

The State of Seagrass Ecosystems and Resources in the Philippines

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INTRODUCTION

A major ecosystem threatened by the multiplicity of demands upon the coastal habitat in the tropical region is the seagrass ecosystem. In the ASEAN region, over 70% of its total population inhabit the coastal zone. Very recently, this area of the marine environment is characterized by a high degree of resource exploitation, raising serious doubts as to its capacity for biological sustainability and normal recovery within this generation.

The islandic nature of the Philippines partly dictates that many population centers be developed around sheltered bays and estuaries, the very places colonized by seagrasses. Because these plants thrive in relatively shallow waters, they are subject to increasing stresses caused by man and his diversified needs. It is not surprising, therefore, to see seagrass beds being filled, dredged and diked for conversion to other coastal uses. These activities of man need to be looked at from the conservation and management points of view.

This paper presents the status and importance of seagrass ecosystems in the Philippines, reviews the problems and issues associated with their conservation and protection and emphasizes their susceptibility and vulnerability in the face of our rapidly deteriorating marine environment. In addition, this paper introduces the potentials of seagrass in restoring degraded coastal habitats and proposes an agenda for action in order to manage the ecosystems and their resources.

Seagrasses: Definition, Systematics and General Distribution

Seagrasses are hydrophytic monocotyledonous plants that are completely adapted to the marine environment. They resemble

true terrestrial grasses in possessing features common in their life history, i.e., rhizomes, which are buried in soft, sandy or muddy bottom, and erect leafy shoots in the water. They, however, comprise only about 50 species falling into 2 families and 13 genera. Family Potamogetonaceae consists of 10 genera and 39 species; family Hydrocharitaceae consists of 3 genera and 11 species.

Sixteen taxa of seagrasses have been identified from the Philippines (Fortes 1986a), of which three are new to the local seagrass flora: (1) an undescribed species of *Halophila*; (2) a new variety of *H. minor*; and (3) *Ruppia maritima* var. *rostrata*. *H. ovalis*, *Enhalus acoroides*, *Cymodocea serrulata*, *Halodule uninervis* and *H. pinifolia* exhibited intraspecific morphological and physiological plasticities that appeared to be generalized adaptive responses to local habitat conditions. *Halophila beccarii* and *R. maritima* var. *rostrata* were found only in brackishwaters, while *H. decipiens* and *Thalassodendron ciliatum* appeared confined to deeper waters of the western and southern parts of the archipelago. Three zones in local seagrass communities are recognizable: (1) Zone 1 (*Halodule uninervis*, HUN, Zone); (2) Zone 2 (*Halophila* - *H. uninervis*, HUW, Zone); and (3) 3 (*Thalassia* - *Cymodocea* - *Enhalus* Zone).

In relation to the Philippine seagrass flora, hierarchical (cluster) analysis partitioned the Indo-West Pacific seagrass ranges into seven discrete provinces (Fortes 1986a). A high probability exists that *Halophila*, due to its wide distribution from Tasmania to Japan, represents a major connection between most of these provinces, strongly influencing the clustering of the seagrass floras in the region. The phytogeographic affinities of the Philippine seagrass flora is primarily to the west with the Indian Ocean and Southeast Asian coasts.

Functions and Uses of Seagrasses

The small number of seagrasses is not proportional to their ecological and economic importance. Seagrasses, due largely to their enormous quantities, form dense beds which cover large areas in the coastal waters. They perform a wide spectrum of biological and physical functions in the marine environment. These functions, summarized by Wood et al. (1969) and den Hartog (1977), include substrate stabilization, sediment production, habitat and nursery for fish and many invertebrates, primary food source for fish, turtles, dugongs and invertebrates such as echinoderms, and an alternative feeding site for commercial and

forage organisms. As a discrete ecosystem, seagrass beds interact physically with coral reefs and mangroves in the reduction of water energy, sediment relationships and flow regulation (UNESCO 1983). Seagrass systems tend to "leak" or export nutrients to nearby ecosystem.

It was Petersen (1891, 1918) who first evaluated the contribution of seagrasses to the coastal ecosystem via its fisheries. McRoy and McMillan (1977) showed that seagrass productivity was as high as those of the world's best agricultural crops and this production was done without energy subsidies. Despite this high productivity, there are very few organisms which actually directly consume them.

The distribution of seagrasses within coastal areas dictates the kind of grazers that are associated with them. Vertebrates such as parrotfishes (Scaridae), surgeonfishes (Acanthuridae), green turtles and sirenians, are the main consumers in the tropics (McRoy and Helfferich 1980). Alcalá (1986 personal communication) observed that rabbitfishes (Siganidae) were also important grazers in local seagrass beds. In the more temperate regions, geese and ducks are the main consumers. Among the invertebrates, sea urchins are the main grazers, although they reportedly possess no enzymes that could digest the plant materials efficiently. Hence, only a small amount of energy stored in seagrasses is transferred to the next upper level in the trophic hierarchy.

Seagrass beds form a community frame that controls the structure of communities. The well-known catastrophic effects of the "wasting disease" of *Zostera* beds along the coasts of the North Atlantic in the early 1930s attest to the fundamental ecological importance of the eelgrass community. Not only were the structure and composition of the associated flora and fauna altered, but regimes in salinity, temperature and the nutrient load in affected coastal waters were also changed drastically. Fishery production declined and an almost complete reorientation in fisheries strategies had to be effected. It was primarily this ecological catastrophe which triggered renewed and significant research activities on seagrasses in most parts of the world.

The role of seagrasses at the ecosystem level is matched by their importance at the component level. McRoy and Helfferich (1980) considered their use under two time categories: historical and contemporary. The first category includes their use as materials for woven baskets by North American Indians; as source of salt, soda and warmth; in coastal Denmark, as stuffing for mattresses and bed ticks and as substitute for animal straw, roof

thatch, upholstery material, as packing and stuffing material and as a component for fertilizer; in the U.S., as insulation for sound and temperature; and in Germany, as a substitute for cotton in the manufacture of nitrocellulose (Cottam 1934) or simply pressed into bales for shipment to manufacturers who derive products from them (Scagel 1961). Soviet workers considered the commercial potentials of seagrass fibers (Anonymous 1967). The Dutch built sturdy and durable dikes from eelgrass when bricks and concrete were not yet available. The Danes made cigars from eelgrass leaves. The Seri Indians used seagrasses in the making of children's toys.

