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COASTAL ZONE POLLUTION IN INDONESIA

A RECONNAISSANCE SURVEY

Office of International & Environmental Programs
Smithsonian Institution

Coastal Zone Pollution in Indonesia with Emphasis on Oil

A Reconnaissance Survey

Lembaga Minyak Dan Gas Bumi, Study Group Pencemaran
Jakarta, Indonesia

and

Office of International and Environmental Programs
Smithsonian Institution
Washington, D.C.

April, 1974

Preface

A number of catastrophic marine oil spills in the 1960's and in 1970 alerted the world to the hazards and impacts of marine oil pollution. In the same period, the emergence of other serious kinds of pollution sparked pollution control initiatives in many countries of the world. The convergence of initiatives in Indonesia to study marine oil pollution and initiatives in the Smithsonian Institution to study various kinds of environmental impacts associated with international development led to the undertaking of the present joint study on oil and other pollution in Indonesia's coastal waters. Preliminary arrangements for the study were made through the Indonesian Institute of Science (LIPI), with visits by Dr. I.Eugene Wallen and Mr. William L. Eilers, Smithsonian Institution, in late 1971. An agreement was formalized with the Ministry of Mines whereby the Smithsonian Institution would work directly with LEMIGAS and its Study Group on Pollution on a survey of the impact of offshore oil exploitation. The scope and objectives of the study were later refined in workshops, as a clearer definition of the marine oil pollution problem was obtained.

The Study Group on Pollution (SGP), based in LEMIGAS, was established to undertake research and studies whose results are intended to guide the Indonesian Government in the formulation of policies, rules and regulations pertaining to the prevention and control of pollution, especially marine pollution by oil.

The SGP was formed in anticipation that increasing offshore drilling and transport of oil would result in pollution, with possible serious consequences.

The Smithsonian Institution's contribution to the joint survey was carried out by the Office of International and Environmental Programs, and was sponsored by the Office of Science and Technology of the United States Agency for International Development (AID). The survey of marine oil pollution was one of three case studies undertaken for AID to review the environmental consequences of various kinds of development. The other two case studies addressed the environmental impact of rapid urbanization (Seoul, Korea) and the environmental consequences of the impoundment of a tropical river (the Akosombo Dam and Volta Lake, Ghana). The purpose of these studies was to develop empirical information needed to formulate policy and planning guidelines which address environmental problems in these categories of development and which are tailored to the environmental and development characteristics of developing nations. The guidelines are to be published in separate documents.

This joint study began at a workshop held in Washington, D.C., in August, 1972, organized by Rio Rachwartono and attended by Dr. Wahjudi Wisaksono, head of the Study Group on Pollution, as well as scientists from the Smithsonian Institution, The U.S. Geological Survey and the oil industry. The nature of the Smithsonian contribution was discussed and the study problem was assessed. The paucity of information on the behavior of oil and petroleum products in tropical marine ecosystems, and the consequent need for original

research, were emphasized. Various themes were explored which are integral to the marine oil pollution problem: geological and other natural hazards to wells and pipelines; underwater drilling and production well technology; monitoring large territories; tankers as a source of pollution; heavy shipping traffic in the Straits of Malacca; and the impact of oil on marine organisms.

To organize the Smithsonian contribution, the alleged damage to Indonesian fisheries by marine oil pollution was suggested as an interface issue, which would bring into play the diverse factors relevant to marine pollution by oil.

The objectives of the Smithsonian contribution were initially defined as follows:

1. To assess status of fisheries in selected zones in Indonesia, and to determine the effect of oil and/or other activities on these fisheries. (The study was to focus on the island of Java, and if logistics could be worked out, the Straits of Malacca). Shipping was singled out as a prime potential source for oil pollution.

2. To develop or help develop an information system for oil pollution.

3. To aid in formulating interim options for prevention until better data are available and taking into account the risk tolerance level.

It was judged that a real contribution could be made by addressing these aspects of the marine pollution problem, notwithstanding the

limited amount of time (two to three weeks for each scientist) and money available for the Smithsonian input. Actual research by Smithsonian-sponsored scientists was not contemplated, rather the field visits would consist of interviews with key Indonesian people and short field trips to update, validate or develop observations and reports. This work would complement on-going research and data collection programs being carried out by the various members of the Study Group on Pollution. Study areas were then defined and U.S. consultants were selected, in joint consultation with the SGP. Also background documentation and maps were collected and organized in preparation for field work.

Prior to the initiation of field work, a second, one-day workshop was held in Jakarta, in LEMIGAS, in which members of the Study Group on Pollution and consultants from the Smithsonian Institution reviewed the oil pollution problem, the state of knowledge, and on-going research. It became clear during that workshop that pollution of all kinds in the nearshore waters of the coastal zone was placing increasing stresses on coastal fisheries. However, little quantitative information on the impact existed. On the other hand, high seas fisheries did not seem to have been seriously affected by offshore oil activities. Therefore, study emphasis was shifted to the coastal waters of Indonesia, and the question of developing interim oil pollution prevention options was de-emphasized.

The joint study centered on the following tasks: field visits in Java to sites where oil and other pollution had been reported, but not documented; a survey in Cilacap of the conditions and resources of a future refinery location; evaluation of fisheries and other resources of the coastal zone and nearshore waters of Java; acquisition of information on pesticides use in order to help substantiate the suspected impact of these chemicals on brackish water fish ponds; review of the overall situation concerning data collection, storage, and use in decision making, relative to marine pollution prevention and control; survey of existing offshore and coastal oil industry installations; reconnaissance survey of oil pollution in the Pulau Pulau Seribu (Thousand Islands) north of Jakarta. Later a survey of Pulau Pari was included, for the purpose of collecting data relevant to a proposed research oil spill.

During September and October, 1972, Jaspar Bilal, Robert Johannes and Peter H. Freeman made field trips to various parts of Java. During this period Morton Gorden reviewed the state of information on marine resources, oil, and oil pollution and data use by decision-makers in Jakarta. In February, 1973, R. A. Lovell and Jaspar Bilal visited offshore oil rigs and coastal installations. Samples collected during these trips were analyzed by LEMIGAS. Later, in connection with a proposed research oil spill, Peter Glynn accompanied by Jaspar Bilal made a reconnaissance survey of reefs

on Pulau Pari, in order to prepare the basis for a research design. But a research spill was not undertaken as part of the joint survey. A separate report on this survey was submitted by Glynn in July, 1973, to LEMIGAS.

The reports submitted by Johannes, Gorden and Lovell, other data collected by Freeman and Bilal, and laboratory analyses of water samples were all incorporated into a comprehensive report, prepared in July, 1973, by Peter H. Freeman. This report "Preliminary Working Papers; Study of Marine Oil Pollution, Indonesia" included an annotated bibliography prepared by Dr. Christopher Onuf, on the biological and ecological effects of oil pollution in tropical seas. A compilation was also included of seaweeds in Indonesia and their susceptibility to oil pollution, prepared by Dr. Arthur Dahl, Smithsonian Institution.

The preliminary working papers constituted the background discussion document for a workshop convened by LEMIGAS, The Study Group on Pollution and the Smithsonian Institution, which took place during Aug. 21-24, 1973, in Jakarta. Three groups reviewed the working papers, and prepared reports, which were then synthesized into a summary of findings and recommendations. These were discussed on the last day of the workshop. Following that workshop, an all Indonesian editorial steering committee edited the preliminary working papers and their work resulted in the present document.

Part I is a summary of the findings and a detailed presentation of recommendations, as developed during the August, 1973 workshop

and later refined by the post-workshop steering committee. Part II is the full report of the joint study.

Names of the workshop participants, steering committee members and the joint study participants appear in the following pages.

Acknowledgments

This joint study represents a collaborative effort in a relatively new field of endeavor which engaged institutions and individuals in Indonesia as well as the United States. It would not have been possible without the enthusiastic participation and extraordinary efforts of all who became involved.

On behalf of LEMIGAS and the Smithsonian Institution an expression of appreciation is extended to the United States scientists who participated in the field survey. Their names are listed in the following pages. On behalf of these consultants, acknowledgment is made of the valuable support and participation of LEMIGAS and Pertamina personnel who arranged field trips, itineraries and interviews. Pertamina's assistance in arranging visits to refineries and to offshore platforms is especially appreciated by the consultants. Also, the Smithsonian Institution is deeply appreciative of the coordination of field survey work and data collection undertaken by Wahjudi Wisaksono and Jaspar Bilal of LEMIGAS/SGP.

LEMIGAS and the Smithsonian Institution are both deeply appreciative of the efforts and participation related to the August, 1973 workshop. The names of all participants are listed in the following pages. Special thanks are mentioned for the active participation of Mr. Anwar Ibrahim, Mr. Kenneth Biglane, Prof. Georg Borgstrom, Mr. Diran, Miss E. Sutopo, Mr. Muljani, Mr. Rio Rachwartono,

Dr. Lyle St. Amant, and the chairmen of the three working groups: Mr. Asikin S. Djanegara, Dr. Aprilani Soegiarto, and Mr. Soetjipto Wirosardjono. Pertamina's assistance in arranging a pre-workshop overflight of Jakarta Bay and the Sunda straits is gratefully acknowledged. An expression of gratitude is due the Jakarta Municipality, who made available the Operation Room for the workshop's plenary session.

On behalf of Lembaga Minyak dan Gas Bumi an expression of appreciation is extended to LIPI and the Smithsonian Institution, whose cooperation made this study possible.

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PART I

SUMMARY OF FINDINGS AND RECOMMENDATIONS

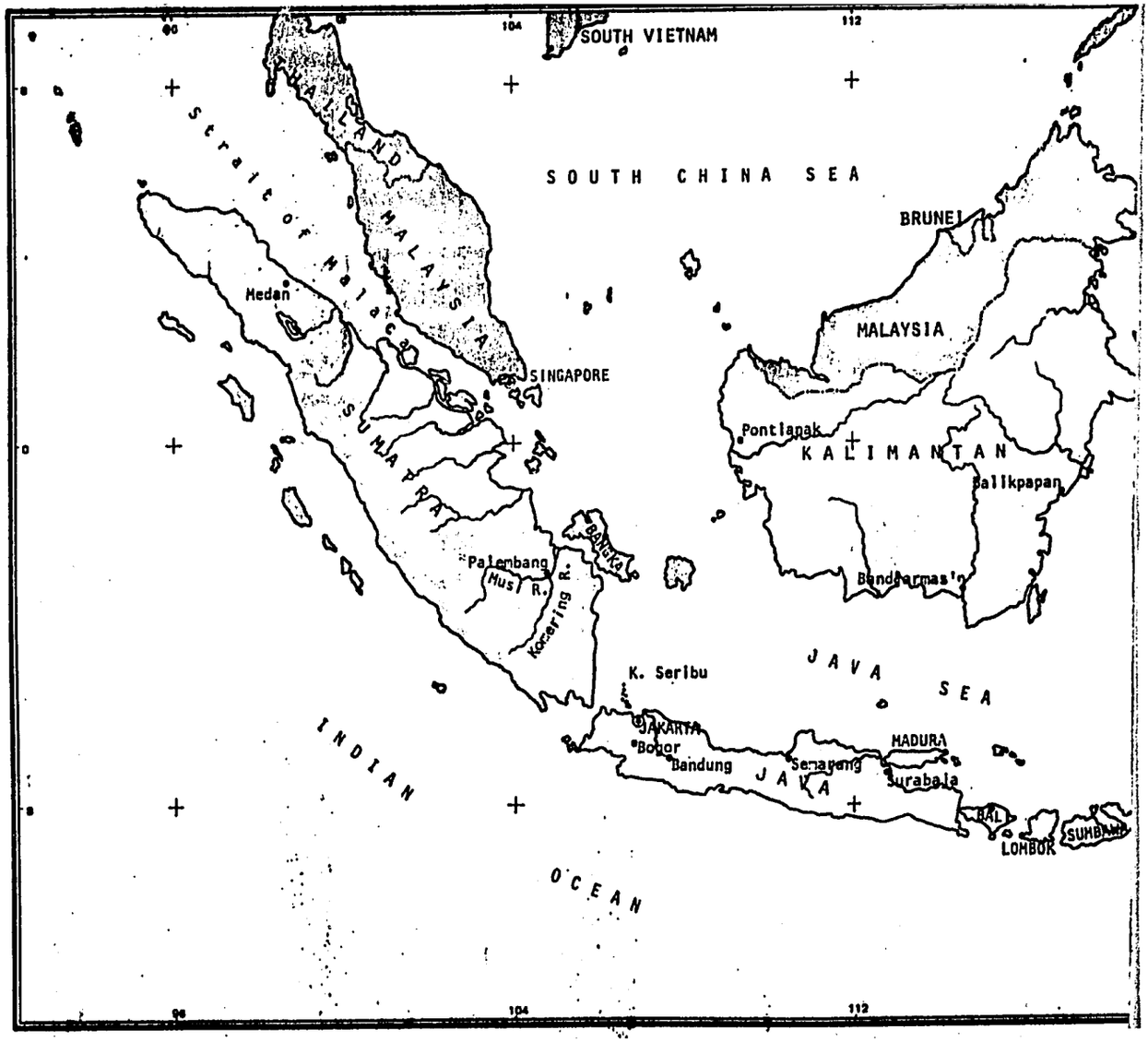
A. Background

In 1972 and 1973 the LEMIGAS Study Group on Pollution (SGP) and the Smithsonian Institution jointly undertook a survey on marine pollution by oil in Indonesia. A major objective of the survey was to determine whether oil pollution and oil activities were damaging or threatening the marine environment, but in the course of the study other pollutants were also considered.

The survey included previous work on oil pollution already carried out by the SGP, a review of world literature on oil pollution in tropical waters, and field observations made by SGP/LEMIGAS and Smithsonian scientists in Java, Sumatra, Kalimantan and Bali. Data and opinions from various government entities and offices were also collected and incorporated into the survey. Preparatory to the survey two workshops were held in 1972, one in Washington, D.C. and one in Jakarta. A final workshop in August, 1973, reviewed the preliminary results, and the proceedings are incorporated into this survey.

1. <u>The Marine Oil Pollution Problem</u>

The international and continental waters of the world's oceans and seas are becoming increasingly contaminated by oil and oil products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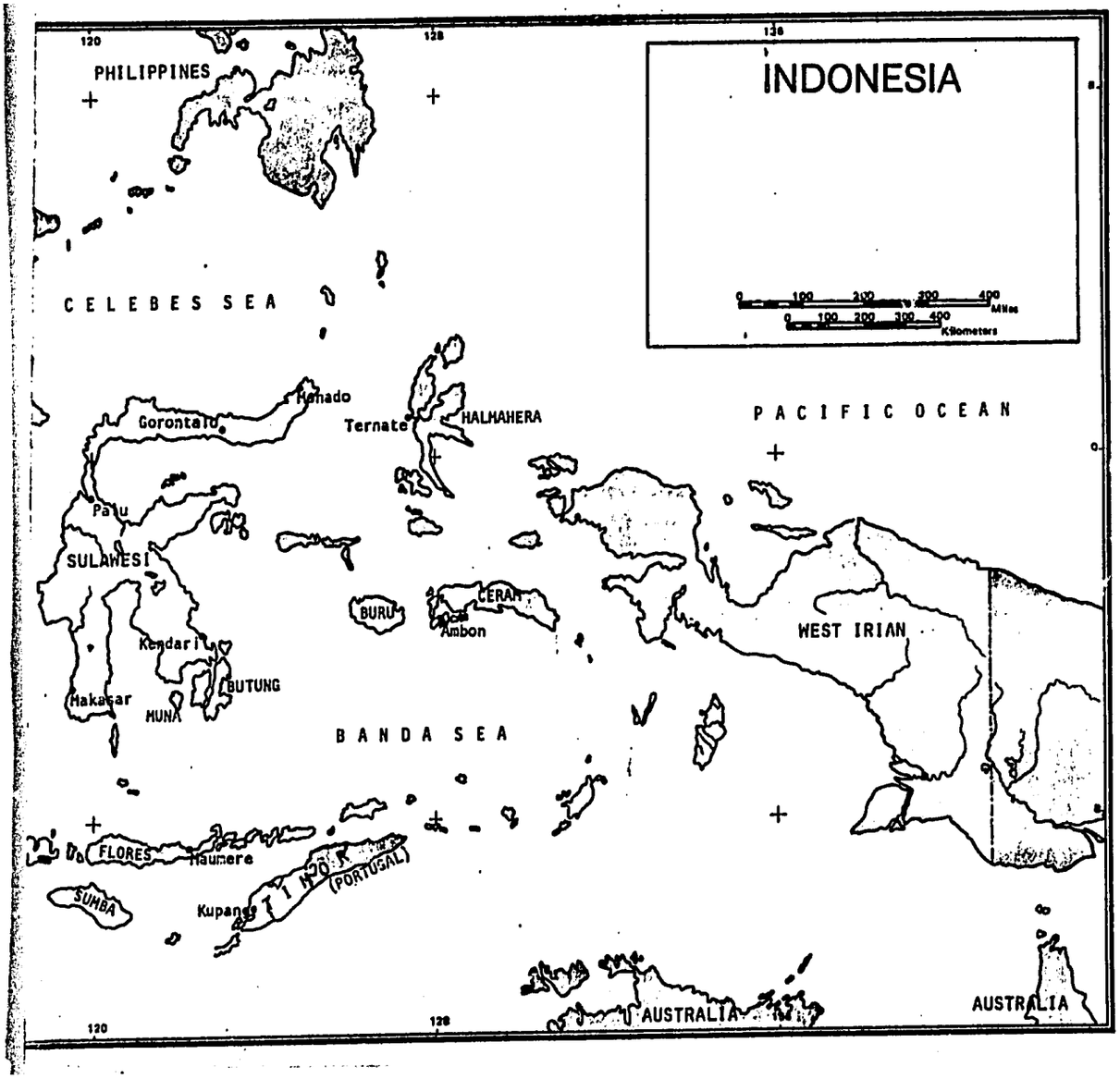
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either from low level, chronic discharges or from catastrophic events such as tanker accidents or offshore well blow-outs. In Indonesia, where both offshore oil production and movements as well as international tanker traffic are growing rapidly, there is a corresponding increase in the potential for marine oil pollution. In other countries of the world various kinds of damage have resulted from oil pollution. Oil pollution on recreational beaches and waters is clearly evident and has resulted in costly clean-up, not to speak of public outcry, in many areas of the world. The biological impact of oil pollution on the tropical marine environment is, however, difficult to assess. The needed research and surveys in tropical seas are so few and fragmentary that useful evaluations cannot be made. Knowledge of the impact of oil on temperate marine environments cannot be applied with confidence to the tropics. The impact of oil on the tropical marine environment needs separate investigation and special attention.

The impact of oil on U.S. coastal waters and outer continental shelf in the Gulf of Mexico does, however, suggest the kinds of damage that may possibly be caused by offshore oil production and transportation activities in Indonesia. There the most serious damage has been to the coastal shellfish grounds and nearshore fish nurseries, as a consequence of physical disturbance of the sea bottom and of changes in the salinity of brackish waters. These effects have been caused by dredging and the laying of pipelines.

Oysters have been tainted by oil from drilling mud.

Marine biologists also suspect that low concentrations of oil may cause subtle changes in marine plankton communities which are the basis for fisheries. However, this relationship has not been clearly established experimentally. Efforts to evaluate accurately the impact of marine oil pollution are made difficult, due to the presence of other pollutants, particularly in coastal waters. Notwithstanding these gaps in our knowledge, the pollution of marine waters by oil and other pollutants is cause for concern because of the known or suspected damage that may result.

B. Survey Findings

1. Hydrocarbon concentrations, indicative of oil pollution, were determined in the Jakarta Bay area by random sampling, and near offshore wells and coastal refineries by spot sampling. The highest concentrations were found in Tanjung Priok Harbour (100 ppm). Lower concentrations (less than 20 ppm) were found near the islands of Nirwana, Ayer Besar, Sakit and Kelor, all in the Jakarta Bay. Water sampled near wells and refineries showed no significant pollution. Both types of operations were in general clean. However, continuous sampling and analysis will be needed to establish the adequacy of present pollution control practices.

2. It seems that pollution by oil in offshore waters is not yet a serious problem in Indonesia. Alleged damage to marine fisheries, suggested by declines in fish catch, particularly in the East Java Region, cannot be attributed solely to oil pollution. This conclusion is consistent with knowledge in other parts of the world concerning the effect of oil pollution and associated activities on pelagic fisheries. It is emphasized, however, that this knowledge is still very fragmentary, especially in regard to the impact of oil on feeding behavior and species composition. Moreover, the Indonesian fish catch statistics reviewed do not prove or disprove the adverse impact of oil pollution on high seas fisheries.

3. Information derived from brief observations and short interviews at some oil installations indicated that pollution of coastal and estuarine waters by oil and by refinery effluents has not had any substantial effect on local fisheries. However, some complaints of tainting should be considered as grounds for maintaining close surveillance of the increasing activities of these installations.

4. "Tambaks" or brackish water fish ponds are the most important coastal resources, in terms of present and potential value, that could be adversely affected by oil pollution. Other forms of pollution are also of immediate concern to "tambak" production: industrial effluents and organochlorine insecticides in agricultural run-off. Domestic waste waters may also be causing problems. This conclusion is deduced from qualitative data and inferences concerning the vulnerability of "tambaks" to all forms of pollution and stresses associated with the flow of tidal and estuarine waters into these ponds.

5. Estuarine and shallow coastal waters are the most important marine zones that could be adversely affected by oil and other forms of pollution. These waters are highly vulnerable to all forms of pollution originating from land or open seas. This importance derives from their indispensable functions as habitats, nursery grounds and fisheries. Many juvenile forms of fish and crustaceans living in these waters, such as Chanos chanos and penaeid shrimps, are sensitive to change in water quality.

6. Knowledge of coral reef ecosystems and of the manner in which they are affected by oil pollution is insufficient to permit conclusions to be formulated. Coral reefs and reef flats may be adversely affected by oil pollution, but their locations in Indonesia do not generally expose them to pollution from terrestrial sources. Unknown quantities of fish and other marine life are harvested from coral reefs, and it is surmised that these products are locally important contributions to the diet of subsistence fisherfolk.

7. Tourism and recreation in the Kepulauan Seribu are adversely affected by beach oil pollution, apparently originating from ship traffic. It is difficult to measure the magnitude and importance of this impact, however. The number of visitors to these islands is increasing. The Bina Ria beach, Jakarta, may also be affected by oil pollution, although a problem may also be posed by domestic and industrial waste waters.

8. In anticipation of a National Environmental Law, several Indonesian agencies have developed regulations for environmental protection. Pertamina observes regulations on the restriction of discharges of oily matter into the sea; the restrictions affect foreign contractors as well. An offshore operation regulation drafted by the Department of Mining is in the process of r tification. In Jakarta's area, the city has

restricted coral and sand dredging to specific areas; also, the city has a regulation pertaining to industrial effluents. On the sectoral level, the Department of Agriculture has the regulation of pesticide use.

9. In several industrial facilities equipment is available for oil spill control and pollution prevention devices have been installed.

10. Reliable information on marine pollution levels and marine resources, based on scientific research, surveys and statistical data collection, does not presently exist. Consequently an accurate assessment cannot be made of either the present or potential impact of various forms of pollution on Indonesian coastal waters and their resources, or the cost of these impacts.

Coastal water pollution is not presently monitored except for visual observations. The toxicity and ecological impacts of various pollutants on coastal water biota specific to Indonesia are only beginning to be researched. Some research on insecticide toxicity in fresh water pond fish was reported, but "tambak" species have not yet been tested. Statistical data on trends in marine catch do not exist in

a form that permits inferences to be made on the probable impact of existing levels of pollution in the coastal zone. There is no information on the significant fish catch or on the amount of catch that is consumed by the fishermen's families.

Because of these information gaps, the seriousness of the coastal zone pollution problem for fisheries cannot be adequately defined, from the point of view of Indonesian scientific data. However, there has been enough doubt raised by international scientists' concern on this matter, that caution should be taken particularly during this period, since the coastal resources in Indonesia are so critical for her economic development. The August, 1973 workshop participants (see Preface) therefore look with favor on those preventive and precautionary programs being followed by existing bio-industries.

C. Recommendations

The major recommendations set forth below are grouped into six major categories:

(1) Monitoring

(2) Environmental assessment

(3) Research and surveys

(4) Data coordination

(5) Policy

(6) Contingency plan

No estimates of financial and manpower needs or schedules have been developed; however, both human and financial resources will be required. The recommendations are founded on the broad principle that economic development should not proceed at the expense of productive resources or of human welfare. Unwanted, yet avoidable, damage can result if development decisions are made in the absence of knowledge of how such damage can take place, and how it can be avoided. It is proposed that this concept constitute the fundamental, if not final, justification for investment of manpower and money in the programs recommended below.

1. Monitoring Oil and Other Pollutants in Marine Environment

A periodic and systematic sampling program should be initiated in certain priority areas, in order to monitor hydrocarbon levels in water, bottom sediments, and biological tissues. In coastal waters near large cities or settlements, pollutants important to public health and fisheries should also be monitored. In certain places along the coasts samples should be analyzed for organochlorine insecticides or their metabolites.

The priority areas recommended for monitoring are: shipping lanes, waters near major offshore oil drilling and production, waters influenced by refinery effluent, coastal waters receiving agricultural run-off and other industrial effluent, and estuaries. It is recommended that a sampling program be established which will gather sufficient data to show the identity, concentration, and distribution of chemical contaminants and the biota of the marine ecosystem, and the effects of the abiotic and biotic systems on each other. To attain these goals the program must consider:

(1) the method of introduction of the contaminant into the marine ecosystems;

(2) the character of the introduction (continuous or discontinuous; seasonal or occasional);

(3) the mechanism of transport, both horizontal and vertical (currents, biological activity, sediment transfer, etc.);

(4) the effects of the contaminant on the kinds, abundance and distribution of biota.

The study of features must be well-coordinated, using a system of standard procedures of sampling, identification, and data storage-retrieval and analysis systems. Each datum must be the result of the highest state of the technological art for that class of data. The program should be planned by a qualified environmental science unit using a wide range of local, regional and international expertise.

The sampling program should include three systems: (1) water, (2) sediment, and (3) biota especially the key indicator species. Each system must be analyzed for heavy metals, halogenated hydrocarbons and petroleum in addition to the standard physical and chemical analysis common to such studies.

Information to be gained from the water samples should provide a long-term accounting of the accumulation of the chemical contaminants and a basis for understanding the pathways by which contaminants are distributed. Sediments are common carriers of contaminants as well as nutrients, and

a careful study of suspended and accumulated sediments should provide, in addition to that listed above, information on the storage of contaminants and their importance in the benthic and filter feeding biota. Biotic sampling should provide an assessment of kinds and relative abundance of living resources for purposes of commercial exploitation and management. In addition, biotic sampling of commercial species and subsequent tissue assay of contaminants provide information on potential health hazards.

Samples should be obtained by inter-island freighters, passenger ships and tankers; by oceanographic or fisheries survey vessels; or by local fishermen. Expanded laboratory analytical facilities as well as coordination of the sampling will be required to obtain standard results.

2. Environmental Assessment

It is recommended that assessments be made of present and planned coastal industries or industrial complexes whose effluent can have, or is suspected to have, harmful effects on the biota and resources of coastal waters. Assessments of existing coastal industries are needed to determine the nature and extent of damage, if any, caused by effluents discharged into coastal waters. Environmental impact assessment should be an integral part of prefeasibility and feasibility studies, and this recommendation is consistent with recent policies

aimed at taking into account the environmental aspects of planned development activities.

Environmental assessments should also be made of planned sectoral programs whose implementation may result in pollution of coastal waters. Such assessments should include not only an inventory of possible effects on physical and biological resources but also a determination of the present and potential utilization of these resources in local economies and their role in the achievement of sectoral goals. The fisheries sector in particular can be negatively affected by marine pollution. It was recognized that this is of paramount nutritional significance to Indonesia. Such effects need to be part of any environmental assessment.

This environmental assessment recommendation will require a variety of data, from on-going research efforts as well as new research and data collection, some of which are contained in the other recommendations presented here.

3. Marine Baseline Surveys and Research

Baseline surveys are required to determine existing conditions of various marine zones and communities which are relatively unaffected by pollution. These surveys are needed to characterize the biota and productivity of such normal zones, so that when pollution occurs its effects can be measured and evaluated. Data should be collected on water and sediment characteristics, species composition and abundance, primary productivity,

food pathways, reproductive patterns, and background concentrations of natural hydrocarbons, heavy metals and organochlorines. Standardized methods and equipment, needed to sample and analyze small concentrations, are required. It is recommended that baseline surveys be undertaken in the estuarine and coastal waters near Cilacap, the Straits of Malacca and of Lombok and future sites of planned coastal industry.

Research is recommended in four areas:

(1) field and laboratory tests on the toxicity and the ecological impact of oil and other pollutants on "tambak" biota and cultivated species, such as Chanos chanos, Tilapia spp., shrimp and prawns;

(2) laboratory toxicity tests on nearshore coastal and estuarine species, to determine the effects of organochlorine and other suspected pollutants;

(3) microbiological breakdown of hydrocarbons and microbiological production of natural hydrocarbons; and

(4) field research on the effects of deliberate oil spills on coral reef biota.

The early work of J. H. F. Umbgrove (1929) and Verwey (1931) on coral reefs in Indonesia is interesting because of the peculiar environmental regime under which these reefs were described to be living. The detailed information available on the coral reefs

off Jakarta would provide an extremely useful reference datum for a modern re-survey of this reef area. If significant ecological alterations are detected which are due to the domestic and industrial pollutants being discharged in the vicinity of Jakarta, these could perhaps provide a useful guide to the influence of human population growth on coral reef ecosystems (Glynn, 1973).

4. Data Coordination

Existing and new data on the marine environment, its resources and their economic and social importance must be gathered and stored for easy retrieval in order to facilitate planning, assessment and research design focused on this important environment. In order to meet this need, it is recommended that a marine data bank and clearing house be established as an integral part of the national data network.

5. Marine Environmental Policy

In order to further on-going efforts to develop environmental policies in general, it is recommended that information be gathered and evaluated in order to develop criteria for formulating policies and standards for protecting and maintaining the quality of the marine environment. Such policies and standards must be based upon the physical and biological conditions of the Indonesian marine environment and upon the contribution to national welfare and the development of marine resources and amenities.

To accomplish this objective it is suggested that a working group be established within existing organizational frameworks already addressing this task. This working group would avail itself of the experience and knowledge in other nations as well as existing information and research on Indonesian marine environments and their resources. Baseline, monitoring and research data of the kind recommended here will be needed to develop realistic criteria. Special attention should be accorded to areas where natural disasters are likely to occur (e.g. earthquakes).

6. Contingency Plan

Detailed information on existing capabilities for controlling spills is required as a point of departure for a coordinated contingency plan. It is recommended that an inventory and evaluation be undertaken of present equipment, procedures, plans, personnel, systems and organizations for controlling spills of oil and other hazardous materials. A study should be made of the economic and technical aspects of various spill control equipment alternatives. The results of these surveys should provide the basis for correcting the existing deficiencies and deciding the best control technology, and ultimately will contribute to the design of a national oil spill contingency plan.

As a specific interim measure it is recommended that all dispersants to be used on oil spills be evaluated and certified

by government institutions (Department of Mines in consultation with other departments), that limitations to their use be specified, and that entities handling these dispersants be notified of these limitations.

PART II

JOINT STUDIES REPORT

A. Introduction

Crude petroleum production in Indonesia passed the one million barrels per day (bpd) mark in 1971, and in that year offshore production commenced. As of June, 1973, total production has increased to 1.2 million barrels per day, with an increasing proportion coming from offshore wells.

Production from the first offshore field, Cinta, was 40,000 bpd by May, 1973, and production from the Arjuna field is expected to reach 73,000 bpd when all known fields are connected. In February, 1973, an additional discovery was made 60 miles southeast of the Arjuna field. Both fields are located off northwest Java. Off the cost of Kalimantan north of Balikpapan, offshore production in the Attaka field has reached 62,000 bpd and is expected to reach 170,000 bpd by the end of 1974. Virtually all of Indonesia's territorial waters are undergoing exploration and drilling. It appears that an offshore oil boom is in the making, stimulated by the low sulphur content of Indonesia crudes and the accelerating world energy demand. Concomitant to this development is the increasing potential for marine oil pollution.

What has been the impact of marine oil pollution in Indonesia and what will be the impact as the volume of offshore production, transfer, and transport increases? Although no serious polluting incidents have yet occurred, offshore oil activities have been blamed for declines in fish catch. The potential for well blow-outs has been demonstrated by two incidents, both gas wells fortunately, and only one offshore. These events, together with major blow-outs, tanker collisions and other polluting disasters in other parts of the world, illustrate the dangers that accompany expanded oil activities in Indonesia.

Despite the obvious importance of the marine oil pollution threat, its magnitude is not easily determined since remarkably little information has been accumulated on the biological and ecological impact of oil in warm tropical waters in any part of the world. How will Indonesia's marine resources be affected by low level or catastrophic oil pollution? What will be the economic and social consequences? How much money and effort should be expended to control oil pollution by the Indonesian Government? What actions and programs are needed? This study attempts to provide information that will help answer these questions.

The present document contains a review of existing knowledge concerning oil pollution in tropical waters, a survey of Indonesian marine resources vulnerable to oil pollution, and a review of the

present status of oil pollution based largely upon field interviews and visits to various installations on and offshore. Original research is not contained in this document.

B. Review of the Biological and Ecological Effects of Oil Pollution in Tropical Waters

1. Introduction

This review is very brief. Its primary function is to serve as a guide to the annotated bibliography. It cannot serve as a valid synthesis of general principles or features of tropical marine oil pollution because none exist, or at least the research has not yet been reported which has demonstrated them. The lack of consistent patterns is hardly surprising considering the immense variety in kinds of oils released to the sea and the variety of conditions under which the oil may impinge on organisms and communities, which in their own turn are so varied. Consequently, it is probably more valuable to make available brief accounts and evaluations of the original sources so that the reader may organize the information to suit his own needs.

The sources reviewed fall into three general categories:

(1) Explicit reports of oil pollution in tropical regions (including the large volume of work from the Gulf of Mexico). In most instances, these sources were identified by using the Oil Spill Index and the collection of the Oil Spill Information Center at the library of the University of California, Santa Barbara.

(2) Reports on organisms or assemblages of organisms studied elsewhere but which are also likely to be

important in the tropics. Particular attention was paid to organisms exploited in fisheries.

(3) Environments which are likely to be particularly important, whether because particularly vulnerable, valuable, or close to large sources of possible contamination.

The subject is open-ended in many directions. The review and bibliography are not exhaustive. Often the evaluations of other work are critical. This is not necessarily a reflection on overall quality because frequently the research was designed to answer other questions than those that are addressed in this review. Finally citations will be made for some themes in the review without all the qualifications and criticisms contained in the bibliography. Often points made in the text are based on suggestive data rather than convincing documentation and should be accepted advisedly.

2. Physical and Chemical Properties of Oil Spilled on the Sea

Crude oils as well as refined products are very complex mixtures of hydrocarbons and substituted hydrocarbons. The properties of the spilled material will depend on its composition. Few petroleum products have been completely characterized, so it is not possible to predict precisely the behavior of oil spills. Gilmore (1970) has made a valuable summary of characteristics of 36 major oil spills which occurred between 1956 and 1969. Vessels

accounted for 75% of the spills, mostly involving tankers. Half the incidents involved crude oil, but it amounted to 80% of the volume spilled. Table 1 presents the available information important in evaluating possible effects of spills. Very importantly, most spills occur close to shore (half within one mile), during high winds (40% above gale force), with heavy seas (40% above 10-feet high waves). The probable results are that at least some oil will reach shore while much will also be mixed into the water column and reach the bottom. If the bottom is soft, some of it will be retained there.

The structures of compounds and their relative abundance in oil will determine the range of effects that a particular spill may have. Solubility, volatility, toxicity and susceptibility to biological decomposition depend on chemical structure and are by no means independent of one another. They act together with environmental conditions to determine the dose and duration of exposure of oil to living things. Gilmore (1970) provides a useful review of conditions under which spills have occurred. Moore _et al_. (1973) give a helpful summary of structure of hydrocarbons and composition of oils as they pertain to solubility in seawater, volatility and biodegradation. McAuliffe (1966) reports the solubility of different classes of hydrocarbons. Baker (in Cowell, 1971, pp. 78-80) concisely relates structure to toxicity.

Table 1. Characteristics of oil spill incidents

	Number of incidents	Median	25 - 75% range
Volume of spills (barrels)	23	30,000	5,000 - 100,000
Distance from shore (miles)	25	1	1 - 10
Extent of coastal contamination (miles)	18	3	1 - 20
Wave height at time of spill (feet)	11	9	6 - 15
Wind velocity at time of spill (knots)	15	20	10 - 45

Source: Gilmore *et al.*, 1970. The median is probably the best estimate of a typical spill while the 25-75% range gives a measure of the variability about the median. The data are interpolations from Figures 3, 4, 6, 10 and 11.

Generally speaking, the low-boiling aromatic fraction of petroleum is the most harmful to living things. This means that if the oil remains on the surface of the sea for more than a few hours, particularly in the tropics, evaporation will eliminate most of the toxicity. Severe biological damage will occur only when exposure is immediate or when fresh oil gets incorporated into sediments, as will happen when a spill occurs over a shallow, sandy or muddy bottom during a storm. In the latter case the toxicity of the oil will persist for a long time because the degredation of the oil is exceedingly slow where the availability

of oxygen is low. The oil may then cause damage long after the spill if another storm disturbs the sediments enough to expose the trapped oil. Although fresh oil is highly toxic, the biological damage will be local. Weathered oil will contaminate much larger areas and can lead to large-scale mortality along shores if undiluted detergents are applied directly in cleaning up beaches. This is what happened along the coast of Cornwall after the wreck of the Torrey Canyon.

3. Biological Effects with Emphasis on Fisheries

There are only a few reports of oil pollution causing severe biological damage. Probably most reports of minor to undetectable damage are correct, but in almost every instance the studies neglected so many necessary elements that they cannot be relied upon. Adequate controls are seldom incorporated. Benthic infauna was usually not sampled. The few good studies, however, may be a sufficient basis to make crude but useful predictions about vulnerability of habitats and kinds of organisms.

The degree of biological damage depends mainly on the kind of oil spilled, closeness to shore, configuration of shore, character of bottom, and weather at the time of the incident. Although the Torrey Canyon was the biggest of recent spills and contaminated the most shore, it caused negligible damage to fisheries (Simpson, 1968). As mentioned above, the extensive damage to intertidal life is attributed (among other things) to the use of kerosene and

aromatic hydrocarbon based dispersants used in cleaning up, rather than the oil itself. Recovery was rapid. The Torrey Canyon spill caused as little damage as it did probably because the inherent toxicity of Kuwait crude is low and the oil was at sea long enough for toxicity to decrease further due to evaporation. The recent blowouts on offshore rigs in the Santa Barbara Channel and off the coast of Louisiana seemed to cause even less damage. Evidence that adaptation to the chronic presence of hydrocarbons in oil-producing regions leads to increased tolerance to spilled oil (Nicholson and Cimberg, 1971; Kanter et al., 1971) is not convincing. It is more likely that less damage was caused because, in addition to the crude oils being low in toxicity and weathering before contacting organisms, dispersants were used sparingly. On the other hand, the Tampico Maru was a much smaller spill where no dispersants were used. Even so, virtually nothing survived and recovery has been slow (North et al., 1965). The severity of effects probably was caused by the high toxicity of the diesel fuel being delivered undiminished to the organisms because the wreck was on shore. High surf emulsified the oil, and most of the oil spilled into a small cove which was for the most part blockaded by the hulk. The West Falmouth spill also was small but did seemingly disproportionate damage. Almost all life in the vicinity was annihilated. In addition, the area harmed actually increased ten-fold in the next eight months. The

collecting of shellfish was prohibited for two years because of tainting (Blumer et al., 1971). In this case, the spill occurred close on shore during a gale. The No. 2 fuel oil contained 42% aromatics. The oil adsorbed to sediment particles, which were suspended in the water column by the turbulence, and was thereafter deposited on the bottom before evaporation and dissolution could diminish toxicity. The spread of contamination was by means of winter storms and currents moving the oil entrained in sediments.

Results from analyses of actual spills seem to support the points developed from a consideration of chemical and physical properties.

