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Seagrasses

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CHAPTER 4

TROPICAL SEA GRASS ECOSYSTEMS AND POLLUTION

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TROPICAL SEA GRASSES

Until recently, studies in the nearshore tropical environment have largely concentrated on the spectacular and complex coral reefs, and the dense, productive mangrove forests. However as marine science focuses on the living resources of the shallow, coastal seas, the vast beds of sea grasses bordering the tropical coastlines are being recognized as important resources. The significance of sea grasses in coastal ecosystems was documented early in the classic studies of Petersen (1918), but little further work on the ecological importance of these highly productive and easily studied areas followed until recently.

Sea grasses are unique among submerged marine and estuarine plants due to the presence of an extensive root and rhizome system. Because of this system — high growth rates, and dense leaf development — sea grasses exert considerable influence over their environment. Wood et al. (1969) summarized the functions of sea grasses in estuarine and marine ecosystems as follows: (1) sea grasses have a rapid rate of growth and high organic productivity; (2) while alive, they act as food for only a limited number of organisms since the demise of the large sea turtles, but provide large quantities of detrital material which, along with its resident microbes, provide a major food source for the estuarine ecosystem; (3) the leaves support large numbers of epiphytic organisms, which under favorable conditions, may be comparable in biomass to the sea grass leaf weight, and which are grazed extensively; (4) sea grasses provide organic matter which initiates sulfate reduction and maintains an active sulfur cycle in the estuarine sediments; (5) the dense leaves reduce the current velocity near the sediment surface and promote sedimentation of organic and inorganic particles; and (6) the roots and rhizomes bind the sediments and hinder erosion of the surface of the sediment.

Sea grasses are widely distributed throughout the shallow coastal seas from the Arctic to the southern tips of Africa and New Zealand. Den Hartog (1969) recognizes 12 genera of sea grasses with 49 species, of which 7 are tropical in distribution. In the Hydrocharitaceae, *Enhalus*, *Thalassia*, and *Halophila* are tropical, and in the Cymodoceoideae, *Halodule*, *Cymodocea*,

Syringodium, and *Thalassodendron* of the sub-family Cymodoceoideae are basically tropical genera, although several of the above genera have some species which extend into subtropical or warm temperate seas. As is common with many marine groups, the highest diversity in the sea grasses is found in the Indo-West Pacific, with all seven genera represented. By contrast the Caribbean has only *Halodule*, *Syringodium*, *Thalassia*, and *Halophila*. Only *Halodule wrightii* and *Halophila decipiens* are common to both areas.

Petersen (1918) was the first to recognize the overall importance of sea grasses in the coastal ecosystem, and in recent years it has become apparent that sea grasses contribute significantly to the maintenance of the coastal ecosystem of the tropics and near tropics in numerous ways (Wood et al., 1969; Zieman, 1974a).

Because sea grass beds attracted little attention scientifically until the late 1960's, there are large gaps in our knowledge of these systems. The best studied of the tropical sea grasses is the turtle grass, *Thalassia testudinum* Konig, of the Caribbean. Although this study is directed to tropical sea grasses, nearly all of the information is drawn from *Thalassia testudinum*, as there is unquestionably far more published material dealing with this species than with all other tropical sea grasses combined. As research progresses, undoubtedly differences in the structure and function of different grass beds will be found. However, judging from the experience of this author and other workers in the field, the similarities between different sea grass communities are more striking than the differences.

Much attention has been drawn to the importance of sea grass beds as nurseries, important in the rearing and sheltering of small fishes and invertebrates (Hutton et al., 1956; Moore, 1958; Tabb et al., 1962; Hoese and Jones, 1963; Wood et al., 1969; Jackson, 1972; Odum et al., 1973). Prominent among the organisms inhabiting the grass beds are commercially important species such as the pink shrimp *Penaeus duorarum* (Hoese and Jones, 1963), mullet (Wood et al., 1969), sea trout, and stone crab (Tabb et al., 1962).

