maintain the accuracy of emergency contact addresses and telephone numbers. Updating of detection techniques for PSP/PFP toxins and the red tide organisms themselves would be necessary because of the rapid progress being made in these areas.

The EU, in addition to executing the red tide monitoring and surveillance program, will be responsible for logging the events during an occurrence and all details of the procedures relating to the action plan.

CONCLUSION

Although Brunei Darussalam does not have a formal red tide action plan, it has followed several procedures to prevent any undesirable public health problem related to the occurrence of red tides in the country or in the neighboring East Malaysian States of Sabah and Sarawak. The formalization of procedures into a National Red Tide Action Plan is desirable in view of the prolonged potentially life-threatening red tide periods recorded recently. The PSP toxin level of 5,354 μg/100 g recorded in green mussels in February 1988 (where 80 μg/100 g is medically accepted as hazardous to human health) provides some idea of the potential danger to human life. Brunei Darussalam was fortunate that such high PSP toxin levels occurred at a time of a red tide alert following the 1987 red tide incident. It was during the alert period that the public was warned not to consume mollusks and planktivorous fish without removing all stomach contents and gills before cooking. There was also a ban on the harvesting and import of mollusks.

The procedures laid down in the proposed red tide action plan will reduce the response time in case of an occurrence. Special attention will be given to public education on and awareness of red tides. Public discipline in responding to a red tide alert will ultimately determine the success or failure of the action plan.

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Appendix 1. Symptoms of paralytic shellfish/fish poisoning, diarrhetic shellfish poisoning and other effects of red tides.

"Red tides" are known to cause at least the following:

Paralytic shellfish poisoning (PSP) - human illness and death resulting from eating shellfish that have filter-fed on toxic microorganisms, mostly dinoflagellates such as *Pyrodinium bahamense* var. *compressa*.

Symptoms:

In mild cases: Tingling sensation or numbness around the lips gradually spreading to the face and neck, prickly sensation on fingertips and toes, headache, dizziness, nausea, vomiting, diarrhea.

In severe cases: Incoherent speech, progression of stiffness and noncoordination of limbs, general weakness and feeling of lightness, slight respiratory difficulty, rapid pulse.

In extreme cases: Muscular paralysis, pronounced respiratory difficulty, choking sensation; death through respiratory paralysis can occur within two to four hours after ingestion.

Paralytic fish poisoning (PFP) - human illness and death from eating whole plankton-feeding fish that have fed on toxic dinoflagellates.

Symptoms: Same as for PSP.

Diarrhetic shellfish poisoning (DSP) - gastrointestinal distress caused by consuming filter-feeding shellfish that have fed on other dinoflagellate species such as *Dinophysis*.

Symptoms: After 30 minutes to a few hours, diarrhea, nausea, vomiting, abdominal pain.

Fish kills - as a result of gill damage caused by chemicals released by some species of phytoplankton.

Suffocation of marine life - due to oxygen depletion, caused by phytoplankton respiration or decay.

Table 1. The PSP/TFP toxin levels recorded in fish/shellfish in Brunei Darussalam from January to August 1988.

Date	Sample (species/common name)	Location	Toxicity (ug/100 g meat)
23 Jan	*Perna viridis (Kupang hijau)*	GAMAFCO (Muara)	77
	Selar kala (Ikan selidai)	Within Brunei Darussalam	61
	Portunidae *(Ketam belok)*	Within Brunei Darussalam	nt
	Penaeidae *(Udang besar)*	Jerudong	nt
	Clupeidae *(Aur-aur)*	Within Brunei Darussalam	nt
26 Jan	*Perna viridis (Kupang hijau)*	GAMAFCO (Muara)	81
	Perna viridis (Kupang hijau)	Serasa	307
	Leiognathus splendes (Bilis)	Pasar Tutong	nt
	Selar mate (Temenong)	Pasar Tutong	44
	Clupeidae *(Kuasi)*	Within Brunei Darussalam	nt
	Acetes (Bubok)	Within Brunei Darussalam	45
	Penaeidae *(Udang besar)*	Within Brunei Darussalam	nt
	Clupeidae *(Kuasi)*	Within Brunei Darussalam	55
	Rastrelliger kanagurta	Within Brunei Darussalam	54
3 Feb	*Perna viridis (Kupang hijau)*	GAMAFCO	1,054
	Perna viridis (Kupang hijau)	Serasa	5,354
	Penaeidae *(Udang besar)*	Within Brunei Darussalam	nt
	Penaeidae *(Udang kecil)*	Within Brunei Darussalam	nt
	Scylla serata (Ketam belok)	Within Brunei Darussalam	nt
2 Mar	*Perna viridis (Kupang hijau)*	GAMAFCO	64
	Perna viridis (Kupang hijau)	Serasa	56
15 Mar	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	66
	Meretrix-meretrix (Kunau)	Within Brunei Darussalam	nt
	Acetes (Bubok)	Within Brunei Darussalam	nt
6 Apr	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	nt
21 Apr	*Perna viridis (Kupang hijau)*	Serasa	246
	Saccostrea cucullata (Teritip)	Serasa	68
28 Apr	*Perna viridis (Kupang hijau)*	GAMAFCO	859
	Perna viridis (Kupang hijau)	Serasa	1,119
	Saccostrea cucullata (Teritip)	Serasa	487
10 May	*Perna viridis (Kupang hijau)*	GAMAFCO	430
	Portunidae *(Ketam suri)*	Within Brunei Darussalam	nt
	Anchovies *(Pusu)*	Within Brunei Darussalam	nt
	Scianidae *(Gelama)*	Within Brunei Darussalam	nt
	Geloina coaxans (Lukan)	Within Brunei Darussalam	nt
	Scylla serata (Ketam belok)	Within Brunei Darussalam	nt
	Penaeidae *(Udang besar)*	Within Brunei Darussalam	nt
26 May	*Perna viridis (Kupang hijau)*	GAMAFCO	69
	Saccostrea cucullata (Teritip)	Serasa	nt
	Gastropod *(Tekuyong)*	Within Brunei Darussalam	nt
21 Jun	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	nt
	Saccostrea cucullata (Teritip)	Serasa	nt
	Meretrix-meretrix (Kunau)	Pulau Muara besar	nt
14 Jul	*Perna viridis (Kupang hijau)*	GAMAFCO	65
	Perna viridis (Kupang hijau)	Serasa	56
3 Aug	*Perna viridis (Kupang hijau)*	GAMAFCO	46
	Perna viridis (Kupang hijau)	Serasa	45
6 Aug	*Saccostrea cucullata (Teritip)*	Anduki	53
13 Aug	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	nt
	Squat Lobster *(Satak)*	Kuala Belait	nt
	Crab *(Ketam)*	Kuala Belait	nt
24 Aug	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	nt
26 Aug	*Anadara granosa (Tambayangan)*	Kampong Sungai Besar	nt
	Siku	Kampong Sungai Besar	nt
4 Sep	Lamellibranch *(Kerakas)*	Pulau Muara Besar	nt
	Anadara granosa (Tambayangan)	Pulau Muara Besar	nt
5 Sep	*Perna viridis (Kupang hijau)*	GAMAFCO	nt
	Perna viridis (Kupang hijau)	Serasa	nt

nt = not toxic.

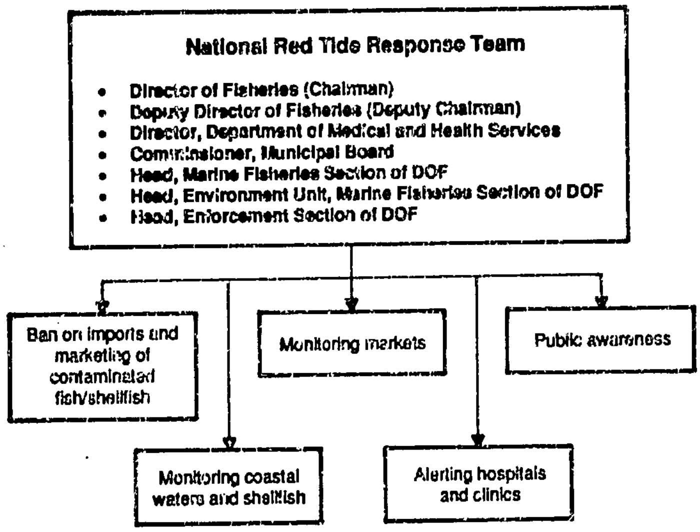

Fig. 1. Organizational structure of the red tide action plan.

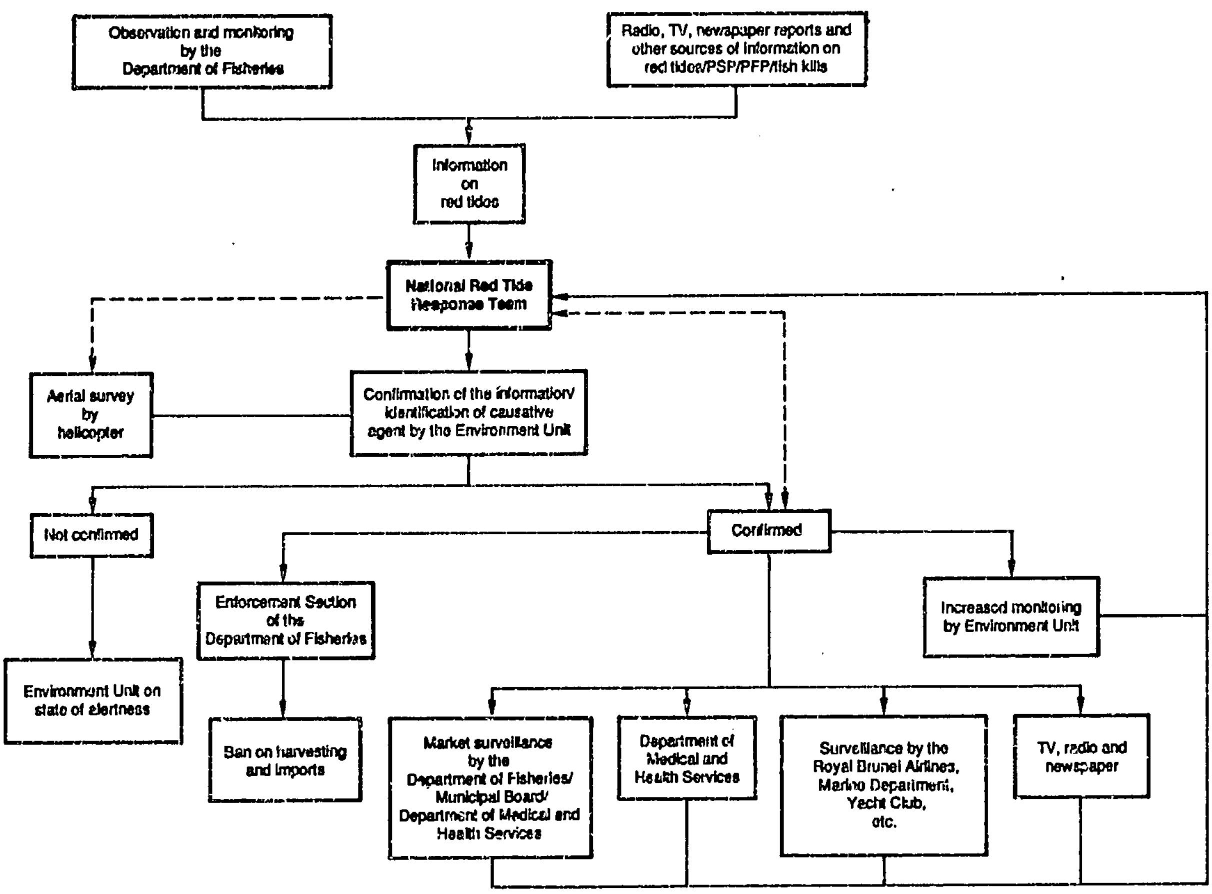

Fig. 2. Action plan in case of red tides.

A community-based resource management approach to address Philippine coastal resource degradation and overfishing

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ABSTRACT

The Central Visayas Regional Project-I (CVRP-I) has been implementing a US$3.5 million coastal resources management project at five sites encompassing 223 km of the central Philippine coastline for the past four years. Artisanal fishermen are recognized as the *de facto* managers of this resource. The project assists in developing a resource management system through community organization and use of simple appropriate technologies.

Habitat management addresses both resource degradation and recruitment overfishing. Methods used by artisanal fishermen include coral reef/seagrass management with sanctuaries, mangrove reforestation and management and artificial reefs. Restoration of the nearshore coastal fisheries can reduce overfishing, allowing the maximization of profit from limited harvests.

Harvest management builds on attitudes and opportunities resulting from successful habitat management and addresses growth overfishing. Methods used to date include small-scale sea ranching and farming, community control of illegal and destructive fishing methods and use of fish aggregating devices (FADs). FADs present an opportunity for low overhead fishing with sustainable harvests for handline fishermen.

Fishing communities have responded very well to this approach. Their direct involvement as primary implementors of successful technologies makes them realize that they themselves can significantly improve what many have regarded as a near hopeless situation.

INTRODUCTION

This paper deals with the approaches used in developing and implementing a coastal resources management project for artisanal fishermen as part of a larger, watershed-based resource management project. The project was prepared for World Bank financing in 1981-82. Implementation began in mid-1984 and is expected to continue through 1990. Approximately US$3.5 million of the $35 million Central Visayas Regional Project-I (CVRP-I) cost is devoted to marine fisheries. Nearly 10,000 families at five Nearshore Fisheries Project sites, encompassing 223 km of coastline on four islands in central Philippines, are expected to benefit directly from Project-I.

CVRP-I is intended to pilot strategies, technologies and approaches in coastal resources management that could then be replicated elsewhere in the Philippines. It is an action-research project that allows results to be used in modifying the approach when warranted. In addition to resource management, the project stresses the decentralization of the decisionmaking power from the central government and the strengthening of local governments and government line agencies to assume responsibility for implementation during the project's life and to continue the program developed after CVRP-I.

PROJECT DESIGN

A situation analysis of Central Visayas artisanal fishermen conducted during late 1981 and early 1982 included conversations with them. Along with the usual pleas for more and better fishing boats and gear from the forthcoming project were other complaints, which included:

- declining catch, both in number and size of fish;
- declining fisheries income;
- increasing number of fishermen;
- few remaining fish in the coast's shallow waters;

- intense competition between commercial and artisanal fishermen;
- intense competition between artisanal fishermen and active, capture-efficient small-scale gears such as baby trawls, *hulbot-hulbot* (a bottom set encircling net), *licum-licum* (a micro purse seine) and large beach seines;
- widespread use of fine mesh nets;
- common use of explosives and poisons;
- widespread damage to and destruction of coral reefs and mangrove forests that result in the declining fish and shrimp harvests by many fishermen; and
- the general failure of government programs to provide artisanal fishermen with powered boats and more capture-efficient gears.

Three conclusions were drawn from the above-mentioned information:

1. All the signs of overfishing were present, including recruitment, growth and economic overfishing. However, little formal scientific evidence was available to support this conclusion, which was politically unacceptable at the time.
2. The destruction of shallow water fisheries' habitats was widespread. This was documented for mangrove forests (Biña et al. 1979) and for coral reefs (Gomez et al. 1981).
3. Uncontrolled access to a common resource was a root cause of most fisheries-related problems.

Whether one subscribes to the definition of common resource by Christy (1982) or by Bromley (1985), uncontrolled access to and overuse of the fisheries resource result in the destruction of that resource, the "tragedy of the commons" of Hardin (1968).

The need for resource management was obvious. Key questions were: "How and where to begin?" and "Who could or would manage the resource?"

The question of who manages the coastal fisheries resource is quite straightforward. Fishermen make the decisions on how the resource will be utilized. Others, such as government agencies, can influence their decisions, but fishermen are the ones who decide each day what will happen at sea.

Control of access to the resource through various forms of allocation is needed to lessen the pressure on the resource and to provide for a more equitable distribution of benefits from the resource. It is also important that fishermen begin to develop a sense of ownership and control over their productive resources. One cannot expect them to manage their resources better if they feel no sense of ownership or responsibility for these resources.

Measures to regulate the harvest are usually attempted in overfishing situations such as these. However, given: (1) the lack of hard data on which to base any recommendation; (2) the need for regulations that would cover large areas extending well beyond the project sites; (3) the widespread disregard for existing harvest management measures; and (4) the lack of official governmental recognition of the need for such measures at the time, efforts in that direction seem futile.

Habitat management presented another opportunity. Many fishermen expressed interest; it could be done effectively in limited areas. Some branches of government openly encouraged it. It also would not threaten, in any way, access to the offshore pelagic fisheries on which most fishermen depend for their daily income.

Three simple and appropriate approaches to habitat management technologies were available for use, although none had been well tested or widely used. The technologies available were: (1) artificial reefs that would be constructed and placed by fishermen themselves, (2) coral reef management including sanctuaries; and (3) mangrove reforestation.

Coral reef management through the establishment of reef sanctuaries by the fishing community was pioneered in the Philippines by Dr. Angel C. Alcala and Dr. Alan T. White at Silliman University. They demonstrated that small island communities could learn to manage effectively their coral reef resources. Likewise, this author while working at the University developed a bamboo artificial reef module that could easily be built and set in place by the fishermen. He also adapted mangrove reforestation and management techniques from those being used by a few of these fishermen.

With this small, largely untested but basic selection of management tools, the decision was made to design the CVRP-I Nearshore Fisheries component with a habitat management approach. From a fisheries management standpoint, habitat management would address primarily the problem of recruitment overfishing by providing improved and expanded nursery areas as well as protected breeding populations. Each technology also carried with it the potential for elements of resource allocation; family management of and exclusive harvest from artificial reef clusters; family-managed mangrove plantations under a 25-year lease (Stewardship Contract); and community-managed reef sanctuaries closed to all harvesting.