Refinery and petrochemical plant effluents, oil handling ports and coastal oil fields cause long-term, low level contamination of the marine environment with oil. It is possible that these continuous discharges will have qualitatively different consequences than the one-time inundations by spills. Most importantly the stress imposed on organisms will not be by hydrocarbons alone. Refinery and petrochemical wastes include relatively high concentrations of phenols, ammonia, and salts, including those of heavy metals. Oil field bleedwater may exceed the normal salinity of seawater by more than three times and the ratios of important ions may be reversed (Spears, 1971). Refineries and oil handling harbors will almost always be surrounded

by other industries and large human populations, also discharging wastes. All the chronic sources of oil pollution commonly are on inshore waters subject to extreme fluctuations of temperature and salinity. Wohlschlag and Cameron (1967), Kloth and Wohlschlag (1972), Jeffries (1972) and Gilfillan (1973) have all shown that levels of oil pollution which could or actually do occur in coastal waters have much more serious consequences when combined with other sources of pollution and natural environmental stresses. The first three citations also indicate that the biggest individuals, therefore both economically and reproductively most valuable, are most vulnerable. Spears (1971) found that a tidal creek receiving oil field wastes was several to many times less productive of commercially important organisms than neighboring uncontaminated creeks. Copeland (1967) and Bechtel and Copeland (1970) observed increased diversity of zooplankton and fish, respectively, with increasing dilution of effluents from an oil refinery complex at Baytown, Texas. The last two studies suffer because they confound the effects of increasing salinity with dilution of wastes. Mackin and Hopkins (1961) showed that oysters are not damaged even by direct contact with oil but St. Amant (1970) has pointed out that other activities of the oil industry have had considerable effect on the oyster fishery in Louisiana coastal waters. Diesel oil added to drilling mud as a lubricant in deep drilling has been implicated in most

cases of tainting. Canalization, necessary in moving heavy drilling equipment in marshland and laying pipelines, has led to increased salt water intrusion into bays, forcing the removal of oyster beds to less suitable grounds further inland. Channeling has also led to accelerated erosion of the marsh. Other effects on living resources are a large reduction in fur yields, a change in species composition of the shrimp catch in favor of the more saline brown shrimp, and the elimination of extensive areas of bay bottoms from trawling by the physical obstructions of wells and catwalks. So far there has not been a detectable decrease in the productivity of the Louisiana fisheries.

In general, the effects of chronic discharges can be serious where dispersion is not rapid, particularly into salt marshes, but when serious it is quite local (Baker, 1973). More widespread alteration and damage to the living environment occurs where oil extracting activity physically disturbs the topography.

Moore et al. (1973) have made a valuable contribution with their extensive and convenient tabulation of toxicity data with accompanying remarks. Table 2 is their summary of that information. It is clear that larvae are the most susceptible, followed by crustaceans and benthic invertebrates, excluding molluscs. Kunhold (1971), Mironov (1968, 1970a), and Wilson (1970) emphasize the sensitivity of larvae. The fact that eggs and larvae of many forms occur only in the topmost layer of the sea, even those that

Table 2. Summary of oil toxicity data

Class or Organisms	Estimated typical toxicity ranges (ppm) for various substances			
	SAD*	#2 Fuel Oil /Kerosene	Fresh Crude	Weathered Crude
Flora	10 - 100	50 - 500	10^4 - 10^5	Coating more significant than toxicity
Finfish	5 - 50	25 - 250	10^4 - 10^5	
Larvae	.1 - 1	.5 - 5	10^2 - 10^3	
Pelagic crustaceans	1 - 10	5 - 50	10^3 - 10^4	
Gastropods	10 - 100	50 - 500	10^4 - 10^5	
Bivalves	5 - 50	25 - 250	10^4 - 10^5	
Benthic crustaceans	1 - 10	5 - 50	10^3 - 10^4	
Other benthic invertebrates	1 - 10	5 - 50	10^3 - 10^4	

*Soluble aromatic derivatives (aromatics and napthenoaromatics)

Source: Moore et al., 1973, Tables 6-10

are benthic as adults, places the most sensitive individuals closest to the source of contamination. In soft bottoms, benthic invertebrates, the next most sensitive assemblage of organisms, are associated with conditions in which oil can concentrate and then persist for long periods. The intertidal region is the other area which will be exposed to big doses of oil, but here

the organisms are generally tough, presumably because their adaptations for exposure to the air preadapt them to cope with short-term exposure to oil. If mortality occurs, it usually will be caused by smothering under a thick layer of weathered oil. In the immediate vicinity of chronic discharges, however, few species will live, particularly if the discharge is into a marsh. Diving birds have not entered into the discussion above but are well-known to be exceedingly vulnerable because of their living habits and their very low reproductive rates (IMCO, 1973).

4. Tropical Marine Oil Pollution

The preceding general analysis of the effects of oil applies to the tropics, although the available data for warm waters are even fewer. Nearshore disasters have been the most damaging. Crude oil was spilled at San Juan, Puerto Rico, when the *Ocean Eagle* ran aground. Although the wreck occurred during big seas, there was no indication of oil in sediments (based on only two dredge samples). The heavy mortality occurred in the high part of the intertidal zone and was mainly due to detergents and shore cleaning (Puerto Rico University, 1968). Areas of mangrove swamp were heavily covered and damage was presumed but not documented (Pearce and Ogren, 1968). Perhaps the most serious outcome was the large scale erosion of tourist beaches which had been treated with detergents. Fisheries were not harmed and recovery of affected areas was rapid (Pearce and Ogren, 1969). The *Argea Prima*

grounded within a mile of the beach and onshore winds beached much of the crude oil pumped out during salvaging. The oil was incorporated into the sediments and caused large-scale erosion of sand, moving it out to a depth of five meters. Mortality was heavy, extending even to the algae. Recolonization was by blue-green algae, rather than by the typical reds, greens and browns. Tourist-dependent businesses suffered locally as did fishermen due to the fouling of gear (Diaz-Piferrer, 1964).

The R.C. Stoner spilled several kinds of aviation fuels after foundering on the coral reef at Wake Island. There was extensive immediate mortality to a wide variety of fish and invertebrates, but surveys two weeks after the spill found fish to be in normal abundance. Damage to hidden invertebrates of the reef flat may have been longer lasting (Gooding, 1971).

The diesel and bunker oil released by the Witwater at the mouth of the Panama Canal accumulated among mangroves and in a sandy beach at least to a depth of 30 cm. It was evident in both places two months later. The meiofauna was drastically reduced while mangrove seedlings and the organisms attached to mangrove trunks were killed (Rützler and Sterrer, 1970). The pipeline rupture at Tarut Bay, Saudi Arabia, caused heavy mortality of the intertidal fauna where slicks were heavy. Some defoliation of mangroves occurred. Catches were reduced while

weirs were contaminated with a brown oil mousse (water-in-oil emulsion), but recovered after a storm cleaned them. No tainting occurred (Spooner, 1970).

In general it appears that where damage occurs it is local. Corals are not damaged unless exposed to air and oil simultaneously. Experiments by Grant (1970) and Johannes *et al.* (1972) corroborate this observation. Lewis' (1971) demonstration of deleterious effects caused by the dispersant *Corexit* and crude oil may not apply to field conditions because he did not permit evaporation. Also effects were reversible in 24 hours except above 100 ppm.

Concern about biological damage due to oil in Indonesia probably should concentrate on five serious threats:

(1) The most widespread damage is likely to result from the physical disruption of nearshore shallow water habitats where oil exploitation is carried out. According to St. Amant (1970), this has been the major harmful impact of the oil industry in Louisiana. He is convinced that proper management can avoid most of this damage.

(2) The one offshore region which it will be essential to protect is between the Spermonde Islands where *Chanos* is believed to spawn and Madura where the fry reach the coast. If indeed the estuarine fish farming of *Chanos*

in Java is dependent on this one spawning ground, one spill could actually eliminate one of the island's major sources of animal protein for at least six months, because the developing eggs and larvae are so sensitive to oil, occur at the surface, and are all produced in a limited area. This is an unlikely event, but its possibility suggests special precautions.

(3) Other conceivable pollution incidents are much more likely to occur but will not have far-reaching biological consequences. If nearshore spills cause very severe damage, they will of necessity be very local for the reasons discussed above. The repercussions will be most serious in nursery areas, particularly if prawns are killed off prior to the filling of local "tambaks". Otherwise the "tambaks" are relatively safe from oil pollution, because they can be closed off from the sea when it is contaminated, assuming of course that adequate warning is given.

(4) Tainting of flesh and fouling of fishing gear may cause local hardship.

(5) Refineries dumping wastes into slowly renewed receiving waters will cause local degradation of the environment, especially in marshes. This should be taken into account in deciding on sites for new facilities.

It is necessary to be aware of other possibilities which are now remote or mere speculation. Gordon and Prouse (1973) have shown that concentrations of hydrocarbons which occur in some coastal waters inhibit photosynthesis. Blumer *et al*. (1971) note that petroleum includes carcinogenic fractions and suggest that marine oil pollution might increase the incidence of cancers. Removal of susceptible organisms may lead to profound changes in the character of a community. This occurs when important grazers are selectively removed (for instance, Crapp in Cowell, 1971, pp. 187-203). Low concentrations of oil can interfere with chemosensory behavior (Jacobson and Boylan, 1973), fish migration (Rice, 1973), and growth and reproduction (Jeffries, 1972).

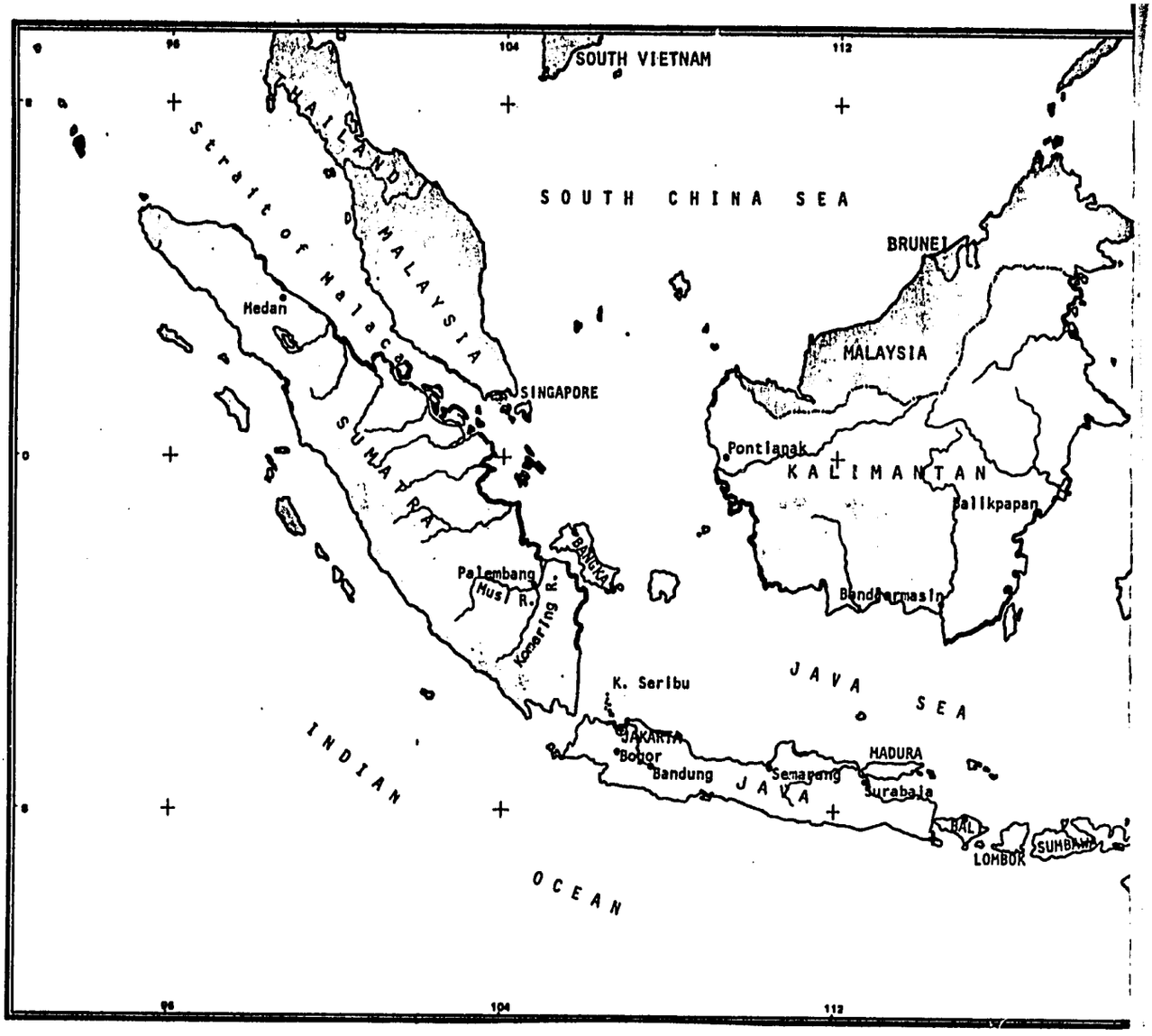
C. Areas and Resources in Indonesia Vulnerable to Oil Pollution

In the Indonesian seas and coasts that are or could be polluted by oil, some zones are more critical than others in terms of both their susceptibility and their importance as resources. Brackish water fish ponds are the most vulnerable resource areas, coastal fisheries are important but less vulnerable, while the deep sea fisheries are least vulnerable, and at the same time least developed. Pollution of any of these zones may be more harmful at times of year when the larvae and juvenile forms of important species appear. The clean sands and shallow waters of the Seribu Islands near Jakarta are important for the success of tourism, and are already showing signs of oil pollution.

1. Coastal Marine and Estuarine Zones

Oil can be carried to considerable depths in the water column, deposited in sediments, and redispersed in the column, affecting bottom organisms as much as 20 m. below the surface (EPA, 1972). The bulk of Indonesia's marine fishing activity is carried out in water no deeper than this (Figure 3). These fisheries account for two-thirds of Indonesia's total fish catch.

Of great importance to tropical coastal and estuarine fisheries are the adjacent mangrove communities. These communities occupy an estimated 6,000,000 ha. (Bardach, MS) along Indonesian coastlines, an area about 1.3 times the size of Switzerland (Figure 4). Not only do mangrove roots provide vital shelter for


SOUTH VIETNAM
SOUTH CHINA SEA
THAILAND
MALAYSIA
Strait of Malacca
Medan
SINGAPORE
SUMATRA
BRUNEI
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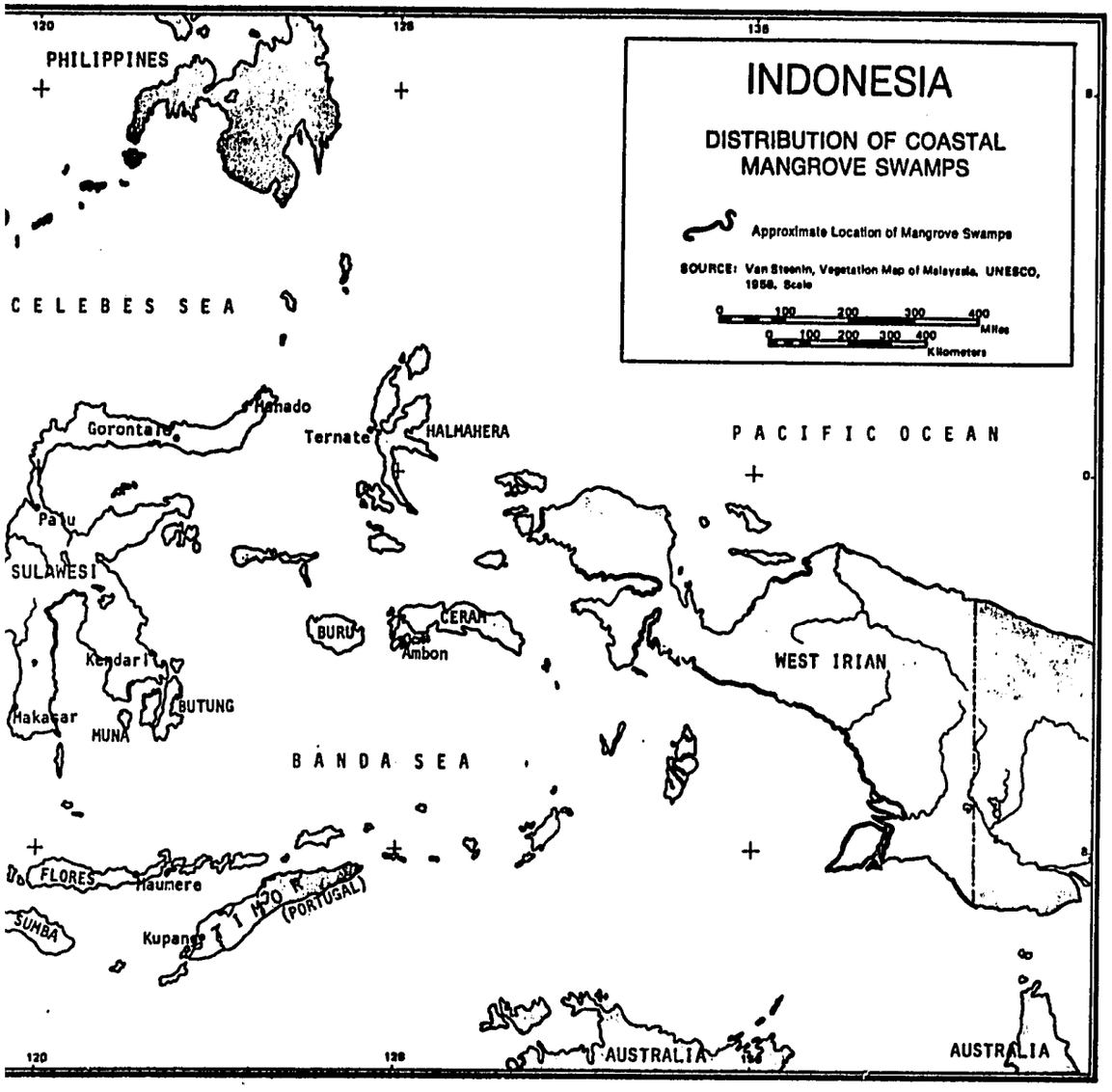
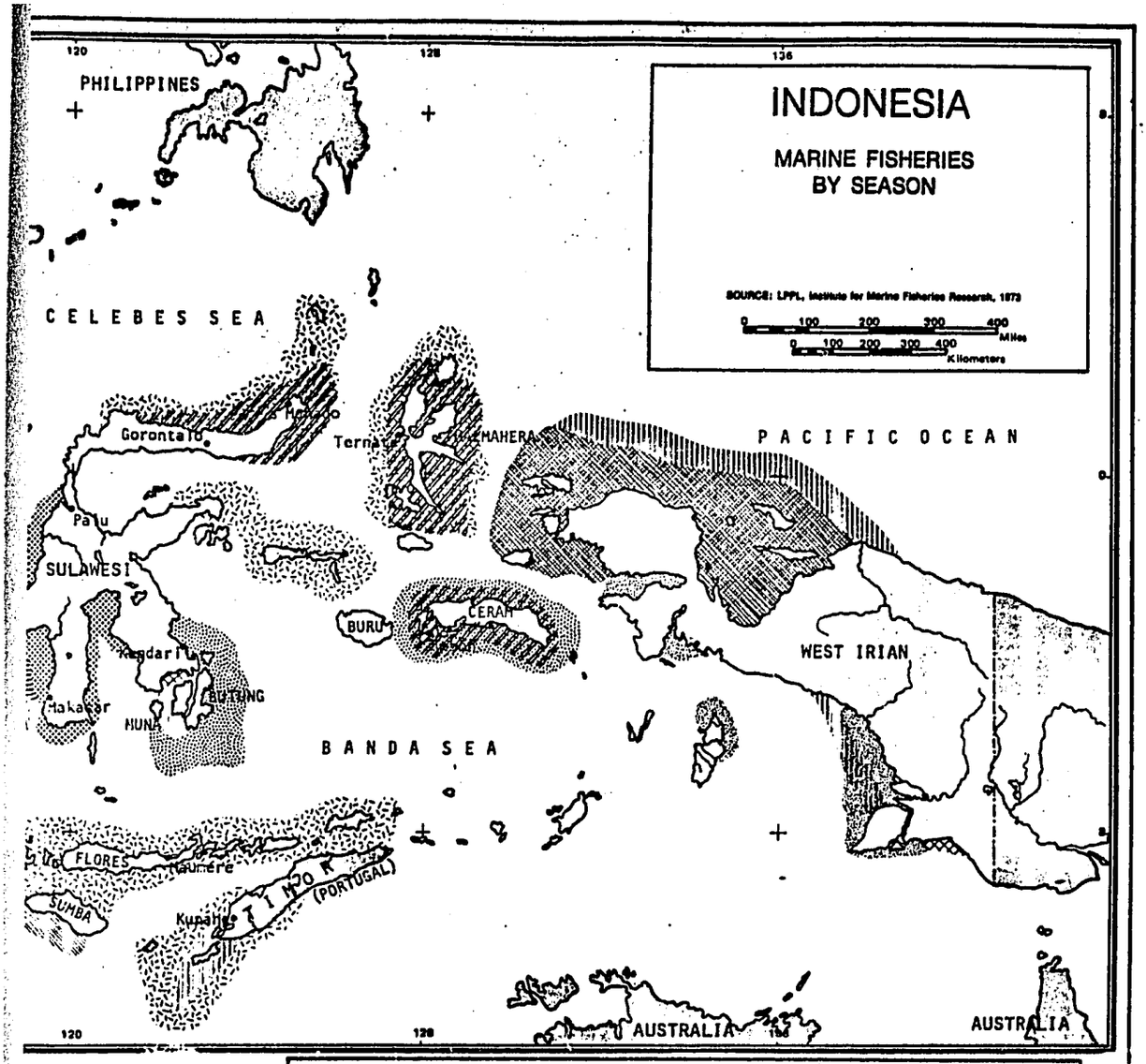
KALIMANTAN
Balikpapan
Banjarmasin
BANGKA
Palembang
Musi R.
Komering R.
K. Seribu
JAVA SEA
JAKARTA
Bogor
Bandung
JAVA
Semarang
MADURA
Surabaya
BALI
LOMBOK
SUMBAWA
INDIAN OCEAN
96
104
112


INDONESIA
DISTRIBUTION OF COASTAL MANGROVE SWAMPS
Approximate Location of Mangrove Swamps
SOURCE: Van Steenis, Vegetation Map of Malaysia, UNESCO, 1958. Scale
0 100 200 300 400 Miles
0 100 200 300 400 Kilometers
PHILIPPINES
CELEBES SEA
PACIFIC OCEAN
Manado
Gorontalo
Ternate
HALMAHERA
Palu
SULAWESI
BURU
CERAM
Ambon
Kendari
BUTUNG
Makassar
MUNA
BANDA SEA
WEST IRIAN
FLORES
Maumere
SUMBA
Kupang
TIMOR
(PORTUGAL)
AUSTRALIA
AUSTRALIA
120
128
138

Type	Season
Kembung - Layang	Mei - Oktober
Kembung	September - April
Kembung	September - Maret
Kembung	Nopember - April
Layang - Kembung - Bawal	Desember - Februari
Layang - Kembung - Bawal	Juli - Oktober
Layang - Kembung - Bawal	Sepanjang tahun (year around)
Layang - Kembung - Bawal	Juli - September
Anchevy	Sepanjang tahun
Ekor Kuning	

Type
Ekor Kuning
Cakalang
Cakalang
Cakalang
Cakalang
Lemuru
Torani
Udang
Julungs - Malalugis



son

anjang tahun
r around)

anjang tahun
r around)
tember - Maret

- Agustus

anjang tahun

KEY TO NAMES

Bawal	Pomfret	*Parastromateus niger* (BLOCH) *Pampus argenteus* (EUPHRASEN)
Cakalang	Skipjack	*Katsuwonus pelamis* LINNAEUS
Ekor kuning	Red belled fusilier	*Caesio erythrogaster* CUVIER AND VALENCIENNES
Julung-julung	Halfbeak	*Hemiramphus spp*
Kembung	Mackerel	*Rastrelliger kanagurta* (CUVIER) *Rastrelliger brachysoma* (BLEEKER)
Layang	Round scad	*Decapterus russelli* RUPPELL *Decapterus layang* BLEEKER *Decapterus macrosoma* BLEEKER
Lemuru	Sardine	*Sardinella aurita* CUVIER AND VALENCIENNES
Malalugis	Round Scad	*Decapterus spp*
Teri	Anchovy	*Stolephorus spp*
Torani	Flyingfish	*Cypsilurus spp*

the young of commercial fish and shellfish and for many of their food organisms, but also, mangrove leaves provide an important source of food for many of these species. The leaves are eaten to only a negligible extent while alive, but are transformed after death into a protein-enriched source of detrital food by decomposer micro-organisms. One study in Florida revealed that about five tons of mangrove leaves are produced per acre per year (Heald and Odum, 1970). At this rate we can estimate that the mangroves of Indonesia would annually produce a significant amount of fish food.

Mangrove leaves are used in Java as "green manure" in brackish water fishponds. The wood is used extensively for fuel and to some extent for lumber. Mangrove wood is also exported to Japan for use in the manufacture of paper and rayon. Mangrove communities appear to be unusually susceptible to oil pollution (Spooner, 1969), but they have been observed to recover (Birkeland *et al.*, 1973).

An oil spill reaching the coastal waters of East Java and Madura could be especially damaging for milkfish (*Chanos chanos*) larvae and fry. These form the basis of the brackish water aquaculture in Indonesia, discussed below. The transluscent larvae and delicate fry are netted by the hundreds of thousands in the shallows near beaches along the north coasts of Madura, Java and south of Makassar in Sulawesi, from October to December. The

exact spawning areas of Chanos chanos are unknown, but in Indonesia are thought to be somewhere south of Sulawesi. Nothing is known about where those Chanos chanos fry go that escape capture and return to sea. Adult Chanos chanos are caught at open sea only incidentally to other fish. In other parts of Southeast Asia, where the milkfish is equally popular, knowledge as to its movements during and after spawning is also scant.

Thus, the most popular and widely cultured "tambak" fish has eluded researchers seeking to understand its reproductive and breeding habits. Consequently, the continuing success of milkfish culture depends upon the seasonal appearance of Chanos fry in the shallow coastal waters of Java and the Celebes (Figure 10). In recent years there have been remarkable fluctuations in the number of fry caught in East Java.

Table 3. Chanos fry caught in East Java, 1967 - 1971

	Million fry
1967	270,248
1968	40,585
1969	136,937
1970	173,958
1971	43,394

Source: Department of Inland Fisheries, East Java, Surabaya

No explanation has been offered, but some of the various forms of pollution discussed in the next section may bear on the Chanos fry catch. Until more is known, any type of pollution must be considered as potentially harmful to Chanos fry.

In discussing the impact of pollution in an area, two types of effects must be considered: the effect on the overall productivity and the effect on the quality of products taken from this area. For example, in the "tambaks" situated 500 yards or closer to the coast, "rebon" (Mysidacea fry) and "jembret" (Mysidacea and Decapoda fry) are caught. These are processed into shrimp paste ("terasi"). Oil pollution of coastal waters, during the season when the "tambaks" are managed so as to catch these crustaceans, could seriously diminish this economically important adjunct of "tambak" fish culture. "Rebon" and "jembret" may enter the coastal "tambak" during April, May, June, October, November and December (Schuster, 1952).

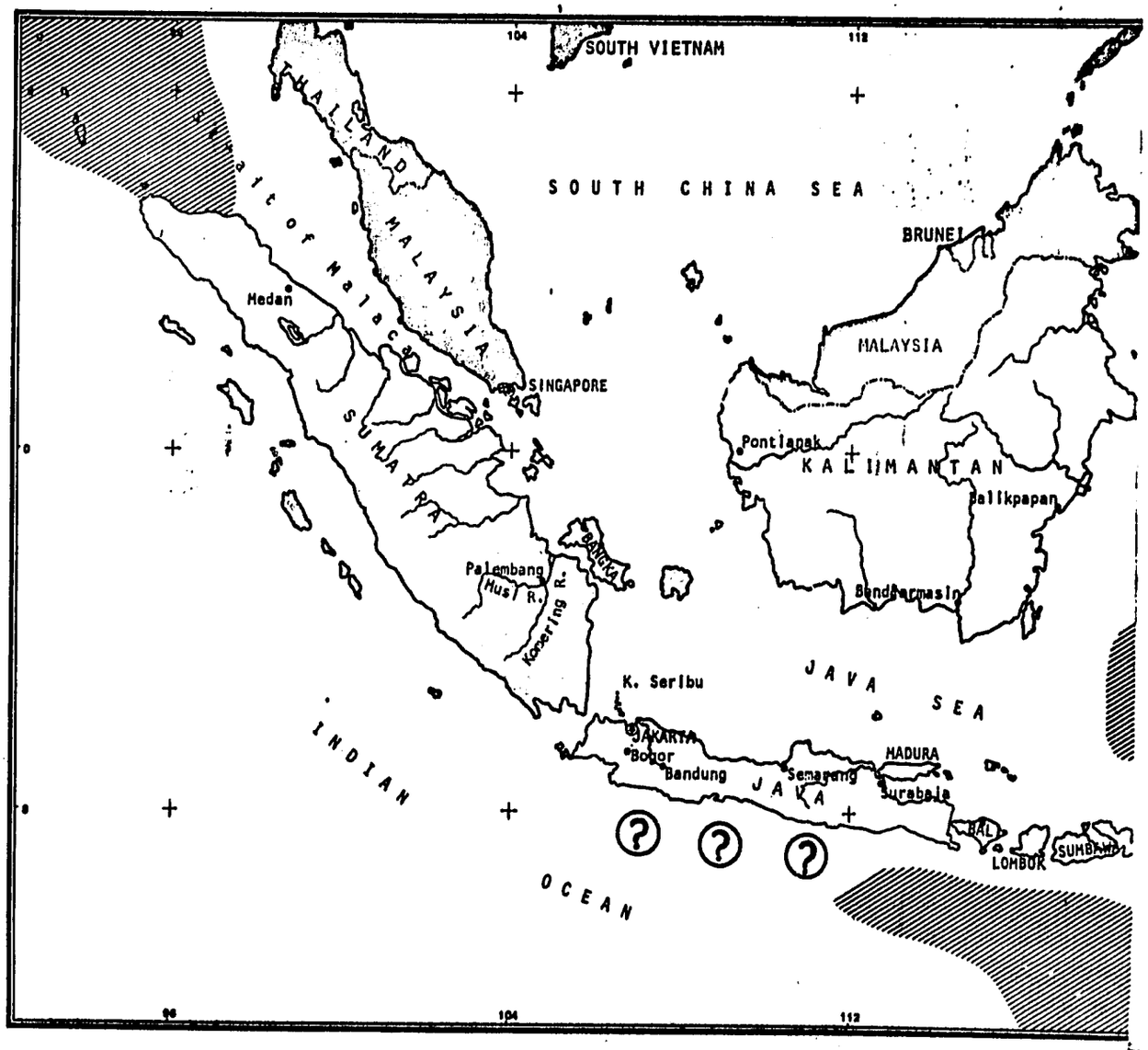
2. Offshore Marine Fisheries

The 1970 offshore catch was 802,000 tons (Table 4). The potential catch has been estimated at 4.2 million tons per season in the so-called "Up-Welling Area" (Figure 4). This includes the Java Sea, East Arafuru Sea, Flores Sea and Banda Sea, and covers 750,000 square kilometers (FAO, 1971). To tap this potential, Indonesia has invested or plans to invest nearly $53 million (Pre-Investment News, January, 1973), a commitment which is

Table 4. Fisheries production in Indonesia, 1960-1970 (1,000 tons)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Production											
Marine	412	525	538	546	590	661	721	790	722	785	802
Inland	347	385	375	386	410	370	400	465	450	429	447
Total	759	910	913	932	1000	1031	1121	1255	1172	1214	1249
Index (1960 = 100)											
Marine	100	127	130	132	143	160	175	182	175	190	195
Inland	100	111	108	111	118	107	115	134	130	127	129
Total	100	120	120	122	131	136	148	165	154	159	163
Composition (%)											
Marine	54	58	59	59	59	64	64	63	62	65	64
Inland	46	42	41	41	41	36	36	37	38	35	36

Source: FAO.


SOUTH VIETNAM
THAILAND
MALAYSIA
SOUTH CHINA SEA
BRUNEI
Strait of Malacca
Medan
SINGAPORE
MALAYSIA
SUMATRA
Pontianak
KALIMANTAN
Balikpapan
BANGKA
Palembang
Musi R.
Komering R.
Banjarmasin
K. Seribu
JAVA SEA
JAKARTA
Bogor
Bandung
MADURA
Semarang
JAVA
Surabaya
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SUMBAWA
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104
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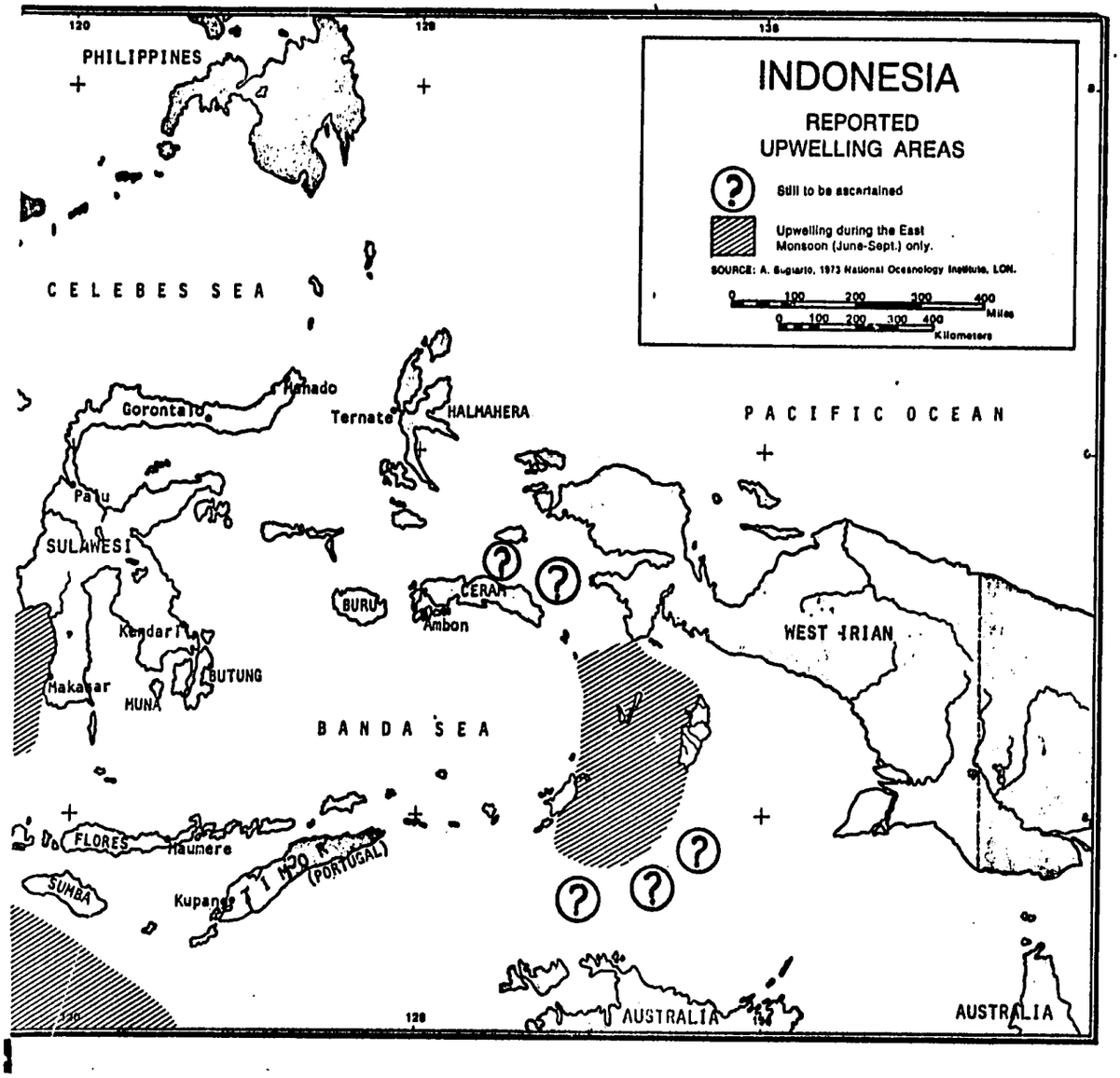
INDONESIA
REPORTED
UPWELLING AREAS
Still to be ascertained
Upwelling during the East Monsoon (June-Sept.) only.
SOURCE: A. Sugiarto, 1973 National Oceanology Institute, LON.
0 100 200 300 400 Miles
0 100 200 300 400 Kilometers
PHILIPPINES
CELEBES SEA
PACIFIC OCEAN
Manado
Gorontalo
Ternate
HALMAHERA
Palu
SULAWESI
BURU
CERAM
Ambon
Kendari
BUTUNG
Makassar
MUNA
WEST IRIAN
BANDA SEA
FLORES
Maumere
SUMBA
Kupang
TIMOR
(PORTUGAL)
AUSTRALIA
AUSTRALIA
120
128
138
130
126

largely justified by greatly expanded export earnings from fisheries. These increased to over $21 million in 1972, or 14 times the 1968 level, and almost 4 times the $5.9 million earnings in 1970. Frozen shrimp and prawns have become the major exports.

Unfortunately our knowledge of the impact of oil on offshore fisheries is very scant. In fact there appears to be only one documented case of oil damage to open water pelagic fishes; the branchial filaments of three species of fishes taken in the vicinity of a large oil spill in offshore waters in the Gulf of Mexico exhibited loss of cells and swelling when compared with specimens taken from control areas (EPA, 1972).

It is probably safe to say that offshore resources are less vulnerable to oil pollution than coastal resources for three reasons: 1) the oil will be diluted more rapidly due to comparatively unrestricted vertical and horizontal diffusion; 2) fast-moving pelagic fish can more easily avoid polluted areas; 3) bottom dwelling species (e.g., shrimp) are further removed from the source of the oil (i.e., the surface) than their inshore brethren.

Many species caught offshore live as juveniles in estuaries along the coasts, therefore, despite the low probability of lethal pollution by oil of offshore fisheries, their productivity could nevertheless be indirectly affected by coastal pollution by oil and other toxic contaminants.

The likelihood that presently exploited fish stocks are being overfished in some areas does exist. Catch statistics do

not include year class breakdowns. It is almost impossible to predict optimum yields or follow accurately fish stock levels. Fisheries personnel report that the widespread liftnet fishery harvests large numbers of very small (down to 3 cm. in length) juvenile fish.

Trends in high seas catches were obtained for two species, mackerel and shrimp, for the East Java region, which includes Bawean and Madura, as well as Surabaya. Catch trends are down for mackerel and up for shrimp. Mackerel or the "layang" lives only in water of a rather high salinity (no lower than approximately 32 parts per thousand). In the East Monsoon (May to October), a stock of "east layang" swims into the Java Sea from the Flores Sea, reaches its most western parts, and may leave it through the Sunda, Karimata and Gaspar Straits (Figure 5). This last, however, is only a hypothesis. Generally speaking, coastal fishing effort is less during the East Monsoon, when the seas are rougher. In the West Monsoon (November to April), a stock of "west layang" enters the Java Sea through the Sunda Strait from the Indian Ocean (Figure 6). It can only be found near the shores of West Java (Hardenberg, 1937).

