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AN ECOLOGICAL BASIS FOR COASTAL ZONE MANAGEMENT IN TROPICAL AREAS

by

Arthur J. Hanson

Proyek Pendidikan dan Penelitian Lingkungan IPB

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1. Introduction

The principles for coastal zone management (CZM) should be based on specific ecological constraints, human use patterns and desired governmental objectives in each situation. The degree to which management strategies evolved in the temperate region, industrialized countries can be transposed to tropical areas is an open question since the natural systems, and their response to utilization differ. The cultural ecology of rural coastal inhabitants is yet another point of difference. Perhaps the most broadly applicable elements in coastal zone management strategies are the ground rules which should govern development of coastal urban centers, harbors and industrial or large-scale infrastructure developments. But no standard formula can be properly applied without consideration of natural and human ecology factors. The most important factors are considered in this paper.

Hierarchical, ecologically-based analysis and management are required to ensure optimal development of the whole system as well as sectoral needs. In the coastal zone certain natural systems such as deltas, small island clusters, large bay or inlets, and interfluvial lagoon or beach areas form logical planning and management units. Within each unit there can be developed a management strategy for individual resources such as fisheries or forestry and for zoned land and water use plus a strategy for handling the problems associated with concentrated human settlement such as cities, ports, recreational areas and industrial locations. The interconnection between systems must also be considered, particularly since the coastal zone receives

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the impact of both upstream and offshore environmental conditions. It is vital to think about ecological scale in time and space when developing a basis for management. The coastal zone is an environment characterized by change over time and strong gradients. Study of system dynamics, and the use of an ecologically-based scale for measurement of environmental characteristics are two matters that distinguish the ecological approach from most regional planning approaches to CZM. A general model for incorporating environmental analysis into regional planning and management, particularly at the project level, will be presented as the concluding section of the paper.

2. Environmental Features of the Coastal Zone

The coastal zone is an interphase, or ecotone environment. Consequently many different ecological conditions can be found in a small area. This complexity creates management difficulties since generalities do not apply to all elements of the system and capacity for different uses varies.

From a physical viewpoint, the tropical coastal zone will usually possess unique climatic features (lower rainfall, wet months, high salt content rainwater), very complicated erosion and sedimentation patterns and very active geomorphological changes. These are linked to wet and dry seasons. Substrate formation in tropical coastal environments is frequently the result of interaction between physical and biological factors, particularly in fish and coral reef areas. Consequently the physical basis of the coastal zone can be drastically changed by destruction of key biological components.

Water resource problems tend to be extreme in almost any coastal environment. The integrated effects of all offshore and upstream activities have an impact on the coastal drainage. It may be subject to periodic surface or groundwater salt intrusion, land drainage can be difficult and flood hazard great. Because tropical rivers have very disparate seasonal flow patterns the water problems are increased. For example, assimilative capacity for wastes becomes variable. Massive longshore pollution possibilities have been a prime factor

in creating world-wide interest in coastal zone management.

The coastal zone is an area of multiple energy inputs and energy stresses. Energy studies are important for understanding both the physical and biological aspects of coastal systems. Sedimentation, tidal propagation, nutrient recycling and animal migration are four examples of processes which can be understood by reference to energy analysis.

The coastal land and waters are gateways or a buffer zone for migrants to and from the sea. Consequently [illegible] species recorded is likely to be highest in the lowland coastal zone compared to other habitats. Within this zone, however, in some habitats species diversity is likely to be lower than average for [illegible] because of unusual stress conditions. For example, a coastal freshwater peat forest more closely approximates a temperate type wetland forest than the tropical rainforest in the total number of tree species. For management such a situation can be welcome.

OAS Caribbean

The pressure of coastal dwelling peoples presents the possibility of unique land or water resource use and cultural patterns evolving in response to specialized conditions. This is very apparent in the case of island cultures. Large numbers of people engaged in artisanal fisheries, salt preparation, swamp forest exploitation, trade and boat construction form the basis for coastal rural activities in many areas. The coastal plain is of course, frequently the most inhabited and fertile agricultural area of a water basin. The coastal fringe, itself, is much more likely to be a problem [illegible] specialized agricultural systems are necessary. The [illegible] settlement in the tropical coastal zone are complicated by the presence of high density rural settlement, frequently [illegible] on a fragile natural resource base, and the rapid [illegible] industrialized "mother" cities in coastal port areas. Cities [illegible] occupied sites where sedimentation has been rapid, [illegible] expansion is limited by natural barriers [illegible], surrounding floodlands, or mountain barriers face particularly difficult environmental choices in their development.

3. [illegible]

The important [illegible] to resource management are: (1) definition of [illegible] or temporal patterns; (2) study of flow, storage [illegible] systems; (3) assessment of the [illegible] hazards and the response of [illegible] systems; (4) analysis of the way [illegible] account in resource use decision-making. [illegible] environmental scientists a[illegible] of the first two approaches. The latter two [illegible] beginning to be adequately explored [illegible] The fourth one, in particular, is critical [illegible] often occurs between those who understand field conditions and those who make crucial resource decisions. This can even be a deliberate strategy to avoid ecologically-sound management decisions if there are other considerations involved.

In tropical areas the choice of what to study is made more difficult by the great diversity of habitat and species. A comprehensive approach is required for study of the coastal zone but it is important to remember that of the many potential limiting factors only one or a few may be habitually important. Detailed studies on key limiting factors are therefore desirable rather than expending all effort in broad-scale problem definition surveys. The occurence of extreme conditions in natural cycles may be the most significant element in creating environmental change. The cycles which are important to coastal zone ecology range from geological [illegible] to the semidiurnal tides. As an example [illegible] affecting energy flow, nutrients and productivity [illegible] are shown in Table 1.