PROJECT APPROACH

The approach deals directly with resource managers (i.e., community-based). The site staff live and work in the fishing *barangay* (villages) and the project management system is designed to allow them to be as responsive as is possible to the community's needs. This includes giving the site manager full control over disbursements at his site. The staff also need to develop and maintain credibility with their clients. In this respect, they were cautioned never to promise anything unless they could deliver.

The development process begins at the *barangay* level with community organization and education in marine resources management. The site staff introduce the project to municipal officials and engage all sectors of the community in an analysis of their situation by identifying the problems, opportunities, constraints and means of overcoming these constraints. As priority problems are identified and constraints lifted, this learning process is repeated in a new situation. The *barangay*'s Development Council becomes the focus of this activity and provides a formal link with the local government. As high priority problems invariably concern declining marine harvests, there is great interest in project technologies that deal with these problems.

Project activities should begin on a small scale and with little or no risk to participants. Informal community leaders who express genuine interest are good starting points. Use of appropriate technologies is essential. Fishermen will respond positively to activities that clearly address a need, that have minimal risk to them and that make sense (or are known to work). As resource management techniques begin to work for one small group, others will see their positive results and thus be more willing to participate. Cross visits by fishermen from a new *barangay* to one where technologies are already in place and working are effective extension tools.

Technologies should also be introduced a few at a time and when the community is ready. Artificial reefs and mangrove reforestation were the initial offerings of CVRP-I. Coral reef management was delayed until the third year of implementation since it requires a higher level of community organization and commitment. This is because a portion of the resource is closed to all harvesting.

Local government, government line agencies and nongovernmental organizations (NGOs) must also be involved in any community-based resource management project. Projects have a limited life but programs begun under these projects can continue only if the needed administrative and technical support services are available. Local government officials are being trained as project coordinators, and those in the line agencies, as support staff. Community organization is often best done by NGOs. Fishermen remain the lead implementors.

RESULTS AND LESSONS

Fishing communities readily adopted artificial reefs, mangrove reforestation and coral reef management as resource management tools. Filipino fishermen, who are reportedly very independent individuals, had no difficulty working together for a common cause with the proper motivation.

Habitat management

Fifty pyramidal bamboo artificial reef modules, 3 m long at the base and 1 m high, were placed in clusters at depths of 15-25 m. Cluster volume was 65 m^3. Only eight to ten such clusters can be placed along 1 km of shoreline in most suitable areas because the water depth increases rapidly, leaving only a narrow band suited for artificial reefs. The family management of each cluster was encouraged to allow the harvest to be regulated at sustainable levels. Harvests from hook and line and/or two fish traps (= pots) per cluster produce sustainable yields of 10 kg per cluster per week. Net income is sufficient to double the annual income of the poor fishing families. After the first four years of project implementation, the equivalent of 26,000 modules (33,800 m^3) have been placed along some 67 km of coastline at project sites by project clients.

In addition to developing populations of reef fish species for harvest, artificial reef areas attract large pelagic predators such as jacks, rainbow runners and narrow-barred Spanish mackerels. The presence of artificial reefs also seems related to the fact that small pelagics, particularly anchovies and sardines, tend to remain in the vicinity for much longer periods than in the past. The reasons for the latter phenomenon are not known but may also be related to the reduction in the use of explosives for fishing at the project sites.

Artificial reefs proved to be an excellent entry point into the community. New fish populations developed on the reefs within months and fishermen clearly saw the relationship between habitat and reef fish populations. Perhaps, the greatest lesson learned by the fishermen was that they are quite capable of solving their own fisheries-related problems. They even modified the module design to make construction and placement easier without losing effectiveness.

The value of mangrove forests as sources of food, wood products and shoreline protection was well known to most coastal residents. They were eager to reestablish mangroves despite the long wait for any potential harvest of wood products, but they lacked planting materials and were concerned about their security of tenure over the area. By mobilizing literally millions of seedlings and providing a 25-year lease agreement (Stewardship Contract) from the Department of Environment and Natural Resources over reforested areas, the project assisted clients in planting 620 ha over four years.

Coral reef management began in earnest in the third year as scheduled. The community was encouraged to protect all living coral and associated seagrass beds from damage. In addition, the establishment of sanctuaries encompassing 15-20% of the better remaining coral reef areas was recommended. Sanctuaries extend seaward from the shoreline to 300 m or more beyond the reef crest and 500-1,000 m along the coast. A frequency of one sanctuary per 5 km of suitable coastline was recommended.

Site-specific recommendations were developed with the community that made the final decision on sanctuary location and size. Local residents also developed and implemented their own management/protection plan. Within two years, 11 of the 37 planned marine sanctuaries were established by the fishing communities in the project sites.

The sanctuaries serve as protected breeding and nursery areas. Increased fish populations were evident within a matter of months in these sanctuaries. Within five years, the harvest of reef fish outside the sanctuaries is expected to increase significantly, perhaps doubling as it did at Sumilon Island (Alcala 1988).

Clients quite naturally wish to protect their own habitat management activities from illegal and destructive fishing activities. This attitude is reinforced with resource management education, training, and the rapid and very positive results from artificial reefs. In addition, a composite law enforcement team (involving local government and several law enforcement agencies) was organized in each municipality to aid in the control of illegal fishing activities. The result has been the near total elimination of illegal and destructive fishing methods within the project sites. This further aided habitat rehabilitation.

Harvest management

Early success in habitat management created situations in which communities began to exercise effective control over their coastal marine resources. They then began asking, "What can we do next?" or "How can we bring back the species that were once common but are now rare or entirely absent in our coastal waters?" The obvious answer was to expand the original scope of CVRP-I and to begin to add harvest management activities to habitat management. Harvest management activities generally address the problem of growth overfishing.

Small-scale sea ranching and farming present opportunities for coastal residents to learn the basics of harvest management literally in their backyards. Unfortunately, the available technologies are: (1) few in number (slipper oyster, green mussel and *Eucheuma* spp.); (2) restricted to limited habitats; and (3) already under trial at the few potentially suitable areas within the project sites. There are, however, a large number of marine organisms, particularly mollusks, with a high value and considerable potential for ranching and/or farming. A program to develop simple technologies for ranching and farming has been established under CVRP-I.

Some examples of progress to date in this area are:

1. Silliman University Marine Laboratory staff mastered the spawning and larval rearing of giant clams (using Australian

funds, not CVRP-I); the staff recruited fishermen ready to try growout methods in "backyard" seafarms. Established *barangay* within CVRP-I sites provided the best available sites; trials are now underway. The economic potential from a few hundred square meters of sea bottom is great.

2. A small but prolific and delicious mangrove snail was introduced in two-year-old mangrove plantations at one project site. Biologists and mangrove plantation owners are monitoring its population and harvest to determine the sustainable harvest level.
3. Ranching methods for three oyster species, which are valued more for their shells than their meat, are now ready for field trials. Methods vary from simple ranching to providing specialized substrates for wild spats to transplanting wild spats to specific substrates.
4. A 3-ha sanctuary has been established by a community for a particularly valuable mangrove clam to preserve its breeding population until a suitable harvest management method can be established to ensure its sustainable yield.

One problem facing the site staff in implementing habitat management has been the limited area available for artificial reef clusters and mangrove plantations. The number of interested participants almost always exceeds the space available. In an attempt to provide more opportunities, the project undertook experiments with FADs.

The *payao*, a bamboo raft anchored in deep water with palm fronds suspended beneath it, is an indigenous FAD. It has been used extensively by Filipino commercial fishermen who harvest with purse seines, and it has been implicated in the massive harvest of juvenile tuna in Philippine waters (Floyd and Pauly 1984) and in contributing to the documented overfishing of small pelagics (Dalzell et al. 1987).

FADs placed 3 km from the shore and harvested only by handline can provide a very low cost fishing opportunity for handline fishermen (US$0.25/day). Average harvests of 4 kg per day per fishermen give a gross income of $2.00, with a net profit of $1.75, which is very good by rural Philippine standards. Fifteen fishermen can be accommodated at each unit and their total daily harvest can approximate the daily growth of the school of fish aggregated below. If commercial fishermen and their purse seines can be kept away, this approach can provide profitable and sustainable fisheries for many artisanal fishermen. It can also address economic overfishing by reducing the fishing cost while assuring a modest but steady catch with a high profit margin.

Sea ranching/farming and FADs are but first steps in developing harvest management strategies for Philippine artisanal fishermen. Harvest management must eventually be extended to all aspects of capture fisheries.

PROBLEMS

As with any project of its size, CVRP-I has had its share of problems. Most have been or are being dealt with. But one issue remains most problematic--the lack of government laws and regulations on resource access. The new approaches to coastal resources management that have been initiated by CVRP-I and by others are not adequately regulated and/or protected by existing laws and regulations. A number of requests have been made but no new rules and regulations that deal with these situations have been issued over the past four years.

Fig. 1 illustrates the situation. One must move from the open-access free-for-all to a well-managed resource with controlled access. The argument seems to be: should there be a move toward communal management or private property rights or none at all. Indecision seems to mean no new regulations.

An examination of existing Philippine fisheries regulations (Table 1) reveals that there exists a mixture of communal and private property rights that affect portions of coastal marine resources. The remainder of the resources remains open access.

The proposed measures (Table 2) also represent a mixture of communal and private property rights which are very similar to the existing regulations. If implemented, the measures would lead to a better managed coastal resource. A flexible regulatory framework is needed within which communities can manage their coastal resources.

SUMMARY

The approach being developed under CVRP-I follows closely the four principles advocated by

Berkes (1987) in the management of common resources:

1. The solution of the common problems starts with the control of the access to the resource.
2. Increasing production from a common property resource depends on the conservation of the resource base.
3. The sustainable utilization of a resource is closely connected to the use of appropriate technology for the harvest of that resource.
4. Local level management improves prospects for the sustainable use of a common resource.

In applying these principles, the following are more specific recommendations:

1. Keep the approach people-centered because fishermen manage the resource.
2. To identify the real problems, assess the perceived problems carefully from the perspective of the fishermen and the various aspects of resource management too.
3. Tie in fisheries development with overall community development and include the local government, line agencies and NGOs in the process.
4. Use simple appropriate technologies for resource management and harvest.
5. Start small and demonstrate success before attempting to expand significantly.
6. Begin with management activities that can be carried out effectively within the project sites to gain the people's confidence before attempting to impose broader regulations.
7. Maintain flexibility so that learning can be used to improve the project as it progresses.
8. Good community organization is at least as important to success as good technologies.

The CVRP-I experience has shown that everyone who has been responsible for much of the coastal resource destruction in the Philippines can be transformed into an effective resource manager. Working directly with resource managers seems to be the key to success.

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Table 1. Some existing Philippine fisheries regulations in which TURFs = resource allocations.

Communal management	Private property rights
Municipal waters (5.6 km from shore)	Oyster/mussel farm permit
Trawl/purse seine ban (7 km from shore)	Seaweed farm permit
Minimum mesh size	Fish corral permit
Closed seasons	Fishpond lease agreement
Prohibit explosives/poisons	Fish cage/pen permit
Coral collection/export ban	Bangus fry concession
Muro-ami net ban	
Commercial *hulbot-hulbot* ban	
National fish sanctuary	

Table 2. Some proposed fisheries management measures based on the CVRP-I experience.

Communal management	Private property rights
Municipal marine sanctuary	Stewardship Contract (SC) over reforested mangrove areas
Mangrove forest management	SC over existing mangroves
Community-based contract	Sea ranching permit
Reforestation in mangroves	Other sea farming permits
Mollusk harvest regulations	Family artificial reef cluster
Communal artificial reef areas with AR-based sanctuaries	Fish aggregating device (FAD) permit

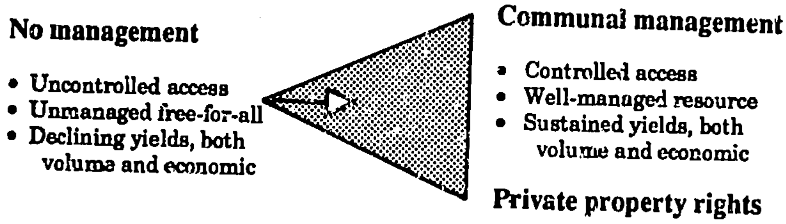

Fig. 1. A coastal resources management continuum.

Management of coastal tourism resources at Ban Don Bay, Surat Thani Province, Thailand

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ABSTRACT

This paper presents major findings and conclusions from a study of the coastal tourism resources management at Ban Don Bay in southern Thailand. Research was undertaken over a period of one year (1986 to 1987), and management recommendations were produced in 1988 as a contribution to an integrated coastal resources management plan for the bay.

Several island groups constitute Ban Don Bay's major tourist attractions. The islands' wealth of natural resources, particularly their white sand beaches, clean marine waters and coral reefs, have begun to draw a considerable number of tourists. Tourism volume at the bay's largest island has grown from less than 15,000 in 1980 to over 300,000 in 1987. This growth has generated both beneficial and deleterious environmental effects. On the positive side, the province has virtually halted blast fishing by the local people, previously a major cause of damage to coral reefs, because officials have recognized the potential economic benefits from tourism. Conversely, tourism development is also to blame for the degradation of the very resources on which the tourism industry relies: tourist facilities are encroaching on beaches; liquid and solid wastes are polluting beaches and marine waters; and anchors from tourist boats are damaging coral reefs. Another major concern is the limited distribution of tourism benefits to the local people.

Recommendations for the enhanced environmental management of Ban Don Bay's tourism resources emphasize strong local participation in decisionmaking and in implementing management programs. Priority is given to initiating: (1) a pilot project to integrate tourism development, resource conservation and community development; (2) an environmental task force to monitor tourism resources regularly; (3) coral conservation zones; (4) comprehensive solid/liquid waste treatment programs; (5) public awareness programs; and (6) a major study on the socioeconomic impact of tourism at the local and provincial levels.

INTRODUCTION

This paper presents major findings and recommendations for Ban Don Bay in Surat Thani Province (Fig. 1) (Dobias et al. 1988). Ban Don Bay's tourism industry is among Surat Thani Province's major income earners. The proper management of its resources in order to sustain high tourism volumes is, therefore, a major concern for the province. Both Thai and foreign tourists who were interviewed at Ban Don Bay's premier tourist island considered the natural environment of the island as its strongest asset and were of the opinion that environmental conservation should be the island's first priority.

The study focused on the bay's four major island groups--Samui, Phangan, Tao and Mu Ko Ang Thong Islands--which contain the bulk of coastal tourism resources (Fig. 2). The general objectives were to:

1. characterize existing conditions as these relate to the development of coastal tourism in the study area;
2. identify the major constraints to the sustained development of these resources within an intersectoral framework; and
3. develop, at the prefeasibility level, measures to mitigate these constraints to achieve the enhanced management of the coastal tourism resources.

The specific objectives were to:

1. promote appropriate development of coastal-based tourism resources, including socioeconomic concerns, within the Upper South project site; and
2. promote the increased coordination among development sectors for purposes of reducing coastal impacts that adversely affect tourism.

When formulating recommendations for the improved management of the coastal tourism resources at Ban Don Bay, particular attention was given to the likelihood that the local/central government would be capable of implementing the recommendations. Of equal concern was that the recommendations provide for the maximum participation of the local people in the management plan's implementation. Finally, emphasis was given to the suitability of the recommendations to be integrated with existing tourism management and development strategies (JICA 1985; TISTR 1985) as well as with those proposed by other subsectors involved in the Upper South project.

THE STUDY SITE

Major coastal tourism resources at Ban Don Bay include white sand beaches, coral reefs, nearshore waters, and island scenery. Each of these resources is present to some extent in all of the island groups (Figs. 1 and 2).

Samui Island

Samui Island, covering 247 km^2, is Surat Thani's premier tourist attraction and Thailand's third largest island. The island's white sand beaches and clean marine waters draw well over half of all the province's tourists each year (65% in 1984). Coral reefs, which are still virtually unexploited by tourism, are located near Samui and its satellite islands.

The flow of tourists to Samui Island began in the early to the mid-1970s (Cohen 1982), but it was during the past eight years that the volume of tourists surged upward (Fig. 3). In 1980, the island received only 14,868 visitors, and in 1981, it had 33,154. In 1982, the volume increased by about 400% over the previous year. By 1987, Thailand's promotional "Year of Tourism," the number of tourists jumped to 306,000 (Anon. 1988), which even exceeded government projections for 2001 (Fig. 4). Table 1 shows the projection of the tourist volume at Samui Island.

With more and more tourists arriving, beach development increased at a faster rate and became a threat to natural resources. The number of hotel and bungalow rooms at Samui Island increased by almost 100% between 1984 and 1987 (Fig. 5). The Tourism Authority of Thailand commissioned a tourism-carrying capacity study of Samui Island to try to quantify its capability to absorb further expected increases (TISTR 1988).

During the past few years, Samui Island has progressed from being a "Class C" (low-budget) resort to a "Class B" resort with higher quality accommodations. This trend is expected to continue. The tourist composition has correspondingly begun shifting from the "backpacker" type (though many low-budget tourists still come) to the more sophisticated class of visitors.

Phangan Island

Just 15 km north of Samui Island is an island two-thirds its size. Called Phangan Island, it has the same major tourist attractions as Samui Island. However, tourist traffic (23,000 persons in 1984) and hotel construction are way behind those of Samui Island. But just the same, growth has also accelerated during the past two years. The island appears to be at the early stages of a large-scale tourism development similar to that witnessed at Samui Island six or seven years ago. Lodging facilities grew from 20 units in 1986 to 50 units in mid-1987, with 556 rooms. By October 1987, 57 establishments were operating with 696 rooms.

The tourist composition is strikingly similar to that of Samui Island six or seven years ago. Most visitors can come on a low budget and spend one month or more on the island because food and accommodations are inexpensive.

The projection of the tourist volume at Phangan Island is also shown in Table 1.