The dip in mackerel catch in the East Java Region is seen in Table 5. The decline in catch can, according to LPPL*, be attributed to declining effort as increasing effort is focused on

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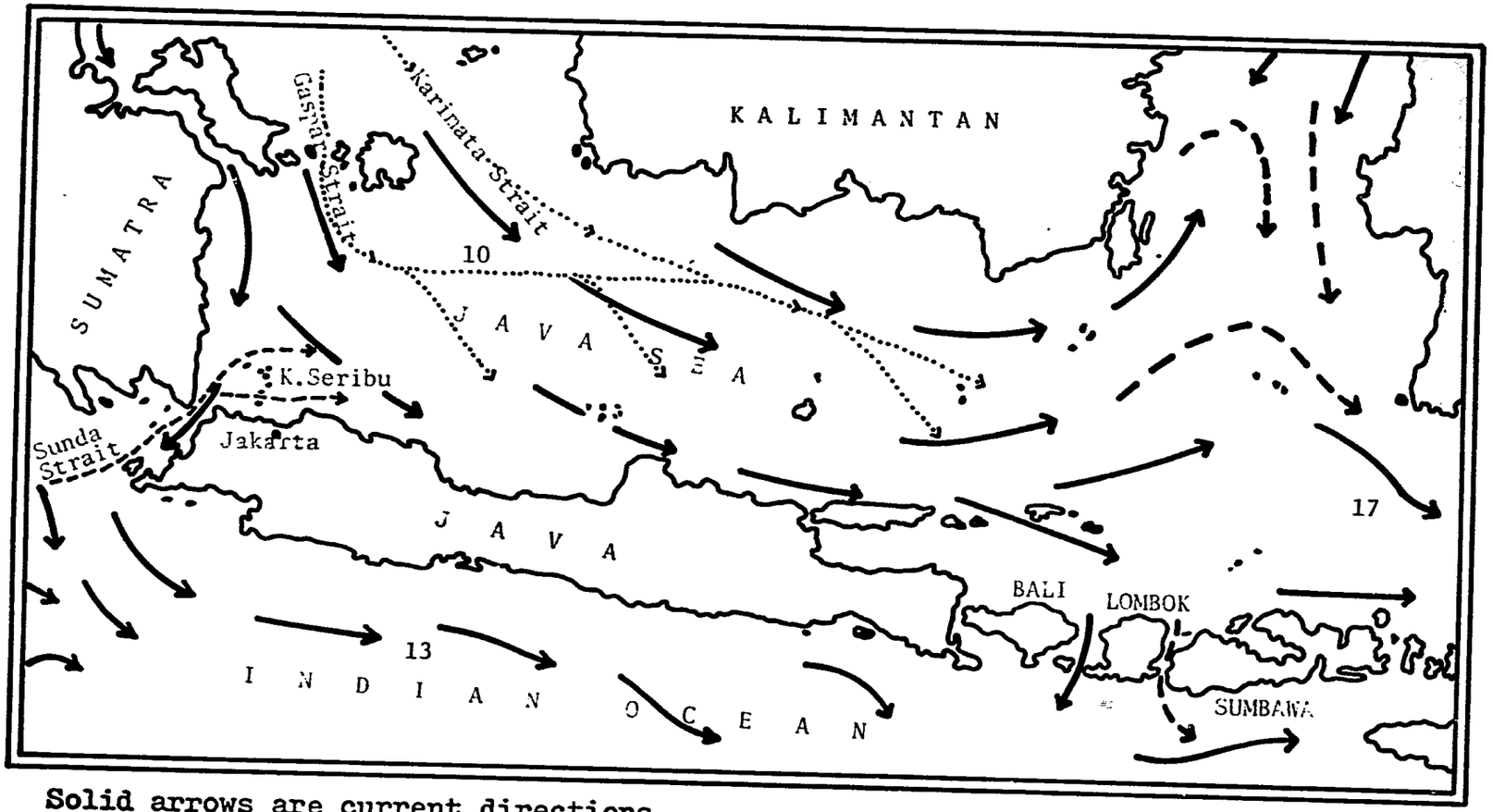
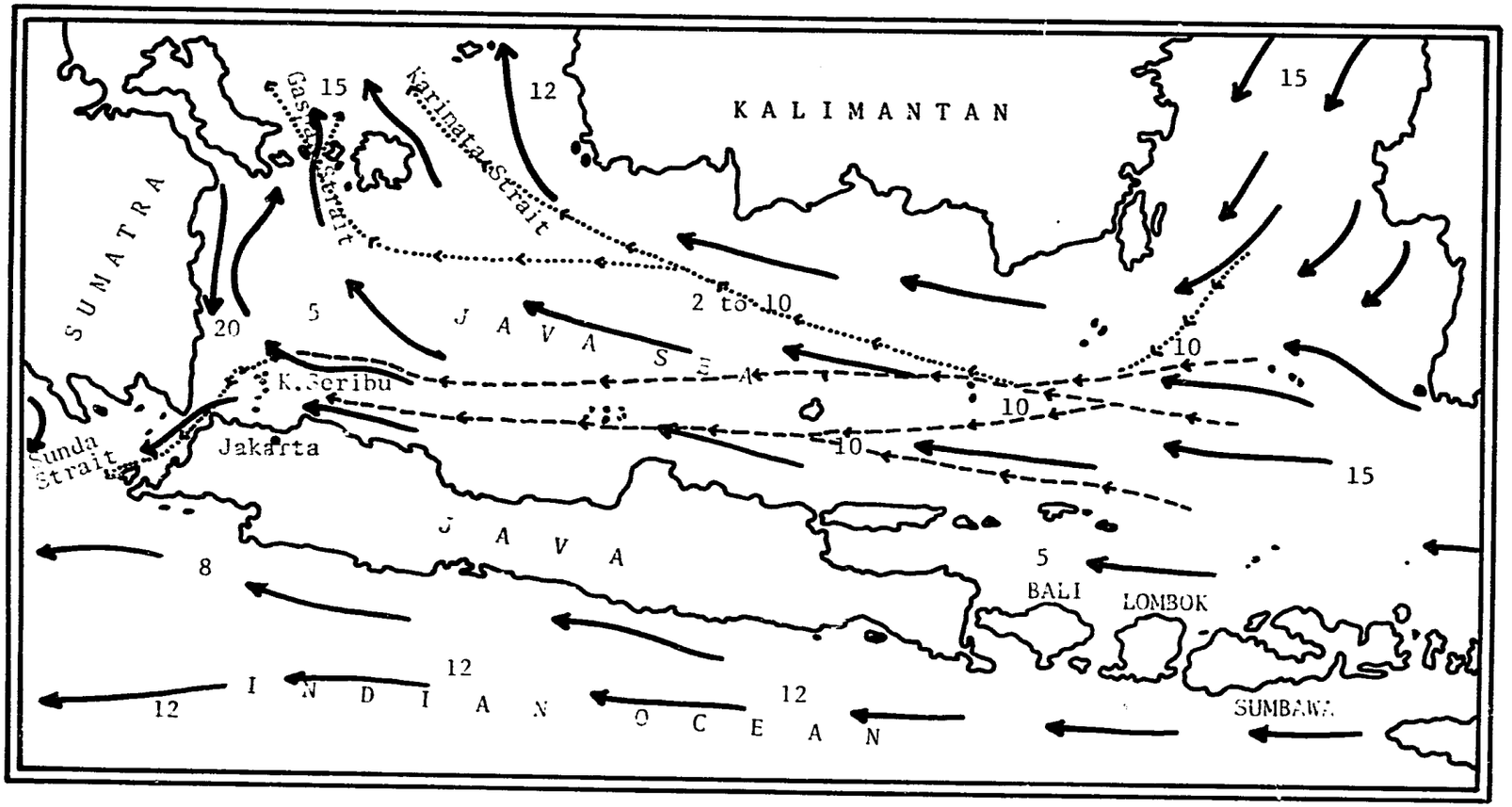
*Lembaga Penelitian Perikanan Laut--Institute for Marine Fisheries Research



Solid arrows are current directions and numbers are current velocities in knots. Dashed arrows are known migration paths. Dotted arrows are suspected migration paths.

Fig. 5 Mackeral migrations, East Monsoon



Solid arrows are current directions and numbers are current velocities in knots. Dashed arrows are known migration paths. Dotted arrows are suspected migration paths.

Fig. 6 Mackeral migrations, West Monsoon

Table 5. Mackerel catch, East Java Region, 1962-1970

	Tons
1962	33,000
1963	32,000
1964	24,000
1965	33,000
1966	25,000
1967	19,000
1968	24,000
1969	12,000
1970	8,000

Source: Soewarno Jogawisastro, Sea Fisheries Service, East Java Region

skipjack and shrimp fishing, and to lower prices of most fin fish, including mackerel. Other factors were cited as possible causes: especially the use of explosives for oil exploration (near Masalembo), a long dry season in 1968 which may have adversely affected the 1969 population of mackerel, and in 1970 the use of dynamite by foreign fishermen (from Malaysia and Singapore). It would be impossible to draw a conclusive relationship between underwater dynamite explosions and reduced mackerel catch in East Java, given the reported decline in fishing effort. Such explosions have not been observed to have caused substantial fish mortalities in the Gulf

of Mexico, where explosives were used for oil exploration (St. Amant, 1970).

Contrary to the declines in mackerel catch, shrimp landings in East Java showed a definite increase in 1971, after falling off slightly from 1968 levels.

Table 6. Marine shrimp catch, East Java Region, 1966-1971

	Tons
1966	357
1967	358
1968	344
1969	347
1970	340
1971	444

Source: Soewarno Jogawisastro, Sea Fisheries Service, East Java Region

In 1971 motorized trawlers began shrimp fishing in this region.

The admittedly few statistics presented here do not serve as an adequate basis for demonstrating that there has been a decline in marine fish stocks, as had been reported at the beginning of this survey on marine oil pollution, nor do observations and data implicate oil pollution *per se*. Explosives for oil exploration, while mentioned as a possible factor, cannot be clearly

identified as having caused declines. Variability of fishing effort and the influence of prolonged dry seasons are more likely causes, if it could in fact be substantiated that stocks are down.

The coincidence of a very low catch of Chanos chanos fry in the dry 1968 season and the low mackerel catch in the following year suggests a possibly important relationship between productivity of coastal waters, as influenced by salinity and possibly nutrient enrichment in terrestrial runoff, and fish catch. If the 1969 catch of mackerel were made with the same effort as in 1968, it could be conjectured that the smaller mackerel catch in 1969 was caused by the lowered productivity of the previous year's coastal waters when the young mackerel were migrating westward, resulting in a reduced breeding stock for 1969. Adverse conditions elsewhere along the migratory route may have had similar effects. Without more information, the reasons for decline are conjectural. However, they do suggest possible research directions, especially given the increasing amounts of insecticides that are being carried into the coastal waters of Java. More is said on this later.

Trends in total marine and inland fish production show a decided increase in marine catch during 1960 to 1970 (Table 4), largely explained by increased effort. These statistics do not prove or disprove the alleged adverse impact of offshore oil activities and pollution on East Java fisheries. It is clear

that better data and timely assessments of the local effects of oil pollution on pelagic fish will be necessary to establish the nature and extent of impact.

3. Intertidal Zones and Reef Flats

In addition to mangrove communities the biological resources of the intertidal zones include: 1) fish and shellfish picked up at low tides: these form a small subsistence fishery in parts of Indonesia; 2) seaweeds (Figure 8): these are eaten in some localities, are exported in small quantities, and are being cultured in several regions with a greatly expanded export industry in mind; and 3) seagrass beds and shallow coral communities (Figure 9): these provide shelter for the young of fishes which subsequently become part of the commercial fishery.

It is not possible to assess the importance of the fishery resources in intertidal areas of Indonesia based on the very fragmentary information presently available. Certain seaweeds are exported and a major commercial species fished in the reefs is *Caesio* spp. (yellow tail), which commands the same price as the *Chanos chanos*. Other reef fishes, commonly called "table fish," also contribute to the commercial catch. But none of these is statistically segregated from the marine catch. It was noted, however, that increasingly less effort is being expended on reef fishing, which traditionally has been practiced by using "drive-in" nets. Groups of men swim driving the fish forwards to the net.

96
104
112
SOUTH VIETNAM
THAILAND
MALAYSIA
Strait of Malacca
SOUTH CHINA SEA
BRUNEI
Medan
MALAYSIA
SINGAPORE
SUMATRA
Pontianak
KALIMANTAN
Balikpapan
BANGKA
Palembang
Musi R.
Komering R.
Banjarmasin
K. Seribu
JAVA SEA
JAKARTA
Bogor
Bandung
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Surabaya
BALI
LOMBOK
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INDIAN
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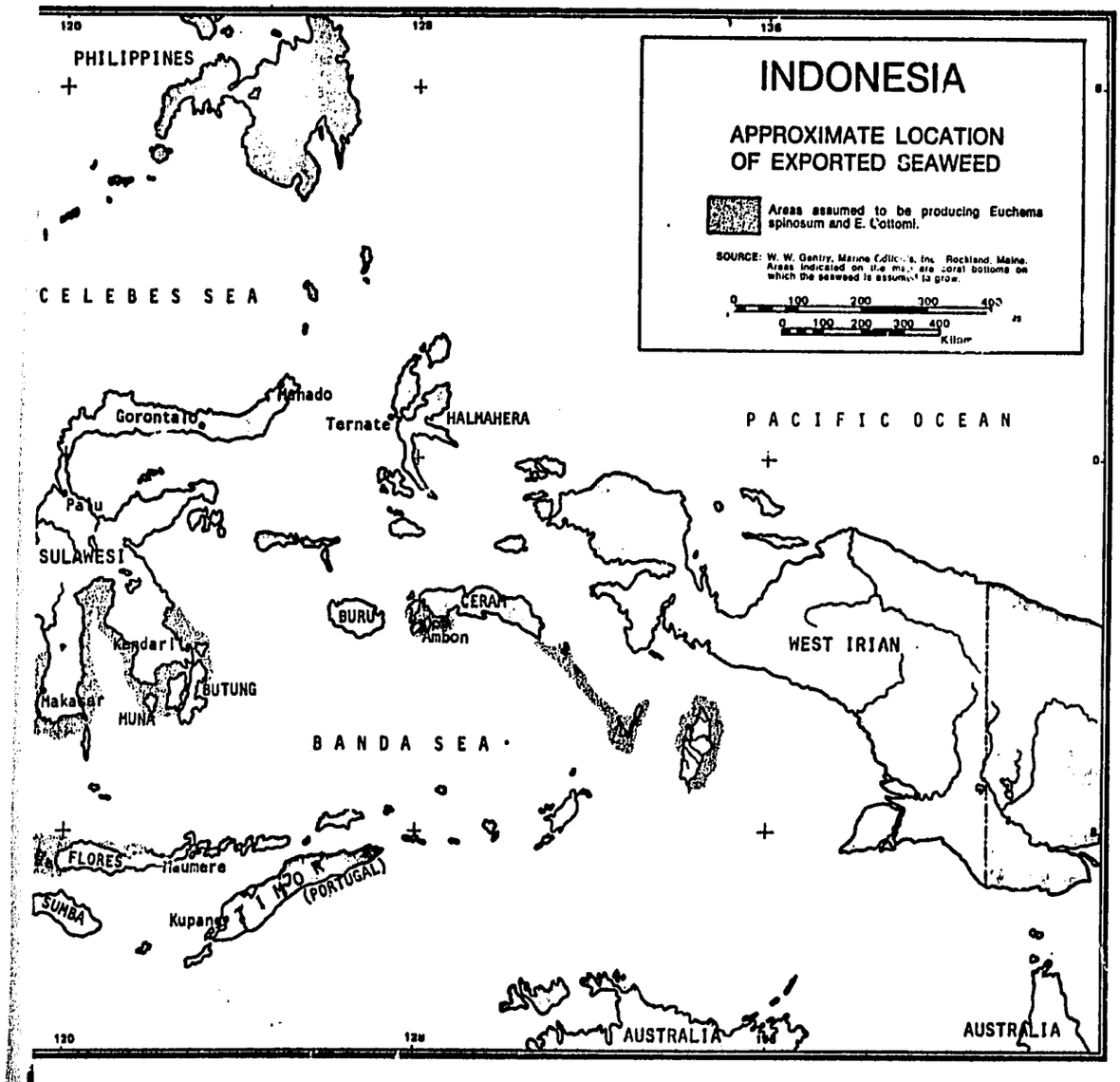
INDONESIA
APPROXIMATE LOCATION OF EXPORTED SEAWEED
Areas assumed to be producing Euchema spinosum and E. Cottomi.
SOURCE: W. W. Gentry, Marine Colloids, Inc., Rockland, Maine. Areas indicated on the map are coral bottoms on which the seaweed is assumed to grow.
0 100 200 300 400
0 100 200 300 400
Kilom
PHILIPPINES
CELEBES SEA
PACIFIC OCEAN
Manado
Gorontalo
Ternate
HALMAHERA
Palu
SULAWESI
BURU
CERAM
Ambon
Kendari
BUTUNG
Makassar
MUNA
WEST IRIAN
BANDA SEA
FLORES
Maumere
SUMBA
Kupang
TIMOR
(PORTUGAL)
AUSTRALIA
AUSTRALIA
120
128
136

SOUTH VIETNAM
THAILAND
MALAYSIA
Strait of Malacca
SOUTH CHINA SEA
BRUNEI
Medan
MALAYSIA
SINGAPORE
SUMATRA
Pontianak
KALIMANTAN
Balikpapan
BANGKA
Palembang
Musi R.
Komering R.
Banjarmasin
K. Seribu
JAVA SEA
JAKARTA
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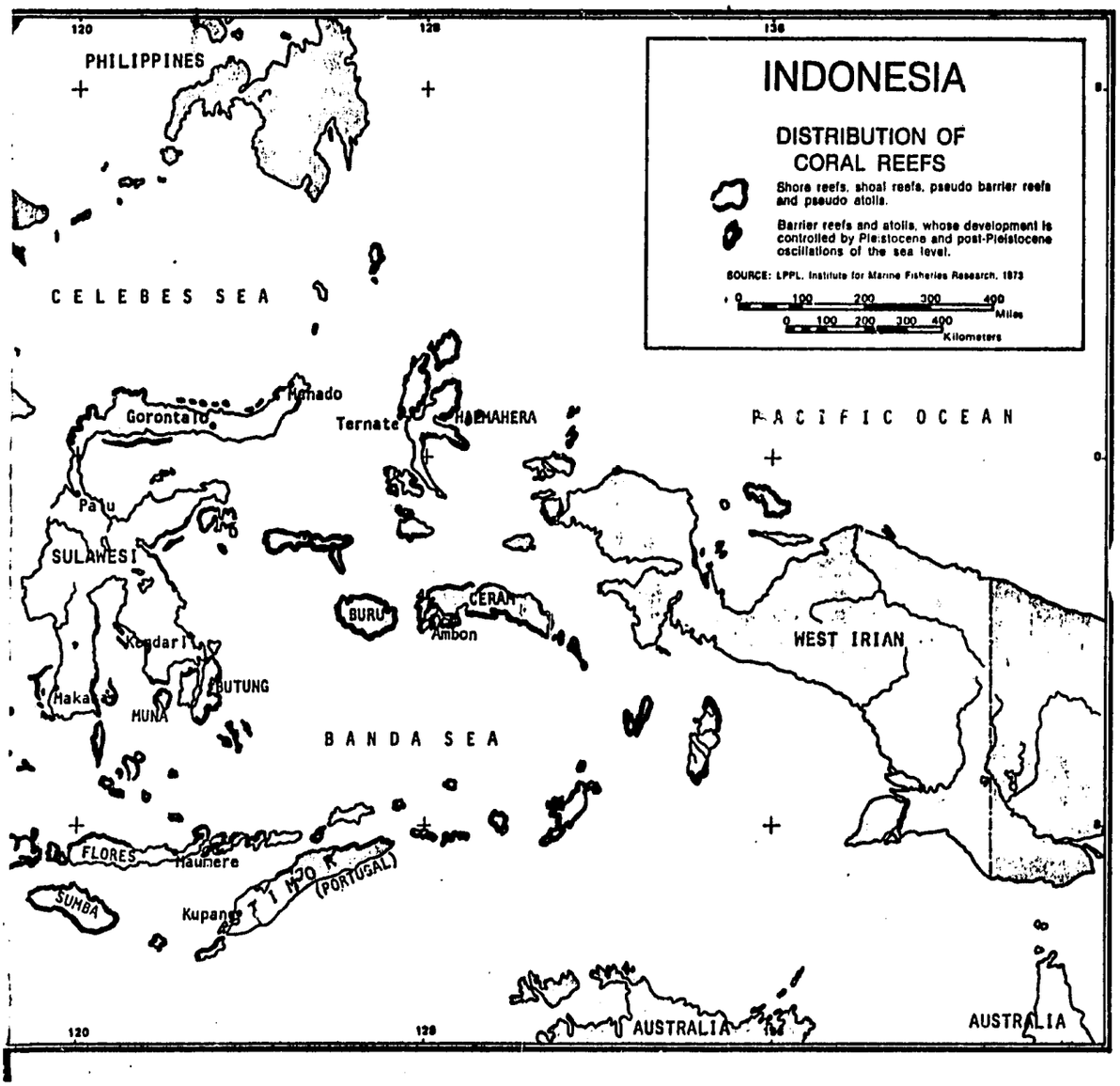

INDONESIA
DISTRIBUTION OF CORAL REEFS
Shore reefs, shoal reefs, pseudo barrier reefs and pseudo atolls.
Barrier reefs and atolls, whose development is controlled by Pleistocene and post-Pleistocene oscillations of the sea level.
SOURCE: LPPL, Institute for Marine Fisheries Research, 1973
0 100 200 300 400 Miles
0 100 200 300 400 Kilometers
120
128
136
PHILIPPINES
CELEBES SEA
Manado
Gorontalo
Ternate
HALMAHERA
PACIFIC OCEAN
Palu
SULAWESI
BURU
CERAM
Ambon
WEST IRIAN
Kendari
BUTUNG
Makassar
MUNA
BANDA SEA
FLORES
Maumere
TIMOR
(PORTUGAL)
SUMBA
Kupang
AUSTRALIA
AUSTRALIA

Improvements in high seas fisheries have centered on expanding the motorized trawler fleet.

The greatest current importance of the animals and algae of the intertidal and reef flat zone is undoubtedly as subsistence food gathered and fished by coastal dwellers. According to Koentjaraningrat (personal communication), there has been no systematic study of subsistence fishing activities in Indonesia. Consequently, the importance of the intertidal zone and reef flats life as a source of subsistence foods is difficult to measure. However, fish and other marine animals taken from these areas are likely to be the sole or primary source of animal protein for many Indonesians, particularly in the smaller islands where fish ponds are not used, and where wild game has disappeared or is scarce. On larger islands such as the Celebes a similar reliance may characterize coastal zone villages.

The susceptibility of the biota in the reef flat and intertidal zones to oil pollution is probably greater than that of any other marine or estuarine communities since on low tides the oil will come into intimate contact with the biota. On the other hand, the dominant species in these areas are short-lived. This means that recovery from a massive oil spill should take a relatively short time--a matter of 3-4 years at most in the case of shellfish beds--a matter of as little as a year in case of algal communities. Algal community composition could be affected by oil pollution. Original communities may be replaced by blue-green algae.

Plate 1. Fisherman with spiny lobster caught from reef in the Kepulauan Seribu (Thousand Islands), north coast of Java.

Plate 2. Coral reef, Pulau Pari, Kepulauan Seribu.

The relative susceptibility of major seaweed species to oil pollution is shown in Table 7. The major commercial species, discussed below, are presently Eucheuma spinosum and E. cottoni, both harvested primarily in Sulawesi, and both high to moderately sensitive to oil pollution as determined by their habitat.

Indonesia is now the major producer of the red seaweeds used in the production of agar, an increasing portion of which is being used in diet foods. Gracilaria lichenoides has been the major raw material source for the domestic agar factories (Michanek, 1971), whereas Eucheuma spp. provides the bulk of the raw agar exports. Since there is a sure market, the cultivation of this genus has been suggested (Soerjodinoto, 1969).

The export value in 1971 of two species, Eucheuma spinosum and E. cottoni, was $1,020,000. The 4000 tons harvested were exported in approximately equal amounts to the U. S., France, and Denmark. The seaweed was supplied primarily from the islands and reef flats in the Makassar area, Gulf of Bone and Kendari (all in Sulawesi); and from Aru and Kae Islands and Ceram.

Tropical aquarium fish are an additional resource of reefs. There are 11 exporters operating in Indonesia (Pre-Investment News, January, 1973). In 1970, almost 100,000 aquarium fishes, valued at more than U.S. $34,000, were exported. The volume of export is increasing very rapidly. The Indonesian Directorate General of Fisheries estimated that the export potential for aquarium fishes in Indonesia is about 3 million specimens per year.

The use of seaweed in Indonesia for human food has been studied in considerable detail by Rao (1965), Zaneveld (1955)

and Soegiarto (1968), and Michanek (1971) has summarized Rao's work. Seaweeds are widely consumed, especially when the rice crop is bad or prices have risen. Seaweeds have relatively high protein and carbohydrate contents. However, Rao reports that little work has been done on the digestibility and nutritional value of seaweed proteins, and algal carbohydrates seem not to be well-utilized by man.

Rao lists more than 20 species of marine algae (see Table 7) which are eaten in Indonesia. The green algae Caulerpa, Chaetomorpha, Codium and Ulva are used raw or in salads, soups or gelatine-like sweets (marshmallows). Brown algae such as Dictyota. Padina, Sargassum and Turbinaria are eaten raw or cooked with coconut milk, pickled or preserved by smoke-drying. The red algae, especially Eucheuma muricatum, but also Acanthophora, Corallopsis, Gelidium, Gracilaria, Hypnea and Sarcodia are eaten fresh, and prepared as jellies and gelatines.

4. Brackish Fishponds ("Tambaks")

In Indonesia, and other countries of Southeast Asia, brackish water fishponds represent an important resource unique to the region. Policies and measures to protect the "tambak" from oil and other pollution will necessarily have to emerge from the indigenous conditions and requirements. Clearly, standards and policies related to the coastal waters of western societies having no tradition of fish farming will not be adequate. Suitable standards should be developed soon since the "tambaks" in several areas of Java are seriously threatened with pollution.

Table 7. Valuable Indonesian seaweeds and their susceptibility to oil pollution

Seaweed species[a]	Location reported[b]	Habitat[c]	Sensitivity of habitat to oil pollution[c]
CHLOROPHYTA (Green algae)			
Caulerpa peltata	Bangka, Makassar	on reef or rocks in shallow water, and to depths of 30 m.	moderate
Caulerpa racemosa	Bali	on reef in pools or holes or intertidally in the surf zone, and to depths of 55 m.	high to moderate
Chaetomorpha javanica	Ambon	in tufts on rocks in intertidal zone.	high
Chaetomorpha crassa	-	forming mats or tangled with other algae in muddy shallows and sand flats.	moderate
Codium tomentosum	Makassar	(possibly on exposed rocks in pools and in deeper water).	moderate
Ulva lactuca	widespread	on rocks, stones, pilings; exposed intertidally; in shallow water or floating.	high

[a]from: Rao, G.N.S. 1965. Use of seaweeds directly as food. IPFC, Bangkok.
[b]Only specific locations are noted here. All species can be assumed to have a general occurrence.
[c]Data compiled by A.L. Dahl, Department of Botany, Smithsonian Institution.

(Table 7, continued)

Seaweed species[a]	Location reported[b]	Habitat[c]	Sensitivity of habitat to oil pollution[c]
PHAETOPHYTA (Brown algae)			
Dictyota apiculata	-	most Dictyota occur on reefs, rubble or sand flats in the low intertidal or subtidal zones.	moderate to low
Padina australis	-	in intertidal pools and shallow subtidal areas of quiet water.	moderate
Sargassum spp. (58 species known in Indonesia)		on rocks from high intertidal to 60 m. depth; in pools; floating.	high to low
Sargassum aquifolium	-	no published data available.	
S. granuliferum	-	no published data available.	
S. polycystum	-	on rocks in the subtidal zone.	low
Turbinaria ornata	Moluccas	in very shallow water in lagoons and on reefs; commonly partly covered at low tide.	high
Turbinaria conoides	Sulawesi	on coral reefs in intertidal zone.	high

(Table 7, continued)

Seaweed species[a]	Location reported[b]	Habitat[c]	Sensitivity of habitat to oil pollution[c]
RHODOPHYTA (Red algae)			
Acanthophora spicifera	Kangean Isl.	on rocks or reefs in shallow water, in either exposed or sheltered locations.	moderate
Corallopsis minor	Sumbawa	no data on this species.	
Eucheuma muricatum	Sulawesi	on coral reefs in shallow areas (some Eucheuma form floating drifting mats in protected waters).	high to moderate
E. spinosum*	Sulawesi	idem	idem
E. cottonii*	Sulawesi	idem	idem
Gelidium amansii	-	on rocks; intertidal and subtidal zone.	high to moderate
G. latifolium	-	no data available.	
G. rigidum (Gelidiopsis rigida)	-	variable genus with variable habitat and occurrence.	high to low

*Principal commercial species.

(Table 7, continued)

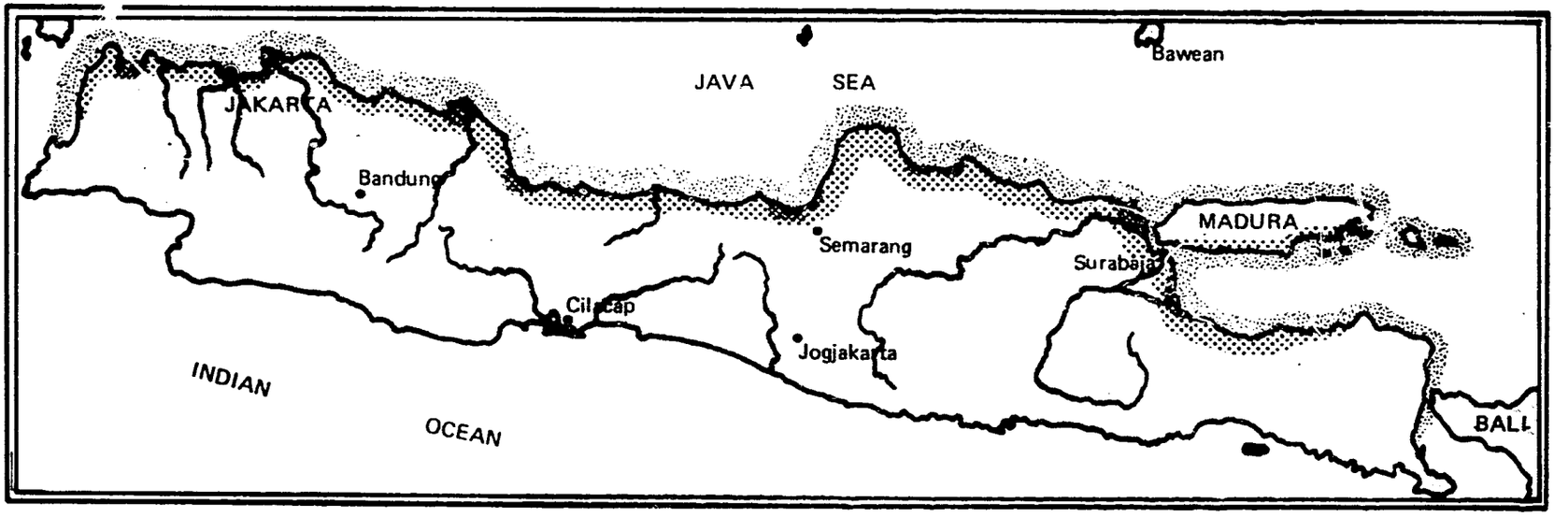
Seaweed species[a]	Location reported[b]	Habitat[c]	Sensitivity of habitat to oil pollution[c]
(RHODOPHYTA (Red algae), continued)			
Gracilaria lichenoides *	-	no data available, but probably on rocks and in sandy areas of low intertidal and subtidal zones.	
Hypnea spp.	-	intertidal and in shallow waters on reef flat or rocks or as mats on sand or gravel in protected areas.	high
Sarcodia montagneana	Moluccas	probably in deeper water, but little information available.	low

* Major commercial species.

Brackish water fishponds, mainly located in Java (Figure 9), contribute a relatively small, but strategically important, proportion of Indonesia's total inland fisheries production. Present production from 177,000 hectares is 52,000 tons, a level that could be at least doubled with improved culture (Table 8). The improvement of shrimp culture in brackish ponds, or "tambaks," has been the object of a $1 million program begun in 1971 by the Indonesian Directorate of Fisheries, with roughly 2/3 of the cost provided by the UNDP (Pre-Investment News, January, 1973). An expanded multimillion dollar "tambak" program is being planned. Fishpond culture has the advantage of being labor intensive. Roughly 500,000 persons depend for their existence on the brackish water fishponds. Improvements will not generate technological unemployment, as will be the case in modernizing high seas fishing. Also, "tambaks" produce protein almost continuously and, in fact, are analogous to the milk cow in this respect.

These ponds are carefully managed aquatic ecosystems. A quotation from Schuster (1952) sums up the principal features:

> Control of the growth of the algae is the basic principle of the tambak industry. There are indications that 25 to 35 lbs. of wet algae are necessary to produce 1 lb. of fish. The culture of Chanos affords an almost direct way of converting this vegetable substance into protein. Being a primary feeder, Chanos short circuits the roundabout ways involved in growing carnivorous fish. The remarkable yields obtained from tambaks without artificial fertilization



APPROXIMATE DISTRIBUTION OF BRACKISH WATER PONDS AND CHANOS FRY COLLECTION, JAVA.

Approximate areas of Fry Collection.

Approximate areas of Tambaks.

Approximate location of Extensive Tambaks.

FIGURE 9

Approximate Distribution of Brackish Water Ponds and Chanos Fry Collection., Java.

> or additional feeding, are explicable only by the direct course followed by the production process. The fact that during hundreds of years the same crop has been drawn from the same plot of land without occurrence of diseases or symptoms of exhaustion may be regarded as a very interesting biological phenomenon. (p. 32)

Table 8. Area and production of inland fisheries, 1969

	Area (1000 ha)	Potential yield (kg/ha)	Production potential (1000 ton)	Present production (1000 ton)
Brackish water ponds	177	600	106	52
Rice fields	3,000	200	600	20
Fresh water ponds	36	2,000	72	42
Fresh water areas	140	300	42	
Swamps	6,000	100	600	315
Total	9,353		1,420	429

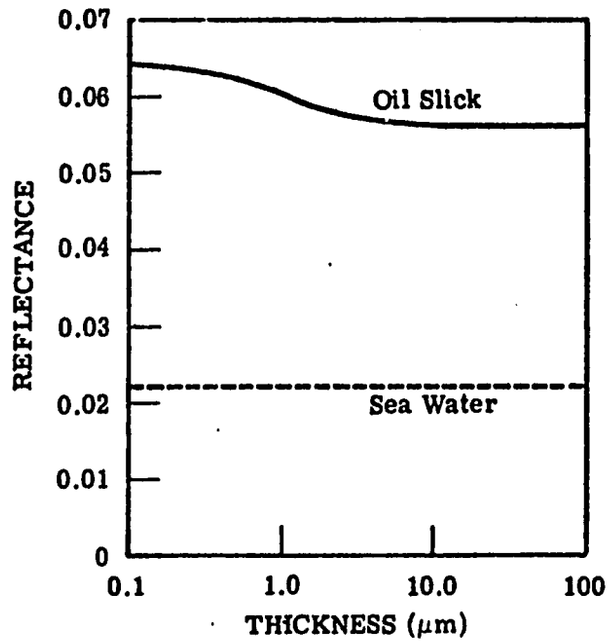
Source: Directorate of Fisheries

The ponds are dependent upon coastal waters for juvenile milkfish, which are netted in shallow water and transplanted to the ponds, as well as juvenile shrimp and other fishes which enter the ponds on the tide and are trapped. Oil--as well as other pollutants--in coastal waters in the vicinity of "tambak" areas can enter the ponds on the tide.

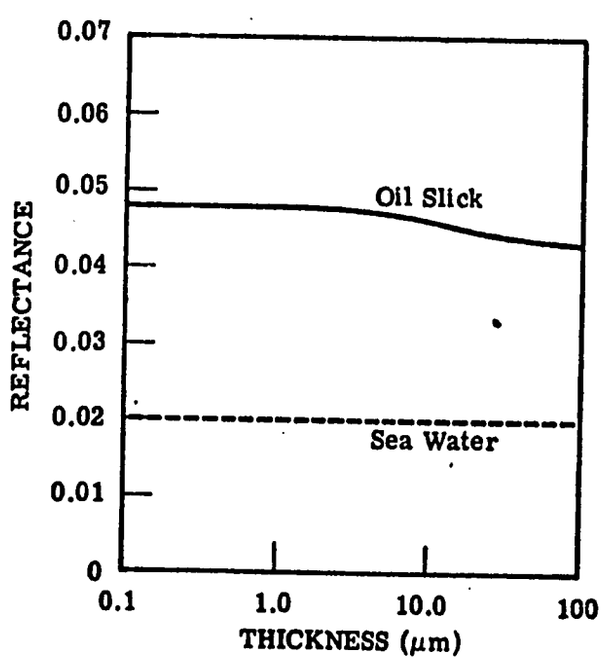
Plate 3. "Tambak" (brackish water fish pond) area, north coast of Java.

No observations or experiments concerning the effect of oil in brackish water fishponds have been made, but certain effects can be hypothesized. The brackish water fishpond, or "tambak," is "physiologically a much more sensitive object than a rice field or a garden," (Schuster, 1952, p. 2). Without an abundant growth of algae (Chlorophyceae, Myxophyceae, and Diatomeae) to generate O_2, the high water temperatures of the relatively shallow "tambaks" would result in a very low level of O_2 and be unsuitable for fish. A film of oil on the surface of a "tambak" could reflect enough light (see Figure 10) to inhibit photosynthesis and perhaps lower O_2 levels. Further, the growth of certain marine phytoplankton has been shown to be inhibited by oil, including No. 2

Figure 10. Specular reflectance at normal incidence for a 9.7° API residual fuel oil slick on sea water



(a) 0.4-μm Wavelength
$n_o = 1.62$, $n_w = 1.35$, $\kappa_o = 0.375\ \mu m^{-1}$



(b) 0.95-μm Wavelength
$n_o = 1.53$, $n_w = 1.33$, $\kappa_o = 0.032\ \mu m^{-1}$

Source: R. Hovarth, R.W.L. Morgan and S.R. Stewart. Optical remote sensing of oil slicks: signature analysis and systems evaluation. Willow Run Laboratories, Univ. of Michigan. 1972.

fuel oil (Nuzzi, 1973) and Kuwait crude (Lacaze, 1969). Also, oil could inhibit the growth of the mangroves, Rhizophora spp. and Avicennia spp., which are widely cultivated in "tambak" areas, where they stabilize the banks, and yield organic matter (leaves and branches), firewood and construction wood (Plate 4). A coat of oil on the roots would impede their function as chimneys or ventilators of the root system, which is buried in anaerobic mud (MacNae, 1968, p. 139). Finally, the oil could either kill or taint fish or shrimp in the "tambak," the outcome depending upon stage of development, type of oil, amount and so forth.

As will be illustrated later, other forms of coastal and estuary pollution, from agricultural, industrial or urban waste waters, could be equally damaging to the valuable "tambak."

5. Freshwaters

In areas where oil handling facilities are located inland, freshwater fisheries are susceptible to oil pollution. An example of this is the oil refinery at Palembang, Sumatra, where refinery wastes have reputedly led to a disagreeable oil taste in the fish caught there.

6. Tourism and Recreational Resources

North of Jakarta an extraordinarily beautiful cluster of small coral islands, the Kepulauan Seribu or Thousand Islands, comprise a tourism and recreational resource of great potential value. They fall within the jurisdiction of the Capital City of

Plate 4. Mangrove, Rhizophora spp., on "tambak" banks. The leaves fertilize the "tambak." The wood is widely used for firewood and piling. The trees regenerate quickly and cut trees are quickly replaced.

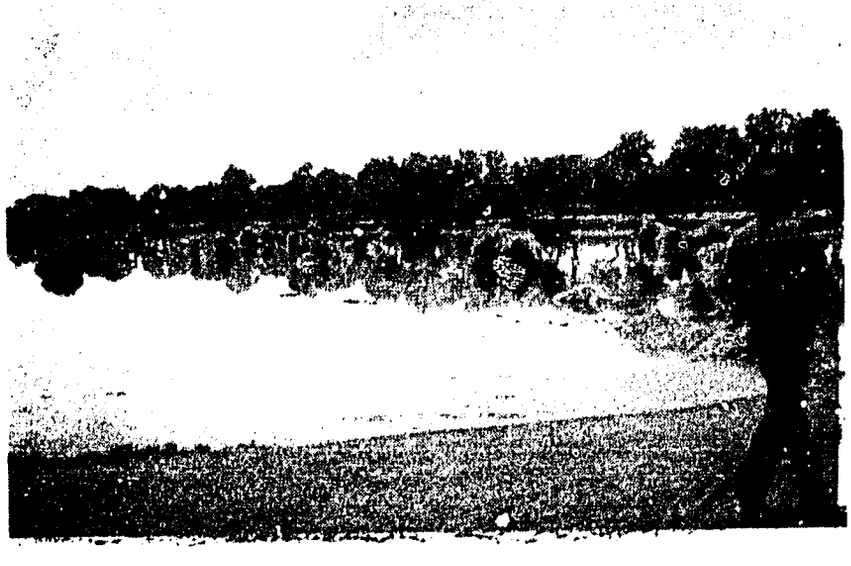


Plate 5. "Tambak" with mangrove fringe on the banks. Rice straw in the "tambak" provides food as it decomposes, and refugium for young fish.