For an understanding of [illegible] to coastal regions of various kinds [illegible] which may be consulted.[1] The objective in the present paper is to demonstrate the breadth of ecological information needed for management of major kinds of systems in Indonesia or other tropical areas. Many of the points put forward in fact, form a test [illegible] for current ecological theory but this is not the forum for their discussion.

Instead I have developed a list of essential elements for resource management-oriented ecological study in the coastal zone (see Table 2). Application of these elements will be examined in two ecological units — the delta/estuary, and small island/coral reef complex. These two ecosystem types are among the most important major coastal types in Indonesia and are perhaps the most susceptible to [illegible] change.

Delta-Estuary Systems

Certain features of delta and estuaries can and do place them among the areas viewed to have highest potential for food production in Indonesia. They have water, flat land, [illegible] fish protein and, in some areas, valuable timber resources. In fact, the delta areas of Java and some locations in Sulawesi do form the fringe of the peneplain "rice bowls." Some of the world's most extensive brackish-water fishpond culture areas is located in the delta zones of these two islands. But it would be wrong to assume that even a majority of Indonesian deltaic areas possess the innately high potential and stability of the more inland lowland rice fields of Java, nor can it be assumed that plant crop monoculture is necessarily feasible, or, if feasible, the best use of the system. A management strategy must take into account basic structural features which are very different among islands, dynamics of physical development of the system, inherent constraints on fertility and the elements of risk attached to human settlement and use of the resource. The linkages between estuary and delta, the input of river and sea water, and their impact on biological resources are the critical matters for study.

1. Structure and dynamics of physical development

Basic geological and geomorphological factors which have determined the regional differences in distribution and [illegible] of fluvial-influenced sedimentary environments include tectonic development, structural juntaposition, characteristics of upland parent materials, river flow, eustasis and ocean currents.[2] The most remarkable feature of the estuaries is their rapid rate of filling by deltaic advancement.[3] The ecological systems which result form a catena

Table 1. Important cycles relating to [illegible] and productivity ([illegible]) classified according to the relevant time span.

Geological periods (thousands to million [illegible])

- Weathering in mountains
- Uplifting in coastal plain
- Changes in sea level

Historical (decade to hundreds of years)

- Long-term climatic trends
- Delta and island formation
- Coastal accretion and accretion
- Organic deposition
- Soil ripening
- Forest growth and succession
- Settlement development
- Human population dynamics

Years (1 - 10)

- Short-term climatic trends
- Shifting of channels
- [illegible]
- Population density [illegible] in flora and fauna
- Land opening [illegible]
- Fructing of some plant species

Seasonal

Monsoon-related

- Insolation
- Rainfall
- Offshore currents intensity, direction and water characteristics
- River flow and flooding

Secondary effects of wet and dry seasons

- Vegetation decay and nutrient availability
- Incidence of forest burning
- Water quality variation
- Changes in species numbers and distribution
- Migrations of organisms into and out of area
- Breeding
- Crop planting and harvesting
- Harvesting of natural products
- Incidence of disease vectors
- Human activities

Lunar

- Tides
- Salt intrusion
- Migrations of aquatic organisms
- Breeding of some aquatic organism
- Flooding and flushing of deltaic area
- Fishing

Diurnal

- Light and dark
- Tides
- Animal feeding and activity cycles
- Human work schedule

Table 2. Essential elements for [illegible] coastal zones.

1. Watershed geochemistry, depositional processes and substrate characteristics.
   - 1.1. Interaction between freshwater and marine water in substrate formation (e.g., beach rock, flocculation of sediments in delta formation.
   - 1.2. Influence of river water chemistry and sediment on delta and coastal water fertility, weathering of upland deposits.
   - 1.3. Biogenic substrate formation.
   - 1.4. Structural nature of sediments and their response to changes in water chemistry.

2. Landforms, geological instability and the relationship of land to sea level.
   - 2.1. Basin geological structure.
   - 2.2. Presence of faults, uplifting and subsidence as factors in coastal landform development.
   - 2.3. Time span for development of important ecosystem types such as deltas, coral reefs or beach formations.
   - 2.4. Periodicity of events important over geological time.
   - 2.5. Importance of ancient coastal features in relation to present sea level and coast, including marine mineral deposits.

3. Soil characteristics.
   - 3.1. Presence of marine-influenced soils such as potential acid-sulphate soils.
   - 3.2. Development of soil structure in areas under marine influence, such as delta sediment "ripening".
   - 3.3. Special problems of soil structure on small oceanic islands, peat soils, porous sands.
   - 3.4. Influence of periodic sea water flooding on soil fertility, structure and toxicity.

4. Water quality and flow.
   - 4.1. Tidal patterns, current directions and landform features [illegible] to alterations to sea flow (e.g., coral reef, [illegible] which alter rates of tidal propagation, man-made structures); tidal energy.
   - 4.2. Degree of salt intrusion in surface or ground water in relation to seasonal river flow patterns, to channel configurations and to substrate characteristics.
   - 4.3. Specialized water quality conditions created by land-sea interaction (e.g., black-water.)
   - 4.4. Mixing processes and dilution of river, swamp and sea water.

4.5. Concentrating mechanisms (e.g., evaporation [illegible]).

4.6. Patterns of flow including annual cycle, [illegible] run off [illegible], critical levels of flow likely to cause damage along, [illegible] high or low tidal levels; energy of river transport system.

5. Rainfall and moisture.

5.1. Distribution patterns in relation to landforms and sea.

5.2. Special features of coastal air, moisture levels including fog and [illegible] formation.

5.3. Probability of extreme climatological conditions and [illegible] or exacerbating influence of land/sea interaction.

6. Solar energy inputs.

6.1. Annual distribution of energy input in various coastal environments.

6.2. Utilization, system absorption and albedo.

6.3. Relationship of solar inputs to other physical forms of energy such as wind.

6.4. High temperature effects.

7. Environmental gradients, spatial patterns and succession.

7.1. Measurements of response to key coastal physical and chemical gradients (e.g., salinity, elevation above MSL, depth of desirable soil deposit).