Tao Island

Tao Island is a small (25 km^2) isolated island located 45 km northwest of Phangan Island. Much of its coast is rocky, but there is an attractive sandy beach in the west. A coral reef near Tao Island contains diverse coral and fish species that offer good tourism possibilities, although destruction from blast fishing and other illegal activities still occurs. Tao Island is visited by only the most adventurous tourists, who are not daunted by its isolation (3.5 hours from Phangan Island) and lack of comfortable facilities. There were about 1,000 visitors in 1984, but the current number is not known. At present, six thatched lodging units exist, with 47 rooms in all.

Mu Ko Ang Thong National Park

Mu Ko Ang Thong National Park, one of 14 marine parks in Thailand, was established in

1980. It covers 102 km^2 of which 84 km^2 are marine. Of the 40 islands that comprise the archipelago, 37 are within the park's boundary. Island scenery, coral reefs, an inland sea and wildlife are its important resources. The park's marine waters, in relation to the waters between the park, Phangan Island and Tao Island, are among the richest fisheries sites in the Gulf of Thailand. Because of this, the islands are heavily utilized by fishermen who have built shelters on several small, isolated beaches.

The number of park tourists was approximately 15,000 between 1983 and 1986, but increased to over 21,000 in 1987. Projection of the tourist volume at the park is shown in Table 1.

Most visitors to the island originate from Samui Island. They spend one to two hours on the main island of Wua Ta Lap, go to a portion of the sea partly encircled by one of the park's islands and then return to Samui Island. The park is not highly developed for tourism. It has only seven 2- or 3-room bungalows and a canteen for park personnel. But there has been pressure from the private sector for its increased development.

MAJOR ISSUES AND CONSTRAINTS

Management and administration

Tourism crosses a multitude of sectoral lines, and so the proper management of its resources must rely on the cooperation of several government agencies and the private sector. However, interagency coordination has been traditionally poor and is perhaps the major constraint to the successful implementation of tourism resources management recommendations. Moreover, existing provincial and local tourism organizations do not influence tourism development to any appreciable extent since the members of the provincial public/private sectors committee seldom come together, and when they do, cooperation tends to be limited to the meeting room. Once the meeting is finished, the different parties go their separate ways.

Tourism management efforts at Surat Thani continue to focus on promotional activities. But while promotion is both necessary and worthwhile, in the light of the tremendous surge in tourism volume, particularly at Samui Island, it no longer needs to receive as much emphasis as before. It would now appear more reasonable to give greater importance to the proper care of its tourism resources, especially considering that both Thai and foreign tourists have identified Samui Island's beautiful natural environment as its strongest asset and perceived resource conservation as its first priority (TISTR 1985).

Lack of tourism management and planning skills was cited by virtually all local leaders as an important constraint. Provincial officials and private individuals are responsible for proposing and especially for implementing tourism plans. Without this local base of knowledge and skill, implementation will be appreciably hindered. Moreover, local leaders should be involved in the planning process at its earliest stages. Unfortunately, they usually prefer to do the planning at the central offices in Bangkok.

Another major constraint is the rapid growth in the tourism volume and the corresponding increase in the development of tourism-related structures. It has reached such an extent that development has considerably outpaced national and local management capabilities.

Based on precedents at other Thai marine parks, rapid tourism development in the absence of an overall park management plan could lead to serious conflicts between resource use and conservation at Ban Don Bay's marine park. A case in point is Ko Samet National Park in eastern Thailand where conflicts between villagers and park officials in 1987 nearly forced the closure of the park. The villagers wished to expand their tourism service operation while park officials refused their expansion requests, citing the environmental damage already done by existing establishments.

Socioeconomics

Tourism development is often cited as a major tool in supporting local and regional socioeconomic growth. However, socioeconomic problems caused by the tourism boom in this province were a great concern of virtually all government and private individuals interviewed during this study. This concern centers around the belief that the majority of the islanders receive few direct benefits from tourism. The indirect benefits they do receive, such as improved transportation routes and public utilities, are thought to be offset by the rising cost of living spurred by tourism growth. Locals complain of young people turning their backs on traditional ways and embracing Western habits. Some even report a marked increase in drug abuse. The socioeconomic impact of tourism on the local people must be better understood so that effective management strategies can be developed.

Coral reefs

Damage to coral reefs has been a main resource conservation problem for many years. Such damage comes primarily from boat anchors and illegal fishing methods using dynamite and poison. Smothering of corals due to siltation has not been described but may be another important factor. Major constraints to effective coral protection are: (1) poor knowledge and skills of the local residents concerning management and protection options; (2) a paucity of boats, equipment and manpower in the Fisheries Department and the National Parks Division, which are responsible for coral protection; (3) the ability of blast fishermen to elude official boats on the open sea; and (4) inconsistency of laws that have proscribed coral collection since 1975 but still allow the trade of coral products.

Tourism has also catalyzed coral conservation efforts. Blast fishing at Samui and Phangan Islands has decreased markedly since 1983 when the Provincial Office publicly emphasized the need to stop such activities to conserve the coral reefs and tourism resources.

Waste disposal

Solid wastes are usually dumped on coconut plantations where they are left unburied and are washed away during heavy monsoon rains.

The treatment and discharge of wastewater from bungalows and hotels are also inadequate. Present national regulations require the preparation of an environmental impact assessment (EIA) (and presumably, the wastewater treatment) of hotels with only 80 or more rooms, but the regulations do not apply to dense groupings of small bungalows. If left unchecked, pollution from wastewater would discourage tourists, the vast majority of whom come to the islands for their pristine waters and beaches.

Public awareness

The province lacks a public awareness program that demonstrates to the local people and the tourism business operators why it is in their best interest to protect the resources and how they can participate in such efforts. Awareness programs are also needed for both domestic and foreign tourists, to let them know how they can help in the conservation efforts.

Water supply

Water supply is a problem on all the islands. Considerable sums of money will soon be spent to improve the water supply on Samui Island. This investment, however, must include provisions for the effective protection and possibly, revegetation of critical watersheds, marshlands and other primary water sources. Without such an action, investment costs may later be compounded considerably due to the deterioration of the water sources. Other related matters requiring serious attention are the proper management, storage and utilization/conservation of existing water supplies.

Visitor safety

Passenger boats that ply Ban Don Bay are ineffectively managed and supervised. Fines for safety violation are minimal. There is also no provision for the authorities to close ferry services or revoke the licenses of boats that violate the safety laws. An accident in 1987 that resulted in loss of lives due to improper boat operation and lack of safety measures, such as the provision of life jackets, highlights the need for strict regulations and controls of boats. Another major accident involving tourists could seriously damage tourism promotion efforts at the bay.

RECOMMENDED ACTIONS

Management and planning

An Environmental Task Force should be created to monitor the effects of tourism development on the resources. It would be responsible for reporting, monitoring and evaluating the results for the Royal Thai Government and recommending measures to mitigate or prevent damage to or enhance the use of tourism resources. The task force would include experts in the fields of marine resources and management, tourism development and management, socioeconomics, solid and liquid waste management and/or other relevant fields. It would be chaired by the governor of Surat Thani Province and would also include local public/private sector representatives. The governor and local officials would provide direction to the task force, ensuring that its work is not just academic but one that will truly address the local needs.

National parks and other protected areas should be required to prepare long-range management plans before any further major development is permitted. This is especially important at Mu Ko Ang Thong National Park in the light of proposals to expand its boundary and of pressures for its large-scale development for tourism purposes. Such plans will help anticipate and prevent or minimize damage to the resources and avoid problems that have occurred at other national parks. It is essential that these plans be accompanied by specific monitoring programs and that funding for park development be contingent on the progress of implementation.

A workshop on tourism management and planning would bring together the province's senior officials and nationally recognized experts from various fields or specializations in resources management. The workshop would be held annually and focus on practical issue/constraint identification and problem-solving. The value of such an approach is that it would provide a regular forum for local decisionmakers who are familiar with the problems related to tourism. This would enable them to explore problem resolution options with experts who can provide suggestions for potential solutions.

An "Upper South Coastal Tourism Committee" should be established to oversee and coordinate coastal tourism development in the Upper South Region (including Ban Don Bay) and to recommend actions and policies to the Cabinet. This would enhance both "bottom-up" and "top-down" communication in the decisionmaking process. Committee members would include department director-generals (or their equivalent) from all ministries that implement or oversee activities affecting tourism development, and senior local officials and private sector leaders. A key component of the committee would be the Environmental Task Force. The committee should be included as a major component in an overall "Upper South Coastal Resources Commission."

Socioeconomics

The dynamics of tourism's impact on the local communities in Thailand are poorly understood. A major research project should focus particularly on the socioeconomic impact on Ban Don Bay, covering especially the more developed coastal resort sites.

A demonstration project integrating appropriate tourism development, resource conservation and community development should be located at the less developed Phangan Island and center on a community-based organization (CBO). The CBO would be supported by a full-time field manager with expertise in community development. Further part-time support would come from outside agencies, providing onsite training and advice in the areas of community development, tourism and marine sciences, as required. The CBO members would elect an executive committee which will coordinate with the above agencies. Financial resources for CBO-related activities would come from a central fund, possibly in the form of a cooperative. Similar approaches have achieved impressive results in Thailand (Payapvipapong et al. 1988) and the Philippines (White and Savina 1987).

Specific goals and activities initiated through the CBO would be identified during joint consultations between CBO members and cooperating agencies, but programs might include:

1. Education and training in tourism development and management. This could include basic management techniques for bungalow operators, foreign languages and tour guide services; proper site development; and the creative use of low-cost, local construction materials.
2. Appropriate promotion and use of coral reefs. The CBO could promote the proper tourist use of coral reefs and, with the help of the experts, devise simple reef management strategies to enhance long-term village benefits.
3. Alternative economic activities. The CBO could provide an impetus for developing alternative income-generating activities such as souvenir/handicraft production, mariculture, etc.
4. Marine conservation education. A part of the CBO center could be devoted to education and awareness displays concerning marine resources conservation. Periodic education sessions could be given to the CBO members and the general public.

Increased support should be given to the Samui Island District Agriculture Office in its efforts to encourage the cultivation of new crops for sale to tourism businesses. Support should also be provided for the development of cottage industries (e.g., souvenir production, bee-keeping, etc.).

Coral reefs

A coral reef management strategy should be developed for the bay. It would rely primarily on the existing knowledge of the coral reef's status rather than on expensive and time-consuming field studies. It would include the establishment of coral conservation zones using existing legislation under the Fisheries Act of 1947.

The local people would necessarily play a key role in the implementation of the coral reef management strategy. The Upper South team has already allocated funds successfully to assist the local people in managing the reefs at Taen Island. The village headman of this island, using his strong influence on the people in the region, has built a base of support for protecting coral reefs that rim the island. The Office of the National Environment Board and the University of Rhode Island have recognized these local efforts to protect a critical marine resource and have promised support. This support will take the form of financial and technical assistance to a locally based conservation club now in the process of being formed by the village headman. Thus, in an area where government has limited manpower and influence, the local people have demonstrated how they can become protectors of ecological and tourism resources.

Legislation should also prohibit the local sale of corals and coral products. Cottage handicraft industries promoted by the government should not include those using corals as raw materials. It has been shown that in situ, coral has high actual/potential economic benefits in the form of tourism and fisheries production, and that healthy coral reefs are becoming increasingly scarce due to various destructive activities, including the collection of corals for sale.

Any construction activity on the islands in the vicinity of coral conservation zones that would result in a significant silt runoff or discharge of inadequately treated effluents into these zones should be strictly prohibited by a Cabinet decree. This would include the mandatory use of the EIA process.

Beaches and marine waters

Zoning plans should be prepared for all major islands/beaches in Surat Thani Province. Emphasis should be given to the monitoring of the zoning plans by the provincial and/or district officials who would report annually to the Interior Ministry. Necessary modifications should also be made based on the annual assessments. The strict enforcement of existing laws prohibiting any development within 10 m of beaches should begin immediately. This should serve as an interim measure while zoning plans are being prepared.

Comprehensive waste disposal programs should be developed, approved and implemented at all major coastal tourism areas in Ban Don Bay, beginning with Samui Island and followed by Phangan Island, Mu Ko Ang Thong National Park, the mainland coast and Tao Island.

Forest and water conservation

Recommendations for forest and water conservation include:

1. classification of watersheds and swamplands that determines priority areas and clearly delineates these on a map;
2. determination of existing land use and forest cover in the classified areas, including descriptions of threats to watersheds, springs and marshes of high value as water sources;
3. formulation of plans for maintenance and/or rehabilitation of priority water sources as determined by the classification scheme; and
4. rehabilitation of critical watersheds that have experienced widespread encroachment. This should include programs for community forestry activities that could provide local incentives for maintaining forest cover and also compensate villagers for the loss of income from existing activities in these watersheds (Ali and Dobias 1985).

In addition, all future water development projects should be required to include protection and monitoring programs for water sources at the earliest stages of project development.

Public awareness programs

Various interest groups can be invited to participate in public awareness programs. Such groups will fall under these categories: local residents, tourism service operators and tourists.

The public awareness program would operate from a "Tourism Resources Conservation Center" staffed by two full-time administrative employees, a small maintenance staff and several part-time volunteer assistants. The center would include facilities for slide shows, movies and informative displays. It would serve as the base for an extension program and as a production and maintenance site for information media.

Boating safety

The Harbor Department should detail two officials at Surat Thani to inspect passenger boats and ensure that they adhere to safety regulations. The old boating safety law should be amended to include increased fines and penalties for violations, and mandatory inspection and official approval of all passenger vessels should be required before licenses are issued.

Evaluation and monitoring programs

Even the least ambitious management plans will likely fall short of their goals if evaluation and monitoring programs are not included as integral components. Evaluation and monitoring are too often considered dispensable by implementing agencies. Yet without such programs, it is impossible to measure the success of management strategies and to devise new strategies to meet changing conditions. Therefore, each of the recommendations presented for tourism management in the Upper South subregion contains prescriptions for evaluating and monitoring activities. Much of this would be undertaken by the proposed Environmental Task Force, but several government agencies would also be given some responsibility.

SUMMARY AND CONCLUSION

The growth of tourism development at Ban Don Bay has proved to be a double-edged sword. Tourism has justified the protection of coral reefs from grossly destructive blast fishing, but it has also contributed to the degradation of beaches and marine waters. The provincial economy has been invigorated by tourism growth, but significant economic benefits apparently have failed to reach a broad segment of the local population. Tourism has introduced rural Thais to people of many nationalities, but it has also occasionally led to cultural problems.

The environmental management recommendations (Table 2) presented in this paper attempt to define how tourism can be used to justify natural resources protection while offering practical steps to mitigate environmental damage caused by tourism growth. A key to the improved management of tourism resources is the provision for a strong local participation in management planning and implementation. The people of Surat Thani Province have demonstrated that they can play a major role. Some outstanding examples are the Taen Island village headman who used his influence to protect the island's coral reefs, and the monk at Phangan Island who used Buddhist teachings to discourage the deforestation of an important watershed. Support for these and other initiatives by the Upper South Project can help Surat Thani Province become a model for responsible coastal tourism development in Thailand.

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Table 1. Projections of tourist volumes at Samui Island, Phangan Island and Mu Ko Ang Thong National Park.

Year	Samui Island	Phangan Island	Mu Ko Ang Thong National Park
1984	142,317	22,910	54,056[a]
1986	165,034	26,258	58,160
1991	188,809	31,246	63,119
1996	216,930	36,901	77,618
2001	246,183	42,592	88,352

[a]There is a discrepancy between this base figure and that recorded by the park (i.e., 54,056 compared to 14,906).
Source: TISTR 1985.

Table 2. Summary of the recommendations on the coastal tourism resources management of Ban Don Bay, grouped according to category and priority.

	Category	Recommendations	Priority[a]
A.	Management and planning	Establish an Environmental Task Force to monitor the plan's implementation and the impact of resource use.	1
		Pilot project at Phangan island.	2
		Prepare and implement the protected area's master plans.	2
		Tourism management and planning workshop.	2
		Establish Upper South Coastal Tourism Committee.	2
B.	Socioeconomics	Pilot project at Phangan Island[b].	-
		Major research project on the socioeconomic impact of coastal tourism.	1
		Support Samui Island District's efforts in "agriculture for tourism" progress.	3
C.	Coral reefs	Establish coral conservation zones, supply mooring buoys and register coral tour boat operators.	1
		Revise legislation and require EIAs.	1
		Extend Mu Ko Ang Thong National Park's boundary.	3
D.	Beaches and nearshore waters	Develop, approve and implement comprehensive solid and liquid waste disposal programs at major coastal tourism sites.	1
		Strengthen regulations governing the discharge of wastewater from hotels and bungalows.	2
		Use simple zoning for all major provincial beaches and adjacent areas and strictly enforce existing legislations.	2
E.	Forests and water conservation	Require water development projects to incorporate watershed and swampland conservation measures at the project's earliest stages.	1
		Develop comprehensive watershed/swampland conservation and/or reforestation plans and projects at important sites.	2
F.	Public awareness	Develop and implement a public awareness program for important tourism resources.	1
		Develop a mangrove interpretation program.	3
G.	Communication	Post Harbor Department officers at Surat Thani.	1
		Strengthen boating safety regulations.	2

[a]Priority 1: Of highest priority and should be implemented at once.
Priority 2: High priority by implementation could be delayed to later years.
Priority 3: Important but of less urgency than (1) and (2).
[b]This pilot project has direct implications on the strengthening of the local participation in tourism resources management and on increasing the local benefits derived from tourism; thus, it is listed twice.