The contemporary direct use of seagrasses is related to their ability to trap and bind sediments and organic material. Hence, they are used in the filtration of sewage (McConnaughey 1975) and stabilization of coastlines (Boone and Hoepell 1976). They are potential sources of useful chemicals (Ovodova et al. 1968; Paimieva 1973; Dudkin et al. 1975), raw materials in paper making (Leopold and Marton 1974), fertilizer (van Breedveld 1966) and fodder (Bauersfeld et al. 1969). Some seagrasses are used for direct human consumption that Ehrlich and Ehrlich (1970) postulated the utilization of seagrasses and the future development of "high yield strains of salt-tolerant terrestrial grasses" to solve the world food problems. There is a great potential for the seagrasses *Enhalus acoroides* and *Thalassia hemprichii* as sources of fodder and fertilizer. Crude protein levels from their leaves reach as high as 23% of dry weight (Fortes 1986b), comparatively higher than those of most terrestrial forage grasses. Low percentages of six-month-old seagrass leaf composts, when mixed with garden soil, appear helpful in the faster growth, better pod fecundity and higher leaf chlorophyll content in mungbeans (Bautista 1987).

THE NEED TO STUDY THE SEAGRASS ECOSYSTEMS IN THE PHILIPPINES

From the viewpoint of productivity, coastal production and their varied roles, the presence of extensive seagrass meadows is favorable and studies on our local seagrasses are most desirable. A greater portion of the Philippine population is living adjacent to coastal waters or to the shores of estuaries. It is almost certain that this percentage will increase in the coming years. As this increase continues, so will the multiplicity of

demands upon the marine environment mainly as producers of food, avenues of transportation, receptacles of wastes, living space and sources of recreational and aesthetic pleasure. Indeed it is no wonder that seagrass beds are being diked, filled, dredged and converted to other coastal uses. At this point, it is imperative that we first know the seagrass resources we have, their role and contribution to coastal stability and productivity. A synthesis of this knowledge is essential for a wise, predictive management of these resources. Only when this knowledge is available can we derive maximum benefits from these nearshore ecosystems.

REVIEW OF LOCAL SEAGRASS LITERATURE: 1819-1991

Despite the high diversity and abundance of seagrasses in Philippine waters, very few papers have been published on the local species. Available records resulted mainly from unsystematic taxonomic accounts done discontinuously from 1819 to 1965. The earliest records date back to the collection of *Cymodocea serrulata* and *Enhalus acoroides* made by Perrottet in 1819 (cited by den Hartog 1970). Blanco (1837) reported *Vallisneria spiralis* (= *Enhalus acoroides*) from Zambales and the same species was reported by Merrill (1918) from Palawan. Ostenfeld (1909) recorded *Halophila ovata* (= *H. minor*) based on Merrill's collection from Manila Bay. Mendoza and del Rosario (1967) included some seagrasses in their vascular plant compendia.

More collections were made in the early and mid-1900s, but these were primarily incidental accounts on the seagrasses accompanying the seaweeds, which were the main objects of the collections. Pascasio and Santos (1930) did a critical morphological study of *Thalassia hemprichii*, and Domantay (1962) reported eight species from the Hundred Islands in Pangasinan. The "collection" type of study on Philippine seagrasses culminated in 1965 with that made by Doty and Alvarez from the Visayan region.

The subsequent records on local seagrasses started with the find of *Thalassia* from Sipalay, Negros Occidental (Fortes 1977). Calumpang (1979) reported some seagrasses from Negros Oriental. Cordero (1981) illustrated, but with the names erroneously interchanged, three common species of seagrasses. Fortes (1981) made the first local taxonomic and distributional study of algal epiphytes on the leaves of *E. acoroides*. In addition, he (1984) reported *Halophila decipiens* from Zamboanga del Sur. The paper of Menez et al. (1983) represents the most compre-

hensive taxonomic and distributional account of the country's seagrasses. However, it was primarily based on the monograph of den Hartog (1970) and old herbarium materials were used in the description of some of the species. In a more recent work, Calumpong et al. (1985) described the taxonomy and distribution of seagrasses from Davao Gulf.

With the exception of the distributional aspects of the local studies, no other works on Philippine seagrasses could be considered truly ecological. However, Fortes (1981) made the first account on the structure and productivity of the epiphytic community on *Enhalus* leaves at Calatagan, Batangas. He (1982) made a preliminary assessment of the organic matter contributions of dominant producer communities including *E. acoroides* at the same time. A joint Philippine-U.S. research project dealing with the distribution, biomass and taxonomy of Philippine seagrasses was concluded in 1985. In Bolinao, Pangasinan, the first ecological assessment and transplant study in the Philippines involving seagrasses has been conducted (Fortes 1984). This activity has been extended to rehabilitate degraded coastal areas in Puerto Galera, Marinduque, Bataan and Manila Bay. Two completed research projects looked into the identification and seasonality of some chemical constituents in *Thalassia hemprichii*, *Cymodocea rotundata* and *Enhalus acoroides*.

A significant contribution to our knowledge of Asian seagrasses was made by Fortes (1986a) who completed a doctoral dissertation on the taxonomy and ecology of Philippine species. In 1987, the first National Conference on Seagrass Management, Research and Development was held, mainly as an offshoot of a resurging interest and awareness on the importance and role of seagrasses in tropical coastal resource management.

The more recently published contributions to local seagrass literature include those of Estacion and Fortes (1988) on the growth rates and production of *Enhalus acoroides*; Fortes (1988a) on the Indo-West Pacific affinities of the local flora; and Fortes (1988b), on the stresses on seagrass ecosystems in the East Asian region. Fortes (1989) came up with a primer on the importance, status and management perspectives of seagrasses in the ASEAN region.