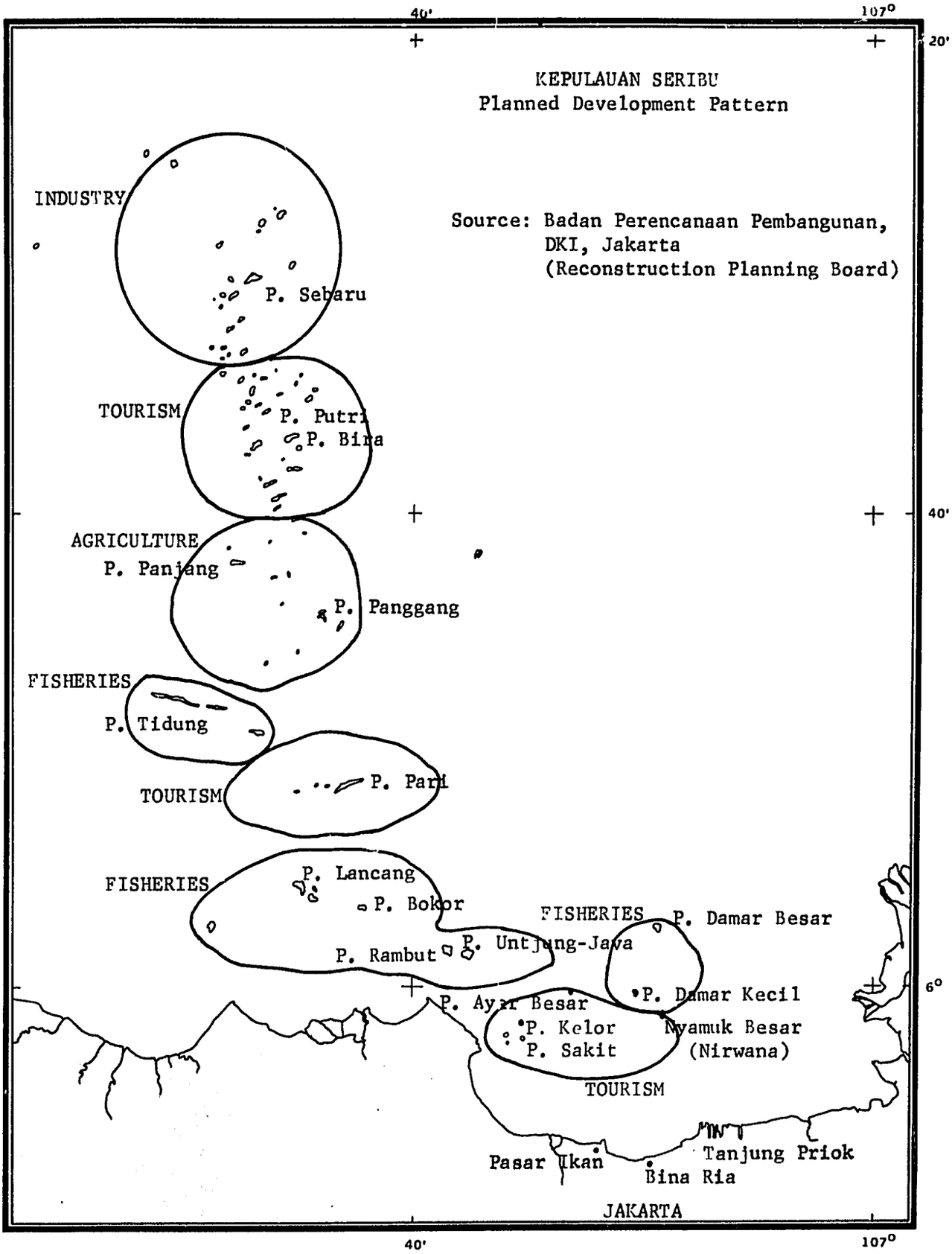


FIGURE 11 Page 69

Kepuauan Seribu Planned Developed Pattern

Jakarta, whose Master Plan includes special measures for these islands, including the development of tourism. The main portion of the islands is a distinct cluster distributed in a north-south oriented belt roughly 15 km. wide and 40 km. long, whose southernmost extent lies about 40 km. west of Jakarta. In between lie large and small islands somewhat randomly distributed along a northwesterly axis.

A limited amount of tourism development has already begun on three of the islands: Putri Kecil, Putri Besar, and Melinju. Further development of eight additional islands is to follow the completion of a short air strip on Pulau Panjang Besar. Presently these islands can be reached only by launch, which takes three to four hours, or by helicopter which is prohibitively expensive. Despite their relative inaccessibility, the islands were visited by 1,900 persons in 1971. Most were foreigners; 300 were Indonesians. Closer to Jakarta, the 15 km. ferry trip to Pulau Air Besar is a popular excursion. Visitors were reported to number 300 to 400 persons a day on weekends.

Presently the main threat to the amenities of these islands is tar balls on the beaches, originating in domestic and international shipping traffic. The more distant cluster of islands is potentially threatened by accidental oil pollution, which could take place in the IIAPCO-ARCO offshore wells, approximately 20 km.

Plate 6. Pulau Putri, Kepulauan Seribu. This is one of several islands developed for tourism.

west of the northern segment of the Kepulauan Seribu. As of 1972, there were two producing wells, a floating 1.2 million barrel storage tank, and one exploration well at this site. If a spill were not controlled and took place during the west monsoon, it could seriously pollute the islands. The northernmost islands are, moreover, slated for industrial development associated with the offshore exploitation, which raises the possibility of some form of pollution. However, the nature of the "industrial" development has not yet been specified.

In terms of money already invested in tourism development which could be adversely affected by marine oil pollution, the Ancol Project situated on the coast just west of Tanjung Priok is the most significant development. This large recreational complex

includes the extensive Bina Ria beach. The beach is a major drawing point of the Ancol complex, and it is threatened not only by low level oil pollution but contamination by waste waters flowing from Jakarta, and polluted waters originating within Tanjung Priok.

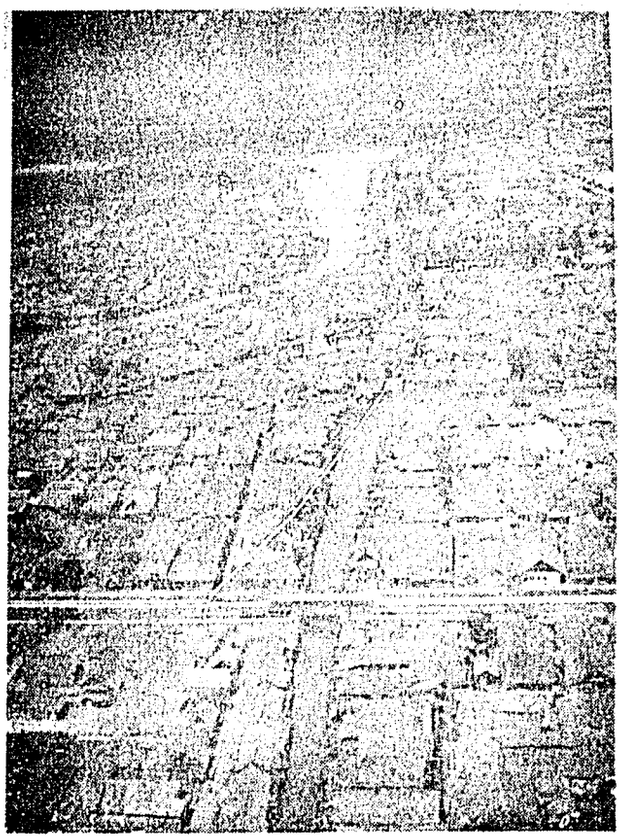


Plate 7. Canals in Jakarta. Urban waste waters and run-off are channeled to Jakarta Bay through a network of canals.

Finally, the beaches and coasts of eastern Bali are in danger of serious pollution should a supertanker accidentally run aground in the passage through the Straits of Lombok. Improbable as this may be--the strait is more than 100 fathoms deep--it is a possibility that cannot be dismissed. Also low levels of pollution,

resulting from the ship to shore transfer of jet fuel and other petroleum products, could affect the beaches in the vicinity of Benoa, where these products are transferred.

D. Oil Pollution

Oil pollution may be defined as the addition of oil, from any source, to Indonesian waters in any amounts that result in a restricted use of such waters by Indonesia, or which affect the health or welfare of the citizens, endanger the fishing resources, or damage the beaches or shorelines of the country.

In September, 1972, and in February, 1973, trips were made by members of the Pollution Study Group and Smithsonian consultants to various parts of Indonesia where oil pollution was reported or suspected: Jakarta harbor and bay, offshore drilling operations in the Java Sea, and various refinery and transfer terminal sites in Java, Kalimantan and Sumatra. Water samples were taken at these sites and results of analyses made to date are summarized in tables below.

The LEMIGAS Pollution Study Group also undertook water sampling and analyses of hydrocarbon content in Indonesian seas during a hydrographic survey in 1970/71. Anomalously high hydrocarbon concentrations were found in samples from various areas, described in later sections of this chapter. LON*, a member of the Pollution Study Group, routinely observes beach pollution on Pulau Ayer, where it maintains a base camp for studies of mackerel and sardine population biology.

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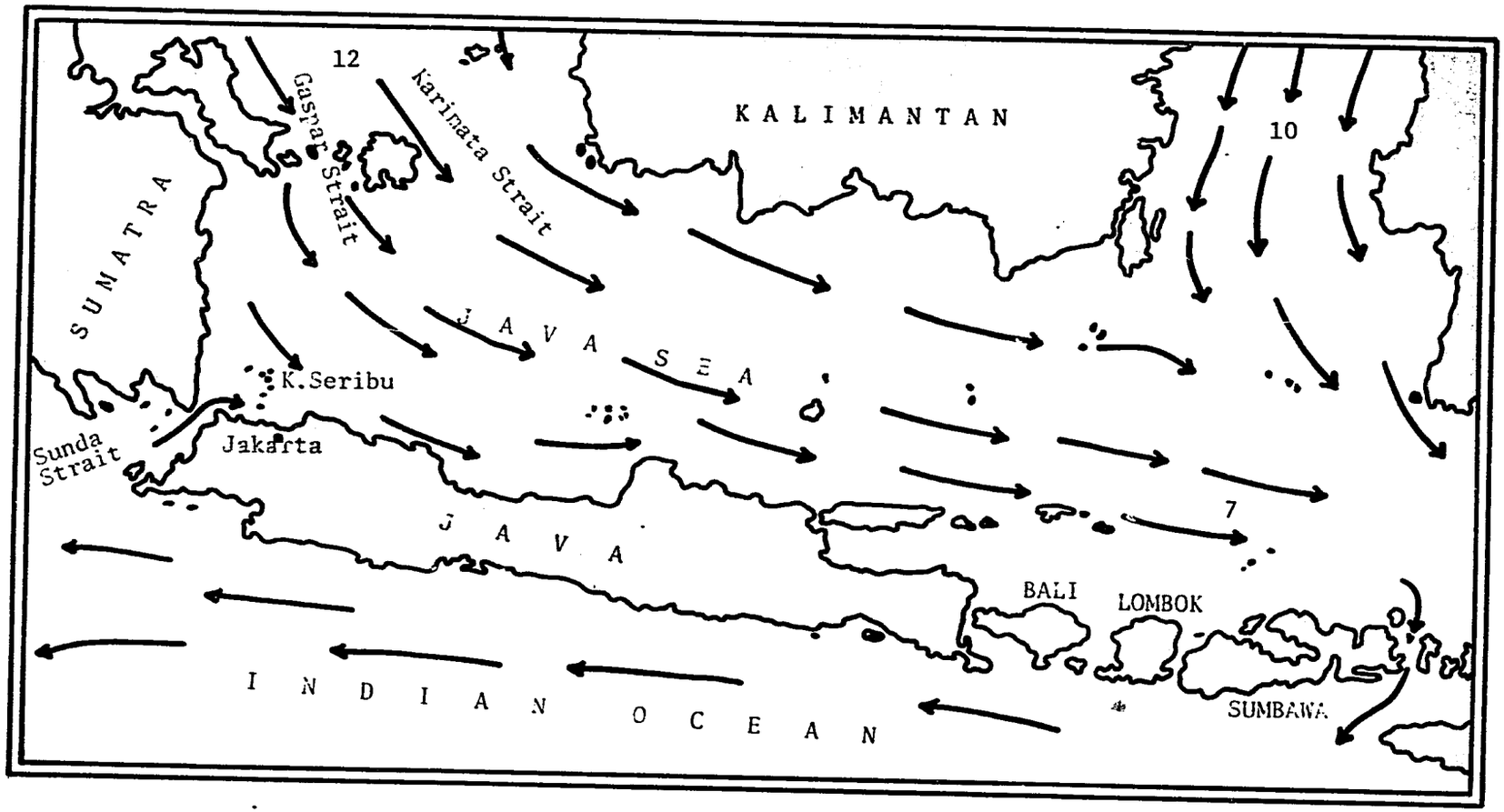
*Lembaga Oceanologi Nasional, National Oceanographic Institute

Observations made in the following sections concerning oil pollution prevention and control reflect the regulations in force prior to March, 1973. A new body of regulations (Minister of Mining Regulation No. 04/P/M/Pertamb/1973) was issued on March 22, 1973 (Appendix 1). It requires that Pertamina and other companies engaged in oil or gas activities prevent and control any occurrence of water pollution, have emergency plans to limit, control and clean any pollution, record spills, and periodically monitor pollution prevention devices. No oil is to be disposed of in water in any form, including oily drilling mud. "Toxic mud" is to be neutralized before disposal. Specific fractions of oil in ppm are stipulated in the regulations, with reference to discharges, although Pertamina apparently does have rules to this effect, which are mentioned in the sections below.

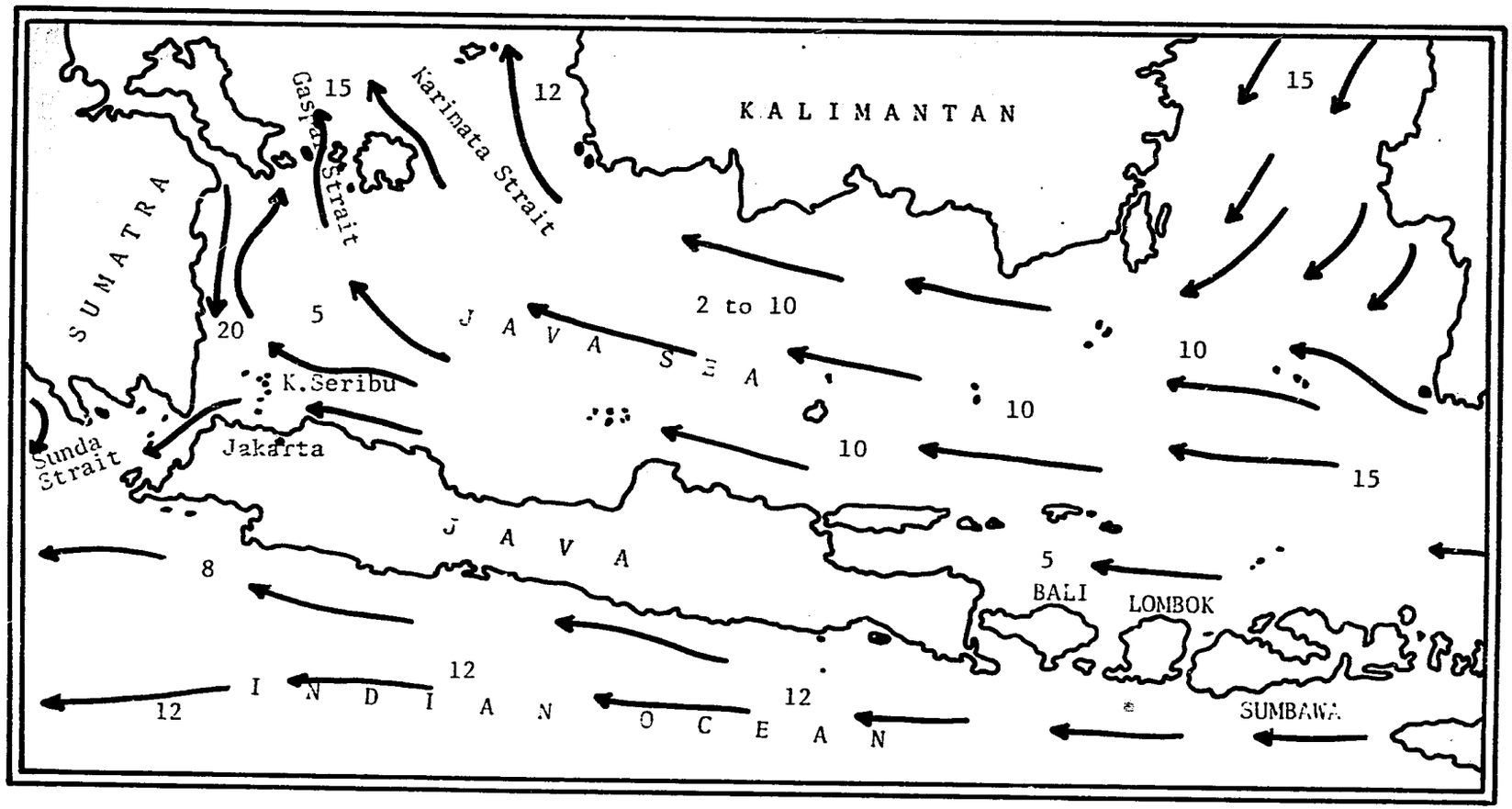
1. Currents and Tides in the Java Sea, Kepulauan Seribu and Jakarta Bay

The fate and effect of oil discharged in the sea is strongly determined by currents and tides. The marine oil pollution that was observed and/or measured, and which is described in later sections, must be understood in the context of current and tidal influences. A short description of the Java Sea is given in this section. General current patterns for all Indonesia are depicted in maps in the following pages.



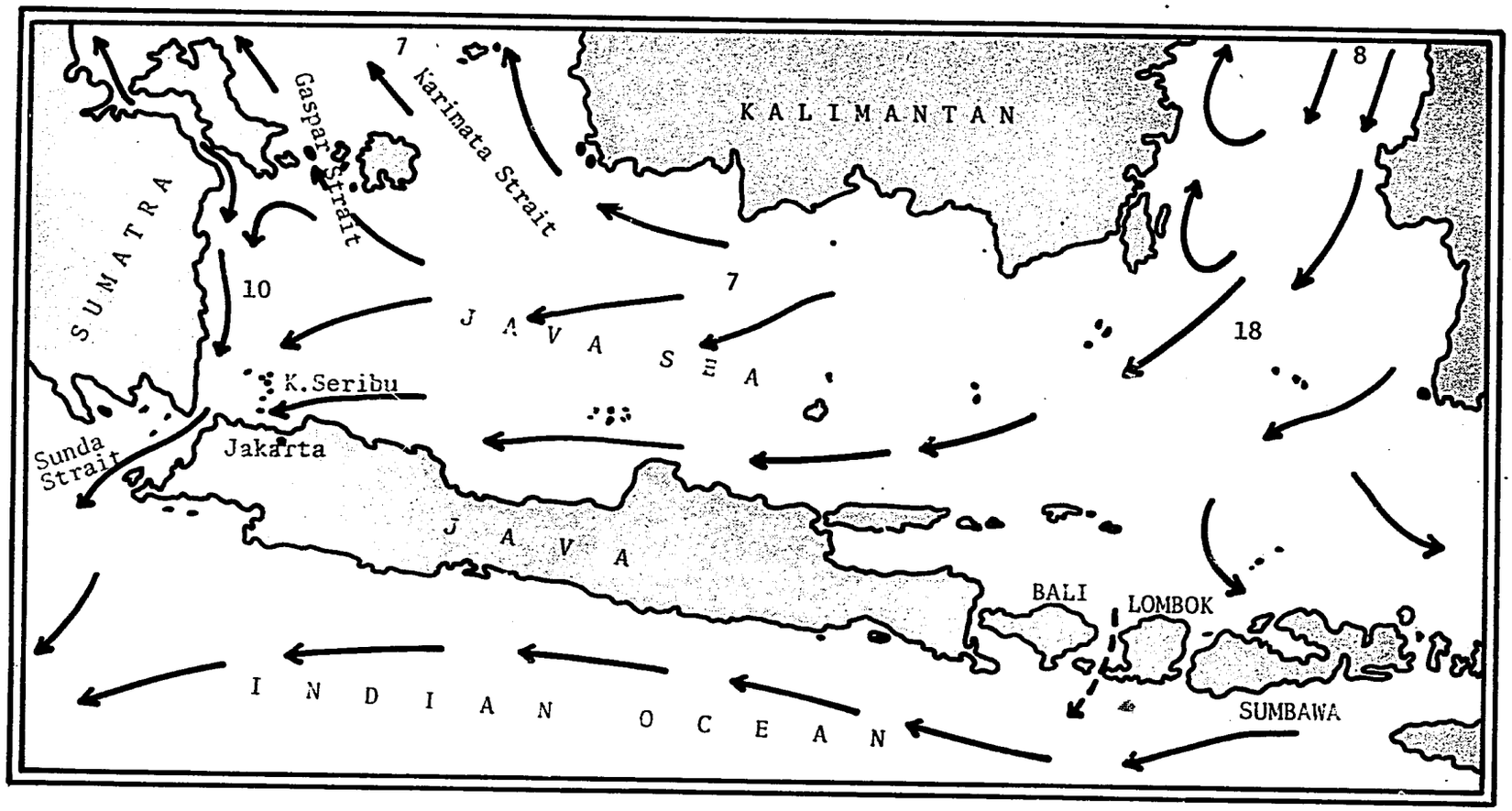
Numbers indicate current velocity in knots.

Fig. 12 Surface Currents, February



Numbers indicate current velocity in knots.

Fig. 13 Surface Currents, May



Numbers indicate current velocity in knots.

Fig. 14 Surface Currents, August

Numbers indicate current velocity in knots.

Fig. 15 Surface Currents, November

In the Java Sea both the wind and the geography of the region affect surface currents. During the East Monsoon (May to September) the currents flow in a westerly direction and turn northwesterly through the straits of Karimata and Gaspar (Figures 13 and 15). During the West Monsoon (November to March) direction is reversed in these straits, and in the Java and Flores Seas the currents flow in an easterly direction (Figures 12 and 15).

Surface current speeds are higher during the West Monsoon than the East Monsoon--0.25 m/sec versus 0.15 m/sec. The greatest rates are during January, March, September and December, with maximum speeds of 0.5 m/sec. Weak and variable currents characterize the transitional months. Below the surface, and to depths of 40 meters, current directions will be similar to the surface, and rates approximately the same--0.2 m/sec during the East Monsoon, and 0.3 m/sec during the West Monsoon. Since the Java Sea is relatively narrow and shallow, it can be expected that surface movements will extend to the sea bed. In the deeper waters (over 40 m) of the eastern region of the Java Sea, and in the Flores Sea, direction is likely to be less positive and the rate will decrease to about zero at depth.

Java Sea currents influence the current system of the Jakarta Bay and the Kepulauan Seribu. Tidal streams are generally weak except along coastal areas, at river mouths and in comparatively narrow passages such as island straits. Fast tidal currents and

considerable range typify some coastal locations. Rates exceeding 3 knots (1.3 m/sec) and up to 9 knots (4.5 m/sec) have been recorded in channels. In river mouths wind has little influence on direction and rate of currents.

In the region of the Kepulauan Seribu, currents conform to the general pattern of the Java Sea, but the monsoonal influence is manifested a month earlier than normal. Measurements were made during October and November, 1970, at Kepulauan Seribu, in the northern portion of these islands. This is the transitional period between monsoons, and the maximum velocity of the general current, resulting from both tide and wind energy, was only 0.08 m/sec. These measurements were taken at low water. At high water, rates tend to increase to 1.0 m/sec, as has been observed in P. Pari and P. Tikus in this island group.

In Jakarta Bay currents are also weak, and show the influence of the monsoonal regime. Maximum rates of the general currents recorded in June, 1972, and in May, 1973, were 0.1 m/sec in an east northeast direction. At the approach and mouth of Tanjung Priok harbor weak permanent currents averaging 0.025 m/sec were recorded; the tidal current was stronger (0.5 m/sec). The highest velocity recorded was less than 1.0 m/sec. The monsoonal influence begins in these waters in May and November. The easterly current is strongest, and the month of maximum velocity is February.

2. The Harbors of Jakarta

Tanjung Priok and Pasar Ikan harbors in Jakarta Bay are both heavily polluted by oil, and to an undetermined but substantial extent by domestic and industrial wastewaters from Jakarta. An area just to the north of the Tanjung Priok mouth is reserved for tanker cleaning prior to entering the harbor for dry dock repairs. Effluent from cleaning is discharged into the bay. Indonesia estimates that provision of slop tanks for receiving this effluent would cost more than U.S. $10 million. Water samples could be taken to determine the extent of pollution in these harbors.

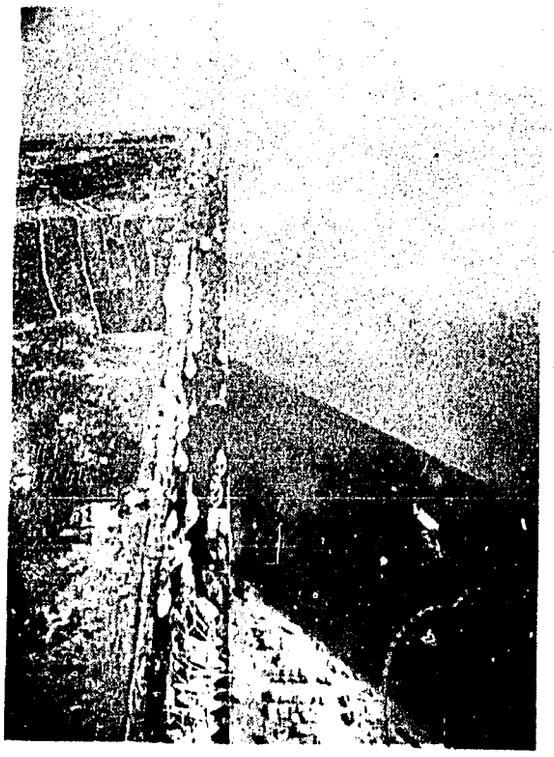


Plate 8. Pasar Ikan fishing harbor, Jakarta. "Tambaks" are seen at the left of the harbor entrance.

Oil spill clean-up equipment is available at Tanjung Priok. P. T. Calmarine, Inc. has been contracted by the foreign contractors of the Arjuna and Cinta offshore fields (IIAPCO and ARCO) for this service. The equipment is the Spiltrol device used successfully by Shell Oil in the Gulf of Mexico, consisting of a skimmer boat with its attached pontoons. It is located at one of the general cargo docks. Other gear is stored at Calmarine's warehouse at an adjacent dock. This includes the auxiliary tanks for receiving captured crude and eight 100-foot lengths of boom to be deployed in the water. This is an offshore model for duty in quite rough seas, but still designed for maximum economy.

ARCO/IIAPCO lease a dispenser pump for dispersant ("Gold Crew" brand), 50 drums of the chemical and a small pump to extract dispersant from the drums, plus a quantity of plastic that has a strong affinity for oil but not for water. This would be used in close quarters where skimming would be impossible. Of course, there are other techniques that could be used in close quarters, such as absorbents, the "slick-licker," oil mop, etc.

The dispersant "Gold Crew" is a solvent-base liquid that becomes sudsy when mixed with oil and water. It is toxic in initial application, according to P. T. Calmarine, who claims it is fully biodegradable several hours after dilution. Indonesia is studying the most suitable dispersants to be used in varying situations.

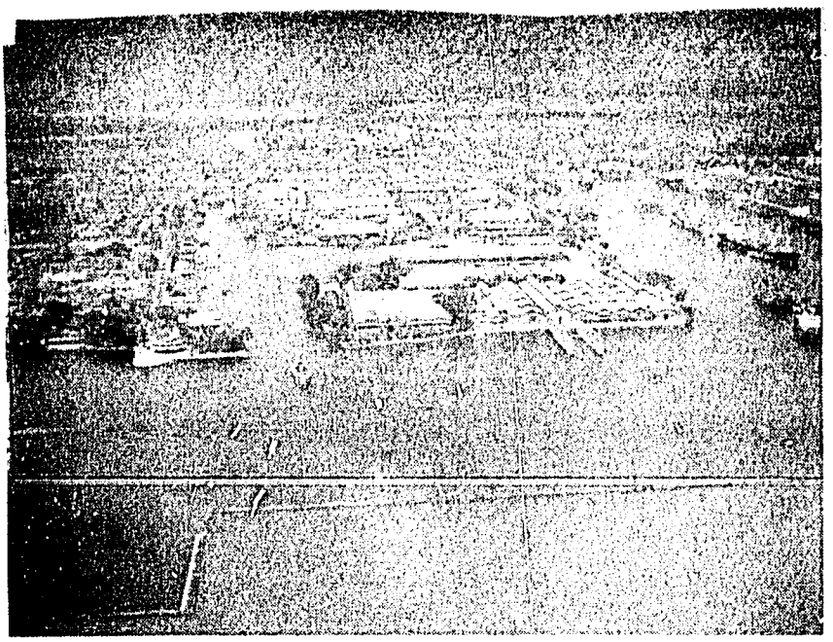


Plate 9. Tanjung Priok Harbour, Jakarta.

In case of a serious spill of products in the Priok area, this equipment could of course also be used on an emergency basis, but no arrangements have been made to prepare for such a contingency. Indonesian Agencies are investigating various technologies for the control and recovery of oil spills and will make recommendations in the near future. (No crude would be involved in an accidental spill at Tanjung Priok, since only refined products come to the marketing terminal here or into bunkering barges.)

Consultants inspected the scene of a 1972 fire at Tanjung Priok which claimed 80 lives and set fire to a number of small fishing boats, several steel vessels and destroyed several buildings on shore. Observers reported that a 20-foot high wall of

fire swept down a deep, narrow waterway from the oil terminal, from shore to shore. The oil marketing terminal lies at the east end of the enclosed Priok Harbor and the deep inlet leads from the terminal to the harbor. At night the inlet is jammed with fishing boats and houseboats which tie up in solid banks. Fortunately, the tide was running out when the fire started. Had it been flowing in, the fire could easily have engulfed several tankers and destroyed the entire terminal complex with a vastly greater loss of life. The fire was attributed to anti-government sabotage, and since the tragedy several steps have been taken to guard against a reoccurrence. Small boats are no longer permitted in the inlet and the entire area has been placed under Pertamina's control.

3. Jakarta Bay and Kepulauan Seribu

The heavily fished Jakarta Bay was not visibly polluted by oil, e.g., no oil slicks with the characteristic sheen were seen. However, from the air long brownish trails were observed in September, 1972, trending with the westerly current from the general area of the Tanjung Priok Harbor approach towards the southern end of the Kepulauan Seribu, and converging on the Outer Channel for shipping traffic, between Pulau Pari and Pulau Lancang. Hydrocarbon analyses were made by LEMIGAS of a number of water samples taken near islands in Jakarta Bay (or Roadstead), in September, 1972. Results are shown in Table 9. Interviews with people on these islands and with Col. Yasa, the director of C. V. Pulau Putri, were undertaken also.

Table 9. Hydrocarbon content of water samples from Jakarta Bay, September, 1972.

Location of sample	Unit	HC	pH.
Pulau Nirwana	ppm	19,66	8,2
Pulau Ayer Besar	ppm	14,11	8,0
Pulau Kelor	ppm	20,6	8,1
Pulau Sakit	ppm	17,14	8,2

Source: LEMIGAS. Samples were analyzed by the Gravimetric Method.

The eastern shores of several islands near Jakarta were lightly but visibly polluted with tar balls on the sand and tar patches on coral rubble in the nearshore reef flats, namely at Pulau Ayer Besar, P. Kelor, and P. Sakit. Inhabitants and visitors reported that occasionally oil slicks float into these islands. LON scientists reported a beach pollution occurrence in the form of tar balls that took place in November, 1971, on Pulau Ayer Besar and Pulau Kecil, a smaller island to the east. This was the second beach pollution occurrence observed by LON personnel.

The Smithsonian/LEMIGAS scientists did not find obvious damage related to the few tar balls or patches that were observed in September, 1972. The tar balls were not only found on the beaches of P. Ayer Besar and P. Ayer Kecil, but on the south coast of the P. Pari group as well. A black layer of sand at the depth of about 5 to 10 cm was found along the beach sands of P. Kongsi. The

oily sand is about 3 to 5 cm thick. Many of the juvenile turtles which are cultured in this area die as a result of this kind of pollution. Only timely surveys and research will enable an assessment of damage from this type of oil pollution. The adverse aesthetic impact is apparent, although difficult to measure.

4. Offshore Oil Activities

Visits were made in February, 1973, to the Arjuna field and Cinta field, both in the Java Sea near Jakarta, and the Attaka offshore facilities off the east coast of Kalimantan. Production from these fields is transferred directly to tankers. Union Oil's onshore transfer terminal for their recent offshore production, also off E. Kalimantan, was visited.

No oil pollution was observed in the vicinity of these operations; on the contrary, high standards of cleanliness were observed. The almost inevitable exception is oily ballast water discharged during loading by those tankers not having compartments to store remnants of oily ballast, such as load-on-top systems. Most of the oily ballast water is certainly discharged prior to mooring. Pertamina is investigating the possible adoption of load-on-top regulations. At all three locations maximum filling rates per hour are between 35,000 and 40,000 barrels. Indonesian seas and weather are generally moderate and the necessity of mooring with large volumes of ballast is reduced, with the possible exception of supertankers. Only one incident of oily ballast discharge during loading was observed.

Pertamina rules prohibit the discharge of oily ballast and oily drilling mud. Oily waste is judged by the appearance of a visible sheen, which must be reported. Visible sheens in clean water usually appear at 20 - 25 ppm. Discharge of paraffin into the sea during well workover is also forbidden. Other required prevention measures include: blow-out preventers, automatic sub-surface shut-off devices, anti-seismic and anti-tsunami platform design, and standby spill control equipment, e.g., dispersants, absorbents, Husky skimmer and booms.

Arjuna field. The Arjuna field had five entities:

(1) Bravo platform, consisting of a residence and work platform, a processing and jumping platform, a gathering platform with two producing wells and spaces for four more, and a flare structure, all connected by bridges;

(2) a drilling rig preparing another set of wells nearby;

(3) a completed platform in production delivering to Bravo;

(4) another flow station (E) 12 miles away with contributing platforms and flare, delivering crude to Bravo by underwater lines;

(5) barge "Arjuna Monrovia" at a single buoy mooring (SBM), receiving production from Bravo at 38,000 bpd, with 1.0 million bbl capacity, and a second SBM two miles off for loading tankers. This was inaugurated in September, 1971.

Diesel oil for power is transported by barge from Jakarta.

Water was observed to be completely clean on the surface. This area is a favored place for small boats of two to three fishermen that fish here on hand lines regularly. Housekeeping on the jackup rig visited, and at the barge and the Bravo station seemed immaculate. Oily wastes are used in drilling mud, and nothing is released into the sea except separator water, which is still a very small percent of oil produced.

When known fields are connected, production here should rise to about 73,000 bpd. In addition, to the south near the Pertamina Jatibarang field, a new field has been discovered and was announced on February 23, 1973. This is still being evaluated. Capacity of the barge and delivery system is roughly 100,000 bpd, or 10 days' storage, on a sustained basis.

ARCO, the contractors of the Arjuna field, had bad luck on a gas well near the shore, in line with Jakarta. This blew out in late 1972 destroying the drilling rig. It was still (1973) boiling gas into the sea, but no oil. A second effort was being planned to plug it but the sea bottom is widely cratered.

A work boat collided with the gathering platform at Bravo in 1972, damaging the legs below the water line and delaying the completion of four wells planned here. The repairs had been completed and the jackup rig was to return to complete the wells. No oil was lost in this accident but it caused costly delays.

The main potential hazard the platform personnel feared was a collision or pipeline rupture from passing vessels that do not respect the prohibited zone around this complex. The zone is registered with hydrographic offices in Jakarta, Japan, England and the U.S.A., with location and description so that vessels can avoid it. However, the field is astride the traditional shipping lanes from Jakarta to the East, and in the past, small fishing boats violated the zones several times each week, attracted by the rig flares which draw the fish at night. Since the boats were not radio-equipped, they were not given warnings but were reported to harbor authorities and Pertamina. Government authorities, recognizing the danger of collisions with the rig or of dragging anchors over the pipelines, are now enforcing the regulations more strictly.

There is a booklet describing port information for this loading port, which was studied. As there is as yet no comprehensive Indonesian law on port regulations at offshore platforms, this booklet is based on U.S. practice. This specifies that only clear ballast will be discharged in the six hours from the time when the tanker secures to the single buoy mooring (SBM) and loading commences. Adequate ballast is required to give the ship headway in open sea mooring. The booklet states: "Tankers with dirty ballast will be rejected and will tender a new notice of readiness on second arrival." To date no tankers have been rejected.

Tankers with ballast-clearing equipment can store their slops, but others without this capability obviously dump dirty ballast in open areas.

Cinta field. The Cinta field is operated by the IIAPCO group of companies and is located on the Java Sea opposite the Sunda Strait about 70 miles northwest of Jakarta. This station has many characteristics in common with the Arjuna field previously described. There are two producing platforms with flares, each delivering to the million barrel barge "Cinta Natomas" at an SBM. About four miles off, a second field is in development with one flow platform completed and a second in construction, together with a drilling rig at work.

Production here was 38,000 bpd. The nearby field "Kitty" was to be connected soon. Another field, "Zelda," to the north was being developed and was to have been connected by the end of 1973. Zelda crude has 100°F pourpoint, so that the undersea line must be insulated to retain heat. Capacity of the barge limits the field now to about 100,000 bpd regular production.

The barge is a new one from Japan just put into service, and an extra crew was at work in the shakedown phase. It had a small crude still on board to make diesel and fuel oil for power, but this had failed and fuel was being brought from Jakarta by barge. Many safety features were pointed out that enabled the wells to be shut down below the water line automatically and that protected the oil and people on the barge.

The barge is large and high, but was riding side on to a strong wind blowing up the Sunda Strait with waves about 10 feet. There is a steady current running out the Strait in February, which accounts for the position of the barge.

No ships pass through this sector so collision damage is minimal.

The personnel claimed that water from the separator enters the sea at 20 ppm oil, in small volume. Some gas is used on board for power. In case of minor oil spills, there are dispersant chemicals and a mixing pump on one of the work boats. This is sprayed on and churned up for fast mixing. This field has been in operation for two years, and only closed to loading for one day due to weather.

The port regulations as to de-ballasting were studied and read the same as the rules at the Arjuna field.

Attaka field. The sea off Borneo is noticeably less saline than the ocean due to the outflow of fresh water off the big island, and to somewhat limited access of sea water onto the continental shelf past all the islands on its borders.

There is a work and residence platform here bridged to a producing and pumping platform. The flare structure is separate. Two drilling rigs are making new wells in the area. There is a deliberate effort to reduce gas produced and flared, with several levels that produce gas being shut in. The platforms have steel edging around all floors and a sump system in which all oil

droppings and rain are trapped and separated. There are automatic devices that in any emergency would shut off oil production by valves near the bottom. Off-duty members of the crew were observed to be catching fish from several points around this platform.

The Fire and Safety Manager said that after loading had commenced on one tanker, a sheen of dirty ballast had been noted being discharged during early loading. Despite port regulations to the contrary, this tanker was not rejected as it was already being loaded. This is the only instance of pollution seen. No action was taken against the tanker except warning. DKKA* was investigating the incident, however,

Santan terminal. On March 5, 1973, Union Oil made a substantial discovery just offshore about 100 miles north of Balikpapan. The Company has elected to bring the crude ashore for separation and storage, then to pump it back out to an SBM for export loading. Their shore terminal, Santan, was put onstream last November and is still being completed as to mess hall and living quarters and landscaping. However, it is a model of new design and neatness and the staff are determined to keep it that way. There is a deep channel dug from offshore through the lowlands into the terminal, and the crude lines are in the bottom of the channel. This allows access for barges with equipment and for work boats because there are no roads here.

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*DKKA--Coordination of Foreign Contractors Division, Pertamina.

There are three tanks of 500,000 bbls each and space for a fourth. This will allow throughput of over 100,000 bpd, if it is found. Production was about 50,000 bpd.

There was only a trickle of separated water flowing into the channel from the separator, and this was completely free of sheen.

There was a complete set of spill pickup equipment here deployed in readiness for use. A central skimmer vessel with side pontoons, rested on wood skids ready to be pulled into the water. There were two auxiliary tanks to be put on the deck of a work boat to receive the oil separated and picked up. The boom sections were on skids in a warehouse. A pump for mixing dispersant was in a cage at dockside ready for use. The Union people stressed both here and offshore their determination to keep this operation clean, safe and well-protected by all possible precautions.

There is a sewage treatment plant at the dock so that effluent discharged into the channel is completely clear.

5. Refineries

Pertamina owns and operates the eight refineries installed in Indonesia. The Cepu refinery, not listed in Table 10, is a LEMIGAS training installation. A 100,000 barrel capacity per day refinery is planned for Cilacap for completion in 1976, and a polypropylene plant under construction in Plaju was to have been completed in mid-1973, with a 20,000 ton per year capacity.

Table 10. Indonesian refineries and capacities
(thousand barrels per day)

Product	MBCD	Plaju (110)	S. Gerong (70)	Dumai (100)	S. Pakning (50)	P. Brandan (3)	Wonokromo (4)	Balikpapan (65)
LPG		x	x					
Avgas		x	x					
Avtur		x	x					x
Mogas		x	x	x(1)	x(2)	x	x(3)	x
Kerosene		x	x	x	x	x		x
Gasoil		x	x	x	x			x
Fuel (diesel)		x	x			x		x
Wax		x(4)	x					x
Solvent		x	x			(Lube. oil)		
Waxy residue		x	x	x	x			x
Asphalt		x	x(4)			x	x	

(1) Straight run
(2) Tops distillate
(3) Heavy gasoline

Source: Pertamina, Refinery and Petrochemicals Division, 1973.

Only the Balikpapan, Sungai Gerong and Plaju refineries were visited and refinery personnel interviewed. A visual inspection of the Wonokromo refinery's effluent outfall was made in September, 1972, but the plant was not toured nor were its personnel interviewed. Also the site of the future Cilacap refinery was visited.

The most important pollutants from the refinery process are desalter water effluent (sulphides, phenols, oil), sour condensates (H_2S, NH_3, phenols), and phenol condensates from cracking operations.