7.2. Community structure and interrelationships with other communities.

7.3. Temporal and spatial succession.

7.4. Barriers to transposing communities or populations.

8. Productivity and nutrient flow characteristics.

8.1. Relationship of physical environment to biological productivity.

8.2. Channels of movement and utilization of biological productivity.

8.3. Nutrient supply from geochemical processes.

8.4. Nutrient recycling in various biological communities.

8.5. Influence of cropping, fertilization or other manipulations on productivity.

9. Specialized biological adaptations.

9.1. Physical or physiological adaptations [illegible] extreme environmental conditions.

9.2. Migratory patterns in relation to environmental characteristics.

10. Patterns of resource use and response of resources [illegible].

10.1. Stability and methods of resource exploitation.

10.2. Dynamics of exploitations and communities.

10.3. Interference of resources [illegible] coastal [illegible] [illegible].

10.4. Response of resources [illegible] resources [illegible] to [illegible] [illegible] [illegible] occurrences of important limiting factors.

10.5. Special problems of [illegible] [illegible] [illegible] pollution.

11. Patterns of human settlement.

11.1. Relationship to natural [illegible] [illegible].

11.2. Limiting factors [illegible] [illegible] [illegible] conditions.

11.3. Constraints on stability [illegible] [illegible].

11.4. Cultural differences in resource utilization.

11.5. Historical role of coastal [illegible] [illegible] [illegible] [illegible] centers.

in which the pioneering mangrove elements move seaward with the advancing sediment front. The deltas are biologically formed in East Sumatra, South Kalimantan and other areas where peat swamp forest is found.[4] The resulting systems are complex and effectively seal the delta interior from direct sea influence. Over short periods of geologic time they have formed very wide coastal zones. By contrast, in Java the high sediment loads and man's activities in land reclamation of subaerial deposits [illegible] the role of natural vegetation in delta formation. The deltas in Java are limited in their extension to the sea, frequently forming inter-deltaic sandy coasts from the coarser sediments.

Environmental gradients in each of these two principal kinds of deltaic-estuarine systems are a very significant matter for CZM. The major gradient is, of course, salinity. Gradients of flooding and ground water level, sediment size and ripeness, organic soil deposits, vegetation and climate create many different environmental conditions in relatively small area.

Within their optimal zone one or a few species may predominate in the community , in contrast to the richness and evenness of species distribution in most tropical associations.[5] There are three points to be made about environmental gradients in relation to management. The presence of flourishing and almost pure stands of trees such as Nipa palm, stocks of valuable fish which have culture potential or other biological resources which seem superabundant is frequently noted. It is generally [illegible] resources could be readily transferred [illegible] they are not already present. The importance of [illegible] in these coastal zones is so great that even replacement within the same area may be impossible. Secondly, environmental gradients reduce [illegible] and area for introduction of cultured species. Where there is not caution, marginal cropping or abandoned land [illegible], as in the Indramayu.[6] The presence of such land creates a demand for reclamation which can be a very expensive solution [illegible] is basically a question of enforced land use zoning. Thirdly, the environmental gradients affect the potential for human settlement by their influence on water supply, transportation, public health and potential for resource exploitation and development.

2. Biological productivity and nutrient flow

Related to the matter of environmental gradients are the peculiarities of productivity and nutrient flow in delta-estuarine systems. These coastal zones are frequently considered to be among the most productive by ecologists. Yet they are, indeed, often marginal lands for agriculture and forestry and harbor some of the least productive fishery habitats known -- the blackwater swamps.[7] To understand the paradox the subsystem elements must be considered, as well as linkages between those elements. In Table 3 these elements and their interaction are shown for coastal swampland in Sumatra. Quantitative measurements are needed to determine what fraction of the production in the system is allochthonous, coming from upstream sources such as the upland swamp vegetation, weed and what fraction autochthonous, derived from the very efficient nutrient extraction form mud by macrophytes in the mangrove forest. The organic depositional environment of the swampland creates a time lag in the leakage of organic nutrients. More attention should be paid to the role of peat leaching processes in fertilizing the estuary.[8] How dependent, for example, are the rich estuarine and coastal fisheries of East Sumatra and Kalimantan on the stock of organic nutrients leached from the peaty soils? Or is the dependence mainly on organic particulate matter carried from the watershed and from the mangrove litter production? The importance of detritus in tropical estuarine fish production is now well established and therefore a cause for concern in any action which removes mangrove or reduces the input of allochthonous organic nutrients.[9] It is very clear that feasibility studies for projects involving estuarine changes likely to have an impact on productivity must go beyond consideration of *in situ* phytoplankton measures of primary productivity to consider the role of detritus food chains.[10]

Plant crop productivity has 3 basic limitations in the delta swampland areas: (1) susceptibility to salt intrusion; (2) peculiar soil conditions (acid sulphate, peat, sandy); (3) water level control (too much or too little). These problems[11] take on different dimensions according to the nature of the watershed. From an ecological management perspective several factors must considered:

Table 3. Postulated nutrient exchanges in the [illegible] coastal zone.