The latest update on Philippine seagrasses is composed of works that focus on their structural affinities (Rollon and Fortes 1991), associated fish fauna (Vergara and Fortes 1991) and on the management of the resources (Fortes 1990; 1991). Few other works now in press deal with the secondary productivity

and feeding energetics of seagrass-associated fish and invertebrates in Cape Bolinao.

BIOLOGY AND ECOLOGY OF PHILIPPINE SEAGRASSES

Although very little is known about the biology and ecology of Philippine seagrasses, there is a practical need to consider incorporating all available scientific findings into their management. Information on the period of flowering and fruiting, adaptations to different habitat conditions and factors controlling their distribution, abundance and production, are important considerations if one is to derive maximum economic benefits from these plant resources. The general favorability of Philippine coastal conditions for seagrass growth and development is reflected partly in the high diversity of the seagrass flora recorded in the country. This diversity results directly from the varied responses of the species to specific environmental conditions that prevail along its coasts. These biological and ecological responses are the key to their sustained abundance, which, from the point of view of a coastal dweller, is a requisite to their full economic potential as a renewable resource for coastal populations.

Flowering, Fruiting and Adaptations

Little is known about the phenology (i.e., timing of biological events, such as flowering, fruiting, seed dispersal, etc.) of seagrasses in the Philippines. In Puerto Galera, Oriental Mindoro, seed germination in *E. acoroides* generally commences in August when daylight hours are short and mean water temperature is low (Fortes 1986a). During this month, rainfall is high, and there is an average twofold increase in the amount of time the plants are exposed to air and sun. Rapid vegetative growth and increase in biomass immediately follow, with a peak in October, lasting till December, when temperature, tidal exposure and rainfall reach even higher levels.

Flowering in *E. acoroides* is generally initiated in late April and continues until late August. This process is directly related to progressions in daylength, temperature and rainfall. On the other hand, growth, biomass and production in the species are inversely related to such progressions. Fruiting occurs at the latter half of the flowering period, with a peak in July when daylength and rainfall have their highest values.

The general form of a seagrass is in itself the most remarkable features which adapts the plant to its environment. Grasslike

leaves and an extensive root and rhizome system enable it to withstand the impacts of waves, tides and shifting sediments in the shallow coastal habitat. However, certain species-specific features have evolved, which make each plant unique, adapting it to prevailing factors of its environment. These survival strategies, at least under Philippine conditions, are achieved through morphological, physiological and behavioral adaptations.

Morphological plasticity is evident in four species, namely, *Halophila ovalis*, *E. acoroides*, *C. serrulata*, and *Halodule uninervis*. *H. ovalis* shows five different foliar forms (ecomorphs) which vary markedly in size and shape of the leaves. It is known that smaller-leaved varieties of seagrass species are more abundant in areas frequently subjected to higher temperatures (McMillan 1984).

In *E. acoroides*, form adaptation is observable in two types of population: short, thin-leaved plants comprising sparser populations of shallow open reef; and long, thick-leaved plants comprising denser populations of deeper protected coves. This variability appears to be a nutrient effect brought about partly by topography.

In *C. serrulata*, the two morphological variants are differentiated by the presence or absence of the long, leaf-bearing branches. Johnstone (1982) suggested that stem length in the species was correlated with the degree of water movement. McMillan (1982), on the other hand, postulated that stem length was the result of a selective process in habitats differing in sediment type and/or depth of submergence, or an adaptation to low or high light conditions. These conditions appear as the most probable causal factors as far as data from northern Philippines are concerned. Poiner (personal communication 1986), from his observations on *C. serrulata* and *S. isoetifolium*, hypothesized that "abnormal" elongation of the stem might be a response to crowding and space competition. The three modifications in the leaf forms of *H. uninervis* (i.e., narrow-, wide-, and intermediate-leaf varieties) appear to be a specific response of the species to the nutrient and depth status of the local environment.

In each species, *E. acoroides*, *C. serrulata*, *H. pinifolia* and *Halophila minor*, two genotype variants are present, each with its own set of unique environmental tolerances: *stenobiontic*, or that variant exhibiting narrow tolerances along gradients in daylength, tides, rainfall and temperature; and *eurybiontic*, that exhibiting wide tolerances to gradients of these factors. It appears that the eurybiontic character, as well as the annual habit, reside in the

narrow, thin-leaved, sparser *E. acoroides* populations occupying the intertidal portions of open reefs. The stenobiotic character as well as the perennial habit, on the other hand, reside in the wide, thick-leaved, denser populations occupying subtidal habitats and protected embayments.

In many coastal parts of the country, anoxia (i.e., very low oxygen condition) often characterizes portions of shallow intertidal habitats as a result of tidal and wind conditions. Such features prevail during summer when water movement is almost negligible, elevating the daily ambient water temperature to abnormally high levels. Under such conditions, seagrasses are overgrown by thick mats of senescent and rapidly decomposing bluegreen or green algae. Consequently, the sediment becomes highly reducing and acidic, indicated by the smell of hydrogen sulfide gas when the plants are uprooted. Even under such conditions, however, *T. hemprichii*, *E. acoroides* and *C. rotundata* grow and develop optimally due to an apparent adaptive metabolic strategy, which enables them to colonize successfully such shallow-water marine habitats that have excluded most other plant groups. Interestingly, it is in these habitats where highest levels in crude protein from the seagrasses have been recorded (Fortes 1986b).

Seagrass Abundance, Biomass and Production

The seasonal abundance of local seagrasses is generally bimodal, with highest values in summer (March-May) and in the wet season (July-November) (Fortes 1986a). Biomass, on the other hand, is highest from June - November. Highest biomass value (61.7 gm organic matter per m²) was obtained from *E. acoroides*. Net production in the species was 1.4 gm carbon per day, while its growth rate average was 1.1 cm per day. The recorded mean turnover time in *E. acoroides* is 115 days, which means that the whole leaf biomass is produced after every 16 weeks, forming 2-4 leaf crops annually. For management purposes, these data suggest a year-round supply of organic matter by the seagrass. The maximum rate of 2.41 cm per day obtained in the species at Bolinao is the highest value so far recorded from the Indo-Pacific region.