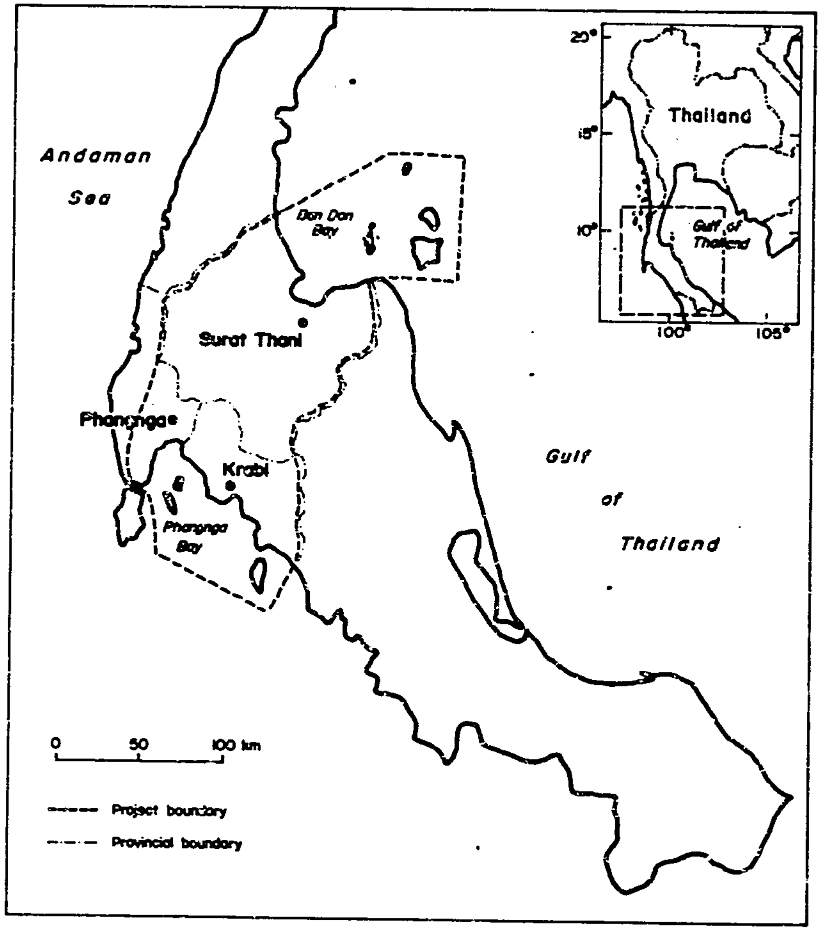

Fig. 1. Upper South project boundary.

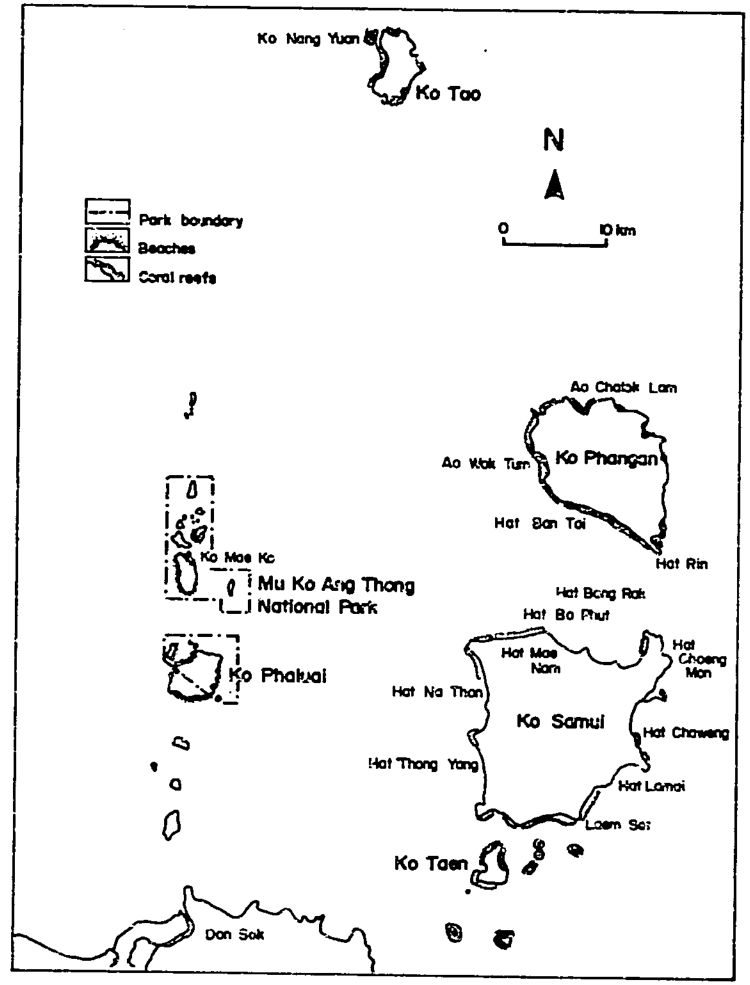

Fig. 2. Major tourist areas at Ban Don Bay.

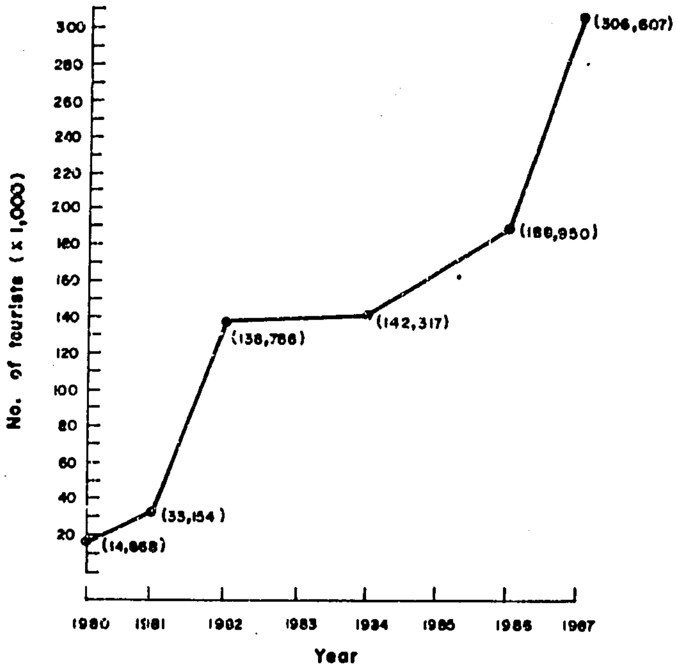

Fig. 3. Tourist volume at Samui Island from 1980 to 1987.

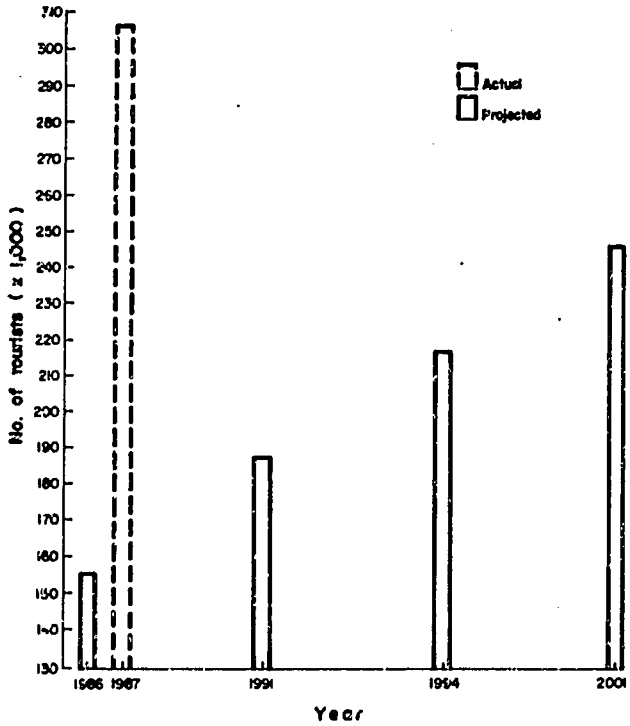

Fig. 4. Actual and projected tourist volumes at Samui Island.

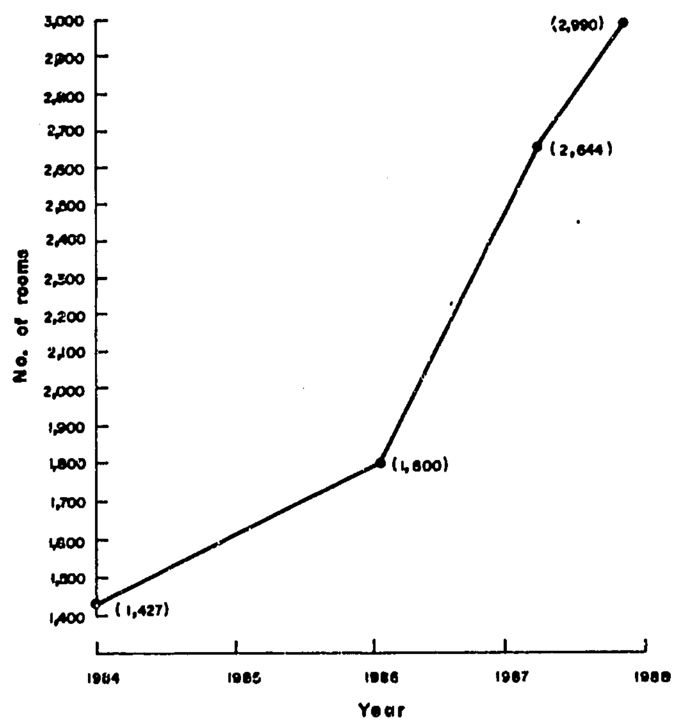

Fig. 5. Increase in the number of rooms for tourists at Samui Island from 1984 to October 1987.

Coral reef management plan for the islands of Ban Don Bay, Thailand

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BUNPAPONG, S. and A. NGERNVIJIT. 1991. Coral reef management plan for the islands of Ban Don Bay, Thailand, p. 405-412. *In* L.M. Chou, T.-E. Chua, H.W. Khoo, P.E. Lim, J.N. Paw, G.T. Silvestre, M.J. Valencia, A.T. White and P.K. Wong (eds.) Towards an integrated management of tropical coastal resources. ICLARM Conference Proceedings 22, 455 p. National University of Singapore, Singapore; National Science and Technology Board, Singapore; and International Center for Living Aquatic Resources Management, Philippines.

ABSTRACT

Coral reefs are an example of a valuable coastal resource that deserves special management attention. At Ban Don Bay, coral reefs have potential for lucrative tourism earnings and as essential habitats for marine organisms.

Most sources of coral damage at Ban Don Bay can be linked to economic uses such as destructive fishing, sale of coral, and siltation caused by bungalow and hotel construction. Major constraints to improve coral protection are: (1) poor local knowledge of management and protection options; (2) a lack of local management authority over coral resources; (3) poor interagency coordination; (4) inadequate laws; and (5) a paucity of equipment and manpower to patrol the reefs.

Programs offering local incentives for coral conservation have been formulated and are discussed. Coral conservation zones are also expected to be declared for Ban Don Bay's most outstanding coral reefs, with only nonconsumptive uses allowed. Outdated legislation will likewise be amended and institutional arrangements improved to implement the management plan.

INTRODUCTION

Ban Don Bay, Surat Thani Province, in the Gulf of Thailand has three major island groups: Ko (meaning "island") Samui, the largest (250 km^2); Ko Phangan (170 km^2), approximately 15 km north of Ko Samui; and Mu Ko Ang Thong, an archipelago of 40 small islands; it is a national park. Each of these island groups contains coral resources of value both to the region's fishing and burgeoning tourism industries.

A management plan was prepared for the coral reefs of Ban Don Bay as one of five issue-oriented approaches for managing its coastal resources. The planning process has been a collaborative effort among three concurrent coastal resources projects handled by Thailand's Office of the National Environmental Board (ONEB). The general outline, rationale and objectives for coral reef management in the bay were presented in 'Recreation and tourism subsector final report" (Dobias et al. 1988) under the ASEAN/US Coastal Resources Management Project. Technical information on the coral reefs and reef zoning was provided through a study supported by the Association of Southeast Asian Nations (ASEAN)/Australia Cooperative Programme on Marine Sciences. Finally, the plan's implementation will be supported in part by the URI/USAID Coastal Resources Management Project. Actual plan formulation was done by a Working Group on Coral Reef Management Planning, which developed a consensus among central and local agencies whose activities/jurisdictions affected coral reef use and management at Ban Don Bay.

CORAL REEF STATUS

Although not luxuriant by international standards, the coral reefs of Ban Don Bay are among the best in the Gulf of Thailand and represent a valuable tourism resource in addition to their ecological functions. In the bay, tourism increased from US$15,000 in 1980 to over US$300,000 by 1987 and is now one of Surat Thani Province's major income earners. This nature-based tourism relies on the diversity and quality of the islands' environment of which coral reefs are an integral part (Dobias and White 1988).

Fig. 1 shows the locations and relative qualities of the area's reefs as categorized by a 1984 study (TISTR 1985). Ko Samui, having undergone the most advanced tourism development and also being the most accessible island, contains few undisturbed reefs. Only the reef at Ko Mat Lang near the northern end of Hat Chaweng is still in good condition. Comparatively healthy reefs capable of attracting tourists and maintaining the integrity of the marine environment are also located along Ko Samui's satellite islands to the south (Sudara 1988).

Coral reefs at Ko Phangan have undergone considerable damage in the past but remain among the most attractive in Ban Don Bay. Two reef areas, which possess high tourism potential, are located along the island's south coast that stretches for around 10 km, and a smaller reef in the northwest (Sudara 1988).

Ko Tao, located 45 km northwest of Ko Phangan, has a beautiful reef containing diverse coral and fish species that offers excellent tourism potential even though destructive activities continue there (Dobias et al. 1988).

Mu Ko Ang Thong National Park is the only marine park in the bay. The park harbors rich fisheries and is thus used heavily by fishermen who inhabit several of its islands. Coral reefs have been seriously damaged there, with layers of silt atop dead massive coral. Nonetheless, the park contains attractive reefs at Ko Sam, Ko Wua Khan Thang and Ko Nai Phut (TISTR 1985).

PROBLEMS AND ISSUES

Coral reef degradation has been a major resource conservation issue in the bay for several years. The problem appears to be most serious at Ko Tao, where reef blasting is still being done by fishermen from outside of the area. They are supported by a small but influential segment of the island's inhabitants who receive part of the catch as a reward for not reporting this activity to the officials.

The frequency of blast fishing at Ko Samui and Ko Phangan has decreased since 1983, when the provincial office publicly emphasized the need to stop such activities. Unfortunately, the use of poison to capture fish has become increasingly frequent, especially at Ko Phangan. When used regularly, poison can be as lethal to coral and its associated fauna as dynamiting (White 1987). Another destructive fishing method recently introduced is to encircle a broad area of corals with small mesh nets and then to pound on the coral rock to frighten the fish, which flee from the coral into the nets (Sudara 1988).

Illegal fishing for club mackerel by trawlers is still common throughout the Mu Ko Ang Thong-Ko Samui-Ko Phangan area. Sometimes these trawlers encroach into reef areas and break corals with their nets. The enforcement of existing fisheries management regulations is not effective, in part because of a paucity of manpower, equipment and budget at the Ko Samui District Fisheries Office (DOF 1983).

Another major threat that is growing in tandem with the tourism boom is siltation and wastewater pollution from beach development. Bungalow and hotel construction at Ko Samui, for example, increased by over 100% during the period 1984-1987 when the number of rooms went from 1,400 to 3,000. There are few regulatory controls to prevent or mitigate such damage to coral reefs.

Damage by boat anchors is still relatively minor, as only 2% (around 8,500) of all Ko Samui tourists visit coral reefs. However, with the expected increase in coral reef tourism, there will be a corresponding increase in reef degradation due to boat anchors if preventive measures are not taken.

EXISTING MANAGEMENT AND CONSTRAINTS

The existing management of coral reefs entails mainly provincial sanctions against dynamite fishing and national regulations against coral collection and trawling. At the national level, coral reefs are protected by two statutes: the Fisheries Law of 1947 and the National Park Act of 1961. The former governs marine fisheries and the conservation of selected marine species. It prohibits the collection and export of corals, the use of poison and explosives for fishing and trawling and push-net operations within 3,000 m from the shore (URI/USAID 1988). The National Park Act, on the other hand, prohibits visitors from littering and collecting corals.

Reef management at the provincial level depends primarily on the provincial policy handed down by the governor. In Surat Thani, the governor issued a policy in 1983 prohibiting reef destruction by hotels after a major resort dug out the reef along its beach front to improve the swimming area. The governor was also instrumental in gaining local cooperation to lessen practices that are destructive to coral, particularly dynamite fishing.

Despite these regulations and policies, coral reef degradation continues at Ban Don Bay because of the following:

1. Public appreciation of coastal resources has been generally low. Little effort has been made to raise public awareness through education programs that demonstrate the value of healthy coral reefs to tourist businesses and to local inhabitants.
2. There is poor knowledge among local people, government officers and tourist operators concerning workable management options that can be carried out at the local level.
3. Government agencies directly responsible for coral reef protection lack sufficient boats, equipment and manpower to patrol the reefs effectively.
4. Poor coordination among government agencies, both at the local and national levels, prohibits effective action to conserve coral reef resources; often, those who make the plans and those who are expected to implement them do not interact, leading to confusion and, in many cases, apathy on the part of the local implementors

An encouraging development in the region has been the formation of a Nature and Environment Conservation Club (NECC) at Ko Samui. The NECC is spearheaded by the village headman of Ko Taen (a small island just south of Ko Samui) who has played a pioneering role in protecting the coral reefs around his island for well over a decade. NECC members include local leaders, community members and bungalow owners who hope to protect the islands' natural environment, maintain the native culture and traditions and promote public awareness on conservation. Formation of the club was motivated primarily by concern arising from the socioeconomic problems precipitated by the tourism boom.

CORAL REEF MANAGEMENT PLAN

A Regional Workshop on Coastal Resources Management (CRM) Strategies and Planning for Ban Don Bay was organized by ONEB in mid-1987 and was attended by over 100 participants, including representatives from central, provincial and local government agencies as well as the private sector. Based on the workshop's outputs and related ONEB efforts to reach a consensus among local agencies and residents, action plans were formulated to deal with CRM issues and problems. Among these were recommendations to alleviate coral damage by offering alternative economic incentives for coral conservation. Table 1 summarizes the issues and recommended strategies and actions for improved coral conservation at Ban Don Bay (Dobias and White 1988; Lemay and Chansang 1988).