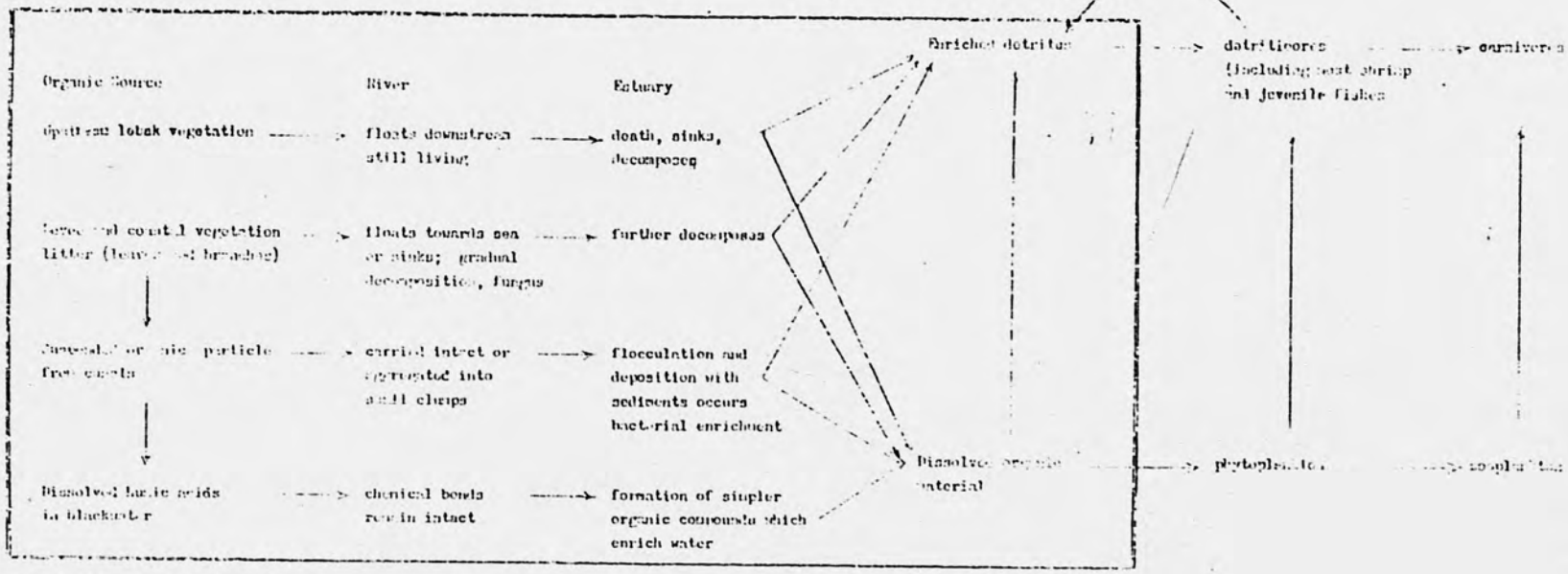
1. Matrix

Inflow to / Outflow from	A	B	C	D	E	F	G	H	I	J	K	L
A seawater		↔	-	-	-	-	-	-	-	+	-	+
B creekish/coastal water	↔		-	↔	+	-	+	-	-	+	-	?
C creekish/water swamp	-	↔		?	+	-	?	-	-	+	-	?
D "white water" river	-	↔	+		+	↔	↔	?	+	?	-	-
E "black water" river	-	↔	+	+		-	-	?	-	?	-	-
F levee vegetation	-	↔	-	-	-		+	-	-	+	-	-
G back swamp vegetation	-	?	+	+	-	+		+	↔	+	-	-
H peat dome vegetation	-	-	?	?	↔	?	+		↔	+	-	-
I f.w. organic soil deposits	-	?	+	?	↔	?	+	+		+	-	-
J clay deposits	-	?	↔	+	-	↔	+	+	+		-	-
K drifting organic matter (from upstream)	-	↔	+	+	-	+	?	-	?	+		-
L rainwater	-	?	-	?	?	-	?	+	?	-	-	

↔ substantial exchange
+ moderate exchange
- negligible exchange

? uncertain

2. Source of detritus and dissolved organic material



(1) [illegible] complete water [illegible] high levees destroy other [illegible] or be justified against alternative [illegible] of more intensive plant [illegible] resistance to salt and changing water level [illegible] waterworks.[4] [illegible] require [illegible] populated by the hardy, [illegible] are capable of [illegible] form usable [illegible] cultivated crops. [illegible] of agricultural land preparation [illegible] sites have very limited application in the [illegible] where potential acid sulphate soil conditions [illegible]. [illegible] closing the discussion with the note that the [illegible] such as Imperata are absent in the secondary [illegible] swamplands. But low value forests comprise the secondary vegetation in many areas.

3. Migration

As centers for animal migration [illegible] wetlands are perhaps less spectacular than temperate and [illegible] flyways and nesting spots for birds. But there is a dependence [illegible] commercially important shrimp of the tropics on estuarine conditions. The widespread occurrence of migrations is explained by the need to match rapid growth phases in the life history to food availability,[13] and sometimes shelter. An understanding, or at least an awareness, of these migratory patterns is absolutely essential for management of fish stocks and for avoiding damage to them by secondary activities such as pesticide spraying.

4. Sedimentation processes

There is ample evidence of man's influence on the ecology of river basins as the cause of accelerated growth of deltas in Java over the past 50 years.[13] The benefits produced by the increased deposition in the coastal zones almost certainly do not exceed the costs to the lowlands and port areas. The costs are associated with flooding; levee, river channel and irrigation system maintenance;

urban water purification, and port maintenance. [illegible] probably does not directly affect [illegible] of the coastal zone because the species [illegible] are adapted to such depositional [illegible] rehabilitation of tilted [illegible] into account the specialized needs [illegible], or salt ponds.[14] The balance [illegible] land use practises are established. [illegible] canal is cut off large areas of delta may suddenly [illegible] for such destruction should be clearly thought out by water engineers and by local officials who might engage in [illegible] activities.

Off Java the nature of deposition in [illegible] may still be an indicator of upland use problems, but [illegible] like Palembang the shallowing of their river is very much a part of a natural ecological process.[16] Consequently sedimentation must be [illegible] into account in the infrastructure development of their coastal zone. The flocculation zone in which sediments are deposited [illegible] the interphase of salt and freshwater will change if canals [illegible] sea water into a freshwater zone. Port sites located near [illegible] shorelines are bound to become obsolete quickly. Virtually any structure which interferes with water current flow has the potential for disturbing patterns of coastal deposition and erosion.