Seagrass density is directly associated with water temperature conditions. In the Philippines, *T. hemprichii* has the widest range of temperature tolerance. In terms of biomass, however, daylength appears to be the most influential factor, while the number of lowest low tides during daytime plays a primary

negative effect on seagrass abundance, biomass, growth rate and production. This is related to the desiccation factor, which affects plant vigor and vegetative reproduction. Generally, salinity and rainfall are ineffective in directly controlling the above features in local seagrasses.

It is probable that daylength, maximum temperature and rainfall, interacting independently or in combination, make up the critical and primary environmental cues that control the reproductive periodicity, abundance and production of *E. acoroides* in the area. This information would be useful in solidifying the ecological basis of seagrass management in tropical coastal areas.

Seagrasses in Philippine Coastal Food Chains

In the Philippines, the trophic hierarchy involved in the processing and transport of organic detritus from seagrass ecosystems to consumers appears rather intricate. Actual observations, surveys and simple experiments indicate that detritivores, herbivores, carnivores and omnivores are all well represented (Fig. 1). However, at this stage of our knowledge on seagrass ecology, our understanding of their relationships is based primarily on qualitative data. Many linkages within the trophic structure remain vague, unquantified or largely unknown.

Organic material in seagrass ecosystems primarily comes from production by the seagrasses themselves. However, contribution from the associated epiphytes and macrobenthic algae (Fortes 1981; 1986a), as well as organic matter from outside the system, i.e., phytoplankton and terrestrial plants, may sometimes be significant. The organic materials are utilized by the fauna either through grazing of the living plant tissues or consumption of the detritus. It is still not known which of these two pathways is more important under local conditions, since the initial linkages between plant production and animal consumption are based largely on direct observation of feeding behavior in the field and, to a very limited extent, under laboratory conditions.

SEAGRASS ECOSYSTEM COMPONENTS AND THEIR USES

A high diversity of plants and animals resides in Philippine seagrass beds. This is due in large measure, to the rich nutrient pool and the high diversity of physical structures that protect juveniles from predation. A large percentage of these biotic components are commercially important. At the component

level, fish and shrimp are probably the most important among these groups, although some coastal villages derive portions of their sustenance from other components of the grass beds. At the ecosystem level, a number of uses and potentials have been associated with the beds. In this paper, only the major components of seagrass beds contributing substantially to the coastal economy of the country, as well as those with important implications concerning conservation, will be mentioned, i. e., benthic seaweeds, epibenthic invertebrates, fish and reptiles and mammals. In addition, some of the ecosystem uses of the habitat will be presented as a strong justification for its total management and conservation.

Benthic seaweeds - Although few seaweeds grow in seagrass beds, they exhibit great abundance and are harvested either as food (e. g., *Enteromorpha* spp., *Ulva* spp., *Caulerpa* spp.) or as a rich source of chemicals for industries (e. g., *Gracilaria* spp., *Gelidiella acerosa*, *Sargassum* spp., and *Eucheuma* spp). It is of interest that the three largest seaweed-producing countries in the ASEAN region (Philippines, Thailand, Indonesia) produce at least 100,000 tons of dried raw seaweeds worth about US \$30 million annually (Rabanal and Trono 1983). The primary components of the harvest are farmed *Eucheuma* and *Caulerpa*, and natural stocks of *Gelidiella* and *Sargassum*.

Epibenthic Invertebrates - This group is composed of shrimps, sea cucumbers, sea urchins, crabs, scallops, mussels, and snails. Shrimp production in the Philippines was 55,700 tons in 1982 (FAO Statistics 1983). This production is directly associated with seagrass beds since it is known that shrimps spend the early stages of their life-history in these areas. Vergara and Fortes (in press) found that of the 1,491 taxa trawled from seagrass beds, fish comprised 28.6% and shrimps, 71.4%.

In Bais Bay, Southern Philippines, the edible mollusks harvested by fishermen yield 69 kg wet weight per hectare of seagrass beds (Alcala and Alcazar 1984). In the same Bay, Alcala (1979) reported that about 1,000 - 2,000 kg of the eggs of the sea hare, *Dolabella auricularia*, valued at US \$228-456, were gathered annually.

Coastal inhabitants of the Philippines gather sea urchins, sea cucumbers and other echinoderms from seagrass beds, mainly as supplement to their daily nutrition and income. Gonads from the urchins are usually eaten raw with vinegar, serving as the "caviar" of the coastal Third World. Marketable crabs (*Portunus pelagicus*

and *Scylla serrata*) are frequently caught by trawls in seagrass beds. Scallops and mussels are more common in muddy protected coves where seagrasses and mangroves abound.

Fish - The economic usefulness of a seagrass bed rests primarily on the fisheries it supports. In developing countries, coral reefs with their associated seagrasses potentially could supply more than 20% of the fish catch (McManus 1988). A total of 1,384 individuals and 55 species from 25 fish families have been identified from 5 seagrass sites in the Philippines (Vergara and Fortes, in press). All members of these families have economic values mostly as food and aquarium specimens. Estacion and Alcala (1986) reported adults of about 52 fish species from 31 families from seagrass beds in Central Philippines. Carangids, clupeids, lutjanids and scarids, all amply represented in the catch, are popular food fishes. At least 123 fish species representing 51 families have so far been reported from both natural and artificial seagrass beds in the Philippines (Fortes, unpublished report). All the species have known economic uses.

Reptiles and Mammals - Some endangered species of reptiles and mammals have been reported in Philippine seagrass areas. Among these species, the green sea turtle (*Chelonia mydas*), the olive ridley (*Lepidochelys olivacea*), the loggerhead (*Caretta caretta*) and the flatback (*Chelonia depressa*), together with the wart snake (*Acrochordus granulatus*) are frequently found in dense seagrass meadows (IUCN/UNEP 1985). Sea turtles at the Turtle Islands off Sulu Sea include seagrasses in their daily diets (Estacion and Alcala 1986). The sea cow (*Dugong dugon*), a mammal considered an endangered species throughout its range in the region, feeds directly on seagrasses, especially *Cymodocea* and *Thalassia*.