In Pertamina refineries, oily wastewaters are run through an API gravity separator. Oily and oil-free drainage from refinery sites are separated, in general. The pH of acidic and basic waste is controlled before discharge. Sludges in general are burned; acid sludge is channeled to an acid "lake" before discharge of acidic water into the sea. The Sungai Pakning refinery is the only plant which uses its desalting equipment to process oily ballast residues from load-on-top tankers. Pertamina should undertake a comprehensive study on waste treatment disposal.

Balikpapan refinery, East Kalimantan. This old (1925) refinery is located on the inside shore of a large tidal bay. A small freshwater supply enters the bay from the hinterland. Dredging is needed every ten years, but is done more frequently.

Special care in the loading of refinery products to vessels is needed here because of the great tidal range. The mean range is 2.3 m and the maximum is 3 m. Careless handling of transfer hoses could result in spillage. At the same time, however, the tidal range assures good water turnover, so that it is less likely that spillage would seriously pollute the harbor.

Relatively little metal scrap has been removed from this area since the refinery was built. The plant suffered heavily from Allied bombing in World War II. Several rusted barges and hulks still line the shore and the banks are oil-soaked from old spills. Pertamina has appropriated funds to clear the scrap and dredge the harbor to accomodate vessels up to 50,000 Dwt.

The town had no native population before Shell selected it for a refinery site, following their crude discoveries in East Borneo and elsewhere in Eastern Indonesia (Tarakan, Bunyu, Ceram, etc.). The population, therefore, is all from South Borneo, Celebes, and East Java and the food supply comes from these same places. Hence, it has a frontier aspect and no social amenities or civic center, even now. Housing is located on the bay and seacoast. Many homes are being built here for foreigners and for Indonesian staff members employed in the intense onshore and off-shore exploration which is now going on, and for which this is the operations center.

it is not used frequently; tankers do not always require this facility. The beach just outside this bay on the seafront was completely clean despite the fact that a number of vessels usually anchor outside the bay while waiting for their turn to load in the harbor. This could indicate that vessels are not discharging oily ballast outside the harbor. Because of the strong tides and currents in the Makassar Strait, any discharge from incoming tankers would be quickly dissipated and not visible.

The Technical Advisory Section head explained that there was a keen competition between three departments (processing, oil movements and wax plant) for safety and cleanliness in specific work areas and practices, with a prize and banquet paid out of penalties.

Sungai Gerong and Plaju refineries at Palembang, Sumatra.

These refineries are located 120 kilometers from the Sumatra coast on a wide curve of the Musi River. This results in accumulation of drift material along the shores and under the docks. The material consists of every variety of natural and man-made things, about 3/4 of which are hyacinth, banana plants and bamboo. The rest ranges from saw logs and whole trees down to plastic caps. The town is upstream and the accumulated drift acts as a natural surface filter which shows striated layers of oily drift. This oil is probably largely lubricating oil from all the towns above. The drift is a fire hazard along the docks and must be

In spite of the littered appearance and oily ground and banks the bay water appeared quite clean with only a broken sheen emerging from water separator streams. The laboratory was asked to take samples from several points and to forward one set to LEMIGAS for HC measurement. The results showed that the pH value was normal and that hydrocarbon content was within acceptable levels, i.e., below 10 ppm.

Crude supplies here are from a pipeline from the interior (Tanjung crude), minor supplies from the old coastal oil fields still in production, feedstocks from Pulo Bukom Singapore and the Central Sumatra refineries, and mainly Minas crude. Throughput is about 60,000 bpd. Finished products are exported in small tankers to East Indonesian points and to Surabaya for which this refinery is the main supplier. There are exports of naphtha and of waxy residue to Japan, and of paraffin wax to many countries. Production of wax at 175 tons per day is very valuable, and is soon expected to go to over 200 tons per day.

Partially processed wax feedstocks are treated with concentrated sulfuric acid. Spent acids are not recovered and re-used, but are neutralized with caustic soda, and diluted with fresh water, and dumped into a low area of several acres called the "acid lake." The odor of H_2S is noticeable.

The harbor has the usual restrictions on discharging oily ballast. There is a line to all docks for receiving slops, but

pulled free by work gangs. The surface sets toward the refineries, and is balanced by underwater currents outwards. The rapid flow of the Komering River which empties into the Musi between the refineries, acts to set up boiling places and standing lines of drift sustained by undercurrents.

These refineries were reported to operate on the following general volumes:

Table 11. Refinery operating volumes, Sungai Gerong and Plaju

Input	Thousand barrels S. Gerong	Plaju
Crude supplied by pipelines	1315	1077
Foreign crude	15	9
Indonesian crude and feedstocks by tanker	432	867
Total run	1762	1953
Daily Run	56.8	63.0
Capacity per day	65	110
Output		
Products by barge to local terminals	10%	n.d.
Products by small tankers (600 T) to coastal points	10%	n.d.
Products exported to Japan and U.S. (fuel oil, wax and naphtha)	10%	n.d.
Products to main Indonesian marketing terminals	70%	n.d.

Source: MIGAS, October, 1972.

Effluents from the oil separator channels that drain the whole Plaju complex flow into the Komering with a barely discernible sheen. This includes process water, cooling water and rainwater. The turbulence in the main river distributes the dissolved oils widely. Sungai Gerong treats its process water in the refining complex and sends the used water into the Musi by an underwater line. Rainwater is in open channels.

There are five tanker docks at each refinery and several waiting tankers moored in a line in midstream waiting for loading. Each is fairly high, having deballasted before entering the river and coming upstream (70 miles). Rules are that only clean ballast is discharged. This is monitored by the Master or Engineer of each vessel and by shore supervisors. Vessels with slops to discharge on a very dirty ballast pump into slop tanks ashore, and these are drained to the refinery's water system to be rerun. We did not, regrettably, ask to see the records of how often in fact these slop tanks are used.

Procedures at these refineries do not seem to have changed for many years. The present senior staff contains many who worked here before the refineries were put under Indonesian control (Plaju late 1965, S. Gerong about 1970).

Draft limitations are one of the most serious disadvantages of these refineries. The river spreads into a broad delta and the mouth requires periodic dredging. Even T-2's cannot move in or out fully loaded. In the past, dredging was organized by

Shell and Stanvac with the government paying a small share, recognizing the use of the port by other vessels for rubber and general cargo. Now the channel needs dredging again.

The river is fished and settlements are located all along its banks. There are no reports of tainted taste or of slicks, although, as with the drift material, hulls of small boats quickly acquire an oily coating.

Samples of river water to 25 cm deep were taken in eight places along the refineries and on the opposite shore where a urea fertilizer plant supplied by gas operates. These were to have been analyzed for HC content by LEMIGAS. Faint sheeny areas were seen at and below Sungai Gerong, suggesting poor surface scouring in these areas.

Wonokromo refinery, East Java. Drums of bitumen which belong to local paving contractors are stored near the refinery until needed by the contractors for their roadwork. Some drums were slowly leaking into the canal and it appeared that this had been going on for many months. Analyses of water samples taken at this site yielded the following results: volatile oily matter--2 ppm; extracted oily matter--2ppm; total oily matter--4 ppm; pH--7.7. Pertamina stated that although the separator appears dirty, it is cleaned daily and the separated oil is removed.

Downstream from the canal a "tambak" caretaker was interviewed to find out if there were complaints about refinery

pollution of "tambaks." There were none, and local inland fisheries personnel did not indicate that there was a problem. However, illegal use of toxic pesticides for fishing was mentioned.

Cilacap future refinery, Central Java. A one-day visit was made to Cilacap, where a 100,000 bpd refinery as well as other industries are planned. The town of Cilacap is the largest fishing port in South Java with about 2000 fishermen. There are three outboard motor fishing vessels and 16 larger inboard vessels. Local fisheries personnel are encouraging motorization and the building of a cold storage facility.

Motorization has already resulted in significant benefits to fishermen by enabling them to concentrate on catching a large species of shrimp which fetches high prices in Bandung, Jakarta and the export market (via Jakarta). The total catch of fish has dropped by more than 50% in the last three years, but the value of the catch has increased by more than 30% because of the increased shrimp catch. The per capita income of fishermen has increased about 30%. Although local fisheries people could not predict how far the fishery might expand with increased motorization, it appears that the potential may be great. Motorized boats are not so limited by the frequent rough weather that plagues the unmotorized fleet.

There are no fishponds in the area. There is a limited fishery for seaweed in the area and an aquarium fishery centered

on coral reefs off the eastern end of Nusa Kambangan. An examination of the reefs in this area was prevented by a combination of rough weather and very poor underwater visibility due to a dense phytoplankton bloom.

The Cilacap area appears to have considerable tourist potential. It offers a variety of lovely scenery, a very long, wide sand beach, a relatively mild climate and an excellent sheltered port. Marlin are a significant portion of the commercial catch and might support a sport fishery.

Apart from municipal waste (which was not greatly in evidence) it appears that the only present potential source of significant water pollution is the oil terminal where oil from small tankers is unloaded for use in the central South Java area. There was no visible oil pollution in the area. However, most of the oil unloaded here is light and would not necessarily leave obvious evidence of its presence in the intertidal area. Survey of oil levels in the surrounding sediments and benthic biota are needed to establish whether or not leakage during oil transfer has had any significant impact on the area. There have been no complaints from local fishermen concerning oil pollution according to fishery officials.

The refinery to be situated on a tidal estuary about two miles north of Cilacap is in the advanced planning stages. The Cilacap area seems a logical spot for an oil refinery because it

is the only harbor that offers complete protection from the frequent rough waters along the entire South Java coast.

If designed and operated with proper precautions it appears that a refinery need not interfere significantly either with the fishery or the tourist potential of the area. The refinery would not be visible to the majority of tourists and is several miles from the closest beach area. The low levels of oil in properly treated effluent would not be detectable by any but chemical means at this distance.

The major threat to the area posed by oil operations is that of a significant oil spill at the oil terminal or refinery. Once the oil flushed out of the estuary, strong frequent onshore winds would probably wash much of it onto the adjacent beach. Perhaps more importantly there is a very extensive mangrove community along both sides of the estuary. Long fenced traps along the dropoff from the mangrove community into the open estuary are used to catch shrimp migrating into the estuary as the tide drops. Since this fishery does not account for a major fraction of the total local catch, Cilacap fishery officials appeared to minimize the value of mangrove communities to the local fishing economy (while acknowleding their importance as a source of fuel). This is not to their discredit since it is only very recently that the true value of mangrove communities to coastal fisheries has really been appreciated anywhere in the world.

It was reported that a fertilizer plant is to be associated with the refinery, but it was not possible to obtain details concerning the processes involved. Should the effluent from this installation parallel that observed at the Gresik petrochemical fertilizer plant, more stringent precautions should be taken to safeguard the local fisheries than that observed at Gresik, since the plant will be located in an area where flushing will be much less effective in diluting the effluent. Estuarine adult fish and shrimp, as well as juvenile ocean fish, could disappear from a major portion of the estuary. The impact on tourist potential could be serious.

Java Shell holds oil exploration rights off central south Java in an area encompassing all of the Cilacap fishing grounds as well as those of another significant fishing center east of Cilacap. The strong, predominantly onshore winds in this area increase the probability that a blowout or other major oil spill would bring serious damage to the reef, mangrove and beach areas in the vicinity.

6. An Overview and Survey of Marine Oil Pollution

Relatively high concentrations of hydrocarbons, ranging from 20 to 100 ppm., were encountered in various portions of Indonesian waters during a 1970/71 hydrographic surface water survey carried

out by LEMIGAS*. Sample locations were plotted and are depicted on a manuscript map, which can be consulted at LEMIGAS. Areas and concentrations were as follows:

- a large area off Kuala Trengganu and Kuantan off the east coast of Malaysia--20-30 ppm.
- the Bangka Strait--20-40 ppm.
- an area west of Pontianac West Borneo--20-48 ppm.
- an area south of Bangka--30-200 ppm.
- areas near Cirebon, Semarang and Surabaya, Java--all from 35-60 ppm.
- an area south of Bali--40=50 ppm.
- An area south of Pulau Kangeon, north of Bali--40-70 ppm.
- several other areas in East Indonesia--40-60 ppm.

While the HC content encountered near the four main prots--Tanjung Priok, Cirebon, Semarang and Surabaya--has obvious relationships to converging ship traffic, other concentrations are not readily explained. However, low velocity circular current patterns were suggested as a possible factor in the capture and accumulation of hydrocarbons. In the Sargasso Sea, the accumulation of various kinds of floating matter such as pieces of styrofoam plastic and degraded oil points to the possibility of significant buildup of pollution associated with converging surface currents.

*Random samples were taken of water at the surface over a period of six months, and analyzed according to the ASTMD 1340 method.

The findings of the survey suggest that local accumulations can occur; however, additional surveys are needed to define further this phenomenon. Also, in order to get accurate bioassay data on oil pollution by petroleum, or its products, on marine life, Gas Liquid Chromatography and IR Spectrophotometry patterns must be developed which can differentiate between biogenic fats and fossil hydrocarbon.

The findings of the survey might be seen as reasons for the Minister of Mines to recommend that the Government of Indonesia sign the Ocean Dumping convention and take other measures to control the dumping of wastes into territorial and adjacent water of Indonesia.

7. Other Observations, Bali and Cilacap

No oil pollution was reported by local inhabitants on the Sanur and Kuta beaches in Bali. A water sample taken from near the transfer terminal in Bali yielded the following: total oily matter--30 ppm; pH--7.8. Water was also sampled at Cilacap terminal; total oily matter was 5 ppm. Local fisheries in Cilacap had received no reports of oil slicks.

E. Other Types of Pollution in the Coastal Zone

In the course of this survey on marine oil pollution, it was evident that coastal and estuarine waters were not only the most heavily fished--in places perhaps overfished--but were also subjected to increasing stress from sedimentation, agricultural chemicals, industrial effluents and municipal wastewaters. It was clear that an assessment of the impact, present or future, of oil pollution on these productive fisheries cannot be undertaken in isolation from these other, potentially damaging forms of pollution. The discussion that follows reviews the various types of pollutants and stresses that are affecting coastal waters, and the brackish water fish ponds, or "tambaks."

1. Sedimentation

There were numerous reports of accelerated sedimentation in the coastal waters of Indonesia. The following areas were mentioned. Fisheries were reported to have declined considerably in recent years in those areas marked with an asterisk (*). No information was available to the Smithsonian group on fisheries trends in the other areas listed.

Java	- Jakarta Bay*, Segara anakan, western Selat Madura*, Pacitan Bay, Indramayu.
Sulawesi	- Kanlau Bay.
Sumatra	- Eastern Sumatra coastline*.

Kalimantan - rivers and estuaries in the vicinity of logging operations.

Erosion is a natural process without which there would be no soil. However, accelerated erosion due to bad land management not only robs the land of its fertility, it also destroys the freshwater and marine communities on which the excess sediment settles. Excessive siltation associated with bad land management is probably the single worst form of pollution in tropical marine environments. Indonesia appears to be no exception. Dredging and mining also contribute to the problem.

In Java excessively rapid runoff and erosion are recognized to be serious problems leading to flooding of lowland fields, damage to irrigation networks, and loss of topsoil. However, biological damage from sedimentation is not perceived to be an associated problem. Notwithstanding the extensive terraces on sloping lands in Java, erosion occurs on higher slopes too steep to terrace. Delta buildup along the north coast is accelerating (Hollerwoger, 1964), and is likely to be adversely affecting subtidal marine communities that require clear water.

In Kalimantan and Sumatra, where the population pressures on agricultural land are much lower, major erosion problems are probably largely of more recent vintage. It can be anticipated that fisheries in the vicinities of the mouths of many rivers here will decline, if they have not already begun to do so, as

a result of the rapidly expanding lumbering industry and the associated acceleration in sediment runoff.

2. Pesticides

The destruction by pesticides of fish being raised in rice paddies is well known in various parts of the world (Kok, 1972). The numbers of such incidents are on the increase in areas where "miracle" (IR) rice strains are grown. Because of their greater vulnerability to pests, these strains receive intensive treatment with pesticides. Some rice paddy farmers no longer even attempt to grow fish because of the pesticide problem. This is reflected in the ever decreasing area of mixed culture activities, especially in Java.

The high yielding varieties of rice are being diffused through the Bimas* and Inmas* "mass guidance" programs of technical assistance to rural farming villages. The amount of pesticides distributed during 1968 to 1972 through the Bimas (and later the combined Bimas and Inmas) program of technical assistance showed an increase and then a decline after 1970 (Table 12) in terms of insecticidal toxicity. This was apparently determined by converting the various pesticides to equivalent amounts of diazinon, a non-persistent organo-phosphorous insecticide.

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*Bimas--Bimbingan Massal (Mass Guidance)
Inmas--Intensifikasi Massal (Mass Intensification)

Table 12. Total pesticides in diazinon equivalents distributed in Indonesia through the Bimas and Inmas programs, 1968/69 to 1971/72

(in kilograms or liters)

Crop year	Diazinon equivalent	Zinc Phosphide[a] equivalent	Others[b]
1968/69	1 500 000	5 830	-
1969	1 619 013	108 943	-
1969/70	2 425 776	73 339	-
1970	190 257	-	-
1970/71	517 505	30 387	15 409
1971	130 465	10 311	11 242
1971/72	273 943	15 992	30 430

[a] rodenticide
[b] dieldrin, aldrin, DDT, malathion, Dipterex, ethyl parathion, Fosferno, Wofatox, Methaldehyde, copper sulfate, other copper fungicide and Warfarin

Source: Badan Pengendali Bimas (Bimas Control Agency), Department of Agriculture

During the period an increasingly greater number of different formulations were distributed, especially organochlorine insecticides (Tables 13 and 14), including some that are highly toxic to certain fish, especially endrin. Because of the persistence and toxicity of this group of insecticides, the potential for damaging ecological side effects from pesticide use increased rather than decreased during the period. Although endrin is rated on par with diazinon in toxicity to insects, it is 36 times more toxic to *Lepomis macurochirus*, the bluegill sunfish (Henderson *et al.*, 1959; Cope, 1965).

In Table 12, BHC is rated only 1/75 as toxic to insects as diazinon, and the increasingly predominant fraction of BHC in the total amounts distributed accounts for the dramatic decrease in diazinon insecticidal equivalence in recent years. According to the type and amount of isomers, its toxicity to fish varies widely. The BHC distributed was the gamma isomer (lindane) formulated as granules containing 6% gamma BHC. Lindane is widely used to control rice stem borer in miracle rices in Southeast Asia. Its application as a systemic to paddy water will preclude the parallel culture of *Tilapia mossambica* (Kok, 1972), and possibly other fish.

The Indonesian Ministry of Agriculture has studied the effects of thiodan, endrin and other pesticides--diazinon, carbaryl,

Table 13. Pesticide distribution[a] in Indonesia in Bimas and Inmas programs - 1968-1972

Insecticide	Unit	1968/69[c]	1969[d]	1969/70	1970	1970/71	1971	1971/72
Dimicron 50% EC/100 E	1	750 000	373 073	778 309	791	-	-	3 355
Diazinon 60% EC	1	-	851 373	27 982	125 743	145 479	28 358	64 490
Thiodan 35% EC	1	-	21 494	760 476	35 703	91 386	21 333	56 810
Lebaycid 50% EC	1	-	-	67 250	12 750	-	-	256
γ-B H C[b] 6G	Kg	-	-	-	497 899	270 869	350 333	737 082
Endrin[b] 19.2% EC	1	-	-	-	5 290	274 669	57 697	116 592
Sumithion 50% EC	1	-	-	-	-	2 359	18 406	19 208
Aldrin[b] 40 WP	1	-	-	-	-	7 815	2 734	10 352
DDT[b] 50 WP	Kg	-	-	-	-	650	388	1 116

a Distribution signifies distribution for use. It does not mean that the chemicals have been applied.
b Organochlorine insecticides.
c Overlapping years correspond to the rain-fed crop.
d Irrigated dry season crop.

Source: Badan Pengendali Bimas. Bimas and Inmas are combined beginning 1970/71.

Table 14. Distribution of certain pesticides in Java by region through the Bimas and Inmas programs 1970 to 1972 (amounts in liters or kilograms)

	1970/71					1971					1971/72				
	Total	Regions				Total	Regions				Total	Regions			
		Barat	Tengal	Jogja	Timur		Barat	Tengal	Jogja	Timur		Barat	Tengal	Jogja	Timur
Organochlorine pesticides															
B H C 6 G	268,123	119,769	10,476	0	137,878	345,658	267,538	42,217	0	35,903	732,332	399,041	6,520	0	326,771
Endrin 19.2% EC	201,785	146,514	13,889	1,369	40,013	65,524	29,652	19,316	306	16,250	44,569	13,338	19,183	104	11,944
Aldrin 40 WP	6,262	3,693	1,489	40	1,040	1,985	255	719	140	871	8,361	1,883	2,868	798	2,812
Dieldrin	607	599	0	8	0	480	479	0	1	0	720	718	0	2	0
D D T 50 WP	451	73	154	0	224	206	162	44	0	0	257	212	10	0	35
Organophosphorus pesticides															
Diazinon 60% EC	177,376	32,100	77,556	39	67,691	21,556	19,869	1,225	44	0	52,877	36,074	2,147	103	14,553
Sumithion 50% EC	5,968	877	2,560	311	2,220	14,131	1,752	5,830	785	5,764	14,194	3,532	1,253	158	9,251
Malathion 50% EC	1,525	156	181	0	1,190	3,092	1,629	51	0	1,412	5,063	2,132	1,196	0	1,735

Source: Badan Pengendali Bimas

Plate 10. Terraced rice fields, Bali.

ferrithrothion (Sumithion), surecide, and triptophos (phosvel)--on the freshwater fishes Punctius javanicus, Cyprinus carpio, and Tilapia mossambica (called "ikan mujair" in Indonesia). Results of tests with thiodan show that at 3.0 ppm concentration, mortality rates in Punctius are 93.3%, in Cyprinus 60% and in Tilapia 56.6%. Toxicity was found to persist beyond seven days. Thorslund (1972) has studied the impact of endrin on paddy rice fish culture. The influence of crude oil and kerosene on histological changes in Tilapia mossambica has also been studied (Djalal et al., 1973). Djalal notes (personal communication) that Tilapia is most sensitive to DDT, followed by dieldrin, lindane (gamma-BHC) and phenol.

In addition to the toxicity hazard posed by organochlorine insecticides, these chemicals are persistent and do not break down fast. Endrin may persist in paddy fields up to a month (Iyatomi et al., 1958). Irrigation water can carry persistent insecticides in solution, in suspension, or adsorbed to silt particles (Hindin and Bennet, 1971). They may be transported through feeder canals to other paddies or "tambaks" in which fish culture is going on, as has apparently happened in East Java.

Complaints of diminished fish populations in Kalimantan rivers are also linked to insecticide pollution. However, in this case the insecticide pollution originates in logs treated to prevent borer attack, and which are rafted down the rivers (LIPI/NAS, 1972).

The use of organochlorine insecticides has apparently decreased since 1971, particularly for rice culture. Endrin, dieldrin and aldrin and thiodan are not recommended for rice pest control. As of 1973, endrin and DDT have been prohibited for agricultural use, while thiodan is prohibited for use on rice culture (Minister of Agriculture Regulation No. 329-Mentan/VIII/73). Also a list of approved pesticides has been issued (Appendix 5), in order to ensure the safe and effective use of pesticides without adverse public health or environmental effects.

Even if the application of organochlorine insecticides ceases, they will continue to pose a hazard. They can carry

over in the soil for an indefinite number of years (Hindin and Bennet, 1971), and their metabolites will be transported from once treated areas to natural bodies of water, as long as they are present in the soil of watershed areas.

For "tambak" species, toxicity tests have not yet been undertaken in Indonesia. However, tests in other parts of the world indicate that there is considerable variation from one fish species to another in their sensitivity to persistent organochlorine pesticides, and that DDT and endrin are the most toxic of this group. Nunogawa *et al*. (1971) have reported on the sensitivity of five species of fish from streams and estuaries in semi-tropical areas to phenol, DDT and dieldrin and lindane. An estuarine fish of the Central Pacific area (*Kuhlia sandvicensis*) was found to be five times more sensitive to dieldrin than was *Tilapia*. It was also more sensitive to lindane than *Tilapia*. It is clear that in Indonesia, serious consideration should be given to the impacts of organochlorine insecticides on coastal and estuarine species.

3. Industrial Pollution

Just outside Surabaya, near Gresik, is a petrochemical fertilizer plant run by the Indonesian government which began operations in May, 1972. The effluent from this plant flows as a small black stream in a canal between some fishponds for several

hundred yards before entering Madura Strait. At the outfall is a sign which states: "Danger, Don't Use, Poison Water." Samples of the effluent were taken by the Pollution Study Group and LEMIGAS. Results of the analyses are shown in Table 15.

Table 15. Analyses of soil and water in the vicinity of P. T. Petrokimia Gresik, East Java*

	Unit	S^-	NH_3	$AsSO_4^{-3}$	SO_4^{-2}	NO_3^-
Soil						
Romo Pond	% wt	0	0	0	0.004	0.04
Tepen	% wt	0	3.4	0	11.9	0.12
Effluent water reservoir near plant	ppm	0	424.8	26.6	1250	224.2
River water 500 m from the beach	ppm	0	96.4	0	215	120
"Tambak" water	ppm	0	42	0	1375	39.6

*Samples taken on September 27, 1972. Analyses undertaken by LEMIGAS. Composition of gases (i.e. CH_4, NH_3, etc.) were not examined.

Source: LEMIGAS

A black sludge derived from the effluent now coats the mud bottom for at least several hundred yards west of the point at which the

effluent enters Madura Strait. It also coats the bottom of the fishponds in the vicinity.

The bottom sediments of adjacent mangrove communities were also coated with sludge. Although the mangrove plants were alive, and to superficial appearance healthy, the benthic fauna typically associated with such communities and observed in uncontaminated areas nearby was almost completely absent. The sludge was not observed to adhere in noticeable quantities to the mangrove roots.

During the early stages of the operation technical problems arose and caused damaging effects to the fishponds (e.g., mortality of fishes in the ponds). Measures have been taken to correct this by collecting the solid waste in containers for further disposal. Disposal of this waste will be a continuous problem, however. It was planned that these containers would be disposed of in the open sea. The Directorate General of Fisheries has directed the Government's attention towards the possible improper dumping of such hazardous materials in productive fishing areas in territorial and adjacent waters of Indonesia. It is urgent that dumping zones with a depth of more than 3,000 m outside "upwelling areas" be selected.

Commercial fishermen said that they no longer caught shrimp or fish in the vicinity, but whether this is mainly due to the presence of the fertilizer industry needs to be further ascertained. When the monsoon shifts and the prevailing currents

reverse direction in the Madura Strait, and if the solid waste were not collected in containers, the pollution from the plant undoubtedly would be carried to the south.

4. Sewage

The effect of sewage on aquatic resources is too complicated to examine in detail here. However, fish production in many freshwater areas and some estuarine areas (such as inner Jakarta Harbor) will be reduced or eliminated due to the impact of sewage. LPPL (Institute for Marine Fisheries Research) also stated that within a one or two mile radius of the mouth of Pasar Ikan, the fishing harbor, there are no fish. In addition to receiving part of Jakarta's waste waters, the area is dredged, and contaminated to some extent by oily water flowing from the harbor.

On the other hand, sewage in appropriate dilutions can actually enhance fish production through fertilization. The biological productivity of outer Jakarta Bay, for example, is probably enhanced by sewage nutrients. Weighing the gains and losses accurately can only be accomplished after extensive research.

Sewage pollution poses a potential public health problem, especially through the exposure of filter feeding molluscs to pollutants. Human disease pathogens, such as the typhoid virus, can contaminate the flesh of these animals. The potential is especially high if the flesh is eaten raw, which is not the custom

in Indonesia. The bivalve, Anadara granosa, is fished 100 to 200 m off the Jakarta coast, particularly just to the east of Tanjung Priok. Its flesh is boiled before eating; consequently, the health risk is diminished. In other parts of the world, clam and oyster ground waters are routinely surveyed for fecal coliform, which is found to be generally associated with typhoid virus, Salmonella and Shigella.

5. Coral Dredging

Coral is dredged or mined from shallow water for extensive use in road building and building construction in Java. Dynamite is sometimes employed. Examination of piles of this coral material in Jakarta showed that living as well as dead coral is used for this purpose. Since corals are essential to the survival of most reef fish and shellfish, its removal will have a deleterious impact. Without a detailed investigation of the problem, it is impossible to say how serious or widespread it is in Indonesia.

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Appendix 1

Minister of Mining Regulation No. 04/P/M/Pertamb/1973

THE MINISTER OF MINING

Considering:

a. that the life and wealth in the waters should be protected and utilized for the greatest benefit of the people;

b. that with the increase of oil and gas exploration and exploitation activities in both Indonesia's territorial waters and continental shelf, increase of the danger of sea pollution is more and more felt in said activities;

c. that therefore it is regarded necessary to stipulate a regulation on the prevention and control of water pollution in oil and gas exploration and exploitation activities.

Bearing in mind:

1. Law no. 4 Prp of 1960 (State Gazette no. 22 of 1960, Supplementary State Gazette no. 1942);

2. Law no. 44 Prp of 1960 (State Gazette no. 133 of 1960, Supplementary State Gazette no. 2070);

3. Mining Police Regulation 1930 (Stbl. 1930 no. 341);

4. Presidential Decree no. 64 of 1971 dated 9 September 1971;

5. Minister of Mining Regulation no. 64/Kpts/M/Pertamb/1968 dated 10 April 1968;

6. Minister of Mining Regulation no. 04/P/M/Pertamb/1972 dated 28 April 1972;

7. Government Announcement of 17 February 1969.

H A S D E C I D E D

To stipulate: REGULATION ON THE PREVENTION AND CONTROL OF WATER POLLUTION IN OIL AND GAS EXPLORATION AND EXPLOITATION ACTIVITIES.

CHAPTER I

GENERAL PROVISIONS

Article 1

Meant in this Ministerial Regulation by:

Directorate: is the Directorate of Oil and Gas.

Enterprise: is Perusahaan Pertambangan Minyak dan Gas Bumi Negara (PERTAMINA) or any company having a working relationship with Perusahaan Pertambangan Minyak dan Gas Bumi Negara under a contract concerning oil and gas mining undertaking, which has been and is responsible for the management thereof, or any service company engaged in the field of oil and gas exploration and exploitation.

Entrepreneur: is the Managing Board of Company.

Minister: is the Minister whose field of duties encompasses oil and gas mining.

Waters: are Indonesian territorial waters and waters on the Indonesian continental shelf.

Article 2

In carrying out its petroleum exploration and exploitation activities the Enterprise is obligated to prevent the occurrence of water pollution and to control any that occurs.

CHAPTER II

POLLUTION PREVENTION

Article 3

The Enterprise is prohibited from disposing oil in whatever form in the waters.

Article 4

Any liquid or solid residues bearing substance dangerous to aquatic life or wildlife or detrimental to any form of life or wealth in the waters should be handled in such a way that no accumulation of the dangerous substances shall occur in the waters.

Article 5

It is prohibited to dispose of drilling mud containing crude oil in the waters, and toxic mud must be neutralized prior to disposal in the waters.

Article 6

Any disposal by fire of crude oil, unused material and waste should be conducted on board a special vessel or barge, on the shore, or at such other fixed places as shall be at a safe distance from any area of activity without prejudice to another party, while unused natural gas must be burnt.

CHAPTER III

INSTALLATION AND FACILITIES

Article 7

Exploration and production installations and pollution prevention and control facilities must be kept in good order and be capable of being operated as intended.

Article 8

Any person working at the installations and facilities referred to in Article 7 should be thoroughly familiar with the maintenance and operation techniques necessary to prevent and clean up spills.

Article 9

The Enterprise is obligated to conduct supervision with the following provisions:

(a) Manually operated pollution prevention and control facilities and installations must be checked out daily.

(b) Automatic pollution prevention and control facilities and installations, including those equipped with remote control and monitoring devices, must be checked out 3 (three) times a day.

CHAPTER IV

POLLUTION CONTROL

Article 10

If pollution occurs, the Enterprise should take immediate action to put it under control.

Article 11

The Enterprise should have an emergency plan of actions to limit, clean and nullify the source of pollution, which plan should be submitted to the Directorate of Oil and Gas for approval.

Article 12

The Enterprise should have or at least make available equipment and material for pollution control purposes, which are approved by the Directorate.

CHAPTER V

SUPERVISION

Article 13

(1) The Enterprise is obligated to record any spill of crude oil and/or other pollutants, with the following data:

a. time and place of occurrence;

b. causes of spill;

c. quantity of spill;

d. actions already taken to control or limit the spill.

(2) Said record must be reported monthly and shown to officials of the Directorate when on inspection.

Article 14

Spills of more than 15 bbls must be immediately reported orally and/or by telephone and/or by teleprinter and/or by telegram and confirmed later by a complete written report to the Directorate.

Article 15

Every person working with the Enterprise must report any occurrence of pollution to the Management of the Enterprise.

Article 16

All expenses for the prevention and control of pollution as well as for the rehabilitation of the consequences resulting therefrom are for the account of the Enterprise concerned.

Article 17

In case of non-observance by the Entrepreneur of the provisions of this Ministerial Regulation, the Minister may temporarily suspend those operations that are considered to be able to cause pollution.

CHAPTER VI

CLOSING PROVISIONS

Article 18

Matters not yet, or insufficiently, provided for in this Regulation shall be stipulated later.

Article 19

This Regulation shall come into effect on the date of stipulation.

Stipulated at Jakarta

on 22 March 1973

MINISTER OF MINING

Sgd.

Prof. Dr. Ir.

Soemantri Brodjonegoro

Copies of this Regulation are sent to:

1. Secretary General of Mining
2. Inspector General of Mining
3. Director General of Oil and Gas
4. Director of Oil and Gas
5. PERTAMINA, Contractors and Service Companies

Appendix 2

Government Regulation No. 7, 1973
Concerning the distribution, storage and
use of pesticides

(English translation not official)

The President of the Republic of Indonesia

Considering:

a. That in the framework of efforts to increase the productivity in the agricultural sector, pesticides play a very important role;

b. That in order to protect human security, natural resources (water, fauna, flora) as well as to avoid environmental contamination, it is deemed necessary to issue a Government Regulation concerning the Supervision of the Distribution, Storage and the Use of Pesticides;

c. That for the implementation of Law no. 11 of the year 1962, concerning Hygiene in Public Enterprises, it is deemed necessary to issue a Government Regulation concerning the Supervision of the Distribution, Storage and the Use of Pesticides;

Bearing in mind:

1. Article 5, clause (2) of the 1945 Constitution;

2. Regulation concerning dangerous materials (Stbl. 1949-377);

3. Law no. 2 of the year 1951 (Lembaran Negara Rep. Indonesia tahun 1951 no. 3) concerning the coming into force of Accident Act 1947 no. 33 of the Republic of Indonesia valid for whole Indonesia;

4. Law no. 9 of the year 1960 (Lembaran Negara R. I. of the year 1960 no. 131, supplement of Lembaran Negara R. I. no. 2068) concerning the principles of health;

5. Law no. 2 Prp of the year 1960 (Lembaran Negara R. I. of the year 1960 no. 14) concerning storehouses;

6. Law no. 11 of the year 1962 (Lembaran Negara R. I. of the year 1962 no. 48) concerning hygiene in public enterprises;

7. Law no. 6 of the year 1971 (Lembaran Negara R. I. of the year 1967 no. 10, supplement of Lembaran Negara R. I. no. 2824) concerning the principles of cattle breeding and animal health;

8. Law no. 1 of the year 1970 (Lembaran Negara R. I. of the year 1970 no. 1, supplement of Lembaran Negara R. I. no. 2918) concerning work safety regulation;

HEREBY DECIDES:

To issue: a Government Regulation of the Republic of Indonesia concerning the supervision of the distribution, storage, and use of pesticides.

Article 1

In the above mentioned Government Regulation it is meant by:

a. **Pesticides:** all chemicals or other materials as well as micro-organisms and viruses that are used for:

- the elimination and prevention of diseases that destroy plants, parts of plants or agricultural products;
- the elimination of weeds;
- the destruction of leaves and prevention of unwanted growths;
- the regulation or stimulation of the growth of a plant or its parts, excluding the fertilizer;
- the elimination or prevention of external diseases of domestic animals or cattle;
- the elimination or prevention of bacteria in water;

- the elimination or prevention of insects and micro-organisms in households, buildings and means of transportation;

- the elimination or prevention of animals that that could cause disease in human beings and animals that have to be protected by the use of pesticides on plants, soil and water.

b. Distribution: the export-import and domestic trade of pesticide, its transportation included.

c. Storage: the having in stock, in yard or room used by the Importer, Merchant or Agricultural Enterprises.

d. Use: the use of pesticides with or without instrument for purposes as indicated in sub a of this article.

e. Applicant: anyone or any legal body that forwards a request for registration and authorization of pesticides.

Article 2

(1) No one and no legal body is permitted to use a pesticide that is not registered and/or authorized by the Minister of Agriculture.

(2) The procedure of requesting registration and authorization shall be fixed afterwards by the Minister of Agriculture.

(3) The distribution and storage of pesticides are fixed by the Minister of Commerce at the proposal of the Minister of Agriculture.

Article 3

(1) Authorization as written in article 2 of above-mentioned Government Regulation is given in the form of permanent authorization, provisional authorization and trial authorization.

(2) Provisional authorization and trial authorization are given for a period of one year.

(3) Permanent authorization is given for a period of five years. Authorization during this period may be renewed or, if necessary, revoked, on the basis of undesired side effects.

(4) Reconsideration or revocation of permanent, provisional, and trial authorizations are executed by the Minister of Agriculture.

Article 4

(1) Authorization is given when the pesticide has been considered to be effective and safe, and to fulfill other technical conditions, when used according to instructions on the label.

(2) The technical conditions and the issue of label will be arranged afterwards by the Minister of Agriculture.

Article 5

(1) A certain cost, defined by the Minister of Agriculture, is charged for the enrollment and authorization to the applicant.

(2) The cost as written in clause (1) of this article is to be paid to the Exchequer Office.

Article 6

No one or no legal body is permitted to distribute, store or use authorized pesticides in any manner, other than that fixed at the issue of authorization.

Article 7

Anyone or any legal body that distributes, stores, or uses pesticides must give opportunity and permission to any official appointed by the Minister of Agriculture to carry out an examination of construction of store house, the way of storing, health and safety regulations, accounting of expenditure, quality of label, packing and residue.

Article 8

He who commits a violation of article 2, 6, 7,and 9 of the above-mentioned Government Regulation will be punished according to article 9, Law no. 11 of the year 1962.

Article 9

Anyone or any legal body distributing and storing pesticide at the moment of validity of the above-mentioned Government Regulation must conform to the above-mentioned Government Regulation within a period of 12 months.

Article 10

Matters directly or indirectly related to human security and health will be taken care of by the Minister of Health and the Minister of Labour according to their respective fields.

Article 11

Matters not yet sufficiently provided for in the above-mentioned Government Regulation shall be fixed afterwards by the Minister of Agriculture and the Minister of Commerce.

Article 12

This Government Regulation comes into force on the day of its enactment. In order that everyone may be informed, the enactment of this Government Regulation shall be published in Lembaran Negara Republik Indonesia.

Enacted in Jakarta
on the 17th of March 1973
State Secretary of the
Rep. of Indonesia

Sgnd

SUDHARMONO S.H.

Mayor General of TNI

Issued in Jakarta
on the 17th of March 1973
The President of the Rep.
of Indonesia

Sgnd

SOEHARTO

General of TNI

LEMBARAN NEGARA REPUBLIK INDONESIA TAHUN 1973 NOMOR 12.

Appendix 3

Procedure for Requesting Pesticide
Enrollment and Permission

Decision Brief of the Minister of Agriculture
No. 280/Kpts/Um/6/1973

(English translation not official)

MINISTER OF AGRICULTURE

Considering: that it is necessary to stipulate about the Procedure of Requesting Pesticide Enrollment and Permission as in the chapter 2, article 2 of Government Regulation no. 7 of 1973;

Bearing in mind:
1. Government Regulation no. 7 of 1973;
2. Presidential Decree no. 9 of 1973;
3. Presidential Decree no. 319 of 1968;
4. Presidential Decree no. 184 of 1968;
5. Ministry of Agriculture Decree no. 284/Kpts/org/8/1969;

HAS DECIDED

To stipulate: Procedure of Requesting Pesticide Enrollment and Permission as follows:

CHAPTER I

The Request of the Enrollment and Permission is sent forward to the Minister of Agriculture in writing, using the questionnaire which is available at the Secretariat of Agricultural-Pesticide Commission.

CHAPTER II

(1) In obtaining the questionnaire as mentioned in Chapter I of this Decision Brief, the applicant is obliged to pay for the administration cost the amount of Rp. 500,- (five hundred rupiahs) in every request of the enrollment.

(2) For the need of the Enrollmental Request and experimental permission, the applicant is obliged to pay the amount of Rp. 5.000,- (five thousand rupiahs) for each of the formulae.

(3) For the need of the Enrollmental Request and provisional or permanent permission, the applicant is obliged to pay the amount of Rp. 25.000,- (twenty-five thousand rupiahs) for each of the formulae.