The environmental impact of major highway construction near the coast on deltaic sediments of [illegible] weight bearing capacity makes this type of activity questionable in [illegible] parts of [illegible]. The exact choice of road [illegible] should be an important element of [illegible]. Special strategies involving [illegible] may continue to be a more satisfactory solution than road construction in delta areas.

5. Stable resource use patterns

Man's choice of flood plains for settlement, agriculture and industrial development is as natural as the hazards attached their use. Both are likely to increase, particularly as continued economic and population growth accelerates the role of forest and land exploitations. There is a need to assess the risk attached to this

expansion. There is risk to long-term [illegible] system productivity and the stability of [illegible]. [illegible] the actual level of risk to individual resource [illegible], [illegible] perceive hazards, are important parts of ecological [illegible] results will have a good [illegible] management strategies [illegible] for land use. It is especially important to realize long-term implications of either planned or unplanned [illegible] in [illegible]. Once established, their presence [illegible] for environmental control [illegible] for production. These demands may, in fact, [illegible] alternative uses of the natural system. [illegible] of such demand and [illegible].

As an example involving intensification [illegible] the flood plain areas of the North Coast of Java. [illegible] are associated with water control, salt intrusion, [illegible] instability, and fish stock fluctuations. The introduction of trawlers, high-yielding rice varieties and the tendency to [illegible] monocultural create additional elements of risk since stability [illegible] declines although average yields may increase. [illegible] been the prolonged wereng infestation in Central Java, associated with the use of low resistance rice varieties. In [illegible] also owned brackishwater fish ponds were able to [illegible] by putting effort into increasing their production. [illegible] also created work opportunities for [illegible] declined in the rice areas affected by the disease. [illegible] similar stabilizing influence on work opportunities [illegible] live near tambak or [illegible] areas. [illegible] recognize the benefits of maintaining diversity of resources [illegible] employment opportunities. By recognizing [illegible] maintaining diversity, uses compatible with localized [illegible] are more likely to be preserved. [illegible] not be expanded into areas where [illegible] would be preserved for fish culture.

Is the deltaic coastal [illegible] hazard to individual resource [illegible] This question [illegible] determining priorities for new development, particularly [illegible] basin

[illegible]. Evidence from population [illegible] outside indicates lower population densities [illegible] rural areas.[19] Such differences can be [illegible] of either economic return or hazard by individual [illegible] assessment by community leaders of these factors. [illegible], may have its own peculiarities. For example, [illegible] irrigation areas near the Musi River, despite their proximity [illegible] to flooding, showed a greater [illegible] in both wet and dry season [illegible] local plain areas over a seven [illegible] period.[20] [illegible] avoid salt intrusion by cultivating only [illegible] forest. [illegible] photography. The [illegible] varies inversely with distance from the [illegible]. Study of response to risks such as this indicates [illegible] might proceed with adaptation to local environments.

Figure 1. [illegible]

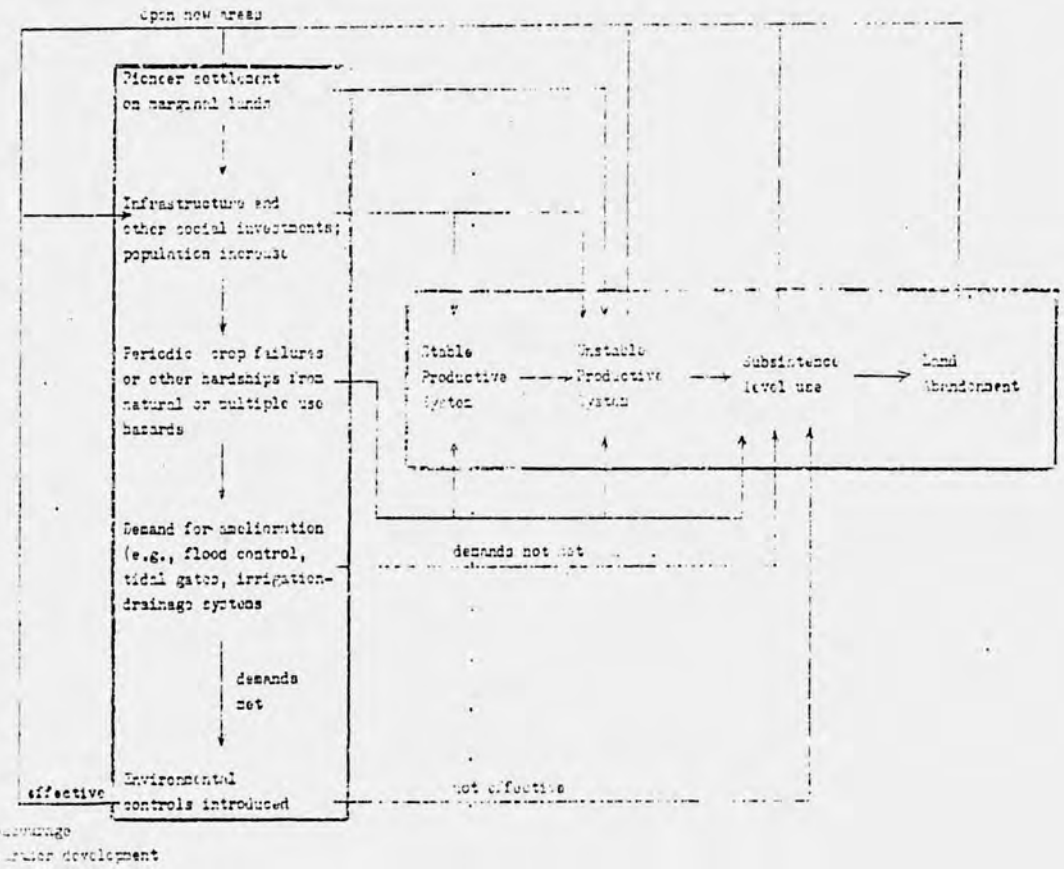
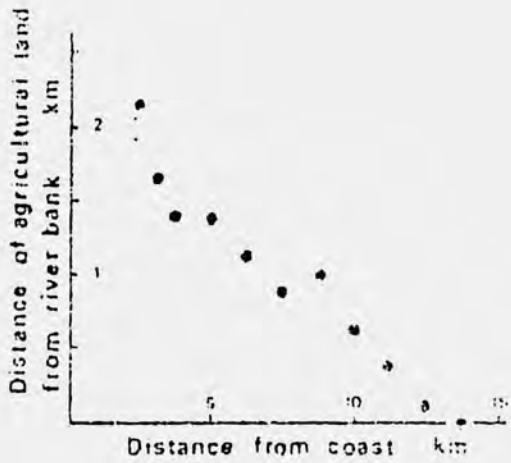
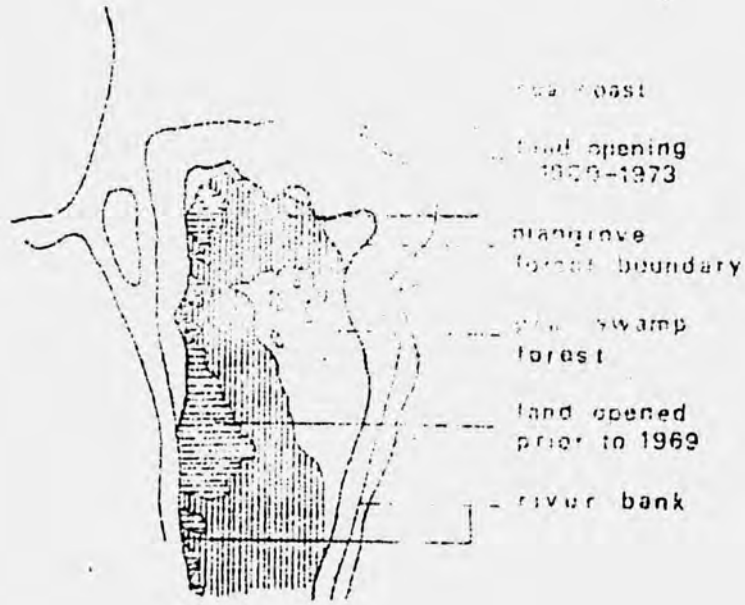