The overall management plan has the following objectives: (1) to formulate zoning plans and strategies for coral conservation; (2) to prioritize recommendations and identify those that can be implemented immediately; (3) to establish a cooperative framework between implementing agencies and local communities; (4) to provide a foundation for public support and involvement; and (5) to promote public awareness programs for coral conservation.

To enhance opportunities for the plan's implementation, two planning approaches were considered essential. The first was to use a "bottom-up" approach, leading to mechanisms for the local control of coral management programs. In line with this approach, it was realized from the beginning that a significant level of implementation could occur only when the programs received the support and active involvement of the local people. Second, coral management programs emphasized that sustainable uses should be encouraged in the context of reasonable control rather than on total prohibitions (which are often not enforceable), thus, allowing the local people to continue to reap benefits from coral reef resources.

Management programs (Table 2) were categorized along issue-oriented lines: (1) recreation and tourism; (2) fisheries management; (3) water quality maintenance; and (4) public awareness and education.

MANAGEMENT PROGRAMS

Most of the management programs outlined will be implemented through local government agencies and nongovernmental organizations (NGOs) with advice and assistance from central government offices and individual experts. In this way, a foundation for local management capabilities will be established and fostered.

Recreation and tourism

These programs consolidate the recommendations made earlier by the ASEAN/Australia Cooperative Programme on Marine Sciences (Sudara 1988) and those by Dobias et al. (1988). Fig. 2 shows the proposed zoning for specific sites that have high tourism potential. Zoning will allow for three levels of use: (1) a sanctuary zone using regulations under the National Park Act and the Fisheries Law that prohibit fishing, collecting or any destructive uses; (2) a conservation zone where tourism activities are allowed under certain restrictions and certain fishing activities are prohibited; and (3) a general use zone where guidelines for habitat protection apply without specific provisions.

1. Demonstration buoys at Ko Taen. A broad outline of activities for placing mooring buoys at Ko Taen was prepared in 1988 following discussions with local leaders and ONEB/URI experts (Dobias and Chettamart 1987). This program will use buoys to demarcate the outer reef at Ko Taen and provide mooring buoys for tourist boats as an alternative to throwing their anchors onto the reef (Fig. 3). Ko Taen was selected for this demonstration project because the likelihood of success is high given the strong local support. Once boat operators become familiar with the use of, and need for, such buoys, the program will be extended to other important reef areas used by tourists.
2. Park zoning and boundary extension to Ko Tao. Multiple-use zoning for marine parks has met with a fair degree of success in many parts of the world (ESCAP 1985; MacKinnon et al. 1986; White 1988). The National Parks Division is now proceeding with the extension of the Mu Ko Ang Thong National Park boundary to include Ko Tao and is also preparing a preliminary management plan for the park. A zoning scheme, to include all three zoning types mentioned above, will be incorporated into the park's plan to allow for better control of multiple uses within the park, particularly of tourism vis-à-vis coral reefs.
3. Sanctuaries at Ko Taen and Ko Phangan. Small areas of special importance will be established as sanctuaries to maintain the integrity of coral reef ecosystems. Only research studies, free of tourism, fishing, collecting and other such activities, will be allowed in these areas.
4. Conservation zones at Ko Samui and Ko Phangan. Several degraded coral reefs here can recover if tourism and fishing are properly regulated. These reefs will be given conservation zone status. Mooring buoys will be placed near them for use by tourist and fishing boats, following the buoy demonstration project at Ko Taen.

Fisheries management

The fisheries management programs aim to: (1) limit and prevent reef damage caused by blasting and fishing gear; (2) avoid damage caused by the collection of coral, aquarium fish and shells; and (3) improve fisheries management regulations and policies.

1. Marine sanctuary at Ko Taen. A marine sanctuary will be declared at key reef areas as mandated by the Fisheries Act of 1947. This act allows for the establishment of zones where all types of fishing are prohibited but where tourism can continue to operate.
2. Fisheries management scheme for reef fishes. This program aims to maintain artisanal fishing as a source of income, to preserve traditional culture and to maintain underwater resources for diving and snorkeling. The scheme will also provide size limits, catch quotas and seasonal closures for endangered commercial species such as lobster.
3. Upgrading of law enforcement on illegal fishing. This program will seek to revise existing laws by including habitat protection objectives. It will also organize cooperative patrol and enforcement activities, identify and fill gaps in the regulatory framework and develop mechanisms which will provide better cooperation among responsible agencies.

Water quality maintenance

1. Mandatory EIAs for beach resort construction. This will include the strengthening of existing laws regarding EIA requirements for hotel/ bungalow con-

struction and prohibiting construction activities adjacent to sanctuary areas.

2. Guidelines for mitigating the siltation of reefs. Broad guidelines for minimizing coral reef degradation from siltation will be drafted. ONEB will then be responsible for producing the final guidelines (possibly in the form of EIA requirements) to be submitted for official action.
3. Water quality monitoring. This will be a regular management activity. Other parameters to be monitored will be live coral cover, reef fish density, anchor damage and the presence of rare or uncommon species.

Public awareness and education

1. Information and visitor service center. A permanent center will be constructed on Ko Samui to produce and distribute public awareness materials on coral reefs and other coastal resources. It will also contain an extension staff that will visit villages and give presentations to government and private sectors.
2. Exhibition and media campaign. A coral exhibition will bring together tourism operators, boat owners and local leaders, perhaps under the auspices of the NECC and the Samui Tourism Business Association. The exhibition will alert the participants on the various programs being undertaken, the rationale for doing them and how the participants can cooperate in coral conservation efforts. Coral reef interpretation displays will be set up at strategic points, with each display focused at a particular interest group. Information materials will be produced and information, disseminated through the print and broadcast media.
3. Training tour guides and operators. A formal training program tailored for Ko Samui's prospective guides, tour agents and national park staff will be offered.
4. School curriculum. The curriculum will cover all major aspects of marine ecology and conservation, including coral reefs. It will be developed for all educational levels. A teacher's manual will also be produced for schools in the province.

CONCLUSION

The management planning process has successfully initiated consensus among the local/central government and the private sector on how to deal with the problem of coral destruction and how to maximize the socioeconomic potentials of coral reefs. Initial emphasis will be given to projects that will demonstrate the feasibility of the strategy and how local people can play a larger role in management/conservation activities. Local involvement, cooperation among various government agencies and a focus on clearly defined issues are key features of the strategy.

ACKNOWLEDGEMENTS

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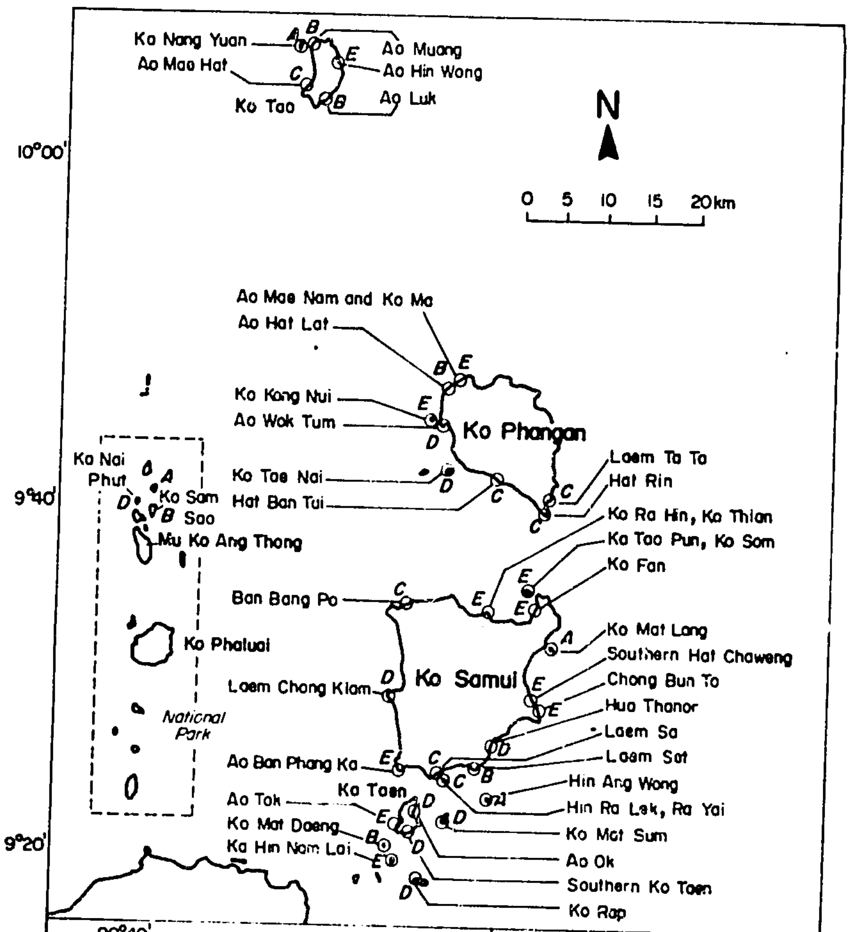
Table 1. Summary of coral degradation issues, strategies and actions.

Issues	Strategies	Actions
Dynamite fishing	Public education and awareness	Produce and distribute information materials; organize a coral exhibition at Samui; train fishermen and boat and bungalow operators; and initiate a conservation program in schools.
	Fisheries management	Declare a fish sanctuary at Ko Taen and provide mooring buoys there.
	Park management	Extend marine park's boundary to include Ko Tao.
	Legislation and local support	Revise the Fishery Law to increase penalties for blast fishing and coordinate with local interest groups to patrol the reefs.
Coral destruction by fishing and poisoning	Public education and awareness	Produce and distribute information materials; alert locals and business operators of economic impact; campaign to emphasize the importance of corals.
	Legislation	Establish size, catch and season limits; issue certificates for aquarium fish operations.
Coral destruction by boat anchors, trampling and collecting	Public education and awareness	Alert local people and business operators of economic impact.
	Tourism and park management	Designate coral and buffer zones; zone critical areas outside the park; establish a scientific research zone in two of the sites; create conservation zones at Ko Phangan and Ko Samui; organize a community-based management scheme for the conservation zones.
	Legislation	Revise the law to prohibit the sale of all coral products.
Siltation and pollution	Legislation and enforcement	Declare and enforce the City Plan Law in specific areas; enforce EIA regulations for waste management and the Sanitation Law of 1941; prohibit construction work adjacent to coral sanctuaries.
	Administration	Give a high priority to environmental protection and management in government agencies responsible for tourism-related activities; improve cooperation and communication between government agencies and local authorities.

Table 2. Summary of priority management programs.

Program	Recommended projects	Priority
Recreation and tourism	• Demonstration of mooring buoys at Ko Taen	1
	• Park zoning and boundary extension to Ko Tao	1
	• Sanctuaries at Ko Taen and Ko Phangan	2
	• Conservation zones at Ko Samui and Ko Phangan	2
	• Multiple-use zoning of Mu Ko Ang Thong National Park	2
Fisheries management	• Marine sanctuary at Ko Taen	1
	• Management scheme for reef fish	2
	• Upgrading of law enforcement on illegal fishing	2
Water quality maintenance	• Mandatory EIAs for beach resort construction	1
	• Guidelines for mitigating the siltation of reefs	2
	• Water quality monitoring	2
Public awareness and education	• Information and visitor service center	1
	• Exhibition and media campaign	1
	• Training tour guides and operators	2
	• School curriculum on marine ecology and conservation	2



Coral quality classification:

A - Undisturbed or little disturbed reef supporting a rich fauna.

B - Have suffered some disturbance but are generally healthy.

C - Have suffered considerable disturbance although some areas remain relatively undamaged.

D - Have been badly damaged and hold little or no attraction for tourism.

E - Generally dead corals.

Fig. 1. Locations and relative qualities of coral reefs in Ban Don Bay (TIS 1985).

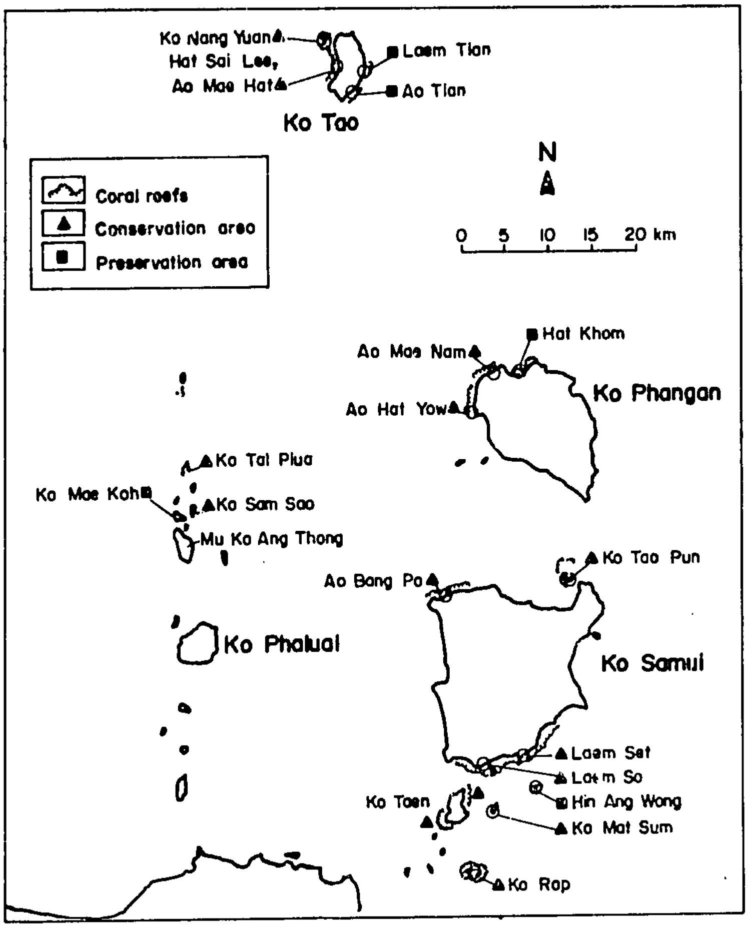


Fig. 2. Proposed coral reef management zones (Sudara 1988).

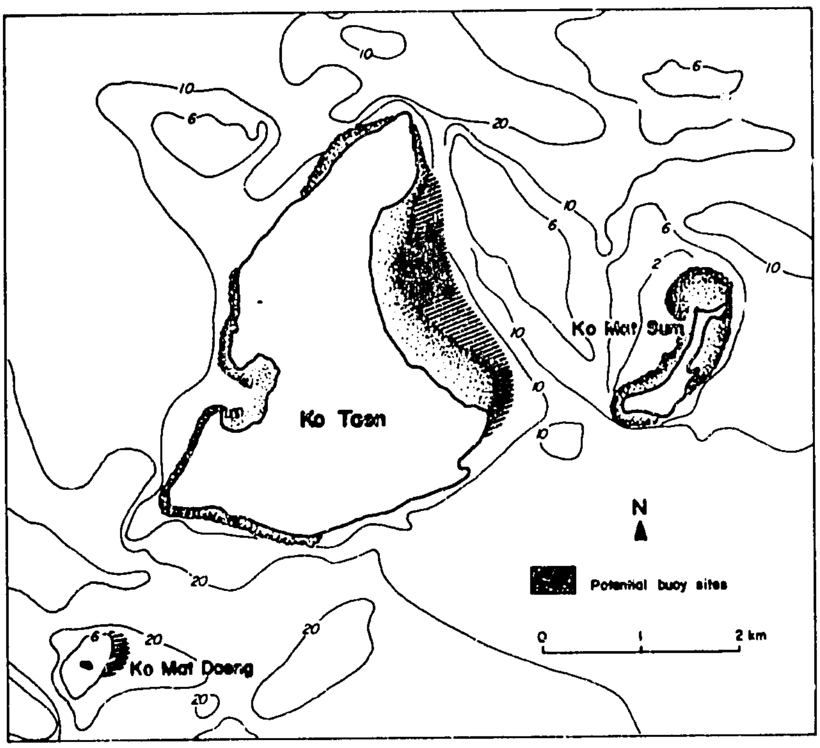


Fig. 3. Proposed sites of mooring buoys for the coral reefs at Ko Taen.

Assessment and management of marine resources in Tarutao National Park, Thailand

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ABSTRACT

The condition of marine resources in Tarutao National Park was investigated and their major management problems were identified under the Office of the National Environment Board/ University of Rhode Island/United States Agency for International Development Coastal Resources Management Project (ONEB/URI/USAID CRMP).

In general, marine resources and habitats in the park have been degraded due to various improper uses. Several coral reefs have been destroyed or seriously harmed by blasting, anchor damage, tourism, storm damage and crown-of-thorns' infestations. Coastal waters adjacent to areas of intensive use have become polluted due to the release of untreated waste effluents. Stock depletion of marine species has resulted from overharvesting and illegal trawling. Because of these, management programs, which emphasize park and public cooperation in the protection of marine resources, are recommended.

INTRODUCTION

Thailand has 14 marine national parks covering a total area of 4,726 km². Essential ecosystems and resources found in these parks support major economic activities such as tourism and fisheries. One of them is the Tarutao National Park, which is located in the lower Andaman Sea, west of Satun Province near the Malaysian border. It consists of two main island groups, the Tarutao Islands and Adang-Rawi Islands, and covers a total area of about 1,490 km², of which 1,260 km² are marine. The park has forests, beaches, aquatic fauna and coral reefs, which play important roles in the local and regional economies and are major tourist attractions. Because of its valuable resources, Tarutao National Park has been included in the ASEAN Heritage Parks network.

However, because of the increasing stress exerted by various user groups, the resources, especially marine, within Tarutao National Park have been degraded. In response to this problem, a Marine Parks Planning and Management Task Force under the Thailand Coastal Resources Management Project (CRMP) has been set up to develop sound management strategies for the conservation and sustainable use of resources within marine parks, especially in Tarutao National Park.