(4) Besides all of the costs as mentioned in articles 1, 2, and 3 in this chapter, the applicant is obliged to pay the

experimental cost to the Institution, or other agency which is appointed, to observe the pesticide considered, if necessary, by the Commission.

CHAPTER III

If the applicant does not give all of the information requested on the Questionnaire, then the processing of the request for enrollment and permission might be postponed or refused.

CHAPTER IV

After the receipt of the administration cost and the needed information by the Secretariat of the Commission, the applicant will be informed that his request is being processed.

CHAPTER V

In the reply mentioned in Chapter IV of this Decision Brief, the applicant will be informed of the kinds of experiments that the Commission considers to be necessary, and the costs.

CHAPTER VI

After hearing the opinion of the Chief Commission, the Minister of Agriculture could give:

(a) Permanent Permission;

(b) Provisional Permission;

(c) Experimental Permission; or

(d) Refusal of the Request.

CHAPTER VII

"Permanent Permission" is given for the pesticide that can be circulated/distributed within 5 (five) years. However, in this period, the directions for use of the pesticide can any time be changed; if necessary this permission can even be revoked because of the pesticide's undesirable side effects.

CHAPTER VIII

Provisional Permission is given for the marketing of specific pesticides according to the requirements determined by the Minister of Agriculture, in those cases in which additional information is needed in order to ensure safe and effective use. Provisional Permission is for only 1 (one) year.

CHAPTER IX

Permission is given for the pesticide that will be used for experiment in accordance with the requirement decided by the Minister of Agriculture within 1 (one) year.

CHAPTER X

(English translation pending)

CHAPTER XI

The administration of the enrollment and the notation of the permit for the Pesticide is done by the organizational unit that carried out the Plant Protection.

CHAPTER XII

The holder of the permission is obliged to send forward the new request for enrollment and permission when the valid time of the permit lapses.

CHAPTER XIII

The other points that are not arranged yet in this decision brief will be regulated separately.

CHAPTER XIV

This Decision Brief becomes valid on the date of the Decision.

Decided in: Jakarta

on: June 11, 1973

Minister of Agriculture

signed

Prof. Dr. Ir. TOYIB HADIWIJAYA

Appendix 4

Pesticide Application Form

Number of receipt:

The Minister of Agriculture
c/o Plant Protection Service
Directorate for Technical
Agriculture, Pasar Minggu
JAKARTA

Attention for the Agricultural Pesticides Commission.

REQUEST FOR THE PESTICIDE ENROLLMENT

1. Name & address of the applicant

2. Commercial name or suggested name and kinds of the pesticide

3. Physical condition & type of formulation.
(emulsion, emulsifiable liquid, powder, dust, particle)

Notes:

(1) This questionnaire should be answered in 6 (six) copies.

(2) If the space in the form is not sufficient, use another page signed by the applicant.

(3) All of the information should be given in detail and completely.

(4) Additional information may be required.

4. Explanation & Composition of the formula.

Name of component (active agent, particular mixed agent, emulsifier, dispersing agent, colouring agent, spreading agent, particle-size).	gram/liter or weight percent *

*State in gram/liter for liquid formulation and in weight percent for solid formulation, or half solid, viscous liquid, or the mixture of liquid and solid.

5. Formulation Stability
(storage capacity, photo influence, temperature, water, cover, etc.)

6. Compatibility of the formula with another pesticide.

7. Chemical characteristics of the Active Agent:

(a) Chemical name (as well as the International Union for Pure and Applied Chemistry)

(b) Empiric formula

(c) Constructive formula

(d) Other names according to the International Standards Organization Synonim (not trade name).

(e) Composition of the technical agent (pureness in percent, kind of mixture, isomer, secondary material).

(f) Stability in the various conditions (in water, organic solvent, air, photo influence, decomposition degree, materials of decomposition).

8. Physical Characteristics of the active Agent:
(melting point, boiling point, vapor pressure, specific gravity, dissolving capacity of the active agent and technical agent in water, also in the common organic solvent, coefficient of distribution in two unmixable solvents, molecular putting out in the various amplitudes)

9. Method of the formulation Analysis

10. Container that will be used (material, form of shape, volume & weight, seal etc.).

11. Application

(a) procedure
(as direct contact poison, respiratoric poison, gastric poison, fungitoxic, fungistatic, or systemic).

(b) Plant pest as well as plant-disease which can be controlled or what kinds of plantation that can be applied for.

(c) Dosage of application:
(concentration of the active-agent--not as a whole formulation--in solution (Kg/Ha).

(d) The amount of application and its duration of time.

(e) Direction for use
(high volume, low volume,
or ultra-low volume).

(f) Phyto-toxicity.

---

12. Data on Effectiveness Test

(a) Laboratory Test

(b) Field Test
(Experimental design, Direction for use, observation method, results).

---

13. Data on Residues
(Results of experiment, method of analysis of the residue, either source material or metabolite, or results on degredation of food stuffs, wild life animal, water and soil).

---

14. Observation on human effects and medical data:

(a) Clinical symptoms.

(b) Special poisoning symptoms.

(c) Diagnosis.

(d) First Aid.

(e) Medical Care.

(f) Health Report of the
Industry, Agriculture, etc.

---

15. Toxicity Test Data on animals:

(a) Acute toxicity on mammal (mention the intended animal of the laboratory trial).

Oral toxicity.

Dermal toxicity.

Respiratory toxicity

Other toxicity, e.g. intra-peritoneal.

(b) Short term toxicity (oral, respiratory, or through other system).

(c) Data on Supplemental Toxicology: (the influence of the active agent on metabolism in the animal after recovery from sub-lethal dosage, carcinogenity, neurotoxicity, potentiation, terratogenity, mutagenity).

16. Toxicity Test Data on fish

(a) Acute toxicity (TLM 24 hours 48 hours and 96 hours for *Cyprinus carpio* and *Punctius javanicus*).

(b) Sub-lethal toxicity on the mature and the cracked egg.

(c) Toxicity to plankton and copepods.

(d) Stability of the pesticide in water, and in sediments.

17. Information about the danger to the wildlife:

(a) Toxicity to birds (acute toxicity, etc.).

(b) Toxicity to other vertebrates (acute toxicity, etc.).

(c) Toxicity to bees.

(d) Toxicity to natural enemies (parasite & predator).

(e) Toxicity to other useful insects.

(f) Field Test & Observation.

18. Special Information: (flammable or not, flash point, explosive or not, corrosivity, destruction method, etc.).

. . . . . .
(place)

. . . . . .
(date)

. . . . . .
(signature)

Appendix 5

List of Pesticides Permitted to be Imported
to Indonesia, 1973

LIST OF PESTICIDES PERMITTED TO BE IMPORTED

Pesticide	Active agent
FOR PLANTATION CROPS	
Chlordane	chlordane
Dicarbon, Sevin 85 SP	carbaryl
Kelthane	dicofol
Anthio 40 EC	formothion
Malathion	malathion
Toxaphene	toxaphene
Dipterex 80 SP	trichlorfon
Azodrin[a]	monocrotophos
Carbon Disulfide	carbon disulfide
EDB-85, Bromofume, Dowfume W 85	ethylene dibromide
Benlate	benomyl
Cuprinol, Copper Uversol	copper naphthenate
Coprantal, Cupravit	copper oxychloride
Copper Sulfate	copper sulfate
Orthocide 406	captan
Difolatan 80 WP	captafol

[a] Azodrin may be used only by skilled workers wearing rubber gloves and a long-sleeved tunic. Further, it may only be used on those plantations not visited by birds, which are not in bloom, and which are not being visited by bees.

Pesticide	Active agent
Du - Ter	fentin hydroxide
Dithane M-45	mancozeb
Shell Collar Protectant, Fomac	PCMB, quintozene
Polyram Ultra	thiram
Fylomac 90	-
Cancertox	-
Diloma K.	-
GP. 2295	-
Tapflux	-
TB 192	-
Dowpon, Basfapon, Gramevin	dalapon
Fernoxone, U-46	2,4-D
Gramoxone	paraquat
Esteron 245 Cone	2,4,5 - T
Tribunil	dimethyl benzothi-azolyl urea
Teopol	-
Medol	-
Talcum powder	-
Citowett	-
Tenac	-

Pesticide	Active agent
FOR FOOD CROPS	
Rice Paddy/Field	
Surecide 25 Ec	-
Phosvel 300 E	leptophos
Sevin 85 SP	carbaryl
Diazinon, Basudin 60 EC/-10G	diazinon
Sumithion 50 EC, Folithion 50 EC	feritrothion
Padan 50 SP/-10 G	cartap
Dipterex 80 SP	trichlorfon
Karphos 50 EC	-
Ambithion 1000 E	fenitrothion + malathion
Prethylene 3 G	chlordimeform
Furadan 3 G	carbofuran
Dimecron 50 EC	phosphamidon
Second crop	
Sevin 85 SP	carbaryl
Phosvel 300 E	leptophos
Diazinon, Basudin 60 EC	diazinon
Padan 50 SP	cartap
Sumithion 50 EC, Folithion 50 EC	fenitrothion
Elsan 50 EC	phenthoate

Pesticide	Active agent
Surecide 25 EC	-
Karphos 50 EC	-
Daconil 75 WP	chlorothalomil
Thiodan 35 EC	endosulfan
Benlate 50 WP	benomyl
Dithane M-45 80 MP, Manzate D 80 MP	mancozeb
Horticultural crops	
Bayrusil 25 EC	diethquinaphione
Phosvel 300 E	leptophos
Diazinon 60 EC, Basudin 60 EC	diazinon
Padan 50 SP	cartap
Elsan 50 EC	phenthoate
Orthene 75 SP	orthene
Dipterex 80 SP	trichlorfon
Cyanox 50 EC	dimethyl cyano-phenyl phosphor-othionate
Daconil 75 SP	chlorothalonil
Dithane M-45 80 WP, Manzate D 80 WP	mancozeb
Antracol 70 WP	propineb
Cupravit 50 WP	copperoxychloride

Pesticide	Active agent
FOR CATTLE RAISING	
DDVP, Mizon	dichlorvos
Diazinon, Neocidol	diazinon
Azuntol, Neldane, Baymix	coumaphos
Dipterex, Neguvon, Anthon	trichlorfon
Malathion	malathion
Benzoas Benzilicus	benzyl benzoate
FOR FISH CULTURE	
Diazinon 60 EC	diazinon
Dipterex 80 SP	trichlorfon
Brestan 60	fentin acetate
Gramoxone	paraquet
Rasfapon	dalapon
Copper Sulfate	copper sulfate
U - 46	2,4 - D
FOR HUMAN HEALTH	
D.D.T.	D.D.T.
Malathion	malathion
Sumithion	fenitrothion
Abate	-
Warfarin	coumarin

CSD-2608 GTS
PN-AAC-772

THE BIOLOGICAL AND ECOLOGICAL EFFECTS OF OIL POLLUTION IN TROPICAL WATERS

An Annotated Bibliography

Office of International & Environmental Programs
Smithsonian Institution

Citations in the annotated bibliography include oil pollution in colder, high latitude waters as well as tropical waters. Those which are specific to warm tropical waters are listed below.

Tropical Regions in General

Anonymous, 1971

Birkeland et al., 1973

Burns and Teal, 1973

Cabrera, 1971

Cerame-Vivas, 1969

Connell, 1970, 1971

Diaz-Piferrer, 1964

Glude, 1968

Gooding, 1971

Grant, 1970

Johannes et al., 1972

Lewis, 1971

Pearce and Ogren, 1968, 1969

Puerto Rico University, 1968

Rutzler and Sterrer, 1970

Spooner, 1970

Spencer and Spooner, 1968

Straughan, 1970

Wohlschlag and Cameron, 1967

Gulf of Mexico

Alpine Geophysical Associates, 1971

Anonymous, 1970

Arlington, 1970

Bechtel and Copeland, 1970

Bleakley, 1969

Copeland, 1965, 1966, 1967

Crowder, 1971

Environmental Protection Agency, 1972

Glasgow, 1971

Gowanloch, 1935

Kloth and Wohlschlag, 1972

Lund, 1957

Macklin and Hopkins, 1961

Macklin and Sparks, 1961

Petty, 1970

St. Amant, 1970

Spears, 1971

Steed and Copeland, 1967

Appendix C

Annotated Bibliography on the Biological and Ecological Effects of Oil Pollution in Tropical Waters

Christopher P. Onuf

This bibliography does not pretend to be complete nor does it include unpublished surveys recently carried out in Indonesia on oil pollution effects.

C. P. Onuf
Santa Barbara
California
July, 1973

Allen, H. 1971. Effects of petroleum fractions on the early development of a sea urchin. Marine Pollution Bulletin 2(9):138-140.

The soluble extracts of the oils used were prepared by vigorously shaking 25 ml. of the oil with 500 ml. of sea water in a separatory funnel. The water was then drawn off leaving almost the original volume of oil behind. Oils had virtually no effect on fertilization. In general, the more highly refined products were less harmful to cleavage and development. The author's reservation about the study is her use of one of the most sensitive organisms known. Trials consisted of observations on 100 individuals replicated 3 times.

Alpine Geophysical Associates. 1971. Oil pollution incident: Platform Charlie, main pass block 41 field, Louisiana. Water Pollution Control Research Series 15080 FTU 05/71. Washington, D.C.: U.S. Government Printing Office.

No adverse biological effects can obviously be attributed to the wild well. Most of the report that deals with biological aspects consists of cataloguing the biological resources of the Mississippi delta, conjecturing about possible consequences such as blooms of noxious dinoflagellate due to nutrient enrichment by the oil and conversion to toxic products upon biodegradation, and listing the fortuitous circumstances which minimized the effects on organisms and fisheries: of important organisms, only shrimp were present in the region at the time of the spill and it was not the season for catching them.

Anderson, E.K., L.G. Jones, and C.T. Mitchell. 1969. Evaluation of ecological effects of liberated oil in the Santa Barbara Channel. Report to Western Oil and Gas Association. 54 pp.

[Two page summary of the Tamipco Maru spill.]

Anonymous. 1970a. Few blowouts reported in Gulf. Offshore 30(3):28.

Of 7800 wells drilled in the Gulf of Mexico since 1956, there have been only 26 blowouts. Only 2 spilled much before the big 1970 blowout and fire.

[This is probably the best evidence for predicting the probabilities of blowouts in other exploitation of continental shelves.]

Anonymous. 1970b. Effect of slicks on fish life is studied with roller device. National Fisherman 51(2), Sec. B:23.

The "roller device" is only used in collecting oil films from the surface of water. No mention is made of the biological experiments that are conducted with the oil that is collected this way.

Anonymous. 1971a. Cuba tackles pollution. Marine Pollution Bulletin 2(3):36.

The grounding of the Oriental Challenger is barely mentioned. An unspecified amount of high octane aviation fuel was pumped into the sea. "Temporary losses of fauna were reported, but in subsequent routine sampling no more dead organisms were found."

Anonymous. 1971b. A harmless oil dispersant. Marine Pollution Bulletin 2(2):22.

Dr. S.A. Broom, University of Washington, tested the effect of concentrations between $5x10^2$ and 10^5 ppm of Corexit 7664, alone and mixed with oil (Kuwait crude), on the photosynthetic and degradative capacities of microflora in beach sand. "There was no significant breakdown of chlorophyll... and the uptake of radioactive carbon remained fairly steady throughout. Oxygen uptake was increased in all cases... but with oil alone was greatest. The lesser uptake in the presence of Corexit was probably due not to toxicity but to the rapid removal of oil, the substrate of the microflora."

Anonymous. 1971c. Oil company not guilty of fish kill. Clean Air and Water News 3(22):336-337.

Arlington, R. 1970. Corpus Christi Bay: a case history of oil and a clean seaport. Offshore 30(6):28-34.

Deals only with administration of oil production and cleaning up policies, which so far has been quite successful.

Baker, J.M. 1973. Biological effects of refinery effluents. In Conference on Prevention and Control of Oil Spills, 13-15 March 1973, pp. 715-724. Amer. Petrol. Inst., Washington, D.C.

The major factor determining the extent of damage caused by refinery effluents is how fast they are dispersed in receiving waters. Where dilution is rapid, no effects are apparent. Where receiving waters are not rapidly renewed, damage is severe and may extend to many acres.

[Data on the characteristics of the effluents add to the usefulness of the review. It is important to note that much besides hydrocarbons is present in the effluents and will contribute to damage. The conclusion that saltmarshes and mudflats are the most vulnerable environments seems justified.]

Bardach, J.E., F. Masaru, and A. Holl. 1965. Detergent effects on the chemical senses of the fish Ictalurus natalis (Le Suer). Science 148(3677):1605-1607.

Detergents caused damage to chemoreceptors of yellow bullheads at concentrations as low as 0.5 ppm. Electrophysiological studies showed impaired function sooner than histological examination. At 1 ppm for 28 days, experimental animals exhibited heightened activity compared to controls, also did not respond to the introduction of food pellets whereas controls did. When returned to clean water, fish returned to normal activity patterns but even after six weeks did not respond to food pellets dropped further away than 12 cm. whereas controls did up to 50 cm.

[Irreversible sensory impairment which interfered with feeding occurred at 1 ppm of detergents. Death occurred at 10 ppm.]

Bechtel, T.J., and B.J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contr. Marine Science, University of Texas 15:103-132.

The biggest contribution of wastes to Galveston Bay is petrochemical industrial effluents into the Houston Ship Canal. Trawls were made in each of four seasons at 27 stations in bay waters and Shannon-Weaver diversities were calculated for all catches. Apparently diversity increases as the wastes are diluted. Increased dominance of anchovies, Anchoa mitchilli, are indicative of deteriorating water quality, as is a decline in the number of large fish.

[The data are not convincing. Correlating diversity with salinity accounts for more of the variance than does dilution of wastes. Comparisons of diversities in different bays are inferred to agree with expectations based on the relationship between pollution and diversity but no account is taken of possible salinity differences.]

Birkeland, C., A.A. Reimer, and J.R. Young. 1973. Effects of oil on tropical shore natural communities in Panama. Smithsonian Institution. Prepared for the Federal Water Quality Administration, Environmental Protection Agency. Washington, D.C. 217 pp.

(Authors' Abstract and Summary Conclusions). The effects of oil pollution on tropical intertidal marine communities were tested by precisely controlled experiments utilizing tarry Bunker C and volatile marine diesel oils. Field experiments were performed on a Caribbean intertidal reef flat community, a Pacific rocky shore community, settling plates in both oceans, mangrove trees sprayed with oil on the leaves and/or stilt roots and on coral growth. Major conclusions from these experiments were:

(1) Although appearing to be in good health after one day in the field following 2.5 hours of exposure to Bunker C oil, the mean growth increments of the hermatypic coral Porites furcata were significantly smaller than those of the controls during the following 61 days. Growth rates provide an indicator of the presence of unobserved physiological stress or damage and a quantitative index of the cost of repair.

(2) The mean growth of Porites furcata heads used as controls did not differ significantly while the mean growth of P. furcata heads subjected to Bunker C differed significantly among themselves. An individual variation in susceptibility to oil pollution is implied.

(3) The mean growth increments of control and experimental coral heads varied significantly in the field over 3 meter distances at the same depth and during time periods of the same length but two months apart. Location and time of year each had a greater effect than 2.5 hours exposure to Bunker C oil so very precise controls are required for pollution experiments.

(4) An increased percent surface coverage of algae was found on settling plates coated with Bunker C oil and in aquaria previously containing some Bunker C oil. After spraying with Bunker C oil, quadrats in the Caribbean intertidal contained more species of algae. The favorable effect of Bunker C on algae may be partially responsible for the increase in algae after tarry oil spills. This effect could be augmented by the failure of herbivore populations to recover as quickly as algae from oil spill destruction.

(5) Unlike Bunker C, the volatile marine diesel oil had a clear toxic effect on fouling communities. Dry weight measurements of production showed that plates coated with marine diesel had a significantly lower biomass of fouling organisms than did the control plates. Surface coverage measurements showed less space occupied by algae and animals on settling plates coated with marine diesel than on control plates.

(6) The spraying of leaves of mangrove trees (Rhizophora mangle) with the volatile fuel oil marine diesel was correlated with reduced leaf coverage or no growth of the trees during the following year. Coating the stilt roots with tarry Bunker C was of less definite effect. This may explain why the most obvious mortality among mangrove trees following the wreck of the SS Witwater was in a band along the windward edge of the forest facing the sea from the other side of a causeway. As Rützler and Sterrer (1970) noted, "high winds caused a spray of mixed seawater and oil to cover mangrove trees...to a height of 2 m above mean tide level" and that the oil had "...already killed many of these plants."

Birkeland, C., A.A. Reimer, and J.R. Young. 1973. (continued).

(Authors' Abstract and Summary Conclusions continued.)

(7) The quadrats on the Caribbean intertidal at Galeta were subjected to 8.6 times the concentration of oil as the coast off West Falmouth, Mass. The West Falmouth oil spill was accompanied by a 94 percent mortality while the animal communities at Galeta underwent no perceptable change. The factor responsible for the difference in mortality was probably the size of area involved. The isolated square meter quadrats were supplied with unaffected plankton and nutrients as the surrounding water washed across.

Baseline surveys were conducted on both the Caribbean and Pacific coasts of Panama. Different zones along the same transect in the Caribbean intertidal were found to differ in magnitude of fluctuations, predictability of change and spatial heterogeneity as measured by patterns of surface coverage on the primary substratum. Changes in structure of macro-invertebrate communities along the Caribbean transect were compared with patterns of temporal variation from data collected for over 500 identified species in 108 samples including a total of over 50,000 specimens. Recruitment to benthic communities was investigated with settling plates. The Caribbean was found to be seasonal in species occurrence while the Pacific was seasonal in productivity.

Bleakley, W.B. 1969. Shell production complex efficient, controls pollution. Oil and Gas Journal 67(36):65-69.

The water pumped back into the Gulf contains 30 ppm oil. Mackin and Hopkins (1961, p. 76) found a high of 226 ppm in 60 determinations of 23 bleedwaters. Their average value was 35 ppm. They cite values from other work varying from 3 to 931 ppm.

Blumer, M., G. Souza, and J. Sass. 1970. Hydrocarbon pollution of edible shellfish by an oil spill. Marine Biology 5(3):195-202.

Gas chromatography was used to determine the fate of No. 2 fuel oil spilled at West Falmouth, Massachusetts. Four months later it was still detectable in sediments. Oysters *Crassostrea virginica* and scallops *Aeguipecten irradians*

picked up an oily taste and exhibited chromatograms similar to those of the fuel oil. The alterations in composition of oil in the sediments and in the shellfish consisted primarily in the reduction of low boiling fractions. The sediments showed a greater decrease in normal alkanes than branched ones, probably due to preferential degradation by bacteria.

[Incorporation of oil into sediments preserves it.]

Blumer, M., H.L. Sanders, J.F. Grassle, and G.R. Hampson. 1971. A small oil spill. Environment 13(2):2-12.

95% of animals captured in trawling immediately after the spill were dead. Fish, shellfish, worms, crabs and other crustaceans were affected. Eight months after the incident the oil had spread to an area ten times that originally affected, reaching the deepest part of the bay. At that time amounts of oil in the sediments 2 1/2 miles from the wreck site increased ten-fold and areas which had been recovering at the periphery suffered mortality again. 500 acres of saltmarsh were contaminated and shellfishing was stopped for two years because of tainting. The second year, prohibitions on shellfisheries actually had to be imposed on areas not affected the first year. Reproduction of polluted mussels was virtually eliminated. Oil penetrated marsh sediments at least to a depth of 2 feet. Apparently the death of organisms in the sediments accelerated erosion. The sediments were then spread to new areas by waves and currents where they caused more mortality.

[The analysis of samples for oil as well as organisms makes this a valuable study. The generally greater damage reported for this spill than others probably owes to the combination of it occurring during a storm in shallow water over a soft bottom in semi-enclosed conditions, No. 2 fuel oil with a high proportion of aromatics being particularly toxic, and the workers looking in the right place. The findings which are important in considering potential dangers of future spills are the persistence of toxic oil in sediments, the importance in shallow water of turbulence and fine sediments in rapidly depositing oil in sediments before the dissipation of toxic fractions occurs, and the spread of damage long after an incident by movements of the sediments. In addition, the long closure of shellfishing might occur elsewhere under conditions where contaminated sediments may get suspended long after a spill.]

Burns, K.A., and J.M. Teal. 1973. Hydrocarbons in the pelagic Sargassum community. Deep-Sea Res. 20:207-211.

Sargassum contain several hydrocarbons which they seem to synthesize but in addition, they contain on the average as much which is due to pollution by petroleum. The animals do not seem to synthesize hydrocarbons, but generally contain larger concentrations of petroleum hydrocarbons than do the seaweeds. There is no evidence of food-chain magnification among the animals analyzed.

[This seems to be the only study reporting concentrations of petroleum hydrocarbons from different trophic levels. If carcinogenic hydrocarbons behave as those fractions studied here, they will not accumulate in fisheries products.]

Cabrera, J. 1971. Survival of the oyster Crassostrea virginica (Gmelin) in the laboratory under the effects of oil drilling fluids spilled in the Laguna de Tamiahua, Mexico. Gulf Research Reports 3(2):197-213.

No evidence is given that there actually was any mortality of oysters due to spilling 970.12 m^3 of drilling fluid into the lagoon. The whole fluid did cause mortality at concentrations of 1000-2000 ppm and 200-500 ppm, but not at 80-120 ppm in laboratory experiments. In tests of separate components of the drilling fluid, mortality was also demonstrated but it was noted that oxidation states in the used fluid were different than for the pure substances tested. Furthermore diesel oil comprised 64.7% of the commercial fraction of the drilling fluid, yet it was not tested alone.

[No useful conclusions are possible without knowing if the original spill actually did cause damage and without the major constituent of the fluid being tested (e.g., the constituent that most likely would be presumed dangerous.) No mention is made if tainting occurred. IMCO (1973) also reviews this report.]

California Water Quality Control Board. 1964. Fuel oils. In An investigation of the effects of discharged wastes on kelp, pp. 63-67. Sacramento.

[See annotations for North et. al. (1965), who review this work.]

Cerame-Vivas, M.J. 1969. Wreck of the Ocean Eagle. Sea Frontiers 15(4):224-231.

This is a journalistic report on the oil spill at San Juan, Puerto Rico. The only items on biological effects were: "Some of the detergents being used in San Juan harbor were lethal to all species observed in concentrations of one part per thousand." and that the absorbent which seemed most effective (Ekoperl 33) did not seem to be toxic.

Clark, R.B. 1972. Ecology of oil pollution. Marine Pollution Bulletin 3(4):63-64.

[A useful general evaluation of oil pollution studies.]

Connell, D.W. 1970. Protecting the Great Barrier Reef. Marine Pollution Bulletin 1(4):51-52.

[Note about proposed drilling.]

_____. 1971. Kerosene-like tainting in Australian mullet. Marine Pollution Bulletin 2(12):188-189.

The taint has led to condemnation of mullet catches in Moreton Bay, Queensland. Gas chromatography has shown that the tainting is due to a combination of n-alkanes and that chromatograms of sediment samples from the Brisbane River near a petroleum storage facility, and a sewerage outfall, and commercial kerosene all have very similar patterns. Concentrations ranged from traces to 5 ppm in the sediments. Other workers have shown that mullet become tainted in water containing 5 ppm kerosene and that detergents promote the acquisition of tainting substances.

[Tainting may be the most important biological effect of oil pollution that is definitely provable in the field.]

Copeland, B.J. 1965. Industrial pollution in marine ecosystems. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée, Pollutions Marines par les Micro-organismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 79-88. Paris.

[Same publication as "Copeland. 1966." (see below).]

_____. 1966. Effects of industrial wastes on the marine environment. J. Water Pollution Control Fed. 38:1000-1010.

By retaining petrochemical effluents in holding ponds (refineries, petrochemical plants) their adverse effects on the marine environment can be virtually eliminated before release into coastal waters. Fresh wastes are toxic and greatly reduce community metabolism (respiration plus photosynthesis). By 30 days holding time, metabolism is greatly stimulated. In addition, there has been a progressive change from respiration dominating to photosynthesis dominating, and finally to balance between the two.

[Probably the same pattern will occur with distance from an effluent source as dilution, aging, and growth of decomposer and plankton populations modify the wastes.

The importance of this paper is that it points out how wastes can be very simply handled to reduce their harm to coastal waters. One chemical plant in South Texas can process its effluents at 12¢/1000 gal. It would take 100 plants of similar size discharging into the same bay to equal the value of fisheries there. This seems to be a strong argument where waste disposal and other functions of receiving waters are in conflict to clean up the wastes first.]

_____. 1967. Biological and physiological basis of indicator communities. In Pollution and Marine Ecology, eds. T.A. Olson, and F.J. Burgess, pp. 285-288. New York: Interscience.

The number of zooplankton species per 1000 animals counted increased from 5 at the source of petrochemical industrial wastes to 19 at a distance of 20 miles.

[No indication is given of composition and quantity of wastes nor of what happens along control transects, where the study was done, or what else might be changing besides concentration of petrochemical wastes.]

Cowell, E.B. 1971. The ecological effects of oil pollution on littoral communities. Elesevier Publ. Co., New York. 250 pp.

(Author's Abstract). Milford Haven is the largest oil port in Great Britain. As of 1969, it handled 40 million tons of oil per year; by 1980, the load will probably be 80 million tons. In the first ten years of the port's existence, there were only four serious spills. These were the only incidents which led to obvious fouling of the shore. The other 400 plus incidents of pollution were treated before they reached shore. The number of pollutions per 100 vessels has generally declined during the period, with the last three years having the lowest rates.

Saltmarshes. The field studies of the spills which affected areas of saltmarsh indicate that recovery is rapid. Although the emergent vegetation is killed, new growth of the same shoots generally occurs. Field experiments consisting of spraying fresh Kuwait crude oil on marsh vegetation (4.51 applied by a sprayer to a 5m x 2m plot), indicate that recovery from one, two and four monthly sprayings is good, but eight and twelve monthly sprayings lead to more lasting damage, killing almost all of the vegetation and exposing mud. Annuals with shallow roots and little or no food reserves die upon one oiling. The dominant grasses are intermediate, responding well to as many as four applications of oil, some perennials usually with a rosette habit and large food reserves (e.g., tap roots) survive eight and twelve oilings. Cover by *Agrostis stolonifera* and *Oenanthe lachenalii* increased as a result of oiling. The season of the application had some effects. Summer spraying harmed annuals (*Salicornis spp.* and *Suaeda maritima*). Oiling, when flower buds are developing, markedly reduces flowering of the important grasses. Oiling of seed during winter may reduce germination in the spring. Possibly oil does more damage in hot, sunny weather. The die off of a *Spartina* marsh near the effluents of an oil refinery was probably due to frequent covering by thin films of oil since temperature, pH, sulfide concentrations and soil aeration did not seem to exceed the tolerances of the plants. Dying vegetation

Cowell, E.B. 1971. (continued).

(Author's Abstract continued.)

was seen to be covered by a light film of oil. The height of the dead marsh was lower than the healthy marsh surrounding, probably due to both increased erosion and the absence of decomposition of dead vegetation. Death due to phenols in the water or residual petroleum products in the soil are unlikely because plants survived and grew in soil and water taken from the vicinity of the effluent. The soil contained 6% diethyl ether extractable petroleum products. Perhaps damage by oil is enhanced by the up to 12°C increase in temperature caused in parts of the marsh by the refinery effluent. Cleaning treatments did not improve recovery of marsh but did not seem to retard it either (burning, treating with BP 1002 and cutting). Untreated oil adheres to marsh vegetation whereas it will lift off when treated with emulsifiers, only to be deposited elsewhere.

Points from discussions. Figures on the extent of oil pollution at Milford Haven presented in the October, 1969, Oceanus, are 50 times to 100 times too great. Also damage to saltmarshes similar to that of the West Falmouth spill is probably unusual because of its composition: 42% aromatics. The amount of oil deposited has an effect. The use of fresh Kuwait crude oil probably accentuates the damage which was observed in the field experiments compared to what would occur in a spill. Even 1/2 hour of weathering on the surface of the water before beaching would appreciably diminish the proportion of volatiles. In the burning experiments, five seconds was enough to make the oil on vegetation unlightable. It was necessary to use the sprayer as a flame thrower to do the burning treatment at all. D.S. Ranwell (Nature Conservancy) made the observation that the ability of saltmarshes to trap oil and their resilience to the damage make them valuable buffers in the vicinity of fisheries. The concern for fisheries centered upon intertidal shellfish beds, flat shallow sandy areas where young flatfish feed and grow and areas important to shrimp fishing.

The marsh grasses *Puccinellia maritima* and *Festuca rubra* when treated with oil showed greater increases in shoot length and dry weight than when untreated. Reasons considered for the stimulation were increased moisture retention

of soils, nutrients released from other oil killed organisms, growth regulating compounds in the oil, nutrients released from the oil itself, and increased nitrogen fixation. The last definitely did occur, nutrients released from dead organisms may have contributed in some cases but no macrofauna were obvious in the experimental turves, the growth regulator implicated in other research, naphthenic acid, did not have an effect and the other possibilities did not produce observable effects. Consequently nitrogen fixation is regarded as the most likely explanation of the observed stimulation. Fresh crude oil is more toxic than atmospheric residue which stimulates growth. Toxicity increases in the series paraffins, naphthenics, and olefin-aromatics. Within each series toxicity decreases with increasing molecular weight. Toxicity increases: hexane-hexene-cyclohexane-cyclohexene-benzene-toluene-xylene-trimethylbenzene. Exposure to air and sunlight of some highly purified oils increases toxicity by oxidizing part to acids and peroxides. Low viscosity equals high toxicity. The effect of oil applied at night when stomata are closed is small. The same emulsion is lethal when sprayed in the light. Very sunny or hot weather increases phytotoxicity of oils applied to terrestrial vegetation. Fresh Kuwait crude oil harms marsh vegetation whereas weathered stimulates it. All emulsifiers tested killed marsh grasses when applied undiluted but had no lasting detrimental effects when diluted to 10%, even when the same amount of emulsifier was applied. Since emulsifiers must be applied undiluted to be effective on oil, they ought not to be used in cleaning saltmarshes. Emulsifiers that arrive on shore from cleaning operations in open water, however, probably will do no lasting harm because they will be diluted sufficiently before reaching shore.

The rocky shore. Monitoring of the shore transects including 22 that were originally set up before industrialization of Milford Haven indicate that pollution has not led to distinguishable changes in the flora and fauna of the rocky shores. Changes of most species abundances were ranges to be expected of natural communities. The distinct increase in *Balanus balanoides* and decrease in *Chthamalus stellatus* almost certainly owes to a cooling trend of the last ten years compared to the ten years preceding. Probably the same cause accounts for the decline of the topshell *Monodonta lineata*. No explanation is offered for the decline of *Littorina saxatilis*.

Cowell, E.B. 1971. (continued).

(Author's Abstract continued.)

Field experiments. "Conclusions," p. 128, seem an adequate evaluation: "Two main conclusions may be drawn from the experiments. First, experimental oiling of the rocky shore did not damage the fauna and flora, except where the application of thick atmospheric residue brought about physical dislodgement of periwinkles and topshells. Secondly, the application of emulsifier caused substantial mortalities amongst many species, but its most damaging consequences stemmed from the development of an algal forest following the destruction of limpets and mussels. The ultimate effects of emulsifier treatment were, therefore, much greater than is apparent from an assessment of mortalities alone."

Laboratory experiments on organisms of the rocky shore. There are distinct seasonal variations in the responses of Thais, Monodonta, and perhaps Gibbula, to emulsifier BP 1002. Generally the limpet Patella vulgata seems to be the most susceptible of all shore animals to emulsifiers followed by Mytilus edulis. BP 1100 seems to be about two orders of magnitude less toxic than BP 1002. For most shore animals the higher the mortality also the longer for survivors to recover from effects of the emulsifiers. This effect is likely to have important ecological consequences for shores which are cleaned since even if the grazers survive, most will be washed out of the treated area. (They retract into their shells when exposed to the emulsifier and do not remain attached). The case histories of recovery from oil spills seem best explained by the dosages of emulsifiers used: untreated areas show no effects, moderate use of emulsifiers reduces populations of sensitive organisms which permits luxuriant growth of green seaweeds but animal populations are soon restored, and heavy use of emulsifiers which reduces many animal populations permits luxuriant growth of algae, which in turn ingibit re-establishment of animal populations.

[The rocky shore studies are not so convincing as the marsh studies because what happens in control areas is never explicitly presented. Green flushes do occur naturally, so their occurrence in areas of pollution is not necessarily caused by the pollution, nor is it clear that the fates of natural as opposed to pollution produced green flushes differ because of the activities of grazers. Laboratory assays of emulsifier toxicity were performed on

50 animals, but were never replicated. How much of the seasonal variation is actually block effects is not certain.]

Comparative toxicity of crude oils. See "Conclusions," p. 180. Figure 4 suggests that a 16°C toxicity is correlated with the content of aromatics and total distillate to 149°C but this relationship does not hold so well at 26°C and may even be opposite at 3°C.

Fresh crude oil is more toxic for all the shore animals tested than is atmospheric residue. *Littorina littorea* suffered 70-80% mortality when gasoline is poured on it but the length of exposure did not alter damage. Kerosene and crude oil were about comparable, increasing from about 10% mortality for 30 minutes exposure to 60-70% mortality for six hours exposure. Diesel fuel and two kinds of fuel oils had virtually no effect. Aeration of fresh crude oil for up to 24 hours did not diminish its toxicity. Some species are vulnerable to the physical effect of smothering: 100% mortality in two days for *Littorina obtusata*, in six days for *Thais lapillus*, but only 6% in five days for *Littorina littorea*. Conclusions include: only lighter fractions, which rapidly disperse are toxic, persistent fractions are not toxic.

In the vicinity of an outfall from a refinery receiving as much as 1000 million gallons of 20-25 ppm oil in a year, the shore was not barren. The fauna seemed normal beyond 50 yards, favored algae take over near the outfall. Lab experiments with the starfish *Asterias rubens* in 200 ppm oil showed diminished feeding on *Mytilus edulis* in eight weeks and death for most in 14 weeks. Similar conditions did not seem to affect *Carcinus maenas*.

On a 5m x 5m area of mudflat, there were 990 lugworm casts. The day after spraying with BP 1002, there were none while no change was seen in a control plot. Excavation three days later yielded no worms.

[The conclusion that heavy fractions are not toxic is contradicted by the effects of the fuel oil of the West Falmouth spill, Allen's (1971) assays of toxicities for sea urchin larvae and North, Neushul and Clendenning's (1965) experiments with the fuel oils and diesel oils on kelps. The chronic effects seem to be as localized as those described by Mackin and Hopkins (1961) for oysters near bleedwater effluents. The general conclusion of the symposium seems justified that oil is one of the least harmful pollutants of the sea.]

Crowder, B.E. 1971. Oil and fishing are compatible, says Crowder. National Fisherman 51(11):22-23.

Increasing production of commercial fisheries has accompanied the increased production of oil from offshore waters in Louisiana. The drilling rigs are responsible for a large and successful sportfishing industry. The article includes the text of a speech by Crowder, an Esso executive.

Deshimaru, O. 1971. Studies on the pollution of fish meat by mineral oils. Bulletin of the Japanese Society of Scientific Fisheries 37(4):297-306. (Japanese, English summary.)

Crude oil at 50 ppm caused tainting of yellow tail Seriola quinqueradiata in five days, 10 ppm in 13 days. Fish tasting or smelling of oil had gas chromatograms almost identical to the crude oil tested.

Dennis, J.V. 1959. Oil pollution survey of the United States Atlantic coast with special reference to Southeast Florida coast conditions. American Petroleum Institute, Division of Transportation. Washington, D.C. 87 pp.

This report presents data on the amount and kind of oil deposits occurring on Miami beaches each day for one year. Much more cursory observations are made of conditions at other locations along the Atlantic coast. The amount of oil reaching beaches at Miami was related to time of year, currents, and prevailing winds. The only biological effects mentioned were on bird life.

[The report is not useful for evaluation of ecological effects. It may provide some useful information on chronic dosage, but probably is outdated.]

Diaz-Piferrer, M. 1964. Effects of an oil spill on the shore of Guánica, Puerto Rico. Deep-Sea Research 11(5):855-856.

On the night of 16 July 1962, the Italian tanker Argea Prima ran aground on the reefs off Guayanilla Harbour on the south shore of Puerto Rico. Unable to obtain assistance, the captain decided to pump about 10,000 tons of crude oil into the sea coincident with the incoming tide to set the vessel afloat. The oil was blown ashore and transported by currents along the beaches as far as the bay at Boquerón on the west coast of the

island. Offshore coral reefs to the west also received a blanket of thick oil.

The first part of the shore affected was Guánica. The littoral zone at Guánica was characterized by a particularly rich and varied marine flora.

Having studied this area carefully, the author was able to note extensive damage caused by the oil. The most important physical damage was the heavy erosion of the beaches from the combined action of waves and oil. An estimated 3000 m^3 of sand disappeared from Tamarindo beach in less than a week. The sand tended to form small spherical masses with the oil. Some of these globules, consisting of small particles of shell and fine sand enclosed in oil (about 50% by mass of oil), were nearly afloat. Denser globules 20% or less of oil contained larger particles of sand, gravel and shell; these remained on the bottom but tended to move seaward.