open new areas
Pioneer settlement on marginal lands
Infrastructure and other social investments; population increase
Periodic crop failures or other hardships from natural or multiple use hazards
Demand for amelioration (e.g., flood control, tidal gates, irrigation-drainage systems
demands not met
Environmental controls introduced
effective
Stable Productive System
Unstable Productive System
Subsistence level use
Land Abandonment
demands not met
not effective

Figure 2. Relationship of Upang delta land development by Chinese agriculturists to environmental factors associated with salt intrusion hazard.





Small Island Clusters

Isolated small islands clusters will never be viewed with the same potential for resource development as the much larger delta-estuary complexes described above. As a structurally-complex substrate in the otherwise relatively formless ocean habitat they create a situation which promotes species diversification[21] and act as a filter to capture ocean water nutrients for maintaining the complexity of the environment and coincidentally providing a home and food for man. Islands formed primarily from reef deposits usually have a simple land system supported by a complex underwater bio-geological complex--the coral reef and flats filled by the remains of calcareous plants. The best studied example in Indonesia is the Thousand Islands of Jakarta Bay[22]. Volcanic islands form a related kind of island ecosystem, generally more complex in structure; and modified by coral reef development[23]. Sea level fluctuations and tectonics are major contributors to present island landscapes. The role of current fluctuations in shifting sedimentary island masses is important[24].

The origins and basic characteristics of small island complexes are reasonably well understood in many areas of the world. Clearly defined management strategies are the exception rather than the rule. Part of the problem is the failure to take a habitat-protection viewpoint. When the reef disappears for road construction materials, or to open harbor areas or through pollution, structural diversity and physical protection are both lost for the island. The efficiency with which nutrients are fixed from the constantly renewed ocean water column declines and the habitat for fish is no longer so great. Strategies to explore the possibilities of using, or even artificially creating, upwelling near tropical island areas have only recently begun to emerge. Human settlement, and resource use patterns, because of, isolation and low carrying capacity of the land, often become very specialized. An appreciation of the diversity is an important element of management. Some of the long term implications of resource use and settlement patterns are discussed below. Much of what is discussed would hold for lagoons and reef complexes associated with large land masses as well.

CAS

1. Resource use land conservation implications

Fishing and simple agricultural practices are the major resource uses in small island areas. Three problems must be considered in fisheries development. One is the apparent attraction of some migratory fish stocks to islands. The classic example in Indonesia is the milkfish (Chanos chanos). Abundant fry needed for tambak pond stocking are taken from small island complexes in some abundance. Shrimp and tuna migrate to island areas as feeding grounds. In Barbados the flying fish migratory pattern seems linked to upwelling processes. Understanding the dynamics of exploited species such as these is a problem of considerable dimension since the fish may be harvested in more than one spot. The local people may be indifferent to conservation measures unless they have a share in the catch. A second problem is the artisanal fisheries associated directly with the reef. The crude catching methods and other factors which cause destruction of habitat are more likely to be the cause of stock declines than ever fishing per se[25]. The third problem is related to the isolation of islands from markets. Lower-value fishery products will not move from the area since transportation costs are high and storage generally poor. From a development perspective the best opportunities will be for high value mariculture products : turtle-rearing, seaweed culture, pearls, cage culture of high value fish. The possibility of industrial supply of sea salt from coastal salt pans represents another kind of opportunity which could be some part of an integrated mariculture complex. Conservation-oriented policy to prevent habitat destruction and to completely preserve the more [illegible] marine areas as reserves is needed.