At the ecosystem level, seagrass beds have the potential to filter sewage, thereby reducing the threat from pollution which would otherwise affect the components of both coral reefs and mangroves. Seagrasses are biotic heavy metal reservoirs or sinks in the marine environment (Wahbeh 1984). But unlike the abiotic sediments, which also act as heavy metal sinks, the seagrass bed may remobilize and transport these elements to higher trophic levels in the food chain (Burrell and Schubel 1977). The habitat is also known to stabilize the coast mainly due to its ability to trap sediments via the extensive mats of root and rhizome systems.

Actual observations and simple experiments indicate that detritivores, herbivores, carnivores and omnivores are all well represented in the trophic hierarchy involved in the processing and transport of organic detritus and nutrients from the ecosys-

tem to consumers even in other nearby ecosystems. It is now indisputable that some seagrass beds in the Philippines are nursery grounds for a number of commercially important fishes and invertebrates. In the Pacific Northwest, there has been a drastic 90% - 99% decline in black brant geese population since 1981, due to the disturbance and noise from boats near the large eelgrass meadows where the geese thrive (Reiger 1982).

SUSTAINABILITY AND VULNERABILITY OF THE SEAGRASS ECOSYSTEM

Primarily because of the shallow existence of seagrass beds, they are susceptible and vulnerable to natural stresses, as well as to acute and sometimes chronic perturbation from man and his needs. In coastal Southeast Asia, cyclones, typhoons, tidal waves, volcanic activity, pests and diseases, population and community interactions (grazing and competition) constitute the natural stressors to this ecosystem (Fortes 1988b). On the other hand, seagrass beds have been the objects of relentless pressure associated with man's basic needs for food production, transportation, waste disposal, living space, recreation and aesthetic pleasure. Unfortunately, not all of these uses are compatible and in many cases, they are mutually exclusive (Fergusson et al. 1980). From the point of view of management and conservation, environmental damage and degradation brought about by natural causes may not be as directly related to man's actions, attitudes and inadequacies. Hence, they will not be given emphasis in this part of the paper. What will be emphasized are the stresses under man's control. It is unfortunate that in Southeast Asia, the effects of the latter are largely unquantified and unmitigated.

In the Philippines some mesoscale changes are becoming easily observable in seagrass areas. Hence, we see sudden changes in their species composition, stunting of growth, phenological alterations in relation to seasons and movement of ecosystem boundaries. These changes are symptoms or large-scale cumulative effects of subtle, unobservable alterations in the biological make-up of the units that compose the four different levels of organization in the biotic environment. These levels are: (1) biochemical and cellular; (2) organismal; (3) population; and (4) community. The responses of organisms to degradative

perturbations, categorized under these levels, are given below (modified from Capuzzo 1981):

(1) CELLULAR	(3) POPULATION
gametogenic cycle	biomass
nutrient storage	productivity
deformity	age/size structure
neoplasms and tumors	recruitment
	mortality
(2) ORGANISMAL	(4) COMMUNITY
feeding	biomass
excretion	species abundance
growth	species distribution
fecundity	species diversity
reproductive effort	trophic interactions
larval viability	energy flow
swimming	spatial variability
	temporal variability

Signs of susceptibility and vulnerability on the part of the components of seagrass beds in relation to environmental impact can be manifested at each of the levels of organization before disturbances are seen at the population or community levels. Hence, impairment of feeding, growth, recruitment, development and energetics resulting from disruptive activities of coastal inhabitants may result in alterations both in reproductive and developmental successes and changes in community structure and dynamics. This in turn would manifest itself as the observable advance or retreat of the physical boundaries of the ecosystem. In addition, remarkable changes in the structure and species composition and spatial or temporal distribution occur.

Disruptions in the responses at a lower level of organization do not necessarily result in degeneration at the next higher level. Only when the compensatory or adaptive mechanisms at one level begin to fail do deleterious effects become apparent at the next level (Capuzzo and Kester 1987). The "wasting" disease that almost completely decimated the eelgrass (*Zostera*) beds of the North Atlantic in the early 1900s attests to the weakness of such compensatory mechanism in a seagrass ecosystem. While the exact cause is not yet fully understood, the death of the beds appears to be related to a major and abrupt change in the climatic

(temperature) regime (Rasmussen 1977) or to the amount of increasing pollution (silt, toxic materials, e. g., heavy metals, pesticides, PCB, detergents) carried by the river Rhine, which empties into the Waddenzee (Phillips and Menez 1988). There are at present indications that a similar catastrophe might occur in Southeastern United States (Fonseca, personal communication). Lewis et al. (1985) documented the loss of 80% of the seagrass stands in Tampa Bay, Florida, from 1880 -1980, which was due to the decline in water quality (increasing turbidity, toxicity) coincident with the influx of people into the area. On the other hand, the "Amoco Cadiz" oil spill in the coast of Roscoff, France, in 1978, demonstrated that the seagrass ecosystem was a resistant unit, the oil pollution causing only a short-term change in diversity without really affecting the stability of the ecosystem (Jacobs 1982).

Each species or small association of seagrasses grows between specific tidal levels. The long-term variations in sea level should lead to a migration of these plants to maintain their position relative to these levels. The primary cause of the decline of seagrasses in Moreton Bay, Queensland, was sand movement towards seagrass beds, physically smothering and displacing them to greater depths beyond their ability to survive (Kirkman 1978).