The oil striking mangrove swamps settled among the roots, and where the amount of oil was great, this habitat was virtually destroyed.

There was a tremendous mortality of marine organisms along the shore. Adult and juvenile lobsters, crabs, sea urchins, star fishes, sea cucumbers, gastropods such as king helmets and queen conchs, octopuses, squids, a variety of fishes, particularly clupeoids, and sea turtles were found dead. It was noted that sea birds were absent from the area. The marine vegetation was seriously affected, especially the plants living in intertidal and sub-littoral zones. Large rocky areas were completely denuded of algae. Marine phanerogams, particularly Thalassia, were badly affected.

Economic damage was also extensive. The loss of entire beaches and large deposits of tarry oil seriously handicapped beach hotels and resorts as well as private individuals with beach cottages. This also directly affects local business dependent on tourists. The fishermen of Guánica had their gear damaged and there was an obvious depletion of the fisheries.

The oil-soaked sand was still evident on the bottom in several feet of water four months later. In October, 1962, algae began to repopulate the rocks and pools of the intertidal zone, almost entirely Myxophyceae.

[This is a valuable study, if the actual report and subsequent observations are available.]

Easley, C.T. 1970. Spill effects claimed grossly exaggerated. Oil and Gas Journal 68(18):69.

[Excerpt from a speech which consisted only of unsupported opinion concerning the potential dangers of oil prospecting on the Great Barrier Reef. The claim was made that 80% of oil spilled at sea evaporates in a short time and bacteria break down the rest. The lack of damage to the reef after the sinking of so many ships in the Coral Sea is cited as indicative that oil prospecting and production will not cause damage.]

Environmental Protection Agency. Office of Water Programs. 1972. Studies and investigations of the fate and effect of the Shell Oil spill, Platform B, Block 26, South Timbalier Bay (December 1, 1970 - November 30, 1971). EPA, Washington, D.C.

The patterns in the distributions of hydrocarbons and organisms in the sediments along transects radiating from the drilling platform are very erratic. There is no relationship between the number of species and hydrocarbons in the sediments, but there is a weak inverse correlation between numerical abundance of the invertebrate fauna and the concentration of hydrocarbons.

[The study was poorly conceived and conducted making it impossible to draw any firm conclusions. No controls were incorporated into the study. There is no indication of expected variability in benthic fauna in the vicinity of drilling platforms under normal conditions. Maxima in diversity and abundance occurred two or three miles from the rig along each of the transects and in most cases achieved lower values at greater distances from the rig than at the closest stations (one mile away from the rig). Contamination by oil was very patchy. Mortality, if important, was very localized and did not affect the number of species.]

Floodgate, G.D. 1972. Microbial degradation of oil. Marine Pollution Bulletin 3(3):41-43.

Bacterial degradation of hydrocarbons is very dependent on the conditions of culturing. Because optimum conditions are not often likely to coincide with the spilling of oil, it is suggested that the breakdown will usually take much longer than in laboratory tests and often will not reach completion. Oil degradation rates under varying conditions in the United Kingdom are tabulated below. It should be noted that seawater temperatures around the U.K. vary from about 2°C to 16°C. The inorganic nitrogen concentration varies from <1 to around 500 μg N l^{-1}.

Floodgate, G. D. 1972.

Oil Degradation Rates

Bacteria involved	Kind of oil	Experimental conditions	Summary of results	Reference
Garden soil aerobes of several genera	Hydrocarbon mixtures in common use	Batch culture. Mineral salts media. Several temperatures between 20°C and 37°C.	0.4-0.75 g m^{-2} d^{-1} of some materials measured at 28°C.	Sohngen, N.L. (1913) Zentralbl. Bakt. Parasitkde. Ab. II:37,595.
Soil aerobes	Emba crude and lubricating oils	Batch culture. Nitrate or ammonia in mineral salts media. 23°C.	1.2 g m^{-2} d^{-1} for crude oil (45% of added oil), 0.4 g m^{-2} d^{-1} for lubricating oil.	Tausson, V.O., and Shapiro, S.L. (1934) Mikrobiologiya 3:79.
Enriched culture consisting predominantly of a marine Pseudomonas	Clear refined mineral oils	Probably batch culture 25°C aged sea water plus 0.5% KNO_3.	The oxidation of the mineral oil was indicated by O_2 uptake, CO_2 output and bacterial growth. The Q_{10} is given as about 3.0 for temperatures between 0 and 40°C. The average amount of oil degraded at 25°C is given as 1.2 x 10^{-10} mg per day bacterial cell. Hence it is calculated that if the oil is uniformly distributed in the water and the population is constant at 8 x 10^6 organisms ml^{-1} then the rate of oil degradation will be about 350 g m^{-3} yr^{-1} at 25°C and about 36.6 g m^{-3} yr^{-1} at 5°C.	ZoBell, C.E. (1964) Advances in Water Poll. Res., 3:85. This paper also appears in Air and Water Poll., (1960), 7:173.

Floodgate, G.D. 1972. (continued).

Bacteria involved	Kind of oil	Experimental conditions	Summary of results	Reference
Mixed culture of oil oxidizing bacteria	American crudes	Batch culture, aerated by shaking. 25°C sea water medium reinforced with 0.01% $(NH_4)_2HPO_4$. About 1 g placed in 100 ml medium. Oil dispersed on ignited asbestos.	Between 17.8% and 98.8% by weight of oil removed in 30 days. Average around 45%.	ZoBell, C.E., and Prokop, J.V. (1966). Z. allg. Mikrobiol. 6:143.
Natural sea water population	Crudes and several refined products	Batch culture. 18°C sea water medium reinforced with NH_4Cl and phosphates	The influence of various physical and chemical factors on oil degradation is illustrated. The presence of nitrogen and phosphate was shown to increase markedly the breakdown of diesel oil in 8 weeks. The presence of easily degraded material "spared" the oil. The effect of temperature is also shown.	Gunkel, W. (1967). Helgolander wiss. Meeresunters., 15:210.
Natural marine populations	"Atmospheric residue" of Kuwait oil	Sea water percolated through columns of beach sand (median grain size 250) with natural meio and micro fauna. Sands were lightly or heavily oiled. 10°C.	Oxygen uptake used as indication of degradation. Using a "B.O.D." value of 5.0, the author calculates a loss of oil from 0.09 g oil m^{-2} d^{-1} to 0.04 g oil m^{-2} d^{-1} depending upon dosing. These rates applied for several months and accounted for 10% of the oil. Preliminary gas chromatograms	Johnston, R. (1960) J. mar. biol. Ass. UK, 50:925.

Floodgate, G.D. 1972. (continued).

Bacteria involved	Kind of oil	Experimental conditions	Summary of results	Reference
Natural marine..... continued.			suggested the main loss of the alkane fraction. The remaining 90% decayed "immeasurably slowly."	
Selected mixed cultures of oil oxidizing organisms	Louisiana crude	Shaken flasks with sea water enriched with inorganic nitrogen, phosphates and yeast extract. Approx. 70 mg. oil added to 200 ml medium, 20°C and 30°C. Also simulated field studies of large tanks (900 l). Sea water enriched with $(NH_4)SO_4$. 500-100 ml of crude added. Temperature ambient 8-15°C. Seeded with oil oxidizing bacterial.	Initial oxidation attributed to breakdown of n-alkanes smaller than C_{18}. The initial rate was followed by a decrease and then another increase. Up to approx 50% of the crude was lost. No evidence of utilization of aromatics was found. In the large tanks the bacteria accelerated the loss of oil and changed its physical character.	Kator, H., Oppenheimer, C.H., and Miget, R.J. (1971). Prevention and control of oil spills. American Petroleum Institute Conference, 1971, pp. 287.

George, J.D. 1970. Sub-lethal effects on living organisms. Marine Pollution Bulletin 1(7):107-109.

A fuel oil spill at Southampton had no discernible effect on the polychaetes Cirratulus cirrata (Muller) or Cirriformia tentacula (Montagu), but where treated with the detergent "Essolvene" mortality occurred. Laboratory experiments demonstrated that animals which survived exposure to emulsifiers failed to develop gonads.

[This study is valuable because the site affected was already under intensive study. Consequently it was possible to ascertain that growth and reproduction were normal in addition to no lethal effects.]

Gilet, R. 1960. Water pollution in Marseilles and its relation with flora and fauna. In International Conference on Waste Disposal in the Marine Environment, 1st, Berkeley, 1959, ed. E.A. Pearson, pp. 39-59. New York: Pergamon Press.

Light oil slicks are common though not continuous occurrences throughout Marseilles Harbor. There is almost no tidal fluctuation. Nothing grows in the splash zone which is covered with oil. Below the surface, life is varied and exceedingly abundant, probably because of the organic enrichment by sewage discharges.

Gilfillan, E.S. 1973. Effects of seawater extracts of crude oil on carbon budgets in two species of mussels. In Conference on Prevention and Control of Oil Spills, 13-15 March 1973, pp. 691-695. American Petrol. Inst., Washington, D.C.

The extract was prepared by shaking 90 ml. of a blend of Mid-Continent Sweet crudes (Mobil) with 900 ml. of seawater at one stroke per second for 96 hours. The hexane extractable hydrocarbons dissolved in the water amounted to 12 ppm. 0, 1, 10, 50% solutions of extract and a 100 ppm emulsion were used at salinities of 31, 21. and 11 $^{o}/oo$. The mussels Mytilus edulis and Modiolus demissus were acclimated for 48 hours to each treatment and replicated five times. Salinity alone considerably depressed feeding rate. Oil at normal salinity depressed net carbon balance above 1% and progressively more so at higher concentrations. Effects of oil and

lowered salinity were not directly additive because oil stimulated feedings as well as respiration up to and including the 10% treatment for Mytilus. Apparently the diatom used as food was not acceptable to Modiolus, so conclusions are impossible about it.

[There is a clearcut stimulation of respiration by oil at the intermediate salinity and the combined effects of oil and salinity lead to a more severe depression of net carbon balance than either alone. The author's conclusion that this would lead to less available energy for growth and reproduction seems reasonable. As usual, the problem is how the results may be extended to field conditions. Except in the vicinity of continuous oily discharges it is unlikely that mussel populations will be exposed to the concentrations tested. Recovery when returned to clean water was not studied. If there are residual effects, it is much more likely that the observed physiological changes will be reflected in growth and reproduction than if the depression of net carbon balance holds only when exposed to the stresses.]

Gilmore, G.A., D.D. Smith, A.H. Rice, E.H. Shenton, and W.H. Moser. 1970. Systems study of oil spill cleanup procedures, In Analysis of Oil Spills and Control Materials, Vol. I. American Petroleum Institute. New York.

[The biological information is so sketchy as to be useless; however, the compilation of statistics on the conditions during which 36 major spills occurred is valuable.]

Glasgow, L.L. 1971. Louisiana fisheries resources pollution problems and recommended solutions. In Pollution Control and the Marine Industry, the Proceedings of the Conference sponsored by the International Association for Pollution Control, held at Rivergate, New Orleans, Louisiana, 1-3 April 1971, ed. J.S. Ives, pp. 15.1-15.6.

[A speech about potential dangers of pollution to the coastal environment. There is no information on biological effects of oil pollution.]

Glude, J.B. 1968. Observations of the effect of oil from the tanker Ocean Eagle and oil control operations on the fisheries of San Juan, Puerto Rico. U.S. Bureau of Commercial Fisheries. Seattle. 42 pp.

200-250 barrels of dispersant were applied, less than half inside the harbor. Talc, trade name "Mistrom Vapor," helped to coagulate the oil which then could be raked or scooped into containers and removed. Since it floats and is insoluble, the material probably did not damage aquatic species. Biological damage noted is the same as that reported by Pearce and Ogren (1968 and 1969), except that in addition an estimated 100 dead anchovies were seen in oil slicks. The absorbent Ekoperl (volcanic ash treated with silicone to enhance absorbing and prevent sinking) appeared to be moderately effective in absorbing patches of oil and did not seem to damage fish populations.

Gooding, R.M. 1971. Oil pollution from the tanker R.C. Stoner. Special Scientific Report--Fisheries No. 636. Washington, D.C.: U.S. Government Printing Office.

The tanker was carrying mainly military and commercial jet aviation fuels. The spill occurred at Wake Island. Apparently all the mortality had already occurred before the survey began. An estimated 2500 kilograms of fish were washed up on shore, more could have been lost seaward. Of fish >15 cm squirrel fishes (Holocentridae), surgeon fishes (Acanthuridae), parrot fishes (Scaridae) and groupers (Serranidae) composed the bulk of the kill and of the survivors as well. The most abundant dead invertebrates were Turbo sp. (gastropods), Tripneustes sp. (sea urchins), some beach crabs and cowries. Hermit crabs were abundant alive and did not occur among the dead. Diving surveys showed fish to be very abundant off the reef slope and perhaps unexpectedly rare on the reef flat. The reef flat is usually depauperate and stormy weather may have contributed to this condition. Probably the spill would have caused more damage if it had entered the lagoon and been trapped. Presumably the invertebrates of the reef flat were hit hard and will be slow to come back. Sharks seemed to be less cautious than usual. Typhoon Sarah removed almost all traces of the spill.

Gordon, D.C., Jr., and N.J. Prouse. 1973. The effects of three different oils on marine phytoplankton photosynthesis. Submitted to: Marine Biology, 2 April 1973.

Rates of photosynthesis of phytoplankton samples collected from the Bedford Basin, Nova Scotia, and the northwest Atlantic between Halifax and Bermuda were measured using a radiocarbon method while being exposed to concentrations of Venezuelan crude oil, No. 2 and No. 6 fuel oil up to 200 ppb. Up to ~20 ppb there is stimulation of photosynthesis, above that it is depressed. No. 2 fuel oil inhibited photosynthesis by 50% at 200 ppb, the others by about 20%. Even at 50 ppb inhibition was >25% and >10% respectively. Ambient concentrations in the Bedford Basin range from 0.5 to 60 ppb with a mean around 20 ppb. The open sea averaged a few ppb. The maximum observed 25 cm. below a 2 day old slick of crude oil was 800 ppb.

[This is the best study that I have seen of effects on phytoplankton because it uses natural phytoplankton communities and levels of contamination which are low enough to occur in coastal and oceanic waters. Their conclusion seems justified that levels of pollution in inshore waters may be sufficient to inhibit photosynthesis slightly but may even stimulate photosynthesis in oceanic waters.]

Gowanloch, J.N. 1935. Pollution by oil in relation to oysters. American Fisheries Society, Transactions 65:293-296.

Observations. Oyster beds in the vicinity of oil wells tapping salt domes suffered such high mortality as to make them economically unfeasible operations, whereas they had been good producers before the drilling.

Field experiments. Oysters were transplanted from healthy beds to areas outside the zone of the alleged pollution and to a bed that had suffered high mortality. In three months, mortality for the control transplant (outside polluted areas) was 9% and 46% inside.

Laboratory experiments. Treatment water pumped from above a healthy bed passed through a layer of crude oil, then baffles so that there was no direct contact between the oysters and the oil. Three similar experiments were run for 109, 60, and 22 days at different times of the year. Mortality of treatments averaged 4 times greater than controls.

Gowanloch, J.N. 1935. (continued).

[The design of the research seemed excellent, but only bits and pieces got reported. I do not know that the reported results for the field experiments were representative or the only ones suggestive that pollution by oil might be important. Also high mortality of transplants to a bed which had suffered high mortality could result from a communicable disease rather than pollution. The laboratory results indicate a difference, but the concentration of oil might have been unlikely to occur under field conditions (3ppm). The experiments were of long duration, applicable to cases of chronic pollution rather than a spill. Finally and possibly very important, high levels of mortality in the oiled water occurred much sooner in the high temperatures of summer. This phenomenon could have important consequences in evaluating the probable effects of oil in tropical waters.]

Graham, R.J., and T.C. Dorris. 1968. Long-term toxicity bioassay of oil refinery effluents. Water Research 2:643-663.

Untreated refinery wastes when diluted to subacute concentrations were no more harmful upon 32 days of exposure than they were in routine 96 hour tests. Effluents taken from different parts in a series of holding ponds caused little mortality even at full strength during routine 96 hour tests, but caused significant mortality in 16 and 32 day tests. Also, the "condition" (weight x 100,000 ÷ length^3) of the fathead minnows exposed to wastes was worse than that of control animals.

[This is a valuable study because it relates routine toxicity test to long-term effects including condition of animals as well as mortality. Although a freshwater fish was used, it is likely that the results will apply to marine organisms as well. The difference in behavior of high toxicity effluents diluted to subacute levels and full strength treated effluents which are also subacute is probably due to the fact that the processes which reduce toxicity in holding ponds do not operate on all the harmful substance. Heavy metals, for instance, may still be present in sufficient amounts to cause long-term damage.]

Grant, E.M. 1970. Notes on an experiment upon the effects of crude oil on live corals. Fisheries Notes. N.S. (1):1-3.

The experiment consisted of placing two turban corals (Favia speciosa) which were 6-inches in diameter in each of 3-15 gallon tanks and adding three pints of Moonie crude oil to two tanks. In one tank the water level was altered by siphoning to expose the corals to the oil layer for five minutes each day. Some of the oil dissolved because the water immediately became uniformly discolored. All corals survived five days, then a further 16 days with the oil layer removed. A soft coral (Xenia sp.) 1-inch in diameter died in two days.

Greze, V.N. 1970. Conservation in the Black Sea. New Scientist 48(724):180-181.

Oil products released from ships sometimes exceed several grams per liter in Black Sea ports. 10^{-4} to 10^{-5} ml/l of oil products have pronounced toxic effects on developing spawn of the plaice-kalkan.

[The report is a review which touches only lightly on oil. The author mentions the work of Mironov, some of which I have looked at.]

Horn, M.H., J.M. Teal, and R.H. Backus. 1970. Petroleum lumps on the surface of the sea. Science 168:245-246.

Tar balls occurred in 75% of 734 neuston hauls made in the Mediterranean and Atlantic from Gibraltar to the Azores. As much as .5 ml/m^2 was found. An isopod Idotea metallica and a gooseneck barnacle Lepas pectinata were commonly associated with the lumps. Stomach contents of the epipelagic fish Scomberesox saurus included tar.

[Although harmful fractions of petroleum are still present within the tar lumps, they probably do not constitute a serious hazard to marine life because an impervious layer encloses them. It is impossible to ascertain if the tar lumps have caused any change in the composition of the neuston because study of the neuston is so recent that the petroleum pollution has always been present. It is not known whether ingested tar gets into tissues. Burns and Teal (1973) suggest that the gills are probably the important route by which hydrocarbons are incorporated into animals.]

Hurst, J.W., Jr. 1955. Oil pollution of shellfish. Maine Department of Sea and Shore Fisheries. 1 p.

Tainting of clams occurred near a fuel depot at Searsport even though there was no visible evidence of oil pollution. 30% of clams tested tasted oily. After a spill at Wiscasset all clams were tainted, but they were not common in the several miles of contaminated beach. In another spill, 58% of the clams were tainted two weeks after the incident; 37% were still tainted after three weeks, but not afterwards. Fishermen suffered an economic loss because buyers refused all clams from this region for several weeks.

IMCO. 1973. The environmental and financial consequences of oil pollution from ships, Appendix 3. Report of Study No. VI submitted by the United Kingdom to Intergovernmental Maritime Consultative Organization.

[This is a very thorough and valuable review. Generally, I concur with their evaluations. I differ from their point of view in regard to baseline studies. Pollution incidents have proved to be so local that almost never is a valid baseline available, nor is it even reasonable to plan for the future. In general, I think that simultaneous controls are more practical and useful.]

Jacobson, S.M., and D.B. Boylan. 1973. Seawater soluble fraction of kerosene: effect on chemotaxis in a marine snail, Nassarius obsoletus. Nature 241:213-215.

Using kerosene extracts prepared in different ways, concentrations of 1 ppb in one experiment and 4 ppb in the other significantly reduced the number of snails responding to oyster or scallop extracts. Three months after a spill at Chedabucto Bay, Nova Scotia, 10-90 ppb of dissolved Bunker C oil were found at stations up to 20 miles away. Naphthalenes, the major component in kerosene seawater extracts have been reported around 1 ppb in the Charles River Basin, Boston.

[The demonstrated effects could be important since similar concentrations do occur in the field. It would have been more useful to have acclimated snails to the kerosene extract first, since in time the snails might be able to distinguish between the food cue and the kerosene inhibitor.]

Jeffries, H.P. 1972. A stress syndrome in the hard clam, Mercenaria mercenaria. Journal of Invert. Pathol. 20: 242-251.

Clams from a polluted part of Narragansett Bay do not get larger than 11 cm. whereas they frequently exceed 12 cm. in cleaner parts of the bay. During the summer mortality of adults is 1% per day (polluted). Young clams are abundant there but must be recruited from breeding populations in cleaner parts of the bay. Polluted animals differ in many biochemical characteristics from clean ones, but in the same way as animals stressed by normal environmental variation such as temperature. The difference is in degree, the pollution adding on to the normal burden of environmental stress. The cause of the pollution stress is the accumulation of a tar-like substance in epithelial then renal tissue which persists at least a year in animals transplanted to clean water. Presumably the tar-like irritant is derived from petroleum products and hydrocarbons from other pollutants. There is also a high incidence of infection by a polychaete parasite in polluted animals.

[The study was conducted in a very heavily polluted estuary receiving large quantities of domestic and industrial wastes. The clam beds have been closed to exploitation for many years. The point which generalizes is that normal environmental stress and pollution interact additively to reduce size of individuals and populations of adults of a commercially important species even where it is not eliminated.]

Johannes, R.E., J. Maragos, and S.L. Coles. 1972. Oil damages corals exposed to air. Marine Pollution Bulletin 3(2):29-30.

Lewis' (1971) study of the effects of oil and dispersants on corals can be objected to because he did not permit evaporation of volatiles which would be likely to occur under natural conditions. Nevertheless, particularly in the Pacific, corals are occasionally exposed to air. In combination with oil, damage might result. 22 species of coral were tested in floating racks which partially exposed part of each coral to air. A .6 mm layer of oil overlay the water. Waves agitated the racks and splashed water and oil on the exposed portion for 1 1/2 hours. Thereafter, the racks were placed in 2 m of water and the subsequent histories

Johannes, R.E., J. Maragos, and S.L. Coles. 1972. (continued).

of the corals followed for a month. No colonies were killed outright, but portions of most kinds to which oil adhered after being fully immersed in water died and macroscopic algae grew on the exposed skeletons. Branching forms suffered more damage than massive kinds.

[The conditions for the contact of oil and corals in air do not occur frequently nor are whole colonies likely to succumb even when they do occur. Probably corals themselves are not particularly vulnerable to oil. (The oil was Santa Maria crude oil, 12% kerosene distillate, 20% aromatics.)]

Kanter, R., D. Straughan, and W.N. Jessee. 1971. Effects of exposure to oil on Mytilus californianus from different localities. In Conference on Prevention and Control of Oil Spills, 15-17 June 1971. Am. Petr. Inst., Washington, D.C.

Mussels collected from different localities differed in their abilities to survive in seawater covered with layers of crude oil. Those collected in the vicinity of a natural seep did best in all treatments but animals collected from two non-seep areas differed considerably in their tolerances. Even without mixing, the thicker the oil layer the greater the mortality.

[Doses were huge, ranging from 1:10 to 1:1000 oil to water. The results are suggestive that the mussels from near a natural seep are more tolerant to oil because of prior selection, but the drastic differences between non-seep regions at all but the 1:10 treatment suggest that other factors are important and the conclusion is by no means certain that natural seep animals are more tolerant to oil because of long-term exposure to oil.]

Kasymov, A.G. 1970. Industry and productivity of the Caspian Sea. Marine Pollution Bulletin 1:100-103.

Concentrations of many pollutants in the region of Baku greatly exceed the maximum permissible concentrations; however, the author singles out petroleum and the petroleum industry as being the major contributors. Petroleum

concentrations mentioned: 27 ppm, 46 ppm, 143 ppm, and 146 ppm. Productivity at all trophic levels is diminishing rapidly, including commercial catches: in 35 years catches have decreased from 300 million kg (excluding herring which was not fished then) to 110 million kg (including 100 million kg of herring).

[Hydroelectric projects on the two big rivers feeding the sea, decreasing sea level and other sources of pollution certainly contribute to the degradation of the sea, but the concentrations of petroleum are so high that Kasymov's assertion that oil is responsible seems justified. The reported concentrations exceed those for other regions (Torrey Canyon surveys, Sweden, Finland and the Baltic Sea as reported in IMCO (1973)) by orders of magnitude, suggesting that the values must be very local maxima. It is unlikely that other areas would be so vulnerable unless they are also completely enclosed and also subject to the uncontrolled emissions of a very large petrochemical industry.]

Kloth, T.C., and D.E. Wohlschlag. 1972. Size related metabolic responses of the pinfish Lagodon rhoinboides to salinity variations and sublethal petrochemical pollution. Contr. Marine Science, University of Texas 16:125-137.

At 20°C in unpolluted water there is no effect of varying salinity between 20 and 45 ppt on metabolic rate (oxygen consumption per hour per kilogram). When the same variation of salinity is imposed on the fish in "sublethal pollution" by petrochemical wastes, there were very marked alterations in metabolic rate: greatest depression at the lowest salinity, increasing with increasing salinity such that it actually exceeded unpolluted metabolic rate for big pinfish at the maximum salinity.

[The simultaneous operation of different kinds of stress magnify effects on metabolism. Under field conditions where temperature is not held at the optimum as it was in these experiments, alterations of metabolism might be more extreme. The shortcomings of the research are that there is no indication how extensive similar or greater levels of pollution may be in coastal waters, acclimation to polluted water was brief (two days), it is only conjecture that the alterations of metabolic rate will manifest themselves in slower growth, increased age at maturity, reduced mating populations and other populational consequences.]

König, D. 1968. Biologische Auswirkung des Abwassers einer Öl-Raffinerie in einem Vorlandgebeit an der Nordsee. Helgolander Wissenschaftliche Meeresuntersuchungen 17:321-334.

(Author's Abstract). Biological effects of the waste water of an oil refinery in a silting area at the North Sea. The knowledge of the effects of oil refinery water wastes on the area of discharge is important for general ecological reasons, as well as for water resources policies and water laws. The amount of mineral oils and of phenols in the purified waste water is, in the present case, tolerable; but the content of these matters concentrates in the mud of the ditches; it exceeds the initial values about 100 times or more (in addition to the amount of oils and fats present in mud organisms). As a consequence, the composition of plant and animal communities of the mud area has changed: Cyanophyceae are now predominant and the usual representatives of the macrofauna have decreased in number or disappeared altogether, except Nereis diversicolor, a rather euryplastic species which occurs nearly everywhere. Further controls are necessary in order to ascertain whether these biological consequences of the wastes disposed remain restricted to the area of little ditches in the immediate neighborhood of the outlets or whether they may affect also animals and plants of mud flat areas farther away.

[It is very important that oil accumulated to over 100 times its original concentration in the mud.]

Korringa, P. 1968. Biological consequences of marine pollution with special reference to the North Sea fisheries. Helgolander Wissenschaftliche Meeresuntersuchungen 17(1-4): 135-136.

[Shelton (1970) makes the points in greater detail. Korringa adds the observation on the psychological effects of an oil spill on potential fish buyers: "The fish sales on the Parisian market dropped to about half their normal value in the period the "Torrey Canyon" was in the news, irrespective of the quality of the fish offered for sale."]

Kuhnhold, W.W. 1971. The influence of crude oils on fish fry. In FAO Technical Conference on Marine Pollution and Its Effects on Living Resources and Fishing, 9-18 December 1970. FAO Rome. p. 157.

Seawater extracts of Venezuelan crude and Iran crude killed cod eggs down to 100 ppm while Libyan crude caused no mortality. Mechanical dispersions were at least an order of magnitude more harmful to day old herring larvae than extracts from the same amount of oil. Corexit alone had to exceed 100 ppm to cause harm. Aging diminished the effect of mechanical emulsions but not of emulsions with Corexit.

[Emulsions whether mechanical or chemical in origin are more harmful than soluble extracts. In addition the chemical emulsion stays harmful longer. Corexit is an excellent dispersant compared to other common ones because of its low toxicity, but it still increases the biological damage of oil by facilitating the formation of emulsions and retarding their loss of toxicity. Both are good reasons not to use dispersants in nursery areas.]

Lalou, C. 1965. Concentration des benzo-3,4 pyrenes par les holothuries de la region de Villefranche et d'Antibes. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée. Pollutions Marines par les Microorganismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 363-365. Paris.

Differences in the concentration of benzo-3,4 pyrenes by sea cucumbers probably are due to the very patchy nature of pollution by this substance (varying from 1 to 175 mg/100g dry weight in sediments collected from different stations). These results are contrasted with the 100-to-300 fold enrichments of some radioactive isotopes in the viscera of the sea cucumbers. These substances are uniformly distributed. Differences for the hydrocarbon between what is in the animal and what is in the neighboring sediments also owes to patchiness of distribution.

[Benzo-3,4 pyrenes are known to be carcinogenic; however, I have no idea if the concentrations found in the sediments or in the sea cucumbers approach dangerous levels. Definitely the holothurians incorporate the substance into their tissue (maximum so far observed - 1 ppm), but there is no evidence of a food chain magnification.]

Lewis, J.B. 1971. Effect of crude oil and an oil spill dispersant on reef corals. Marine Pollution Bulletin 2(4):59-62.

In one experiment, small coral colonies were exposed to concentrations of 0, 10, 50, 100, 200, 500 and 1000 ppm of Corexit. In the other, Barbados crude oil was used at the same range of concentrations. Tests were replicated 20 times in 350 ml finger bowls sealed by glass plates with stopcock grease. The effects of the pollutants were rated by behavior and exposure of septal filaments. The corals used were all common Caribbean forms: Porites porites (Pallas), Agaricia agaricites (L.), Favia fragum (Esper), and Madracis asperula (Milne-Edwards and Haime). All were sensitive to both crude oil and Corexit upon 24 hours exposure, more sensitive to the latter. The branching types were more affected than the encrusting. Both pollutants had harmful effects at 100 and 500 ppm and recovery was not complete (24 hours exposure then 24 hours to recover).

[Sealing the finger bowls prevented evaporation of the volatile fraction of the oil. I do not know if that is a reasonable treatment for tests in the tropics where such evaporation is going to occur rapidly in the event of spills. Also there certainly should have been a dispersant mixed with oil treatment.]

Lund, E.J. 1957. Effect of bleedwater, "soluble fraction" and crude oil on the oyster. Texas University, Institute of Marine Science Publications 4:328-341.

The author used rate of clearing of turbid water and rate of formation of castings as the best measures of the effects of various kinds of oil pollutants on oysters. He also repeated Galtsoff's (1935) pumping rate experiment. The threshold of sensitivity to bleedwater (salinity 120.4^{o}/oo) on clearing rate lies between 3% and 6% whereas for pumping rate 10% or more is required. "Soluble fraction" by counter current extraction had no discernible effect even at the highest concentration used (12%). Flowing water making non-turbulent contact with a layer of crude oil produced no effects in a closed system as judged by clearing rate nor in an open system (water pumped from the Gulf continuously for 11 days) as judged by the volume of castings produced. No adverse effects were observed for the test animals in the month after the experiments.

[The experiments were controlled and in most cases repeated; however, in some cases interpretation is difficult. All the clearing experiments lasted one day or less and the castings experiment was 11 days. Perhaps deleterious effects would be expressed at lower concentrations after longer exposure. There is no indication of what the concentration of hydrocarbons is in the soluble fraction. This objection is probably not important because the concentration is likely to be much greater than what could occur under natural conditions. Non-turbulence at the oil-water interface may be a problem. Winds must produce white caps in the Gulf some of the time. Emulsions would result.]

Mackin, J.G., and S.H. Hopkins. 1961. Studies on oyster mortality in relation to natural environments and to oil fields in Louisiana. Texas University, Institute of Marine Science Publications 7:1-131.

(Authors' Abstract). Field and laboratory studies and examination of historical records were made in the tidal waters of Louisiana to determine the possible role of operations of oil companies on mortality of commercial oysters, *Crassostrea virginica*. Periods of disastrously high mortality were found in past records, both before and after the beginning of oil operations in the area. According to official figures, 1940-1947 as a whole was a period of good production, but there was a decline in 1944-1947 due mainly to a sharp drop in St. Bernard Parish, outside the area of major oil operations.

Field studies showed that oysters had a consistently high mortality rate throughout the warmer half of the year in the study area, and that mortality rate increased with salinity increase within this area. There was no such correlation with proximity of oil fields.

Chemical studies revealed measurable quantities (0.001 to 0.010 percent dry weight) of unsaponifiable carbon tetrachloride extractives, called "hydrocarbons" by some chemists, in all mud samples tested, including many from locations where no pollution seemed possible. In some cases the quantity of such materials was correlated with the amount of plant debris in samples, and it was found that unsaponifiable material could be extracted by carbon tetrachloride directly

Mackin, J.G., and S.H. Hopkins. 1961. (continued).

(Authors' Abstract continued.)

from plants in areas distant from any source of petroleum. Within oil fields, the amounts of unsaponifiable carbon tetrachloride extractives were highest (up to 5.8 percent) in mud samples taken near bleedwater outlets and other known centers of pollution, and were correlated with high (up to 0.00578 percent) "pentane and heavier hydrocarbons" as measured independently by a commercial laboratory. Water samples showed minute quantities (approximately 1 ppm) of substances identifiable by routine analysis as "hydrocarbons" to be very widely distributed in Louisiana bay waters. These substances showed highest concentrations (up to 226 ppm) in oil field bleedwater and were still high (up to 7.6 ppm) in bay or bayou waters near the point of discharge, but decreased rapidly with distance from the source "Hydrocarbon" content of mud and water was no higher in areas of high oyster mortality than in areas of low mortality. Calculations showed that bleedwater alone could not significantly increase the hydrocarbon content of mud or water on the commercial oyster beds where mortality occurred even if none were destroyed. Bacteriological studies showed that crude oil and its fractions were rapidly destroyed by bacteria living in Louisiana bay muds. Accidental oil spillages were found to cause enough oily taste to make nearby oysters unpalatable for periods ranging from several days to several weeks, but did not kill any oysters on commercial beds. In one case, however, a few intertidal oysters were killed by smothering.

Laboratory experiments showed that bleedwater, crude oil, water extracts of emulsions of crude oil, and the principal constituent of drilling mud (barium sulphate) had no effect on survival of oysters over periods of several months, when the concentrations tested were far above the maximum that could be maintained on an oyster bed. Quebracho, another constituent of drilling mud, caused some increase in mortality when used in concentrations much higher than could occur on an oyster bed. In physiological experiments, bleedwater and water extracts of crude oil slowed water pumping and filtering rates of oysters when used at concentrations much higher than could be expected in oyster-growing waters, but these effects were temporary and reversible.

In field experiments, spraying oysters repeatedly with crude oil and keeping them under a surface layer of crude oil did

not affect survival or growth over a period of months. In other field experiments oysters were kept for months at various distances from bleedwater outlets, underwater natural gas discharges, and other sources of pollution. A discharge of 6600 barrels of bleedwater per day at Lake Barre increased mortality of oysters as far as 50 to 75 feet from the point of discharge, and apparently caused decrease of shell growth and glycogen storage in oysters as far as 150 feet away, but had no detectable effect at greater distances. Field experiments at Dog Lake, Caillou Island, Lake Pelto, and Bay Sainte Elaine oil fields did not show any adverse effect of bleedwater, natural gas, or small oil spillages upon the setting, survival, growth, or fattening of oysters. High explosives used for seismographic exploration in the manner prescribed by Louisiana law did not injure oysters either immediately or over a period of months.

It was concluded that oil production factors of the kinds tested could not be responsible for the oyster mortalities spread throughout the large area where damage was claimed. The widespread mortalities that did occur during the study period were correlated with high temperature and high salinity, but not with proximity to oil operations. (End of authors' abstract.)

[This is a superb study. It is very thoroughly documented and deals with a great variety of aspects. The background information on natural levels of hydrocarbons in sediments from many areas where oil prospecting and production had never occurred, from other areas where the probability was high that no oil pollution had ever occurred, and from areas of oyster production, both which had suffered high mortality and which were healthy is invaluable for comparative purposes. The variety of treatments in both laboratory and field experiments included all stages of the oysters from settlement to old age, covered all seasons, included long term trials (over a year in some cases), considered growth as well as mortality and short term physiological responses, in one case involved a complete facsimile of commercial oyster production on areas exceeding one acre, tested components of drilling muds and even the effects of explosions under condition used for seismic prospecting, etc. All experiments had controls.

The report also evaluates Gowanloch (the same study, but appearing in different sources as I have reported on) and

Mackin, J.G., and S.H. Hopkins. 1961. (continued).

Galtsoff (1935). For three of Gowanloch's transplants, no oysters were recovered because of the deterioration of the racks. The last one not reported yielded only 17 oysters at the end of the study, none of which were dead. It was from a "polluted" location. Also the areas he selected for treatments and controls were different in ways besides oil pollution. Repeats of Gowanloch's crude oil experiments did not confirm his results. Galtsoff's results of adverse effects on diatom cultures were for such high concentrations of bleedwater and crude oil that they could not possibly apply to conditions in the field in Louisiana. Owen (1955) got enhanced growth of mixed cultures of diatoms the more oil he added, apparently contradicting Galtsoff.

The only mortality that could definitely be attributed to the oil spills observed in this study were approximately a dozen oysters apparently smothered in the intertidal zone. Where the few oysters had died so did some mussels, Brachidontes recurvus. No other plants or animals seemed to be affected. "Polydora, Cliona, Membranipora, Thais, Eurypanopeus, Callinectes, Balanus gobies and a few toadfish were found associated with the oysters. Algal growths were unaffected. In the marsh, there were thousands of Littorina, Uca, and a few Sesarma, which did not move out of the oily area. Goby eggs were particularly numerous attached to the oyster shells, especially in boxes." (Boxes are the still attached valves of dead oysters.) The only clearly detrimental effect of oil on oysters (except in the immediate vicinity of bleedwater effluents) seems to be tainting which was observed to last from a few days up to a few months.

Summer water temperatures usually range from 27°C to 32°C. Small bayous which drain from exposed mudflats may reach temperatures up to 40°C, so this work definitely is pertinent to the warm water tropics.]

Mackin, J.G., and A.K. Sparks. 1961. Study of the effects on oysters of crude oil loss from a wild well. Texas University, Institute of Marine Science Publications 7:230-261.

An oil well was out of control and on fire for two weeks. Most of the volatiles probably were burned away. It is

impossible to estimate how much oil was spilled; however, it was enough to leave a heavy oil slick a week after the spill was stopped, which extended as much as three miles from the source. Two weeks after the spill, oil was still obvious in the vicinity of the well but not elsewhere. Three months was the last time at which visual evidence of oil could be stirred from the bottom. Transplants from the most heavily affected area were moved to four polluted and two unpolluted areas. Oysters from a distant unpolluted bed were introduced to within 25 feet of one of the two transplants to an unpolluted area. Mortality, cause of mortality, growth, new settlement and size attained by the new set were all followed at all stations. Observations of the associated fauna were made each month. The study lasted from February to September. No differences that could be attributed to oil were found. In fact mortality was normal and growth was particularly good for the study as a whole by comparison to other studies which have been done in the Gulf. Most mortality was due to the fungus Dermocystidium marinum. There was no synergistic effect between the disease and oil.

[The data that they present on dry weight of flesh per volume of shell capacity suggest that control areas may be slightly better.]

Mallet, L. 1965. Pollution par les hydrocarbures en parliculier du type benzo-3,4 pyrenes des rivages Mediterraneens Francais et plus specialement de la Baie de Villefranche. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée, Pollutions Marines par les Microorganismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 325-330. Paris.

Concentrations of the carcinogenic substance benzo-3,4 pyrene are variable in the south of France but reach high levels in some places at the mouth of the Rhone (up to 96.6 μg/100 g dry weight of sediment), and at Villefrance 500, maybe 1800 μg/100 g. For a sample separated into components: plant fibers, 150 μg/100 g; black mud, 400. Variation with depth in the sediment: 180-500 in top 33 cm, 37-73 in the next 30 cm and 2.6 and 1.6 at 100 cm and 200 cm.

Mallet, L., and J. Sardou. 1965. Recherche de la presence de l'hydrocarbure benzo-3,4 pyrene dans le milieu planctonique de la region de la Baie de Villefranche. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée, Pollutions Marines par les Micro-organismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 331-334. Paris.

Benzo-3,4 pyrene ranged from 0-40 μ/100 g of sample in planktonic samples. Transport is believed to be through the air rather than by interaction with sediments. Definitely some of the hydrocarbon is incorporated in the tissues of the organisms since saponification greatly increases yields.

[There is no analysis by taxa or trophic level and no indication of concentration in the water.]

Mann, H. 1965. Effects on the flavour of fishes by oils and phenols. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée. Pollutions Marines par les Micro-organismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 371-374. Paris.