2. Human settlement patterns

Because freshwater supply is limited and soil characteristics are poor the role of annual plant crop agriculture is limited. Estate crop introduction (especially coconuts) should be a part of a management strategy. From an ecological perspective the simple land systems should be relatively simple to manage. The possibility of damage from introduced pests is a hazard since indigenous control organisms are not likely to be found. Invading species can quickly reach epidemic levels[26].

The evolution of distinctive cultural [illegible] from isolating mechanisms. Small islands, although [illegible] boat commerce, are such a mechanism. [illegible] are distinctive reflecting need for local [illegible] and environment limitations. The [illegible] probably has kept many island systems [illegible] capacity. This is no longer the case. Consequently [illegible] keep population in balance with resource availability.

3. Monitoring change

The lack of ecological knowledge concerning [illegible] marine resource development is a serious constraint for management of small island complexes in Indonesia. There is a [illegible] to protect the habitats for uses which may [illegible] years time, as, for example, tropical mariculture, [illegible]. It is important to develop a monitoring system based on physical, biological [illegible] parameters sensitive to various detrimental effects of [illegible] change in these areas. Such a program should [illegible] scale port, urban, or industrial complex.

Incorporating Ecological Information into Decision-Making Processes

The two ecosystem types discussed above provide examples of the scale needed for environmental management units in the coastal zone. They form a physical matrix in which more sectorally-oriented programs can be developed. They are usually not coterminous with [illegible] boundaries used in planning and administration. When regional planning covers a whole geographic unit such as now occurs in Indonesia, it becomes feasible to consider developing a strategy for [illegible] plan. It is also reasonable to consider CZM at more localized units of government. The outputs from the planning process should include land and water use zoning; priorities for locating industry and [illegible]; an environmental inventory of the coastal zone; an understanding of interactions between the system components; and any serious constraints on use. It is also, of course, important to clearly perceive what are the desired uses of the coastal zone. These are likely to differ from location to location and over time.

A sequential process towards planning for [illegible] has been suggested[27]: (1) Determine man's desires in using the coastal zone; (2) Determine capacity of the coastal zone in relationship to these desires; (3) Determine what uses are compatible with capacities and how various uses impact the natural coastal zone system; (4) Determine what the trade-offs must be if capabilities and uses are not matched; (5) Determine how the need for capacity match can be communicated to the public; (6) Determine what mechanisms are necessary and possible to regulate and promote compatible uses.

A major initial need is to develop a sense of [illegible] capabilities. Brahtz[28] has suggested five categories: essential, supplemental, mutually exclusive, competitive and indeterminant. Various matrix representations are possible to define the degree of use interactions[29]. As a method of presenting a summary of the ecosystem and uses constraints such graphical representations are useful. They also form the first stage for quantitative analysis of ecosystems.

Determining trade-offs where incompatabilities exist is often difficult since natural ecosystems have many intangible value and sometimes few direct monetary returns. The development of biological resource based activities in the coastal zone is one important way ground this problem. For example, on the North Coast of Java because there are brackishwater fish ponds it is possible to assign substantial economic value to this habitat which in its original form might be considered wasteland in many parts of the world. It is up to the ecologist to ensure that the interconnections between systems (eg migratory species habits) are known and understood by the planners who prepare feasibility studies or conduct project evaluations.

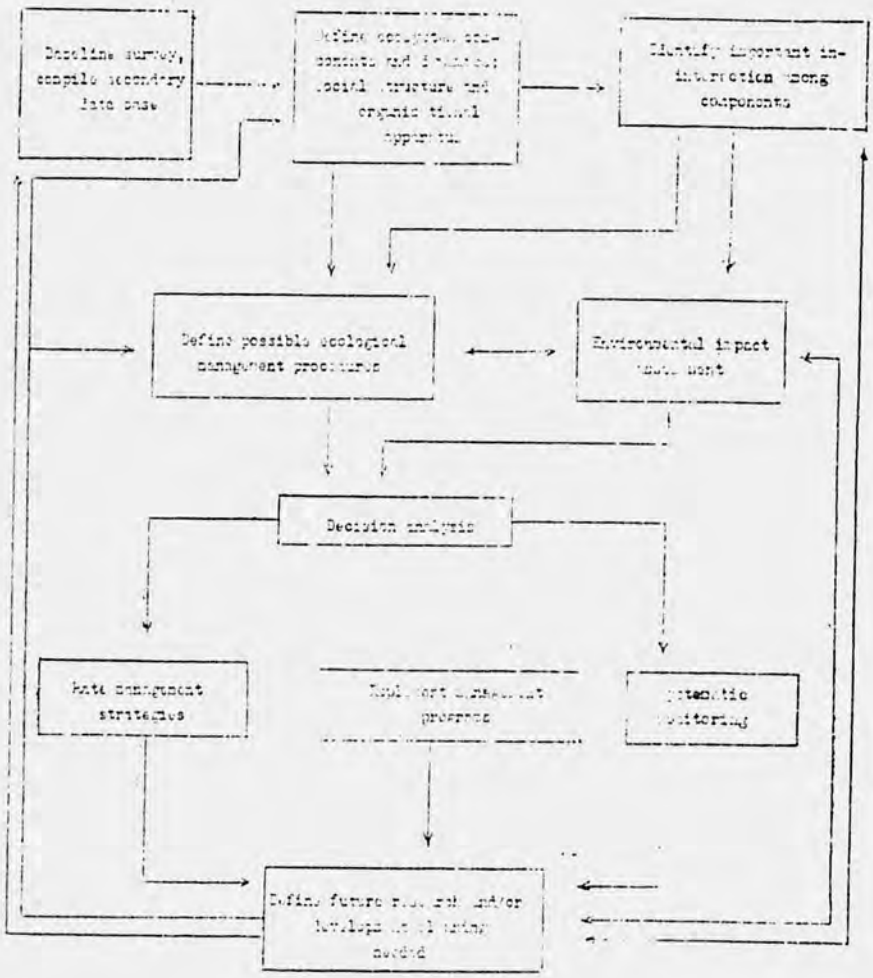
Much of the actual implementation of change in the coastal zone of Indonesia is likely to occur via development projects carried out by government agencies, or by public or private corporations. This reduces the problem of management somewhat since it provides a definitive contact point for regulation, or environmental management input. There are two major approaches which should be carried out for effective ecological input into management. The first is the environmental impact assessment approach. As a first stage endeavour environmental impact assessment is important since it can clarify the nature of problems. The ecological