The CRMP study has identified major issues associated with marine resources conservation in the park and has developed preliminary measures for the improved management of these resources so that they can better support sustainable tourism and local uses. The preliminary recommendations emphasize that management programs should help conserve valuable marine resources, generate benefits for local communities and involve the public in park management.

METHODOLOGY

A survey of the marine environments and resources in Tarutao National Park was undertaken in April 1988 to determine existing conditions and associated management issues. This included the physicochemical properties of the coastal waters, such as transparency, salinity, pH, suspended solids, total alkalinity, dissolved oxygen (DO) and biological oxygen demand (BOD_5), which were measured and analyzed using the methods described by the American Public Health Association (APHA 1985).

The egg and larvae of marine species were also collected from various coastal areas using a plankton net of the 100-μ mesh size. Samples were analyzed for abundance and composition at Kasetsart University in Bangkok.

Observations of coral reefs were made by diving and snorkeling, and reef conditions were recorded by underwater photography.

EXISTING CONDITIONS OF MARINE AREAS

Coral reefs

There are virtually no reef communities remaining around Tarutao Island that have not been degraded to some extent by human use and/or natural calamities. Most of the reefs are found in the area of the Adang-Rawi Islands, but their conditions varied considerably (Fig. 1). The reefs were classified as:

1. Intensively damaged, with dead corals found over extensive areas due to crown-of-thorns'. (*Acanthaster planci*) infestations, reef blasting, and anchor and storm damage. This was observed in the southern coasts of Adang and Rawi Islands and in the northeastern coast of Ri-Pe Island.
2. Seriously damaged but still ecologically valuable as fish habitats and could recover if given adequate protection. Such reefs are located in the eastern and western coasts of Adang Island and in the northern coast of Rawi Island, formerly destroyed by reef blasting but with remnants of massive structures still useful as shelters or spawning grounds for reef fish populations where the regeneration of new corals was observed within the reef communities.
3. In fair condition with damage limited to a few localized areas. These remain valuable for recreational use and are composed of various coral species, of which at least 50% are undamaged. These reefs are dispersed as small reef communities surrounding Ka Ta Island, in the northern coast of Hin-Ngam Island and in the northern and western coasts of Ri-Pe Island. Nevertheless, these reefs are still subject to anchor damage, crown-of-thorns' infestations and local fisheries activities (e.g., creating channels in the reefs to allow the passage of fishing boats).
4. In pristine condition. This includes only one small community of soft corals in the deep waters between Adang and Hin-Ngam Islands.

Water quality

As shown in Table 1, physicochemical properties of coastal waters around the Adang-Rawi Islands are suitable for supporting aquatic life and recreational activities. The coastal waters around Tarutao Island, in contrast, have relatively high suspended solids with low light transparency, especially at the Talo-U-Dang Bay. Furthermore, the biochemical oxygen demand (BOD_5) value observed in the bay (4.6 mg/l) is higher than in the open sea. This condition might be a natural occurrence generated by the comparatively stagnant water characteristics that bring about the intensive growth of phytoplankton (Khokiattiwong et al. 1986).

The water quality at the Pante-Malaca Bay in Tarutao Island, which receives untreated wastewater from tourist lodging areas, has a tendency to become polluted. It was observed that the BOD_5 value of the water in the bay is substantially higher than in other areas and that it has a relatively low DO concentration. The trend toward the increasing number of tourists in the park, from 12,202 in 1985 to 18,195 in 1987 (Chettamart et al. 1988), will lead to the increased degradation of the water quality in Pante-Malaca Bay in the future, if immediate preventive measures are not made.

Marine fauna and fisheries

The abundance of fish eggs and larvae in the coastal waters of the park is shown in Table 2. It was found that the fish eggs and larvae of marine species are more abundant in the waters adjacent to mangrove forests, especially at Ma-Kham Bay, than in the reef areas. They were hardly detected in the offshore waters near sandy beaches. Thus, the mangrove and reef areas require strong protection to preserve them as vital spawning and nursery grounds for many marine species.

Interviews with local fishermen revealed that there are a large number of gill net operations in mangrove coastal areas where mullets, groupers and sea bass are abundant. Illegal trawler operations in Ma-Kham Bay are also frequently reported. Intense fishing is conducted in the reef areas of Adang-Rawi Islands where aquarium fish and other valuable species are harvested intensely by gill nets and deepwater traps. Also, reef blasting and shell collection are still practised occasionally in the reef areas.

ISSUES AND RECOMMENDED MANAGEMENT PROGRAMS

The major marine resources management issues of Tarutao National Park were identified and preliminary management programs were formulated. The programs' objectives are to conserve and protect marine resources to support multiple uses. The proposed measures will focus on coordination between the public and private sectors so that management strategies can be implemented effectively.

Coral reef issues and management

There are a few reef communities of relatively good quality remaining in the park, and these are continually being degraded by improper fishing and tourism activities such as reef blasting, anchor damage, coral collection and littering. These problems result in part from the lack of awareness on the value of coral reefs among users. These issues are common to coral reefs in Phuket and nearby areas (Lemay and Chansang 1988). Crown-of-thorns' infestation is another problem in the reef management of the park.

Programs for reef management should minimize the destructive impact from various human activities and natural phenomena and they should also enhance public appreciation of coral reefs through these:

1. Crown-of-thorns' infestations have to be controlled. This could be implemented initially by hiring local divers to inject a chemical solution, as suggested by coral specialists, into the starfish. This operation should be monitored to determine its effectiveness while exploring other control measures.
2. Expand information services for tourists, guides, boat operators, tour agents and local residents to make them more appreciative of the values and benefits of coral reefs. These services should be conducted continuously by coordinating efforts between the park and concerned private organizations. Guidelines for the proper access of coral reefs should be prepared and implemented.
3. Formal training programs on reef protection should be offered to guides, tour agents, boat operators and national park staff to ensure the appropriate use of reefs. The training should be supported by local institutes or universities. A core group of two to three park staff trained in basic coral reef ecology and monitoring should be created to monitor reef conditions and serve as a liaison between the park and the tourism industry.
4. "No anchoring zones" should be designed for heavily used coral reefs. Mooring buoys should be installed for recreational passenger vessels at these sites. Demarcation buoys should also be installed to keep vessels out of vulnerable reef areas. The placement of buoys needs the cooperative effort of park officials, local divers, coral reef specialists and tour companies to implement the program successfully.
5. Illegal reef blasting should be stopped by improving the existing law enforcement capabilities of the park.

Water quality issues and management

The increasing pollution of nearshore waters which receive waste effluents from intensive use zones, such as tourist lodging areas, is a problem since this reduces the park's capacity to serve various recreational activities.

Water quality management should limit the impact of pollution on recreational waters and coral reefs.

1. A wastewater treatment system within the intensive use zones, especially at Pante-Malaca Bay, should be developed. The system should be constructed in such a way that it is in harmony with the surrounding area and does not require a large budget. Simple oxidation ponds might be sufficient for this purpose.
2. Carrying capacity studies should be done for each intensive use zone to set guidelines to prevent the further impact of tourism on the environment. Intensive use zones should not be allowed in areas where receiving waters are sensitive to development impacts, such as at Talo-U-Dang Bay.
3. Any shoreline development should avoid the erosion and drainage of wastewater

into the reef areas. One measure to prevent this is the establishment of buffer zones between the residential areas and reef areas such as between communities on Ri-Pe Island and the reefs in the island's southern coast.

Marine fauna issues and management

Illegal trawling in areas adjacent to mangrove forests and intensive artisanal fishing in the reef areas are considered major problems that lead to the stock depletion of both commercially and ecologically valuable species within the park.

Reduction of harvesting pressure so that the sustainable yield of marine species can be achieved by the following:

1. Coastal areas adjacent to mangrove forests and reefs should be declared as "reserved zones". Within these zones, fisheries regulations, such as size limits, catch quotas and seasonal closures, should be established. The declaration of such zones should be accompanied by a strong public awareness program that will encourage better understanding between local and park officials. This is important since there is evidence that populations of lobsters, cowries, giant clams and some aquarium fish in the western coast of Thailand have been reduced substantially due to overharvesting (Tantanasiriwong 1978; Boonyanate et al. 1986). Therefore, the program should emphasize these valuable species and include those that play vital ecological roles (e.g., trumpet snails).
2. For long-term management, the possession and trade of depleted or endangered species must be prohibited by the enforcement of regulations. This program will need the cooperative effort of several government sectors to attain the desired results.

CONCLUSION

Marine resources within Tarutao National Park are deteriorating rapidly due to inappropriate use. The recommended management programs all recognize that traditional uses must be incorporated when planning, where possible, and that the coordination between the private and public sectors is vital to implementation. The improved flow of benefits from the park to the local communities must likewise be emphasized. These recommendations for the management of the park have to be integrated into the park's "master plan" prior to implementation.

The establishment of a Park Management Coordination Committee, which will include representatives from the park, province, local community and tourism industry who will support the park administration's programs, will help ensure their successful implementation.

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Table 1. Marine water quality in Tarutao National Park, April 1988.

Parameters	Stations[a] 1	2	3	4	5	6	7
Water temperature (°C)	31	30	31	31	30	30	30
Transparency (m)	0.8	1.5+	1.2	1.7	1.5	5.0+	5.0+
Salinity (ppt)	34	30	30	28	32	30	32
pH	8.3	8.3	8.2	8.2	8.3	8.2	8.2
Dissolved oxygen (mg/l)	5.2	5.4	5.7	5.0	4.1	4.9	5.7
BOD_5 (mg/l)	1.3	2.2	4.6	1.2	9.7	0.5	1.6
Total alkalinity (mg/l as $CaCO_3$)	160	160	180	170	180	170	170
Suspended solids (mg/l)	106	103	147	123	99	78	77

[a]Stations:
1. Son Bay, Tarutao Island
2. Ma-Kham Bay, Tarutao Island
3. Talo-U-Dang, Tarutao Island
4. Talo-Dap Bay, Tarutao Island
5. Pante-Malaca Bay, Tarutao Island
6. Lam-Son Point, Adang Island
7. Talo Reepa Bay, Adang Island

Table 2. Abundance of fish eggs and larvae of marine species, Tarutao National Park, April 1988.

Stations[a]	Numbers per m³: Fish eggs	Fish larvae	Mollusk larvae	Shrimp larvae	Crab larvae
1	-	-	944	64	96
2	-	-	1,800	-	-
3	-	-	304	112	272
4	10	16	582	118	58
5	-	16	624	-	-
6	-	-	12	-	-
7	6	-	848	-	-
8	-	-	10	-	-

[a]Stations:
1. Son Bay, Tarutao Island (mangrove zone)
2. Ma-Kham Bay, Tarutao Island (mangrove zone)
3. Talo-U-Dang Bay, Tarutao Island (mangrove zone)
4. Talo-Dap Bay, Tarutao Island (mangrove zone)
5. Pante-Malaca Bay, Tarutao Island (mangrove zone)
6. Lam-Son Point, Adang Island (sandy beach zone)
7. Talo-Reepa Bay, Adang Island (reef zone)
8. Talo-Ngo Bay, Rawi Island (sandy beach zone)

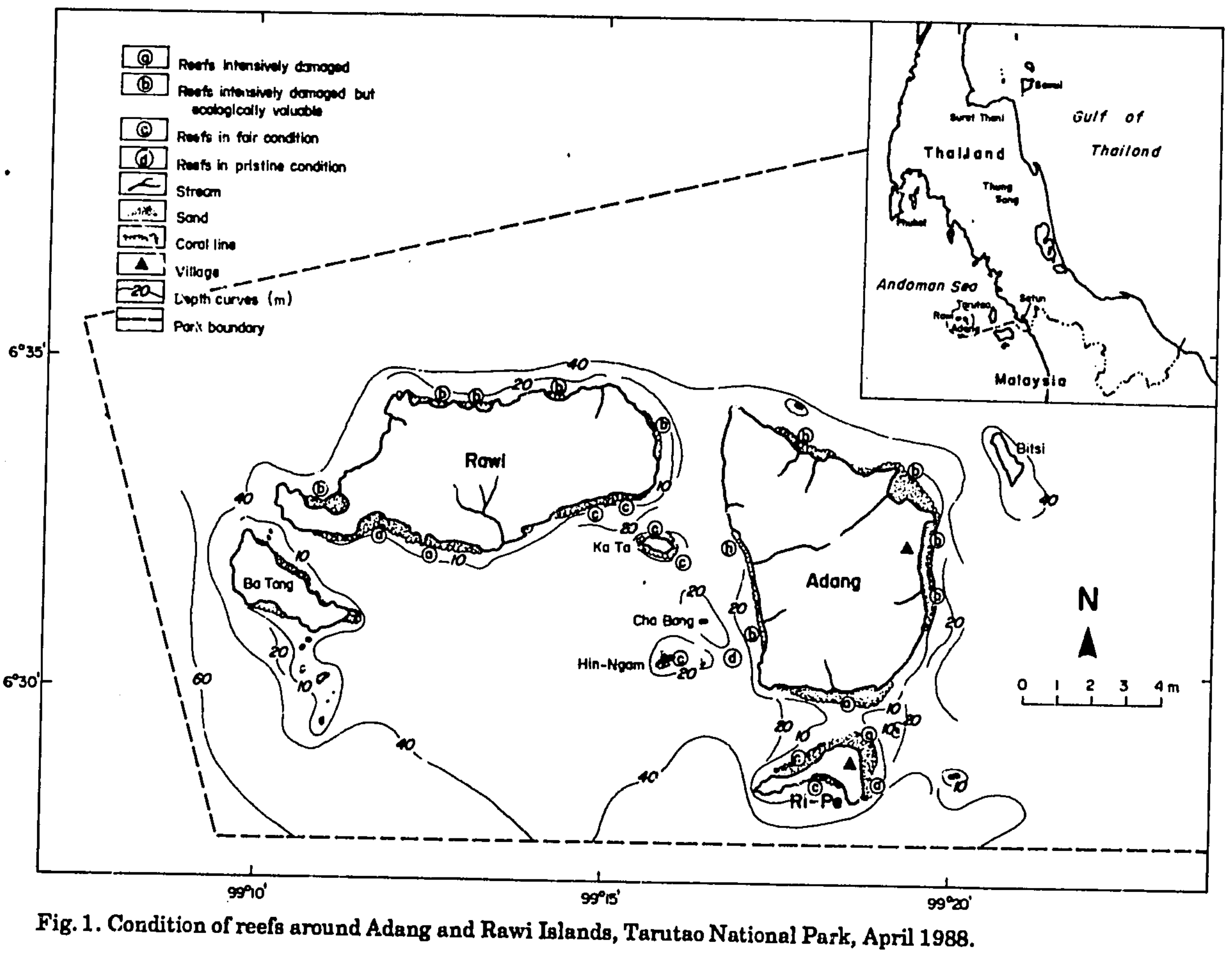

Fig. 1. Condition of reefs around Adang and Rawi Islands, Tarutao National Park, April 1988.

The University of Rhode Island's International Coastal Resources Management Project

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ABSTRACT

Coastal resources management (CRM) is needed to reduce the adverse impact of a major population increase on the environmental quality of coastal areas worldwide. The University of Rhode Island's Coastal Resources Center (CRC) operates cooperative CRM programs in Ecuador, Sri Lanka, Thailand and the United States. In each country, CRC works with CRM in-country teams to formulate, implement and test local and national CRM strategies. Management recommendations from previous studies usually exist, so CRC focuses more on program implementation. CRC helps to review any existing research and recommendations; defines future studies or activities that will have the greatest likelihood of being directly applicable to formulation and management strategies; designs procedures to assess the impact of coastal ecosystems; strengthens the in-country professional staff to plan for and manage coastal development and infrastructure; and helps countries develop the institutional capabilities to address resources use conflicts effectively.

INTRODUCTION

Nearly three-fourths of the earth's population is concentrated in the coastal zone. As this population doubles, perhaps by 2020, most of the increase will concentrate in tropical coastal areas. To help protect these environments, the University of Rhode Island's Coastal Resources Center (CRC) was created in 1971 to undertake the research, planning and policy formulation required by state agencies charged with the management of Rhode Island's coastal ecosystems. CRC also collaborates with leaders of developing countries in formulating, implementing and testing integrated CRM programs.

ELEMENTS OF COASTAL RESOURCES MANAGEMENT

There are several CRM elements that CRC provides on a regular basis, namely:

1. training programs and workshops for institutions, agencies and officials to strengthen their in-country technical capability and comprehension of the forces affecting trends in coastal ecosystems, so that as decisionmakers, they will be better able to address resources use conflicts;
2. public education and outreach programs through schools and media to increase their local involvement in CRM and thus assist officials in the decisionmaking process;
3. advice and assistance on special area management planning for agencies and officials so that they can focus on issues and formulate comprehensive and integrated CRM strategies in selected demonstration sites where management options are tested against real issues; and
4. national policy development to establish realistic, implementable, nationwide environmental quality protection standards linked to consistency reviews.

Emphasis on implementation

CRC reviews existing research and recommendations and defines further studies or activities that will have the greatest likelihood of being directly applicable in the formulation and implementation of management strategies. It develops procedures to assess the impact of coastal development proposals. CRC investigates the forces that affect trends in the condition and use of coastal ecosystems. The center also strengthens the in-country professional staff in planning and managing coastal development and infrastructure, including the development of institutional capabilities to address resource use conflicts effectively.

CRC's critical step is in the implementation of appropriate CRM strategies. In many countries, good studies and CRM recommendations have been provided by local and foreign consultants. Their value is limited, however, because they have not been implemented. Often, this is because no implementation capability is available or similar problems have not been addressed in the past, so that the proper linkages have not been established among the regulatory and implementing agencies. Thus, CRC stresses training, public education, special area planning and national policy development to foster appropriate CRM implementation.

Phased approach

CRC has four approaches for the implementation of its strategies:

1. recognize a country's social history, environmental assets and development goals;
2. emphasize the development of public participation;
3. focus on a relatively few, well-defined CRM issues; and
4. build in an orderly and low-risk manner the designs of succeeding phases that depend on the responses to previous phases.