Chlorine compounds of phenol tainted carps at 0.015 and 0.06 ppm (O- and p-chloride phenol), if exposed for long periods, 0.001 O-chloride phenol will taint eels and oysters. Eels kept in the water of Hamburg harbor became tainted. Two weeks were required to dissipate it. Ingestion of tainted food imparted foul taste to fish. Presence of detergents increased incorporation of phenols by fish. Phenols are incorporated above ambient concentrations in some organs of carps (gills and livers). Fish tainted by 6 ppm oil from refinery wastewater lose taint in three weeks in clean water, but also lose 20% of their weight. Phenol concentrations were measured after the fish were in the water (16°C) three days.

Water of aquarium	Phenol in the fish
5 ppm Phenol	3,5 mg/kg
5 ppm Phenol + 0,5 ppm Dodecyl-benzolsulfonat	6,0 mg/kg

Water of aquarium	Phenol in the fish
5 ppm Phenol + 1,0 ppm Dodecyl-benzolsulfonat	7,0 mg/kg
5 ppm Phenol + 2,0 ppm Dodecyl-benzolsulfonat	6,5 mg/kg

McAuliffe, C. 1966. Solubility in water of paraffin, cyclo-paraffin, olefin, acetylene, cyclo-olefin and aromatic hydrocarbons. J. Phys. Chem. 70:1267-1275.

(Author's Abstract). The solubilities in water at room temperature of 65 hydrocarbons have been measured using a gas-liquid partition chromatographic technique. For each homologous series of hydrocarbons, the logarithm of the solubility in water is a linear function of the hydrocarbon molar volume. Branching increases water solubility for paraffin, olefin, and acetylene hydrocarbons. The increased solubilities due to branching apparently are not due to a structural feature of the molecules, but to the higher vapor pressure of the branched-chain hydrocarbons compared with the corresponding paraffin or olefin hydrocarbon. The "structure" of water is such that, for the same hydrocarbon vapor pressure, approximately the same weight of a C_2 through C_9 paraffin hydrocarbon dissolves in water. For a given carbon number, ring formation increases water solubility. Increasing unsaturation of the hydrocarbon molecule, chain or ring, increases solubility of the hydrocarbon in water.

[Experiments with terrestrial organisms indicate that aromatic compounds are most toxic. McAuliffe's work shows that aromatic compounds are most soluble in water. In order to do harm to a marine organism, a substance must be toxic when it comes in contact with the organism, but perhaps more importantly, mechanisms must exist to bring about that contact. The combination of inherent high toxicity and high solubility make aromatic compounds doubly dangerous. High solubility is associated with high volatility as well. Both features mean that rapid dissipation will occur, suggesting that harmful effects will be local. Balancing off toxicity and rapidity of dissipation, it is still likely that low-boiling aromatics are the most harmful fraction of petroleum.]

Mironov, O.G. 1967. Effects of low concentrations of oil and petroleum products on the development of the eggs of the Black Sea flatfish. Voprosy Ikhtiolgil 7(3):577-580.

[Article is printed in Russian. Judging from the tables, concentrations ranged from 10^{-1} to 10^{-5} ml/liter of petroleum product. Effects ceased to be striking at 10^{-4}. 10^{-2} caused 100% mortality in three days for all types of petroleum products tested. Probably tests were conducted with 20-30 eggs in 180 ml.]

_____. 1968. Hydrocarbon pollution of the sea and its influence on marine organisms. Helgolander Wissenschaftliche Meeresuntersuchungen 17:335-339.

The hyponeuston (organisms of the top 0-5 cm of the sea) includes the early stages of many pelagic and benthic organisms which are generally more sensitive to oil pollution than adults. For instance, pre-larvae of plaice in 10^{-4} to 10^{-5} mg/l of crude oil and diesel oil experienced 40-100% mortality.

[Recruitment of marine fish seldom is limited by the number of eggs available, and young stages usually suffer very high mortality. Nevertheless, the reported concentration is low enough to occur at least locally in the sea. If spawn are concentrated in such a locality, fisheries might suffer.]

_____. 1969a. Development of some Black Sea fishes in polluted waters. Journal of Ichthyology 9(6):919-922.

Concentrations of 1-100 ppm of petroleum, solar oil and black oil all had adverse effects on early developmental stages of the Black Sea anchovy, Engraulis enchrasicholus ponticus Alex.; the Black Sea scorpion fish, Scorpaena porcus L.; and the sea parrot Crenilabrus tinca L. Solar oil was most harmful to the first and second species whereas black oil was for the third.

[There is no indication of the composition of the oils.]

_____. 1969b. Effects of oil pollution on some representatives of the Black Sea zooplankton. Zoologischeski Zhurnal 48(7): 980-984.

(The article is printed in Russian. English abstract follows.) "The effect of Maigobek oil, mineral oil and black oil at concentrations from 0.1 to 0.001 ml/l upon adult forms of Acartia clausi Giesbr., Paracalanus parvus Claus., Penillia avirostris Dana, Centropages ponticus Karav., Oithona nana Giesbr. as well as on larval forms of A. clausi and O. nana has been studied. Planktonic organisms were found to be sensitive to the presence of oil in the seawater which accelerated their death already at the concentration of 0.001 ml/l. At the concentration of 0.1 ml/l all organisms died within the first day."

_____. 1970a. The effect of oil pollution on flora and fauna of the Black Sea. In FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, 9-18 December 1970. FAO, Rome.

Of eleven phytoplankton species tested, nine required 100 to 1000 ppm to kill 100%, but one died completely at 0.1 ppm. At 1 ppm five species of zooplankton had 42-95% greater mortality in 100 hours than controls. There was little difference in sensitivity comparing oil, "mazout" (bunker oil?) and diesel oil. Molluscs varied in sensitivity but most withstood 1000 ppm for 10-15 days. Crustaceans were also variable, Diogenes pugilator succumbing in 10 ppm, others withstanding 1000 ppm. The worm Nereis diversicolor was sensitive to 1000 ppm mixed in sediments. Fish eggs were destroyed at 0.1 - 1 ppm, fish larvae at 10-100 ppm while adults survived 250 ppm. Some plankton showed adverse effects to 5, 30, and 60 minute exposure to 1000 ppm.

[There are internal inconsistencies in the data presented. The experimental designs are not described so that interpretation is difficult. Probably internal comparisons are reliable: larval stages may be orders of magnitude more sensitive than adults. Most phytoplankton are resistant but a few are sensitive so that oil pollution is likely to cause a change in species composition. Short-term exposure to high concentrations can have delayed effects.]

_____. 1970b. Microorganisms growing in oil and oil products in western and central regions of the Mediterranean Sea. Revue Internationale d'Oceanographie Medicale 17:79-85.

28 of 54 water samples taken from different parts of the Mediterranean west of Greece contained bacteria capable of growth on diesel oil or crude oil. The greatest number of samples indicating the growth of microorganisms in oil were taken in regions of visible oil pollution. Some isolates lost the ability to grow on oil when kept on a common agar medium. Microorganisms capable of using hydrocarbons grew better on peptones. This suggests that the bacteria will utilize more accessible sources of carbon first, thus lessening the effectiveness of self-purification, especially when domestic sewage is present.

Mironov, O.G., and L.A. Lanskaya. 1967. Growth of diatoms in seawater polluted by petroleum products. In Biology and distribution of plankton of the southern seas, Moscow, USSR Academy of Sciences, pp. 31-34.

(Article is printed in Russian.) Two kinds of petroleum products were tested. Dytilium brightwelli and Coscinodiscus granii were sensitive down to the lowest concentration tested (.001 ml/l). Melosira moniliformis, Grammatophora marina and Chaetoceros curvisetus only showed effects at or above .1 ml/l.

Mitchell, C.T., E.K. Anderson, L.G. Jones, and W.J. North. 1970. What oil does to ecology. Water Pollution Control Federation Journal 42(5):812-818.

[Two page summary of the Tampico Maru spill.]

Moore, S.F., R.L. Dwyer, and A.M. Katz. 1973. A preliminary assessment of the environmental vulnerability of Machias Bay, Maine, to supertankers. Department of Civil Engineering, Massachusetts Institute of Technology. Report No. 162.

This report includes a tabulated review of many reports on toxicities of oils to marine organisms. In addition it attempts to incorporate projections of the area and extent of damage to the coast by different sized spills different distances from shore at different seasons.

[This is the most useful compilation of toxicity data that I have seen. No attempt is made to judge the reliability of the sources, but the general remarks and conclusions seem reasonable.]

Morris, B.F. 1971. Petroleum: tar quantities floating in the northwestern Atlantic taken with a new quantitative neuston net. Science 173:430-432.

Estimates of concentrations of tar in surface waters are 20 mg/m^2 for the Mediterranean and 1 mg/m^2 for the North Atlantic.

[The calculations based on assumed half-lives of tar lumps and proportion of spilled oil which becomes tar lumps are so conjectural as to be of little value. It is not known whether the contamination of surface waters is presently an equilibrium situation nor is any mention made whether a relationship exists between amount of tar and amount of dissolved or dispersed hydrocarbons, which might be more influential on marine life.]

Nelson-Smith, A. 1972. Oil pollution and marine ecology. London: Elek Science. 260 pp.

[This book is a useful review covering physical and chemical attributes of spilled oil as well as ecological and economic consequences. It suffers by not attempting to provide a critical evaluation of the material cited. So many sources are covered (25 pages of bibliography) that the net result may be a fair presentation of the field, even accepting without remark many dubious results.]

Nemoto, T. 1971. La pesca en el Lago de Maracaibo. Informe Technico No. 24. Caracas.

[Not seen. Cited in IMCO (1973). Apparently the oil industry has not had an adverse effect on the fishery.]

Nicholson, N.L., and R.L. Cimberg. 1971. The Santa Barbara oil spills of 1969: a post-spill survey of the rocky intertidal. Biological and Oceanographical Survey of the Santa Barbara Channel Oil Spill, 1969-1970, ed. D. Straughan, pp. 325-400.

Plants and animals were sampled along intertidal transects at many stations along the coast of Southern California, both in areas affected by the spill and others well away from it. No damage clearly attributable to the spill was evident; however, a drastic decline in the variety of algae was noted along transects that had been sampled by Dawson ten years before. Coal Oil Point had less variety of organisms than other areas which were not so close to active offshore natural seeps.

[Sampling along line transects is not at all suitable for determining the variety of plants and animals which inhabit a particular locality. It is not clear that Dawson's survey was done in this way. More importantly it yields a gross misrepresentation of conditions at Coal Oil Point. Contrary to their conclusion that it has a less varied assemblage of organisms due to chronic exposure to oil from a natural seep, it is locally regarded as the richest bit of rocky intertidal. Furthermore, the majority of invertebrates on their list which they did not encounter during their 12 samplings, I have found during casual examination of the area. Finally, several of the organisms that they list are sand dwellers. Why should they be included in surveys of the rocky intertidal? This is a poor study and the conclusion that the fauna and flora of Coal Oil Point is less varied than non-seep areas is unwarranted.]

North, W.J. 1967. Tampico: a study of destruction and restoration. Sea Frontiers 13(4):212-217.

[The article from Pollutions Marines par les Micro-organismes et les Produits Petroliers is a much more detailed presentation of this material.]

North, W.J., M. Neushul, and K.A. Clendenning. 1965. Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. In Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranée. Pollutions Marines par les Micro-organismes et les Produits Petroliers. Symposium de Monaco, Avril, 1964, pp. 335-354. Paris.

The Tampico Maru ran aground across the mouth of a small cove off the Pacific Coast of Baja California. It released 59,000 barrels of dark diesel oil (80% heavy distillate and 20% residual fuel oil); 1/3 upon stranding, the remainder over a period of months. The spill affected 1000 m of coast. Only the 100 m x 100 m cove was studied. The only animals to survive were a sea anemone (Anthopleura xanthogrammica and/or elegantissima) and the periwinkle (Littorina planaxis) which probably escaped contact with the oil by being so high on the shore. The most abundant dead animals cast up on the beach were abalones, lobsters, sea urchins, pismo clams, mussels and sea stars. Intertidally the algae were destroyed, subtidally they were greatly reduced, as indicated by the number of forms not seen until three years later. The kelp Macrocystis pyrifera became extremely abundant shortly after the accident, probably because the important herbivores were eliminated and the wreck acted as a breakwater. Even after the ship broke up and heavy surf tore out most of the big individuals, many more juveniles were present than is typical of undisturbed areas. As well as the absence of herbivores, the absence of filterfeeders may contribute to the great success of young stages. Gradually the cove has been repopulated by a wide variety of plants and animals in abundance; however, the major herbivores are still absent or present in reduced numbers. The algal community is probably different from what it would have been without the oil because of the very large influence which the present dominant Macrocystis wields by shading and completely modifying the structure of the area. (There is much epiphytism.) The influence extends to the animals as well.

Lab experiments were performed on the toxicities of diesel oil and fuel oil emulsions and surface films to sea urchins and kelp. 0.1% emulsions were the highest concentrations that were stable. The lowest concentration used (0.01%) reduced photosynthetic capacity in three days and eliminated it in seven days. Boiler fuel was much more toxic than diesel oil. Even short exposures to oil had large effects several days later: three hours exposure to .1% boiler fuel eliminated photosynthesis after four days in fresh seawater; twelve hours were required for diesel oil. Sea urchins retract their tube feet within 20 minutes when exposed to .1% diesel oil. They recovered immediately when returned to fresh sea water after minutes exposure and recovered overnight after one hour exposure. Probably mortality was due to being washed ashore after retracting tube feet.

North, W.J., M. Neushul, and K.A. Clendenning. 1965. (continued).

[Two or three years were required to restore a rich and varied community; however, even after seven years it is qualitatively different from what it had been. There is a problem ascertaining how much the long term differences are attributable to the wreck. First, there was no thorough survey prior to the wreck and second, there was no control study. It is essential to know what is happening simultaneously in similar undisturbed areas to be able to interpret the progression of species records which they obtained. Nevertheless, the conclusions seem justified and the long-term consequences of the selective elimination of one trophic level may apply in other cases as well.]

Nuzzi, R. 1973. Effects of water soluble extracts of oil on phytoplankton. In Conference on Prevention and Control of Oil Spills, 13-15 March 1973, pp. 809-913. American Petroleum Institute, Washington, D.C.

Cultures of *Phaeodactylum tricornutum*, *Skeletonema costatum* *Chlorella* sp., and *Chlamydononas* sp. and a natural sample of seawater were exposed to water soluble fractions of No. 2 and No. 6 fuel oils and outboard motor oil prepared by agitating 1% oil in growth medium or filtered seawater for one hour, then letting it separate in a separatory funnel for 24 hours. Fuel oil No. 6 and outboard motor oil had little effect whereas fuel oil No. 2 extracts retarded growth for all except *Chlamydononas* at 50% extract. Fuel oil No. 6 had no obvious effect on the natural sample, outboard motor oil stimulated growth of most things identified, and fuel oil No. 2 slowed growth of everything.

[Adverse effects are clearly demonstrated for fuel oil No. 2 extracts under the culture conditions used. Probably its toxicity is due to its relatively high proportion of soluble compounds (0.053% compared to 0.005% for No. 6). If this figure is reliable, the concentration of hydrocarbons in the extract is 5 ppm and gross effects are apparent at or below 2.5 ppm. The most serious obstacle in applying this result to field conditions is that the culture vessels were sealed. Presumably evaporation and diffusion might limit the duration and volume of exposure to similar concentrations.]

Pearce, J.B., and L. Ogren. 1968. Observations on the effects of oil from the tanker Ocean Eagle on marine organisms of San Juan Bay and vicinity. 21 pp.

5.7 million gallons of Venezuelan crude oil were being carried by the Ocean Eagle of which an estimated 1.2 million gallons spilled. The oil extended along fifteen miles of coast after four days (March 3-7, 1968); ten to twelve foot waves and moderate northerly winds prevailed. The oil spill had little observable effect on the ichthyofauna or on benthic organisms in spite of the fact that conditions permitted large scale vertical mixing. These findings were based on three trawl and two dredge samples. There was no evidence of oil in the sediments. There were observable effects in the intertidal zone, most pronounced on sessile and sedentary forms. High littoral and supralittoral zones were most affected. Xanthid and grapsoid crabs were oiled and dead. Uca did not seem so susceptible but may have died in their burrows. The authors suggest that many species were affected in the mangrove swamp because of the heavy coverage by oil but note that comparative studies with unaffected areas are required. (Neither were actually done.) On rocky areas barnacles were killed but motile forms such as Nerita, chitons and pagurids found protection under rocks or in tidepools. One observer noted a thousand dead sea urchins.

The effect of the oil spill on fisheries seemed to be small, perhaps partly attributable to being the slack season. Also shellfishing is not well developed. It is suggested that the small amount of damage may have been due to the very limited use of detergents.

_____. 1969. Observations on the effect of oil from the tanker Ocean Eagle on marine organisms of San Juan Bay and vicinity. II. Observations one year after the catastrophe. 16 pp.

Three million gallons were estimated to have been released. Observations one year after the spill did not indicate that major changes in or deterioration of the marine environment had taken place. No evaluations were made of smaller benthic and planktonic species. It is inferred that they could not have been seriously affected or it would have been reflected in the macrofauna. A local observer stated that 300 pelicans died, but the local commercial fishery suffered no obvious loss.

Petty, C.E. 1970. Louisiana's omnipresent offshore operations. Our Sun 35(3):3-11.

There is no evidence of damage to the shrimp fishery by oil. Concentrations in seawater of as little as 1 ppm of oil can be concentrated to several hundred ppm by oysters in two weeks; 10-15 ppm will affect taste. Erosion and alteration of hydrological conditions are the other important consequences of oil industry activities.

Puerto Rico University, Department of Marine Sciences. 1968. Ocean Eagle oil spill. U.S. Office of Naval Research, Cerame-Vivas, M.J. 14 pp.

Damage was complete to littoral species along five miles of coast in the vicinity of the entrance to San Juan Harbor. Limpets and chitons were probably killed by detergents or oil-detergent emulsions or were swept off oiled surfaces. Four months later "Intertidal aquatic life was well recovered from the conditions present in the harbor shortly after the oil spill; i.e., March 3-9, 1968, and there was no evidence of oil or oil residues in these intertidal areas." Small populations of several grazing gastropods were found but sea urchins seemed to be absent. Ulva was abundant in some places. Recovery "has been very excellent, but not quite complete."

Toxicity tests indicated that all detergents examined were harmful to fish and invertebrates (Polycomplex A-11, Janoslor 60, Hemco #2 and Muratti). 100 ppm killed everything in 24 hours, usually much sooner. Adverse effects at lower concentrations may have been lethal by the usual 48 or 96 hour criterion for tests. 34 dead fish were seen during a two hour cruise along the shore. Another time, an estimated 100,000 sardina Opisthonema oglinum were seen 95% of which bore abnormal lesions.

[The toxicity tests are useless for comparative purposes, not being conducted under standard conditions and, at least for the invertebrates, involving only one urchin at each concentration (three species of sea urchins were the only invertebrates tested). The reports of the initial surveys are not at all informative and do not always agree with the reports by Pearce and Ogren. The survey four months later is impossible to evaluate except to say that the oil itself was no longer evident and that some organisms were present.]

Rice, S.D. 1973. Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. In Conference on Prevention and Control of Oil Spills, 13-15 March 1973, pp. 667-670. American Petroleum Institute, Washington, D.C.

Bigger fry are more susceptible to oil pollution than small but also they show an avoidance response at much lower concentrations. Big fry avoided 1.6 ppm oil but did not respond to .75 ppm. Their TL_m was 110 ppm at that time.

[As well as size, season and water temperature were different. The author's speculation that pollution well below lethal levels could have adverse effects by altering migration routes seems reasonable. He cites a study that just that did happen to Atlantic salmon in response to zinc pollution.]

Rosenthal, H., and W. Gunkel. 1967. Effects of crude oil-emulsifier mixtures on marine fish fry and their food animals. Helgolander Wissenschaftliche Meeresuntersuchungen 16(4):315-320. (German, English summary.)

Mixtures of the emulsifier "Moltoclar" and Irak crude oil at 1:4 were lethal down to 2.5 - 5.0 ppm emulsifier. Sublethal damage was clear down to 0.5 ppm in two days' time. Crude oil alone did damage the fry (*Clupea harengus* L. and *Agonus cataphractys* L.).

Rützler, K., and W. Sterrer. 1970. Oil pollution: damage observed in tropical communities along the Atlantic seaboard of Panama. Bioscience 20(4):222-224.

Approximately 20,000 barrels of diesel and Bunker C oil were released in December, 1968. Some of it came ashore in the vicinity of the Smithsonian Tropical Research Institute at Galeta Island. The authors made their observations two months after the spill. Along stretches of rocky shore many plants in the supralittoral zone were killed. Spray and high tidepools were still covered by as much as 2 cm of oil and were devoid of life. They assumed damage to gastropod and barnacle populations but the tar crusts were being repopulated "by the usual variety of intertidal organisms." The coral reef did not seem to be harmed. Sandy beaches looked clean but contained oil beneath the surface

Rützler, K., and W. Sterrer. 1970. (continued).

at least to a depth of 30 cm. One analysis showed that 121.9 g wet weight of sand contained 31.8 g of water and 6.2 g of oil. No interstitial copepods could be found. Ciliates were abundant, presumably feeding on bacteria which were decomposing the oil. The authors suggest that there was dramatic reduction of the meiofauna population due to the oil. An area of mangroves was thickly covered with oil. Many seedlings had died. It was too early to judge damage to adult trees but probably the black mangrove Avicennia would suffer because of covering of their pneumatophores with oil. "A strong reduction of the fiddler crab population (Uca sp.) could be observed in comparison to other mangrove areas." 100 cm mud samples contained up to 21.4 g of oil. The algal community of red mangrove roots were practically eliminated as were oysters (Crassostrea sp.), mussels (Brachidontes sp.), barnacles (Balanus sp.), sponges, tunicates and bryozoans. It is suggested that damage to the mangrove habitat would affect fish and crustaceans of economic importance. The authors observed dead and dying young sea turtles (Carretta sp.).

[The authors do document the persistence of massive doses of oil in sediments two months after the fouling originally occurred. The direct observations of mortality in the mangroves is convincing; however, based on the information that the authors present, there is no reason to accept the conclusions about interstitial fauna which depend upon comparisons with samples from North Carolina and Florida. Since Sterrer works with meiofauna ordinarily, his impression probably is valid, but not on the basis of what he presents. It is impossible to evaluate their supposition of damage to economically important crustacea and fish which depend at some stage upon mangrove swamps. Nowhere do they mention mortality to fish, nor whether they were absent from the area during their observations. I doubt that any of the species that they listed as suffering high mortality figured importantly in the nutrition of economically important organisms.]

St. Amant, L.S. 1970. Biological effects of petroleum exploration and production in coastal Louisiana. In Santa Barbara Oil Symposium, held at the University of California, Santa Barbara, 16-18 December 1970, pp. 335-355.

Production of Louisiana fisheries has increased simultaneously with the increasing activity in Louisiana oil fields. So far, at least, reduction of stocks due to oil is not interfering

noticeably with commercially important groups, if it is occurring at all. Oysters, shrimps and menhaden make up the bulk of catches valued at about $150 million each year. Most work has been done with oysters. The consensus is that oil is not directly responsible for oyster mortality; however, in many indirect ways the oil industry has been detrimental to oyster production. Directly assessable factors are loss of suitable grounds to oil production activities, increased silting and, most important, tainting. The important source of tainting is drilling muds that have been treated with kerosene for deep drilling. The kerosene being adsorbed to particles sinks to the bottom and gets filtered out by oysters. A less tangible impact of oil production may be the incursion of high salinity water further inland because of all the channels which have been dredged. Oil may not have caused the high mortalities of the 1940's, but it might have been responsible for the increased salinity which did. The only reason that high production has been maintained is that the whole system of planting and cultivation has been changed to avoid serious losses to the fungus disease which thrives in high salinity. Shrimp catches have not declined because of oil but the changed salinity regime probably caused the switch from 95% white shrimp (Penaeus sertiferus) and 5% brown shrimp (Penaeus aztecus) in catches to 50% each which has occurred in the last 30 years. Oil platforms and submerged spoils from drillings are navigational hazards and reduce the area in which trawling operations may be conducted. Seismic testing does not kill many fish but can make the bottom unsuitable for trawling if detonated too near the bottom. Regulations now make this danger rare.

[I think that this is an excellent overview with a much broader perspective than Mackin's work. Unfortunately the broader problems do not lend themselves to the direct tests that make Mackin's work so impressive. For instance, implicating the dredging and canal digging which went along with drilling 30,000 to 40,000 wells in altering the salinity of the inshore region is eminently reasonable but not provable. The really valuable contribution of this report lies in bringing up the factors which Mackin failed to consider and putting a very different emphasis on other factors. Mackin did not discuss the accelerated erosion which accompanies canal digging and the large scale disturbance to the swamp caused by moving big equipment from place to place for prospecting and putting in new wells. Also Mackin tested components of drilling mud as possible causes of oyster mortality but did not mention their use with kerosene and the concomitant danger of tainting. Although oil is not a direct source of mortality, it probably does have serious adverse effects on Louisiana fisheries.]

Shelton, R.G.J. 1970. The effect of oil spills on fisheries. In Coastal Water Pollution. Pollution of the Sea by Oil Spills. Colloqium held in NATO Headquarters, 2-6 November 1970, pp. 10.1-10.8. Brussels.

The damage to fisheries caused by oil depends upon the composition of the oil, where the spill occurs and how it is treated. In the open sea, even treatment with the most toxic dispersants did little recognizable damage. Over fishing grounds sinking is inadmissable, not because it is likely to kill fish, but because it will certainly cause tainting and foul gear. This is particularly true for dry powders which produce big globs. Beam trawling for flatfish and shrimp is susceptible to contamination by any kind of sinking. Also, bottom currents as slow as 1/2 knot will move the oil out of the area where it was sunk. Even if the fish are not tainted before catching, they will be after cooking if even small lumps of oil accompany them or if the fishermen handling them have oil on their hands and clothes. Any kind of treatment is not advisable in bays and estuaries with fisheries.

[The report seems to be a balanced evaluation. Oil by itself is not particularly harmful but sinking it or treating with detergents may make it so. Tainting is the most serious danger. The author mentioned the possibility of food chain concentration analogous to DDT but indicated that so far there is no evidence that it occurs in the sea.]

Simpson, A.C. 1968. Torrey Canyon disaster and fisheries. Fisheries Laboratory, Burnham-on-Crouch, Essex. Laboratory Leaflet (New Series)No. 18. Great Britain. 43 pp.

Although 120,000 tons of crude oil were spilled and 2.5 million gallons of emulsifiers were applied, little damage to fisheries could be detected. This is attributed to the lack of intertidal fisheries in Cornwall and the removal to deeper water of susceptible forms because it was winter. Even during the periods when emulsifiers were being applied in largest quantities to beaches, concentrations of detergents 100 yards beyond the low water mark were no more than 0.15 ppm. The 15 measurements reported from 100 - 600 yards from shore and surface to bottom ranged from 0.01 ppm to 0.15 ppm with bottom samples being about half those on the surface. Several diving surveys showed few dead of commercially important

species: isolated individuals of crabs, lobsters, sea urchins and young fish. Only in shallow water close to areas of application did the abundances of fish seem lower than normal. Some tainting of lobsters and crabs occurred among commercial catches. Fishermen were advised to move storage pots to deep water. Catches of no commercial species were abnormal in quantity or quality.

[Damage would have been much greater at a different season or if oil had reached estuaries where oysters and mussels are cultured. The conclusion that benthic forms are safe is generally borne out by catch results but is contradicted by the observation during one diving survey of a thick layer of oil overlain by sand in 25 feet of water. Tainting is the greatest danger both of the animals by their own activities and by contamination of gear. Direct damage may be minor but the indirect increases in operating costs due to temporary restriction of fishing from the closest or best grounds, premature termination of trawling when slicks are encountered and cleaning up gear may add up to serious levels. The report only deals with commercial forms; however, it is mentioned that damage to intertidal organisms was very extensive. Simpson suggests that exposure of nursery areas would have large effects because eggs and larvae of many important species are at the surface. This could conceivably lead to the elimination of a whole year's class.]

Spears, R.W. 1971. An evaluation of the effects of oil, oilfield brine and oil removing compounds. In American Institute of Mining, Metallurgical and Petroleum Engineers, AIME Environmental Quality Conference, 7-9 June 1971, pp. 199-216. Washington, D.C.

Laboratory tests on the toxicity of the listed components were performed on pinfish, brown shrimp and blue crabs and these results used to interpret field studies on contamination of the environment and the abundance of commercially important kinds in one contaminated stream compared to five streams that were relatively free of human disturbance. The contaminated stream received 30,000 barrels of oil brine per day; 16.0 mg/l of oil reached the bay. The productivity of uncontaminated streams was 4-30 times greater for shrimp, 2-25 times greater for blue crabs, 5-16 times greater for game fish, and 1.4-11 times greater for forage fish than in the polluted stream.

Spears, R.W. 1971. (continued).

[The comparisons among streams are convincing that oil production activities are reducing the abundances of important species; however, there is no way to judge if the effects extend into the bay. Also it is not clear if any of the indices of environmental harm derived from the 48 hour median tolerant limit are valid.]

Spooner, M.F. 1970. Oil spill in Tarut Bay, Saudi Arabia. Marine Pollution Bulletin 1(11):166-167.

At least 100,000 barrels of Arabian light crude oil were spilled into the bay. Corexit 7664 was used to disperse some slicks which were being carried out into the Persian Gulf. Otherwise dispersants were not used. Natural emulsions were produced at the edge of slicks with concentrations of 50 ppm. Oxygen in the water seemed to be adequate for biodegradation. The trawling fishery for shrimp did not seem to be adversely affected. There was no evidence of oil in the guts. Fish were not tainted. Weirs were contaminated with brown oily mousse, catches declined presumably because the fish and shrimp avoided them. A storm cleaned them up and catches returned to normal. In the area affected by heavy slicks most of the intertidal fauna was killed with exception of the gastropod Cerithium. Dead included crabs, bivalves, and limpets. Numerous dead fish were washed up on the shore. On mud, some mat crabs were killed but others survived. Swimming crabs and shrimp from fish traps had shed limbs and were obviously sick. The mud of the mangrove swamps was usually free of oil. Some plants were losing all their leaves but many survived. After three months most areas looked clean. Algae were growing in one area, presumably because of depletion of grazers. Crabs had not yet reinvaded one area where they had been killed off.

[This is a superficial account but nevertheless valuable for considering Indonesian problems. The whole bay is shallow (less than one fathom), the habitats around it are common to Indonesia (mangroves, mudflats, sand and coral), the fisheries are probably quite similar. I don't know if the oil is similar. My impression is that more important than destruction of life may be the damaging of fishing gear, particularly weirs.]

Spooner, M.F., and G.M. Spooner. 1968. Problems of oil spills at sea as illustrated by the stranding of the General Colocotronis on Eleuthera, Bahamas, March 7, 1968. West of England Steam Ship Owners Protection and Indemnity Association. London. 22 pp.

Most of the oil was successfully off-loaded. Detergents and dispersants were used sparingly and apparently did not harm marine life. Oil which reached the shore only did so near the ship. Coral rock and coral sand are porous and absorb oil. Attempts at cleaning are probably futile. Chitons and limpets graze upon the patches of oil thus cleaning the rocks without apparent harm to themselves. "Rough and preliminary" experiments on the toxicity of dispersants indicate that Enjay 7664 does not do damage even at the high concentrations of 1000 and 100 ppm. In ascending order of toxicity above Enjay 7664 are Polycomplex A (also a water base solubilizer) Magnus and Drew. Animals tested were:

26 small reef pool fish (Abudefcluf saxitilis)
250 small gastropods (zebra nerites) - Activity levels gave clear results.
50 spider crabs and other crabs - These proved unexpectedly resistant.
20 sea urchins - fairly sensitive.
72 tiny bivalves - sensitive but not satisfactory material.
10 chitons - tough and slow.

"Full details of methods and results have been submitted to interested biologists and chemists."

[It is impossible to determine whether the toxicity tests were of dispersants alone or dispersants plus oil. For the most part the report consists of administrative recommendations.]

Stander, G.H., and J.A.V. Venter. 1968. Oil pollution in South Africa. In International Conference of Oil Pollution of the Sea, Rome, 1968. Report of proceeding (London?), pp. 251-258.

In the Esso Essen incident millions of sand-hoppers (Talorchestia sp.) were killed. Fresh periwinkle (Oxystele sp.) and limpet (Patella sp.) shells suggested appreciable mortality in some areas but many survived. Subtidally there

Stander, G.H., and J.A.V. Venter. 1968. (continued).

was no evidence of damage. "Three planktological surveys in the area where the oil was originally released revealed no unusual conditions which could be attributed to oil pollution. A marked plankton mortality which was observed and affected mainly cold-water forms, e.g., Centropages brachiatus, Ctenocalanus vanus, Paracalanus parvus, Paracalanus crassirostris, could be explained by the intense interaction between warm water of Angulhas Current origin and cold Benguela Current water."

Steed, D.L., and B.J. Copeland. 1967. Metabolic responses of some estuarine organisms to an industrial effluent. Contr. Marine Science, University of Texas 12:143-159.

The average concentration of oil in the effluent was 15.9 ppm; however, sulfates, sulfides, phenols and suspended solids were all present in higher concentrations. Estuarine fishes Cyprinodon variegatus, Lagodon rhomboides and Micropogon undulatus and shrimps Penaeus duorarum and P. aztecus were exposed to dilutions of 1-8% effluent in unpolluted bay water (Port Aransas, Texas). Most concentrations tested were below TLM_{48} for the species. The authors conclude that low concentrations depress metabolic rate but as concentrations approach TLM_{48} metabolic rate exceeds normal. In one long-term experiment (six days) at 1/2 TLM_{48} for C. variegatus, there was initially a depression in metabolic rate compared to controls maintained in clean water, followed by an increase at the termination of the trial. These results are used to suggest long-term effects in nature: slower growth, lower fecundity, shorter life-span all contributing to declining populations. This coupled with reduced success in interspecific contact may lead to replacement by less valuable forms.

[Probably the other components of the effluent are more harmful toxicants than the oil; nevertheless, it certainly is relevant to consider the effluent as a whole since oil refining is a very common intrusion in the coastal environment. Short-comings are that no information is given on how far from the effluent source the tested dilutions would be achieved, the concentrations tested really were not much less than TLM_{48}, the data for the three fish do not support the generality of the low level metabolic depression, near TLM_{48} metabolic stimulation claimed by the authors (the pattern is only clear for Cyprinodon variegatus), test

animals were given only three to four hours to acclimate The discussion is relevant and interesting but probably is not justified on the basis of the data presented.]

Straughan, D. 1970. Redressing the balance on the reef. Marine Pollution Bulletin 1(6):86-87.

Living corals are not likely to come in direct contact with oil. Also they are slimy and probably oil will not stick. Possible dangers are the soluble fractions of the oil and reduction in the penetration of light. Intertidally oil would probably stick to the dead coral and coral rubble. Even if volatile fractions evaporated, the danger of smothering would remain. The intertidal mudflats especially in areas of mangroves could be seriously affected because the vegetation would retain the oil. Also oil can penetrate into crab holes. In the absence of dispersants oil will not penetrate muds but will float off with each high tide. Coral sands tend to absorb oil. It is difficult to predict if the oil would wash off easily.

[This is conjecture which seems reasonable but is unsupported by data.]

Tagatz, M.F. 1961. Reduced oxygen tolerance and toxicity of petroleum products to juvenile American shad. Chesapeake Science 2:65-71.

No shad died in 42 hours exposure to 1.8-2.9 ppm oxygen nor to 68 mg/l gasoline and 84 mg/l diesel fuel oil. In combination, however, all fish died in one hour for gasoline and five hours for diesel fuel oil.

[In coastal waters which receive other kinds of wastes, it may be extremely important that synergistic interactions exist between low oxygen and petroleum wastes, since that is where both circumstances are most likely to occur. It would be valuable to know how much lower concentrations of petroleum products would have to be not to cause damage. The nominal concentrations are undoubtedly higher than the fish actually experience because the oil was applied to the surface and solution was accomplished only by the circulation of water at one gallon per minute dripped through the oil layer.]

Tarzwell, C.M. 1971. Toxicity of oil and oil dispersant mixtures to aquatic life. In Water Pollution by Oil, ed. P. Hepple, pp. 263-272. Institute of Petroleum. London.

There is a 700-fold difference in toxicities of different emulsifiers. Mixing with oil increases the least toxic emulsifiers by up to 60-fold but does not increase the effect of the most toxic emulsifiers much at all. Emulsifying oil in water by physical means alone greatly increases its toxicity. The rest of the report consists of very brief reviews of other studies.

Tegelberg, H. 1971. Razor clam mortality at Pacific and Copalis Beaches, March, 1964. Department of Fisheries. Management and Research Division. (Olympia). Washington. 21 pp.

A conservative estimate of mortality was 300,000 due to the spilling of gasoline, diesel fuel and furnace oil on the beach. Areas 1/2 mile distant from the site of the grounding showed declines of 37% and 50% since the fall of the previous year. The former was partly due to commercial fishing but not the latter. The rest was believed mainly due to petroleum. There was no indication of long-term damage. As well as the direct loss of revenue from death of clams, the closure of the commercial season and temporary closure of sport fishing led to further loss to fishermen and tourism.

Wells, P.G. 1972. Influence of Venezuelan crude oil on lobster larvae. Marine Pollution Bulletin 3(7):105-106.

"Emulsions of crude oil are lethal to larvae of the American lobster at concentrations of 100 ppm and appear to have sublethal effects down to 1 ppm."

[The author points out that the preparation of the emulsion might be so different from those produced under natural conditions that the toxicity might be increased. The point stands that adverse effects on a commercially important crustacean were expressed at low concentrations. Probably the lethal level of 100 ppm would not be attained over large areas simultaneously and whether lower doses would effect recruitment, even if destroying a large proportion of larvae, is debatable.]

Wilhm, J.L., and T.C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18:477-481.

Species diversity is a sensitive indicator of pollution. In streams receiving oil field brines, diversity decreased below an effluent outfall, then progressively increased further downstream. In oil refinery effluent holding ponds, the diversity of insects increased from the pond receiving the wastes to the last one in the series. Reanalysis of Reish and Winter (1954) using species diversity revealed that areas near oil fields that they judged not to show evidence of damage had around half the diversity of nearby areas. (Reish, D.J., and H.A. Winter, 1954 . The ecology of Alamitos Bay, California, with special reference to pollution. California Fish Game 40:105-121.).

[Changes in relative abundances of species may be the important consequence of pollution, which may not be shown by only counting number of species or overall biomass. The reservation about the technique must be that the areas compared are indeed similar except for the pollution. This may not have been true for some of the examples used. The adequacy of controls is of utmost importance.]

Wilson, K.W. 1970. The toxicity of oil spill dispersants to the embryos and larvae of some marine fish. In FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, 9-18 December 1970. FAO, Rome.

Corexit is very low in toxicity. Emulsifiers in kerosene base solvents are somewhat less harmful than in aromatic hydrocarbon solvents but are still orders of magnitude more harmful than Corexit. The tolerance of various fish larvae to BP 1002 (aromatic hydrocarbon solvent) ran: herring > lemon sole > pilchard > sole > haddock with plaice being most tolerant to 10 ppm but between pilchard and sole at 100 ppm. Larvae were most sensitive between hatching and first feeding and much more sensitive than advanced embryos. Exposure to as little as 2.5 ppm BP 1002 as eggs for 96 hours or as larvae for 48 hours lowered the proportion metamorphosing; 10 ppm virtually eliminated development as far as metamorphosis. Larvae which survived to metamorphose after exposure to 7.5 ppm were not different in appearance from controls. 0.5 ppm altered the behavior of herring larvae.

Wilson, K.W. 1970. (continued).

[This seems to be a well executed and useful piece of work. The concentrations used are probably too high to be applicable to field conditions but the information on relative tolerances of kinds of larvae and stages of development can be applied. The delayed effects of exposure to high concentrations for a brief period may be realistic and suggest that direct spraying where larvae occur would do damage even if dissipation is rapid.]

Wohlschlag, D.E., and J.N. Cameron. 1967. Assessment of a low level stress on the respiratory metabolism of the pinfish (Lagodon rhomboides). Contr. Marine Science, University of Texas 12:160-171.

Waters from the Corpus Christi turning basin are mainly polluted by petrochemical wastes. The concentration is not known. Undiluted water killed 5-10% of the fish in five days. The experiments were run with half diluted and clean seawater at 10°, 15°, 20°, 25°, and 30°C and acclimated for three days. Oxygen consumption of the fish when resting and when moving at 10 m/min. were then measured. Big fish were more sensitive to the pollutants than small and the effect was accentuated at the temperature extremes.

[The study does demonstrate that sublethal effects of a mainly petrochemical waste may have important ecological consequences. The depressed metabolism in polluted waters probably would lead to reduced growth, reproduction and perhaps life span. More important may be the synergistic interaction of different kinds of stresses operating simultaneously. The difficulties in applying the study to the problem of oil pollution are that other contaminants were present and that the concentrations are not known.]

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