PERSPECTIVES AND ADVANCEMENTS IN SEAGRASS ECOSYSTEM MANAGEMENT

Institutional Linkages

The last two decades saw a rapid increase in pressure on the shallow coastal resources of the Philippines. This resulted largely from the increasing industrial and commercial development of the country's shorelines, coupled with the multifaceted demands of the population for food, transportation, waste disposal and living space. Fortes (1988b) mentioned the natural and man-induced stresses on seagrass habitats in East Asia, implicating the need for intensive and sustained investigations of these resources. Indeed, if one considers the fundamental functions of seagrass ecosystems in mitigating, if not completely solving, the coastal environmental and socio-economic problems of the ASEAN region, it would be worthwhile, even imperative, to manage the resource. The marked dependence of ASEAN countries upon their marine resources makes the improvement of marine environmental quality a policy objective common to the countries of the region.

Management policies and conservation projects specific on seagrass ecosystems are yet non-existent in the Philippines. However, in 1986, UNDP/FAO, in association with UNEP, has formulated for the region a project on coastal fisheries rehabilitation through seagrass transplantation. A regional study under the ASEAN-Australia Coastal Living Resources Project is currently investigating the structural and functional aspects of local seagrass resource. The Environmental Management Bureau of the Department of Environment and Natural Resources has embarked on projects which, together with that initiated with MARCOPPER to rehabilitate the mine tailings causeway at Calancan Bay, would serve as a framework for coastal protection with seagrasses playing a major role.

Among the ASEAN countries, only the Philippines, through inter-agency cooperation, has formulated a National Seagrass Management Program and proposed the creation of a Philippine National Seagrass Committee. These steps are aimed at optimizing the use and conservation of seagrass systems. The Program is envisioned to consist of five parts, namely: resource mapping and survey; research and development; information dissemination, education, training and publication; environmental management; and policy and legislation.

Mapping of Local Seagrass Resources

Mapping of seagrass areas for coastal management purposes has been undertaken successfully in some parts of the Philippines. More importantly, the identification of the centers of distribution of seagrasses in Bolinao Bay and in other study sites would indicate the greater probability that these areas are nurseries for juveniles of some economically important species of vertebrates and invertebrates. In addition, they could be rich collecting grounds of these species. For practical purposes, the data would facilitate the classification of seagrass beds for coastal zoning and conservation purposes. Their availability makes ground truth surveys more economical and efficient.

For selective protection and use, the seagrass beds of the Philippines were classified (Fortes 1986c) into categories on the basis of the degree and nature of alteration to which they were subjected and their general community response to specific habitat conditions. Hence, seagrass areas may be *pristine*, *disturbed*, *altered* or *emergent*.

Pristine seagrass meadows are those with high or low diversity of species, bordering land masses far removed from

human habitations, disturbed only by the normal intensity of natural elements. These meadows form climax assemblages in shallow waters, usually dominated by *E. acoroides*, *T. hemprichii* and *C. rotundata*. This type of habitat should be preserved and protected from any form of alteration, to be made available only for scientific and educational purposes.

Disturbed seagrass meadows are highly or lowly diverse beds occupying bays and coves, adjacent to human habitation. These are the constant objects of man's activities and impacted by domestic and industrial effluents. These meadows may yield the highest biomass, protein levels and production rates and should be the subject of effective mitigation measures.

Altered seagrass meadows are low species diversity areas, permanently and completely changed or converted to other coastal uses, like salinas and fish or shrimp ponds. They can be reconverted into seagrass areas through massive transplantation and rehabilitation. This type of seagrass habitat should be the subject of proper multiple use programs.

In the "emergent" category, seagrass community diversity is low, controlled in large part by extreme physico-chemical conditions. *Ruppia maritima* and *Halophila beccarii*, which form extensive growths in almost freshwater or in brackishwater, and terrestrial macrophytes and herbs may co-exist with the seagrasses.

At six sites in the country, seagrass surveys yielded a total area of 50.88 km² (Fortes 1989). The seagrass areas at the sites may be broken down as follows:

Site	Total	Seagrass area, km ²		
		Pristine/%	Disturbed/%	Altered/%
Bolinao Bay	37	0	37.00/100	
Pagbilao Bay	1.89	0	1.89/100	
Puerto Galera	1.14	0	0.87/ 76	0.27/24
Calancan Bay	0.12	0	0.07/ 58	0.05/42
Ulugan Bay	2.97	0.50/17	2.25/ 76	0.22/ 7
Banacon Is.	7.81	0.20/ 3	7.61/ 97	
TOTAL %	50.88	0.7/1.4	49.69/ 98	0.54/0.6

Although comprising a very small percentage of the total coastal area in the Philippines, the six study sites, among a few others, have been chosen to represent the wide range of habitat differences characterizing the marine environment of the archipelago. In addition, these sites are being subjected to the various impacts of both natural and man-made stresses. Hence, only Ulugan Bay (Palawan) and Banacon Is. (Bohol), areas relatively removed from human habitations, have semblances of pristine seagrasses. On the other hand, almost all of the seagrass areas surveyed are markedly disturbed.

Seagrass Bed-Coral Reef-Mangrove Ecosystems Interactions

While much has been done to understand coral reefs and mangroves (but much less, seagrass beds), information regarding interactions among these marine ecosystem "triumvirate" remains fragmentary and decidedly inadequate. However, there is a rapidly increasing consensus among marine scientists that in order to achieve any sustainable form of renewable resource development, more emphasis must be given to the interactions at the ecosystem level, rather than at the lower levels of organization of the marine environment. Burbridge (1988) agreed when he emphasized that such an objective was attainable if priority was given to the study of factors, such as the effects of changes in the hydrology of rivers, conversion of swamp forests to agriculture, the reclamation of mangroves for fishponds and their impact on marine fisheries and other activities. The prevailing sectoral approach to marine resource management and conservation is based upon a single exclusive purpose, disregarding the fundamental concept of biological continuum, which is the key to the integrity of the marine environment as an integrated macroecosystem. Indeed it is increasingly being realized by the scientific circles that one of the causes of failures in marine resource management has been the failure of leaders and investigators to view the marine habitats as one interacting macroecosystem.