input should not be a one-time effort. Environmental impact assessment should be long-term, incorporating resource inventories, baseline and monitoring studies. The second approach is to develop a focus of natural resource management in which institutional studies, long-term ecological research and socio-economic analysis are all [illegible]. Together these two approaches form a base for environmental input to [illegible] the coastal zone. The stages and [illegible] in this [illegible] environmental management scheme are shown in Figure 5.

Conclusion

Hopefully this introduction will provide [illegible] detailed consideration of case studies drawn from the [illegible] ecological units of the coastal zone and the sectoral approaches which are likely to lead to development in the coastal zone. There is need for more dialogue between the regional planners, who often produce averages without appreciating diversity and extremes and the environmentalist who, when they are lucky and skilled enough to discover critical variables, fail to communicate their information to decision-makers. Finally, it should be an important goal of the meeting to examine CZM within the framework of present institutional structure. There are multiple channels through which management inputs need to [illegible] generally unaware of how this can be done.

Figure 5. An approach to environmental analysis for planning and management.



11. A useful guide to technical solutions are the proceedings of the regional symposium on flood control, reclamation, utilization and development of delta areas. [illegible] Water Resource Series. Also, see Chapter 9 in Drainage of Agricultural Lands, Division of Soil Conservation Service, U.S. Dept. of Agriculture, Soil Conservation Service, Fort Huntington, New York. 1973.

12. See recent advances at IRRI in breeding for deepwater varieties of rice, Bangladesh symposium 1977.

13. See various articles in Ahmed, K.U. et al. (note 1). Also, Fish and the Mekong project. 1970. Mekong Secretariat; Sukkum, J.R. 1966. The role of estuaries in the development and perpetuation of commercial shrimp resources. Ann. Biol. Ser. Ap. Publ. 3 : 10 - 30; Mohamed, K.H. and P.V. Rao 1971. Estuarine phase in the life-history of the commercial prawns of the west coast of India. J. Mar. Biol. Assoc. of India 13 (2) : 149 - 161; Martosubroto, P. dan A. Sudhanajat 1973. Ekologi dan Perikanan di Cimanuk Muara. LPPL.

14. IBRD irrigation rehabilitation project reports. 1980 ff. Directorate General of Water Resources Development, Jakarta.

15. Examples are seen in many areas of Java, for example in Jakarta Bay (Verstappen, H.T. 1953. Djakarta bay. A geomorphological study of shoreline development. Drukkerij Trio, 's-Gravenhage), Indramayu delta (Hanamura, Y.D., Japri Hutabarat dan Siti Djoharah. 1975. Sedimentasi Tepi Baru Cimanuk. Lembaga Geologi dan Pertambangan Nasional, Bandung).

16. Obdeyn, V. 1941. Zuid Sumatra volgens de oudste berichten. 1. De Geomorfologische gesteldheid van Zuid Sumatra in verband de opvulling der meren. Tijdschr. K. Ned. Aardrijksk Genoot 58 : 190 - 214.

17. The reclamation of land in Segara Anakan estuary is [illegible] to occur. A healthy fish and shrimp fisheries would likely be destroyed. See feasibility plans for Citanduy project. Directorate-General of Water Resources Development.

18. Personal communication from members of joint [illegible] study team in Kerinci.

19. Tambak areas generally support fewer people than corresponding rice culture areas.

20. See Bagian Laporan survei ekologi Delta Upang-Banyuasin. Bagian IV. Tata Survei Ekologi IPB. Proyek Pendidikan dan Penelitian Lingkungan.

21. N.D. Newell has examined the question of why the present reefs of the Indo-Pacific area have some many plant and animal species compared to other tropical areas (i.e., Caribbean). He correlates the diversity with the more extensive area of habitat found in the Indo-Pacific. As well, the high diversity compared to temperate regions is likely the result of an accumulation of relict species. (Newell, N.D. 1971. An outline history of tropical organic reefs, American Museum Novitates. No. 2465. 39 pp.)

22. See Verstappen 1953 cited above; Umbgrove, J.H.F. 1947. Coral reefs of the East Indies. Bull. American Assoc. of Petroleum Geologists 2[illegible] : [illegible] - 7[illegible].

23. Shepard, F.P. Submarine geology. Harper and Row, New York. Third edition; Wiens, H.J. 1962. Atoll environment and ecology. Yale University Press, New Haven. 5[illegible]2 pp.

24. Verwey, J. 1931. Coral reef studies III. Geomorphological notes on the coral reefs of Batavia Bay. Treubia XIII.

25. Johannes, R.E. paper on coral reef pollution in FAO Symposium on marine pollution. Fishing News Books.

26. Mac Arthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton University; Carlquist, S. 1965. Island life. Natural History Press. 451 pp.

27. Ketchum, B. 197[illegible]. Water's Edge: Critical problems of the Coastal Zone. MIT Press, Massachusetts; see also J. Clark 1974. Coastal ecosystems. Ecological considerations for management of the coastal zone. The Conservation Foundation, Washington, D.C.; National Estuarine Pollution Study, U.S. Congress 1969.

28. Braktz. Coastal zone management.

29. see example for Jakarta Bay in Hanson, [illegible]. 197[illegible]. [illegible] studi-studi yang integral tentang laut-laut Bahasia. Seminar Laut Nasional, [illegible].