PILOT PROGRAMS

CRC operates collaborative projects in Ecuador, Sri Lanka and Thailand through agreements with the United States Agency for International Development (USAID). The time for CRM is now appropriate in many developing countries because some techniques can be adapted from the United States and several European countries, which have more than a decade of experience in designing and implementing integrated CRM programs. Examples from developing countries, particularly in Southeast Asia, are also useful.

Ecuador

CRC assists the Directorate for the Environment, Ministry of Energy and Mines of Ecuador to develop management strategies for the generally arid and sparsely inhabited 1,800-km mainland coast. Here, coastal development has been dominated by boom-bust cycles--shipbuilding died around the turn of century when forests were depleted, and this has been followed by booms in taiga, cacao, coffee and bananas.

One of the major issues is related to the current expansion of shrimp production in coastal ponds. The industry, which employs nearly 100,000 people, makes Ecuador the world's largest producer of farm-grown shrimp. Due to poorly developed guidelines for land use, the construction of shrimp ponds has caused big losses of mangroves even within national park areas. In 1984, 11% of the country's original mangroves were lost and in 1988, more than one-third.

Urbanization is also a major issue. Guayaquil and other urban areas are growing explosively, and there are no realistic prospects for sewage treatment or land planning in most areas. Also, newly initiated nearshore oil drilling has created considerable concern about its impact on water quality. CRC's initial efforts are to protect and maintain water quality and wild shrimp stocks; simplify and improve the permit system for new ponds; evaluate economic policies affecting the shrimp industry; develop a technical assistance program and training options for mariculturists; and initiate public education programs. Current efforts are designed to:

1. form a citizen corps to improve the enforcement of existing statutes throughout the coastal area, particularly in policing the aquaculture permit system;
2. designate special management zones for aquaculture, mangrove production and water quality in areas that serve as microcosms for the resolution of priority issues and create a committee for each management zone;
3. create advisory committees to represent the full range of interests of a special management zone, together with the appropriate agencies of local and regional governments;
4. establish a small and well-defined national group to provide high-level governmental support for CRM, assure political and administrative backing to solve conflicts, obtain international support and promote interagency cooperation;
5. establish a public education program on priority coastal issues to improve the understanding of their solutions; and

6. conduct training courses to facilitate the implementation of CRM programs.

Sri Lanka

CRC assists the Coast Conservation Department (CCD) of the Ministry of Fisheries of Sri Lanka in preserving and managing critical coastal habitats nationwide. Although coastal management programs date back to the 1940s, serious environmental problems are becoming more threatening in populated coastal areas.

A major problem is the loss of coastal land to erosion, which results from powerful monsoons and other natural forces, despite the presence of many natural defenses such as nearshore reefs that buffer the energy of large waves and sediments from rivers that replenish eroded beaches. These defenses are also being compromised by various human activities. Corals are being mined illegally to produce plaster, mortar and sand to supply the needs of the construction industry. The CCD strives to control these problems.

Sri Lanka's coastal management plan, which has been completed, tries to avoid moving too quickly to solve several management issues in many areas. Rather, it focuses on major issues, such as coastal erosion and the, loss or degradation of natural coastal habitats, historical, archaeological, scenic, recreational and cultural sites along the coasts.

The management plan and CRM's efforts in Sri Lanka intend to:

1. strengthen CCD's enforcement capability through the standardization of responses to shorten the time for processing permit requests, including computerized permit monitoring;
2. ensure consistency between the National Coastal Management Plan and the Coast Conservation Act;
3. resettle squatters away from erosion-prone coastal areas and develop alternative livelihood projects for them;
4. transfer CRM's authority and responsibility from the central government to the provinces for regulation, planning and permits' inspection; and provide training to district officers on coastal management;
5. map and describe the historical coastline and scenic sites;
6. establish a postgraduate course in CRM; and
7. build community support for CRM through public education programs.

Future efforts include studies leading to the publication of a CRM planning document, the *Status of the Coast 2000.*

Thailand

CRC assists the Office of the National Environment Board (ONEB), Ministry of Science and Technology in Bangkok, Thailand in the formulation, implementation and testing of local and provincial CRM programs aimed at formulating a national CRM policy for incorporation into the Seventh National Economic and Social Development Plan.

Thailand's coastal population varies from sparse to dense. Its coastal waters are often severely degraded by siltation, pollution and overfishing. Mounting pressures are being added by an expanding tourism industry, which is a major foreign exchange earner. Coastal tourism is surpassed only by tourism in Bangkok.

CRC is midway through a three-year cooperative CRM project with ONEB, which includes:

1. a provincial CRM demonstration project in Phuket;
2. a public awareness and involvement program;
3. formulation of national CRM policies;
4. training in CRM for governmental personnel; and
5. marine parks management demonstration projects.

Phuket is CRC's initial demonstration site. It had 27 hotel rooms in 1969 and by 1987, these had increased to 6,000. However, the infrastructure (roads, sewers and services) had largely been neglected, and the degraded environment reflected a critical need for comprehensive, long-range environmental planning. The current level of 0.5 million tourists per year in Phuket has been projected to reach 3 million per year by 2000. Other problems affecting the island include the encroachment on public lands by rubber plantations and tourist development and the destruction of coral reefs by boat anchors, sediments from inland quarries, construction and offshore tin mining.

Among CRC's activities in Phuket, which are designed to maintain a robust economy, are:

1. protecting coral reefs and other nearshore marine resources by implementing community-based management projects;

2. improving water quality by assisting in the implementation of the local sewer district for the Patong watershed, constructing a demonstration septic system for houses and developing a stormwater system;
3. developing administrative means through the provincial and local governments to plan and manage future land use, including the building of public roads and facilities, and stabilizing tin, gravel and lignite quarries;
4. publishing a resource profile of Phuket to be used as a guide in management;
5. developing a legal framework for environmental protection;
6. building a public awareness program on CRM through school and media campaigns; and
7. training hotel sewage plant operators, tour boat guides and local officials to focus on resource management issues in relation to their respective roles.

Recently, CRC signed a second USAID agreement, which will last until 1996, to advise ONEB and other Thai agencies and institutions. This agreement will include the:

1. formulation and implementation of special area management plans for particular resources, such as coral reefs and mangroves, water quality, etc. (CRM will be established in five new sites in addition to Phuket.);
2. incorporation of the collective experience from special areas into national CRM policies;
3. project integration and outreach through various media campaigns, public meetings and school programs with the aim of building public participation in CRM;
4. strengthening of the research and management capability of selected Thai institutions through seminars, observation tours in the United States, direct participation in ongoing CRC activities in Thailand and assistance in developing CRM curricula in Thailand; and
5. increasing the instructional capability of selected Thai agencies and institutions through postgraduate courses from various US universities; special long-term, nondegree internships in the US; and in-country CRM training programs.

Abstracts

Invertebrate and seaweed fisheries in the reef flats of Lingayen Gulf

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ABSTRACT

The reefs of Bolinao and Cabarruyan Island on the northwestern margin of Lingayen Gulf produce a harvestable biomass of at least 29.3 t km^{-2} $year^{-1}$. Thirty-nine percent of these are finfish, 33%, invertebrates and 28%, seaweeds. Among the important invertebrates are octopus, gastropod shells, abalone and sea urchin. Of these, the most abundant are the gastropod shells, which contribute as much as 25% to total production. The natural stock of commercially important species of finfish and invertebrates are overexploited.

About 1,760 households depend directly on these resources for their living. They exploit the reefs at a rate of 56 human-hours km^{-2} d^{-1}. On an average fishing day, a reef fisherman can bring home 11.5 kg of produce, from which he earns about US$20.40 monthly. Compared to his family's needs, he earns barely a third of what a family of six should spend to subsist.

The dwindling per capita production clearly indicates the need for coastal resources management intervention. Foremost in a manager's agenda will be the issues of habitat conservation, alternative livelihood and catch distribution. Here are some recommended measures: establish seed areas and identify those areas that should be rehabilitated by the municipal governments and declare a closed fishing season for key resources like siganid fry and spawners, sea urchin and abalone.

The pelagic fisheries of Lingayen Gulf

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ABSTRACT

Lingayen Gulf is a major fishing ground for large tuna and small pelagics. The average annual tuna catch in 1986 was 5,118 t, which was 46% of the total annual catch in the gulf. Yellowfin tuna caught by hook and line ranged from 90 to 160 cm and from 20 to 168 kg. The skipjacks ranged from 22 to 64 cm and from 0.3 to 4.5 kg. The small pelagics consisted of anchovies (13.5%), roundscad (12.9%), half-beak (5.6%), Indo-Pacific mackerel (4.8%), sardines (4%), flying fish (4%) and big-eyed scad (3.1%), which collectively comprised almost 50% of the total catch of small pelagics.

Fishing is done by both commercial boats (3 GT and more) and artisanal boats (motorized and nonmotorized) below 3 GT. The commercial fleet is dominated by bottom trawlers which, in 1987, had 24 medium and two large boats from 20 to 30 GT. Artisanal fisheries operate some 20 types of fishing gear. The most productive were the gill net (33.7%), round haul seine (26.5%), cast net (8.5%) and hook and line (3.3%), which collectively landed over 70% of the municipal fish catch in 1986.

From 1977 to 1986, the average pelagic fisheries production was 9,487 t or only 37.2% of the total fish production in Lingayen Gulf. Of this, 5,024 t or 64.5% was caught by the artisanal sector, the rest by the commercial sector.

Given this baseline on the Lingayen Gulf fisheries, this paper shows the lack of information on pelagic resources in the gulf and the poor knowledge of commercial operations on pelagics outside the gulf but often recorded as Lingayen Gulf in origin. The paper, based on secondary information, suggests that: (1) tunas are not recognized as a major resource in Lingayen Gulf and (2) bamboo rafts should be used to aggregate tunas for artisanal-scale handling operations since these greatly enhance the income of fishermen as has happened in other areas of the Philippines.

An assessment of water quality for Lingayen Gulf

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ABSTRACT

Assessment of the water quality in Lingayen Gulf was done for 18 months beginning March 1987 in 15 offshore and river stations. The following parameters were covered: pH, temperature, dissolved oxygen (DO), salinity, transparency, suspended solids, nutrients, heavy metals and coliforms.

DO values were less than the National Pollution Control Commission (NPCC) standard of 5 mg/l and were recorded constantly in river stations in Coliat, Inerangan, Patalan, Agno and Dagupan. These low DO values coincided with high nutrient concentrations, suggesting that these areas were loaded with waste.

Inerangan River frequently yielded a high amount of suspended solids, which range from 1,597 to 5,566 mg/l. Agno, Dagupan and Patalan were identified as critical areas. Agno River contained the highest levels of Pb and Cd, which range from 4.920 to 5.400 ppm and from 0.032 to 0.049 ppm, respectively. The NPCC limit is 0.05 ppm for Pb and 0.01 ppm for Cd.

Sediments from Dagupan gave the highest Hg concentration at 0.32 ug/g dry wt. No NPCC limit was available for Hg in the sediment, but its relatively high level in Dagupan might indicate a high level of the metal in the shellfish gathered in the area. Both the Patalan and Dagupan Rivers had coliform levels exceeding 2,400/100 ml. According to NPCC, coliform level should not exceed 1,000 most probable number (MPN)/100 ml. All other parameters were within the limits set by NPCC.

Aquaculture in Lingayen Gulf: patterns, levels of practices and development potentials

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ABSTRACT

This paper reviews the status of brackishwater aquaculture in the eight coastal municipalities of Pangasinan in Lingayen Gulf, Philippines. This is based on a survey conducted from July 1987 to March 1988 covering 499 farms and representing 11% of the total brackishwater fishponds in the area. Average production was low at 896 kg/ha/year as compared to other areas in the country.

Aquaculture development in Lingayen Gulf is discussed in the context of pond culture intensification of milkfish and shrimp and expansion through the establishment of mariculture projects. Potential mariculture sites including cultivable species in Lingayen Gulf, especially in Pangasinan, have been identified. Preliminary results of ongoing farm testing activities for oyster culture and cage culture of siganid are also presented.

Socioeconomics of two coastal communities engaged in milkfish fry gathering, La Union, Philippines

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ABSTRACT

This study investigated the milkfish fry gathering industry in two adjacent communities in Lingayen Gulf, Philippines. One site has beaches classified as part of the national seashore park and the other falls under municipal management and is concessioned at present to a group of resident small-scale fishermen.

Differences in the economic structure of the two communities were identified and evaluated. Market systems employed were defined and analyzed in terms of maximum returns to milkfish fry gatherers. Significant economic and social contributions of milkfish fry gathering were enumerated and their implications probed. The major problems ranged from gear inefficiency and storage to dwindling annual catch. Recommendations included the regulation of net types, which capture spawning milkfish, the development of stocking ponds near fry grounds to minimize mortality rates and the adoption of more efficient economic arrangements for marketing.

Blast fishing and government response in Lingayen Gulf

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ABSTRACT

The use of explosives in fishing is illegal and punishable with stiff fines and prison terms. Nevertheless, it persists in a number of coastal villages in Lingayen Gulf. This paper is an ethnographic study of a fishing village in the gulf area based on primary and secondary data gathered from April 1987 to March 1988. It describes (1) how blast fishing is practiced in the village; (2) the perception of the village residents regarding the illegal practice; (3) the factors that affect its continued use; and (4) the measures taken by government agencies to check its use.

A study of microbial indicators in Segara Anakan, Java, and its adjacent waters

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ABSTRACT

Bacterial counts were measured in water samples collected from Segara Anakan and its vicinity for a period of one year. The bacteria were divided in three categories. Heterotrophs and halotolerants were measured as indicators of organic matter concentration and aquatic terrestrial influence, respectively. Coliform, fecal coli and fecal streptococcus, collectively referred to as indicator bacteria, were used to measure the extent of sewage pollution. Pathogenic bacteria, such as *Salmonella paratyphi*, were cultured from water and sediment samples to estimate the pollution in the estuary.

The data show strong correlations between the bacterial counts and the environmental factors at the locations where the samples were collected. Water from stations close to the river mouths and villages had higher counts of halotolerant and indicator bacteria. Coliform counts were observed to be as high as 2,000/100 ml and fecal coli, to be as high as 200/100 ml. The ratio of coliform to fecal coli was used as a measure of the relative age of the marine environment of the pollution from major rivers.

Count fluctuations from station to station were also shown to be influenced by temperature and season and organic matter concentrations. Average counts for all ten stations showed predictable patterns when plotted over the one-year period. Higher amounts of halotolerant and indicator bacteria were consistently found during the rainy season when runoff and river discharge were greatest. Heterotrophic bacteria peaked in average concentration at 123 x 10^3 ml during the rainy season but also showed a smaller rise during the dry season. The lowest counts for all bacteria were from samples collected during transition periods (between rainy and dry seasons). The authors refer to their results to point out the problems of seasonal water quality and health risks caused by excessive pollution in the Segara Anakan estuary.

Local environment awareness and attitudes toward coastal resources management in Segara Anakan-Cilacap, Indonesia

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ABSTRACT

This study evaluates environmental laws and regulations that are related to Coastal Resources Management (CRM) in Segara Anakan-Cilacap and their effectiveness in protecting the living environment. These laws are: (1) Agrarian Law No. 5/1960 and related governmental regulations, which legislate the means for private control over land; (2) Forestry Law No. 5/1967 and related governmental regulations, which legislate the national control and management of mangrove forests; (3) Local Government Law No. 5/1974 and related governmental regulations, which give jurisdiction to local government over land within its boundaries; and (4) Environmental Law No. 4/1982 and related governmental regulations which prescribe the national use of the environment and its resources.

There are two opinions about CRM because of the different orientations to Segara Anakan-Cilacap's land use planning. The Department of Forestry (Perhutani-State Forestry Corporation) officials claim that their department is the only institution authorized to control coastal forests, including mangroves. On the other side, the Cilacap local government claims that it has the authority to develop and use the areas under its jurisdiction. The local government has encouraged Segara Anakan-Cilacap people to develop agriculture as an alternative to traditional fishing. To do this, they should cultivate the surrounding land by clearing mangroves. Such deforestation erodes natural habitats and affects fisheries abundance. Forestry officials say that agricultural development increases mangrove deforestation.

These fundamental legal problems need to be resolved. Furthermore, any plan concerning the development and management of Segara Anakan-Cilacap should consider the interest of the local people and the environmental characteristics of the area.

Social change in Segara Anakan-Cilacap, Indonesia

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ABSTRACT

Segara Anakan-Cilacap on the southern coast of Java has extensive natural resources. Its mangrove forest is the largest in Java. The lagoon and its tributaries are inhabited by a variety of fisheries resources on which many local communities depend.

This study analyzes social change, which is caused by alterations in the basic environment in the communities of Segara Anakan-Cilacap.

An example is the high sedimentation in Segara Anakan, which originates from rivers flowing into the lagoon, and the upland erosion that has increased dramatically. Both have changed the basic physical environment of the lagoon and have created problems such as:

1. decreasing income for the 7,813 people, 87.5% of which are fishermen (1987);
2. changing land use--mangrove areas have been converted into paddy fields, especially where land accretion has occurred;
3. conflicting interests between the village people of Segara Anakan-Cilacap and the State Forestry Corporation about ownership of the accreted land; and
4. managing the Segara Anakan-Cilacap environment to provide better protection for nursery grounds of offshore resources.

Data surveys show that the majority of the Penikel village people of Segara Anakan-Cilacap expect to change their livelihood from fishery to agriculture or in combination. Public officers' attitudes tend to support this change, although they are compounded with environmental problems and the poor local economy. There is no change agent or proper institution in Segara Anakan-Cilacap to support a comprehensive shift in livelihood and the better management of lagoon resources. Thus, the study suggests that a plan should consider a new institution to coordinate a management plan and that existing local institutions be involved in the planning process. Local communities should also be an integral part of planning and implementation because they have the largest impact on local resources use.