An integrated study of seagrass-mangrove-coral reef ecosystems is the most practical approach towards the sustainable development and conservation of these ecosystems. It treats the resource-base as a dynamic system where biophysical, socio-cultural and economic factors continuously change and interact. From the discussions presented, it is clear that many species of fish, invertebrates, birds and mammals move between mangrove

forests and seagrass beds, exchanging energy and energy sources. Tidal flushing and faunal feeding and movement extend the sphere of influence of seagrass beds and mangroves well beyond their physical boundaries. To save the mangrove trees would do the gray snapper little good if the associated seagrass beds were destroyed. Pink shrimp populations would be enhanced by the preservation of seagrass beds and mangrove-lined waters. Indeed, a most plausible (but for a poor maritime country like the Philippines, a most impractical) conclusion is that the best management practice is to preserve Philippine seagrass and mangrove ecosystems. Central to this concept, however, is the preservation of adjacent ecosystems that are linked significantly by functional processes. In Southwest Florida, the continued and enhanced role of the mangrove forests is highly dependent on the continual and effective preservation of the Everglades and Big Cypress Swamp.

Seagrass Role in Environmental Impact Mitigation and Habitat Restoration

In developing countries, resource management decisions are normally compromises, which place higher premium on economic imperatives at the expense of the environment. Hence, destruction of portions of seagrass areas are sanctioned with some specified precondition to at least mitigate the impact in order to compensate for the unavoidable loss of important ecosystem components. At this point, two considerations must be made. First, if any biologically productive habitat is destroyed, it is improbable that its original productivity can be returned. This is because the biological and physico-chemical interactions, which took hundreds of years to evolve and be developed among its components, are permanently disrupted. This is true even if a new habitat is established elsewhere within the system (Thayer et al. 1984). Secondly, mitigation rarely creates a new and similar habitat where the original components would normally thrive. What current mitigation achieves is often a transitory enhancement, since no long-term additions to the system are realized. Only the creation of an entirely new, previously biologically desolate aquatic habitat (that has not been created at the expense of another biologically productive habitat) can be considered and allowed as true mitigation.

Transplantation

Seagrass transplantation has been developed as a viable means to initiate the recovery or restoration of degraded or destroyed coastal habitats. Restoration techniques using seeds, seedlings and vegetative materials offer a great potential for investigating basic biological problems, which may prove useful in understanding biotic responses to degradative impacts. With this information, techniques could be developed to recolonize areas, which have lost their plant cover or to create new areas, which would restore and create associated plant and animal communities that lead to food resources.

Phillips (1980), applying most known techniques in seagrass transplantation, found differential success according to the species and methods used. He concluded that the sod method provided the greatest potential in the establishment and growth in all species tested. In the Philippines, Fortes (1984) initiated the first local transplantation of seagrasses as a means to rehabilitate highly silted areas in Bolinao Bay, Pangasinan. In 1986, FAO-NEPC tested the transplant and rehabilitation potentials of some selected seagrass species against pollution from phosphate and copper mine tailings, and domestic industrial effluents. However, these two undertakings were basically experimental so that the results could not provide conclusive data as to the true restoration potentials of the seagrasses. In Calancan Bay, Marinduque, existing eight-month-old transplants (using plugs of *Halodule uninervis*, sprigs of *Cymodocea rotundata*, and seedlings of *Enhalus acoroides*) are showing highly positive indications (in terms of spread, mortality and growth rates) that the methods are potentially useful in rehabilitating a portion of the tailings causeway.

Artificial Seagrass Systems

A new approach that is gaining interest and acceptance in coastal restoration ecology utilizes artificial seagrass systems (ASS). Indirectly, it has been used to enhance the biological productivity of coasts (Barber et al. 1979) and sediment stability, especially of degraded fishery habitats. Apparently, the enhancement effect of the system is achieved via the creation of more ecological niches available for occupancy mostly by juveniles of fish and invertebrate fauna. In addition the epibiota that grow on

the system are direct food sources, while the system itself serves as a refuge and spawning ground, especially for fauna of economic value. It could also be surmised that the physical components of the ASS act as effective and durable structures in stabilizing the sediments.

Bell et al. (1985) have shown that ASS attract vagile macrofauna typical of real seagrass beds. Hill (1988, personal communication) has demonstrated that strips of solar mat (plastic material used in heating swimming pools) are effective as ASS. Using a slightly modified ASS established at 5 m depth in a highly silted area, Fortes and Espinosa (unpublished manuscript) found 986 fish individuals representing 70 species and 27 families in Bolinao Bay (Pangasinan) from June 1988 -November 1989. Interestingly, these figures are significantly higher when compared to those they found from four natural seagrass sites in the bay for the period (229 individuals, 29 species from 24 families). These results indicate that the artificial structures indeed have great potential to attract fish. Of further interest are the percentages in species overlap between the two systems (in terms of fish families = 47.1%; species = 20.2%), which suggest that ASS support a relatively distinct ichthyofaunal composition. However, results from morphometric measurements also suggest that mostly juveniles to medium adults comprise the fish fauna. This finding confirms the nursery role of both systems.

As an important component of the Calancan Bay Rehabilitation Project in Marinduque Island, the use of ASS has been intensified primarily to attract fauna and improve the biodiversity of the lower western half of the mine tailings causeway at the bay. The system makes use of cheap plastic and PVC materials, constructed to simulate stands of *Thalassia hemprichii*, *Halodule uninervis* (wide-leaf variety) and clumps of *Enhalus acoroides*. Monitoring of the relative success of the system in terms of fish and invertebrate recruitment, yield and epibiotic composition has recently been initiated. A cost-benefit analysis is being made to evaluate the economic feasibility of the system.

MANAGEMENT GOALS AND NEEDS

It is unfortunate that there have been practically no significant positive results that lead to the conclusion of coastal resources'

successful management and conservation. Such is the case although schemes to manage the coastal resources have been initiated and implemented for some time in the Philippines. With seagrass ecosystem in particular, similar efforts are as yet at the very initial stages; but there are indications that these systems will not be prone to the fate, which has befallen mangroves and coral reefs. More importantly, the sets of activities proposed by Fortes (1987) for the research and development (R and D) of seagrass beds are largely applicable to that of mangroves, making management goals and needs closely similar for these two ecosystems. Indeed this striking similarity between these two closely evolved systems directly implies similarity in approach to understanding their responses as an integrated system to environmental impacts.

Management Goals

In retrospect, management and conservation of Philippine seagrass beds as an ecosystem would tend to be difficult. This is in view of the current state of knowledge people have on the fundamental interactions that connect seagrass, mangroves and coral reef ecosystems. In addition, people in a developing country like the Philippines tend to place a higher premium on economic gains, no matter how short-lived these are, at the expense of marine environmental imperatives and without regard to the costs of ecosystem rehabilitation and restoration. The need arises for management and conservation of these resources along major relevant goals. These goals include:

1. To preserve the natural interconnections known of the ecosystems;
2. To protect their ecologically valuable and economically harvestable fisheries;
3. To protect the coastlines from erosion, siltation and pollution;
4. To establish seagrass, mangrove, coral reef reserves for research and educational purposes; and
5. To preserve the aesthetic and recreational qualities of the natural shorelines.

Specifically, the key areas of research in the management and conservation of seagrass beds include:

1. Acquisition of baseline data on their inter-connections and the quantification of these interactions with coral reefs and mangroves;
2. Time-series study on the stability dynamics of the ecosystem anchored on a thorough understanding of their biophysical and hydrological conditions;
3. Mapping of seagrass beds using remote sensing technology and ground truth surveys in order to pinpoint areas suitable for restoration;
4. Studies on the ecosystem-level functions in restored or rehabilitated seagrass areas;
5. Studies on the vulnerability of the ecosystem and their components to and their recovery from human impacts; and
6. Coordination of all technical information on the ecosystems and their resources.

Socio-Political Needs - The environmental crisis in our coastal zone is largely rooted in an improper system of Philippine socio-cultural values. It arises directly from the tendency of policy-makers to deal with environmental problems mostly with curative rather than preventive measures embodied in a framework of inconsistent policies. In order to obviate this problem, certain pointers, some of which are not uncommon in marine resource management circles, need to be emphasized:

1. To ensure that local decisions and actions on ecosystems management are based on local perspectives;
2. To make the public aware and appreciative of the intrinsic value of the ecosystems in relation to the total environment; to make the public initiate positive action for the cause of the few who make extra effort to properly manage and conserve these ecosystems; to make the public sympathetic to such cause;
3. To formulate sound legislation that would prohibit specific activities disrupting the ecosystem connections and degrading their resources;

Management Needs

To effectively address the above management goals, certain specific needs arise. These necessary factors or attributes are based on the dictum: SOUND ECOLOGY IS GOOD ECONOMICS. Primarily they can be divided into technical or scientific needs and administrative or socio-political needs.

Technical Needs - Management and conservation within the physical boundaries of seagrass beds, mangrove forests and coral reef cannot succeed outside a sound ecological framework. Nor is the "lifting" of oceanographic principles, largely developed to manage and conserve temperate coastal resources, an adequate basis for the management of these resources. Management planning requires adequate field data for each specific ecosystem for the identification of those interconnections, dynamic qualities and populations which need protection, as well as the explanation of how these may be vulnerable to disruptive human influences. Persons primarily involved in the management process must base decisions on solid scientific grounds, not solely on the laws of short-term economics. Otherwise, remedial expense or irreversible losses will be encountered.

Technically, what is required is to identify and initiate studies in representative natural seagrass, mangrove and coral reef ecosystems in regional and local areas, so that we may know what constitutes harmful activity or even change in the ecosystems. Without baseline data obtained from the few remaining natural and unspoiled systems, we will never have a measure of human impact on these systems and will never attain wise management and stewardship of their resources.

In developing countries, it is not a sound policy to advocate the physical separation of the users from their source of nutrition and livelihood. However, the continued availability to these people of the resources depends on the maintenance of natural genetic and species diversity in these systems. Biological productivity depends largely on the availability of nutrients, light and temperature. Hence, the stability of the systems becomes a function of the stability of these factors and the genetic and species diversity present. Human interventions, such as farming of the desired species, may increase the short-term productivity of ecosystems, but they may also lead to an extinction of genotypes and species or to the spread of less desirable ones.

4. To encourage and facilitate the coordination of all information with major coastal projects;
5. To incorporate a holistic approach in planning for both scientific research and decisions that are related to the marine ecosystem;
6. To encourage and facilitate the cooperation among institutions and social groups on marine environmental issues;
7. To choose strategies that do not equate management with control; and
8. For the educational system to inculcate environmentalism at all levels, as well as the practice of environmental ethics.

To effectively manage and conserve the seagrass ecosystems, it is necessary to relate them with management problems of associated nearshore habitats and adjoining tidal lands. It is the natural movement of water that provides the fundamental connections between the two ecosystems. Hence, in the planning process, it should be recognized that some activities in these associated areas can have far-reaching effects through their influence on water quality.

Seagrass beds must be managed on the basis of a philosophy of conservation. Most importantly, it should begin by preventing further degradation and loss of existing ecosystems while accommodating traditional and contemporary needs, with adequate provision of reserves suitable for protection of the biodiversity within them. These unexploited areas may serve as a refuge for fauna and flora and as sources of materials for restoring areas in which management strategies failed.

As renewable resources, seagrass ecosystems must be managed on a sustainable use basis. This concept places economic benefits at par with the maintenance of the ecosystems as close to their original state as possible. However, depending on established priorities, a compromise allowing sustainable yield and reasonable resemblance to an undisturbed system may be reached. During the First National Conference on Seagrass Management Research and Development in December 1986, Fortes (1987) proposed an R and D program for seagrass ecosystems and their resources. The central issue in the proposal was multidisciplinary in approach because resource manage-

ment "...begins with the ecologist's discussion of the productivity of the ecosystem, continues with the lawyer's discussion of the legal nature of resource utilization, includes the economist's concern for efficient use of equipment and facilities and the politician's concern for proper allocation of the shore among the users."

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