Economic analysis of existing income sources of Kampung Laut, Segara Anakan-Cilacap, Indonesia

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ABSTRACT

The poor socioeconomic situation in Segara Anakan-Cilacap is at the base of the resource management problems there. This study analyzes the economic activities, level of income and the contribution of fisheries in relation to other livelihoods. It makes recommendations on how to increase income and decrease dependence on fisheries for the population of 7,812 or 4,602 households.

Baseline surveys showed that the mean income is below the national poverty threshold of 320-480 kg of rice or its equivalent and that 74% are fishermen, 17% are farmers and 9% have other occupations. About 70% of all household income still comes from fishing, which has declined significantly in the last ten years.

Offshore fishing outside the lagoon is the most profitable; this is done through the use of gill nets by fishermen with outboard motors for their boats. In the lagoon, the most profitable and nondestructive methods of fishing are done through the use of trammel nets (*jaring ciker*), bamboo traps (*wadong*) and lift nets (*pintur*). The latter are used for crab fishing and are recommended to replace the fine-meshed nets that are depleting the fish stocks. The use of these methods is to be encouraged while considering maximum sustainable yield.

Farming contributes to only 8% of the household income, although an undisclosed amount is derived from mangrove exploitation for wood, charcoal and some wildlife. Aquaculture of tilapia is feasible. Marketing can be improved and postharvest processing is encouraged to increase income from the present fish catch. Households earn more--above their average income--in doing certain day-labor activities such as frog keeping, water fetching and construction work.

The sociolegal and institutional aspects of coastal resources management in Segara Anakan-Cilacap, Indonesia

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ABSTRACT

The institutional framework for Coastal Resources Management (CRM) in Segara Anakan-Cilacap and other regions in Indonesia is generally based on Law No. 4/1982, which regulates the principles of environmental management. On the national level, the management should be implemented by a coordinating body, chaired by a minister. The sectoral part is managed by a ministry or a nonministerial institution in accordance with its specific function. Environmental management in the regions is enforced by the local government. An important regulation derived from the above law is Governmental Regulation No. 29/1986, which is concerned with the analysis of an environmental impact.

Each law regulating certain aspects of the environment stipulates rules on the authority of governmental institutions to manage limited parts, without considering the need to coordinate activities. Law No. 4/1982 is supposed to have an impact on coordination, but it has so far been ineffective.

To establish an applicable institutional framework, it is necessary to:

1. review the environmental laws and other lower-level statutes with empirical data that will affect land use under the Department of Forestry, the Agrarian Land Board Office and the local government (Bupati);
2. encourage local government officials to become responsible agents of change in implementing programs that could move people to follow environmental management regulations;
3. form and authorize a coordinating body at the local government level to implement environmental management programs; and
4. establish better coordination among environmental study centers in universities to improve policymaking.

The local agencies and leaders who should be involved in a CRM program are the regional planning agency (BAPPEDA), the local government (Bupati), the Agrarian Land Board Office, the Department of Forestry or the State Forest Corporation (Perhutani), the Department of Fisheries, the local police and the village council and chief.

Heightening media interest in coastal resources management in Thailand: trends for April-June 1988

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ABSTRACT

The Coastal Resources Management Project (CRMP) of the Office of the National Environment Board (ONEB) of Thailand places a high priority on the use of different types of mass media to reach the general public, teachers, administrators, politicians and private investors for the scientific and technical aspects of CRM. In Thailand, there are 22 daily and weekly national newspapers--13 in Thai, 2 in English and 7 in Chinese--with a combined circulation of more than 2 million, of which 50,000 is in Chinese. There are 94 weekly, biweekly and monthly magazines; 10 TV stations covering 80% of the country and over 400 radio stations. There are also over 100 local weekly newspapers in all 72 provinces, excluding Bangkok.

A census of all the major newspapers had been undertaken for three months (April-June 1988) for topics related to CRM in any capacity. This census found 378 news items--114 articles and 264 news-briefs and reports. The most frequent topic was coastal development, followed by coastal agriculture and fisheries, environmental problems and pollution; coastal parks received the least attention. The *Bangkok Post* (in English), for instance, had the most news items on CRM. Coastal development and environment were the most frequently reported topics, while coral reefs and mangroves were the least.

The CRMP intends to use the print and the broadcast media as much as possible by inviting them to project activities and providing them with press releases and CRM bulletins.

Local characteristic patterns of coastal natural resources utilization: a case study of Pak Kra Dae, Ban Don Bay

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ABSTRACT

This study documented the local patterns of coastal resources use in the fishing community of Pak Kra Dae, Ban Don Bay, Thailand. An anthropological approach, composed of several interview techniques, was used to gather qualitative data from 127 households. Most Pak Kra Dae villagers had at least four years of mandatory education and about 8% had six years. All were Buddhists and most were of Chinese descent.

The main occupations are crab fishing, oyster culture and push-netting. Secondary jobs include small business, wage employment, shrimp culture, trawling, labor in a rubber plantation or dried shrimp factory, poultry raising, government employment and machinery operation. The average annual income per fishing household was US$3,200. Additional income was averaged at US$2,000/year in less than 50% of the households.

Mangroves are traditionally used as a fishing ground, source of firewood, charcoal, and in construction materials. Currently, the remaining mangroves are preserved as windbreakers although the areal coverage is declining.

The villagers' level of awareness of seawater quality is high. They complained of the pollution of the water coming from the factories and shrimp farms; they also thought that water could not circulate well enough to carry away the pollutants. Thus, they have moved their oyster beds farther offshore. Inshore fishing also decreased, so deepsea fishing has become more common.

The major issues on resources use, as seen by the villagers, are the depleting mangrove forests, worsening water quality and declining inshore fisheries. They saw the causes of these as beyond their village's control and, thus, they are forced to adapt to the changing environment. The village, however, preferred to maintain the mangroves on which inshore fisheries are dependent.

Land zonation for appropriate land use in Phangnga and Ban Don Bays, Upper South, Thailand

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ABSTRACT

The Ban Don Bay coastline covers about 1,100 km² and that of Phangnga Bay covers 1,180 km². Rapid development is affecting land use in both bays. Common-use conflicts include brackishwater aquaculture development in the mangrove/estuarine areas and agriculture in coastal habitats or in inappropriate land and unplanned urban development. There is no zonation plan for land along the coast, except guidelines for forest management.

The project surveyed existing land uses; established criteria for land uses vis-à-vis land use capability; developed map overlays and zonation plans; and formulated strategies for implementation.

For Phangnga Bay, it was concluded that pond aquaculture is not appropriate because of high tidal fluctuation; high sediment loads adversely affect bay cage culture; and mangroves are relatively intact except in those areas used for traditional exploitation (e.g., charcoal-making). In this bay, the mangroves should be maintained because of their unsuitability for pond culture. Cage fish and mollusk culture can be promoted instead. Sedimentation caused by tin mining should be regulated. All deforestation should be stopped.

For Ban Don Bay, it was concluded that pond culture development, which has replaced 77 km² of mangrove and 20 km² of paddy land since 1967, should be stopped. A zonation plan is recommended that preserves all remaining mangroves, allows continual pond culture and shows potential areas for brackishwater culture. In particular, mangrove strips of up to 70-m wide along rivers and coasts should be reforested using local participation. Pond culture should be sustainable with respect to soil and water conditions, ecological impacts on the soil and the downstream water quality from pond culture. Areas for the expansion of aquaculture should be qualified by the potential for acid-sulfate formation depending on their pH. Education of the local population and law enforcement are recommended to implement such a zonation plan.

Perceptions and acceptance of tourism-related resource development among residents of Samui Island, Thailand

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ABSTRACT

Samui Island is attractive to tourists because it has a combination of recreational marine resources. However, inappropriate and unregulated tourism development may be degrading this natural heritage that both local residents and tourists value. This paper highlights how these resources are connected to the lifestyles of the residents, and how residents and their resources are connected to tourism.

The perceptions of the local residents toward resource management problems were obtained from a survey on the island, covering four different types of communities.

The survey focus was on: satisfaction with life; perceptions of what comprised "the good life"; and how the quality of life could be improved.

The communities were also asked about their present work problems in fishing, tourism, transportation and about general problems relating to land, water for agriculture and for drinking; food supplies; environment; the efficacy of government agencies and services; sales of handicrafts and other goods to tourists; debts; education; employment opportunities; security; migration; energy supplies; road safety; and religion and media in the context of further tourism expansion and resource exploitation.

Evaluation of the mangrove development potential of Phangnga and Ban Don Bays for the coastal zone management of Thailand

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ABSTRACT

Phangnga Bay on the western coast and Ban Don Bay on the eastern coast of the Upper South region of Thailand were once endowed with rich and diverse mangrove forests. Due to human activities, mangrove resources have been seriously degraded, especially in Ban Don Bay. The existing mangrove forests of Phangnga and Ban Don Bays are approximately 19,637 and 4,160 ha, respectively.

Land uses in Phangnga Bay are shrimp ponds (125 ha), agricultural land (3,994 ha) and mining (672 ha). In Ban Don Bay, shrimp ponds and agricultural land are the two main land use types with areas of 5,331 and 2,723 ha, respectively. During the past ten years, more than 60% of the total mangrove forests along the coast of Ban Don Bay were converted into other types of land use; in Phangnga Bay, mangrove forests converted into other types of land use reached 20%.

The average stem density of mangroves in Phangnga Bay is greater than in Ban Don Bay at 632 trees/ha. *Rhizophora apiculata*, the most commercially important species, has the highest stem density (238 trees/ha) in Phangnga Bay. But in Ban Don Bay, this species has a low density, with an average of only 76 trees/ ha. *Avicennia* has the highest stem density in Ban Don Bay. Most mangrove areas in Phangnga and Ban Don Bays have low stem volumes, averaging 38 and 85 m^3/ha, respectively. The low stem volume is due to the high density of small-sized trees (4-10 cm in diameter) and the selective cutting of large trees (>10 cm in diameter) for use in charcoal-making, firewood, posts and poles. However, the natural regeneration in terms of the densities of samplings and seedlings is good in both bays.

Management issues identified are the: conflicts in mangrove land use; the lax harvesting system; insufficient manpower and facilities for forest protection; the lack of public support for forest conservation; and the inadequate cooperation among mangrove resource institutions concerned. These problems were identified as the causes of the degradation of mangrove forests and the alteration of the physical conditions of the areas.

Management measures aimed at mitigating the continued destruction of mangrove resources are: mangrove land-use zoning; strict harvesting control; continuous protection activities, with adequate enforcement mechanisms and sufficient manpower and facilities; reforestation; and the establishment of public awareness programs.

Upper South wildlife resources in Thailand: considerations for management

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ABSTRACT

Wildlife in Ban Don and Phangnga Bays in the Upper South area of Thailand was assessed by measuring species diversity, occurrence and abundance. A census of birds, mammals, amphibians and reptiles was taken by direct observation, habitat inventory and from interviews with local residents.

The major wildlife habitats in Ban Don Bay are mangroves (46 km^2), *Melaleuca* (216 km^2), evergreen forests (2,089 km^2) and agricultural areas (5,694 km^2). In Phangnga Bay, mangroves (246 km^2) and coastal lowlands (3,606 km^2) are the major habitats. A total of 81 families of wildlife consisting of 242 species (159 birds, 35 mammals, 18 amphibians and 30 reptiles) were found inhabiting Ban Don Bay, while 55 families with 157 species (120 birds, 7 mammals, 4 amphibians and 26 reptiles) were found in Phangnga Bay.

Birds had the highest diversity in both areas, with insectivorous species in evergreen habitat types as the most common. The study observed five rare and endangered wild animals, which included two mammals, a white-handed gibbon *(Hylobates lar)* and a serow *(Apricornis sumatraensis)* in the evergreen forest; and a mammal, the smooth-coated otter *(Lutra perspicillata)*; a bird, the masked finfoot *(Heliopais personata)*; and a reptile, the saltwater crocodile *(Crocodylus porosos)*, in the mangrove forest. Three sites of outstanding shorebird concentrations were found in Phangnga Bay, of which two are not protected or managed. Thirty-six legally protected areas covering 6,667.5 km^2 have been established in the Upper South area and represent all main habitats.

Habitat destruction, resource use conflicts in protected areas and illegal hunting are the main problems in the Upper South's protected areas for wildlife. Recommendations include adopting development plans for agricultural expansion which also protect natural habitats, more intensive surveys of endangered wildlife and further education for the local residents near the protected areas.

The use of GIS for socioeconomic analysis and planning of coastal resources: preliminary experience from a research project in Malaysia

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ABSTRACT

A key aspect of coastal resources development planning involves an analysis of the socioeconomic characteristics of the area concerned. While there has been some development in the scientific literature on the use of GIS as a tool for the physical resources assessment and planning of coastal zones, the application of such a tool in the socioeconomic area has been less advanced, especially in the developing countries. The lack of a proper spatial framework for socioeconomic data collection and the high cost for GIS have been the major reasons for this. However, recently available GIS software for personal computers offer hope for change. This paper reports on preliminary experiences in applying GIS techniques for various socioeconomic planning analyses in an ongoing research project on coastal resources management for the South Johore coastal region in Peninsular Malaysia.

This paper also provides an overview of the various typical socioeconomic analyses and planning issues, particularly those in coastal resources management, where socioeconomic assessment should relate to the physical resources available in the area. It discusses the database requirements to address these issues and illustrates the typical data constraints in the study area, the South Johore coastal region in Peninsular Malaysia. It briefly reviews how GIS can be used profitably to address questions, considering the particular data constraint of the problems encountered. A specific GIS software, SPANS, is used for this purpose. This paper then presents some representative analysis results that have been obtained using the SPANS package in the research project. Finally, the paper discusses some potential applications and their implications on the socioeconomic data collection methods and database development framework of the various government agencies concerned.

Household survey on perception and utilization pattern of Singapore's coastal area

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ABSTRACT

This paper presents the results of a questionnaire survey consisting of about 1,000 households selected from the various parts of Singapore through a stratified random sampling procedure. The survey, conducted in June 1987, was the first of its kind. Its objectives were as follows: (1) study the community's awareness of marine issues and concepts; (2) identify the citizens' preferences for marine resource commodities; and (3) examine the general perceptions on the use of the limited coastal area.

The results were somewhat mixed. Respondents' awareness of marine issues and concepts was poor, although the results varied widely across the levels of educational attainment. Citizens' preferences for seaside accommodation and marine recreation also depended heavily on their income and educational levels. The relatively well educated and wealthy citizens preferred seaside to inland living. The results did not show any clear indication of the citizens' perceptions on the pattern of use of the coastal zone. There was, however, general optimism about the prospects of Singapore's marine industries.

A proposed management plan for the coastal area surrounding the Southern Islands of Singapore

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ABSTRACT

The Southern Islands of Singapore comprise over forty islands off the southwestern coast of the main island of Singapore. The area is bounded on the south by Indonesia's territorial waters. Separating the two territories are the Main Strait and Philips Channel, which, together with the Malacca Strait, constitute one of the busiest international shipping routes in the world. The coastal area (including the waterfront land on the main island's coast) has been developed over a period of one and a half centuries but more so after World War II and especially since the 1960s. The main developments are in shipping and port, manufacturing industries--including petroleum refining, petrochemicals, storage of liquid products, shipbuilding and repairing--and other heavy industries. Several of Singapore's power generation plants are also located in the area. The pressure to develop water resources has impounded several of the rivers on this stretch of the mainland's coast. Concurrently, major efforts have gone into developing recreational and tourist facilities on Sentosa and many nearby islands. Three of the southernmost islands are reserved for military use. Much of the coastal area surrounding the Southern Islands and the activities there have undergone tremendous changes over a very short period of time. This coastal area clearly requires a management plan to ensure, on the one hand, that vital development needs are not hampered and, on the other, that the consequences of environmental pollution and degradation are controlled so as not to affect adversely other resource uses (both present and potential) such as fishing, aquaculture, tourism and recreation, and education and research. There are also cultural and aesthetic aspects of the area that should be preserved and enhanced. Ways should also be found to preserve the small community in Pulau Sakeng and to draw together the diverse elements of coastal area management. At this stage, the proposed management plan is intended to stimulate discussion rather than produce a final solution.

Economic analysis of coastal resources: problems of valuation and evaluation

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ABSTRACT

Economic analysis of coastal resources is needed to evaluate fully alternative development scenarios. Because of the links between the physical, economic and social systems in the coastal zone, actions taken in one part of that zone can affect other coastal resources and resource users. Economic analysis helps to explain the magnitude of these impacts and interactions as measured in monetary terms.

In this analysis, one encounters two major areas of difficulty: (1) how to place monetary values on various goods and services, some of which are not commonly bought or sold and (2) how to analyze various alternative development options. The former is a question of *valuation*; the latter is one of *evaluation*.

In recent years, analytical techniques have been developed to place monetary prices on many environmental and resource goods and services; the use of these techniques is discussed. The process of comparing alternatives, or evaluation, raises important questions about the physical boundaries of the analysis, appropriate prices and discount rates to be used, and how to balance private and public benefits. Examples of the application of both valuation and evaluation approaches are presented, based on the analysis of mangroves and a specific bay ecosystem in the Philippines.

Issues in designing a coastal resources management program

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ABSTRACT

The Association of Southeast Asian Nations (ASEAN) confronts many coastal management problems such as the depletion and degradation of habitats, the depletion of fish stocks, coastal flooding, water quality problems and the like. However, the social, economic, political and administrative conditions and traditions of its member-countries are sufficiently different that no single coastal management model is likely to be appropriate for all countries in the region. Although they have no single optimal model, their tasks of program development are very similar. Thus, there is much to be learned from comparing planning and management experiences.

However, each member-nation must carefully tailor its own program to include:

- an identification of specific coastal problems to be addressed;
- an identification of priorities among these problems;
- an analysis of specific processes that caused these problems;
- an identification of specific management techniques (such as development guidelines) designed to mitigate these problems;
- a set of organizational arrangements and administrative processes for implementing a management program; and
- the designation of a geographic area within which management will occur.

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