Whereas some animals have been recorded as feeding directly on turtle grass (Randall, 1965a, 1967; Ogden, 1972), since the decimation of the green sea turtle by overfishing there has been little direct grazing pressure on these beds except in certain localized situations. Most of the green leaves remain untouched until they die and are cast off from the plant, when they decay and are converted to detritus (Fenchel, 1970; Odum et al., 1973; Zieman, 1974a). In *Thalassia* beds, at least 90% or better of the energy makes its way to the higher trophic levels via the detritus food chain. Some of this detritus may be transported offshore to provide food far from the site of growth (Menzies et al., 1967; Menzies and Rowe, 1969).

Tropical sea grass beds are frequently found in the vicinity of coral reefs and the interactions between these two communities appear important. Particularly at night, fish, including valuable commercial species, leave the

reef to forage on species living in the grass beds (e.g. Earle, 1971). Populations of fishes living in reef communities are larger where the reefs are adjacent to seagrass beds (Randall, 1965; Starck and Davis, 1966; Ogden, 1972).

Tropical sea grass beds are among the most productive of natural ecosystems. Productivities of 1,300 to about 3,000 g dry weight/m per year have been recorded (Odum et al., 1973; Zieman, 1975).

Grass beds also stabilize both organic (Wood et al., 1969) and inorganic sediments (Ginsburg and Lowenstam, 1958; Scoffin, 1970; Zieman, 1972) and offer a substrate for epiphytic flora and fauna. Scoffin (1970) observed that in dense, long-bladed beds of *Thalassia testudinum* currents up to 40 cm/sec measured immediately above the blades are reduced to zero at the sediment-water interface.

Extremely high rates of nitrogen fixation have been reported by Goering and Parker (1972) by the epiphytes of *Thalassia testudinum* and by Patriquin and Knowles (1972) by bacteria in association with the roots. This implies that sea grass communities may be important sources of newly fixed nitrogen in the characteristically nitrogen-poor waters of the coastal tropics. McRoy et al. (1973) found much lower values of nitrogen fixation than the previous authors however, and the importance of this process in sea grass beds cannot be determined without considerably more research on different species in different areas.

Thalassia has been used as a feed supplement for sheep (Bauersfeld et al., 1969) and chickens (Alvarez, personal communication, 1973) and as fertilizer (Van Breedveld, 1966).

Sea grass beds are especially vulnerable to degradation by human-induced stresses as they inhabit only the shallow marginal seas where the activities of man are the greatest. Their mode of growth is unique for marine plants, and they are subject to damage from stresses or pollutants both in the water column and in the sediments.

POLLUTANTS AND STRESSES OF TROPICAL SEA GRASSES

In the tropics, there are only a few scattered examples of pollution studies in sea grass communities to draw from, and much of the information is in the form of difficult-to-obtain reports. Thus much of the discussion here will, of necessity, be drawn from these studies.

Dredging and filling

Of all forms of man-made or induced disturbances of the estuarine and nearshore environments, dredging and filling presents the greatest potential for damage to the sea grass beds and has undoubtedly caused the destruction

of more desirable grass bed habitat than any other form of pollution. Dredge and fill operations, which remove or dredge material from one portion of an estuary to another area to be filled, damage sea grasses in a variety of ways.

The most obvious destruction comes from the physical removal of the dredged material whether by a hydraulic dredge or by dragline and the covering of other marine areas with the resulting fill material. These two joint processes cause the destruction of sea grass beds for an indeterminate, but often considerable length of time, as the resulting sediments are not initially suitable for colonization by sea grasses. In the Caribbean region, large areas of the highly productive turtle grass, *Thalassia testudinum*, have not recovered many years following dredging operations.

In addition to the direct physical damage, secondary effects can be pronounced. Sea grasses generally require high light levels to sustain populations, and the available light is greatly decreased in the vicinity of dredge operations due to the turbidity caused by suspended sediments, despite protective devices designed to contain the suspended material such as turbidity curtains or screens. The fauna associated with grass beds are highly susceptible to damage both from the effects of direct siltation and suffocation, as well as from low oxygen levels due to the high oxygen demand of the decomposing suspended organic matter.

An area where extensive dredging and filling operations have been used to create waterfront homesites is Boca Ciega Bay, Florida. Here Taylor and Saloman (1968), found that between 1950 and 1968, 1,400 acres (ca. 567 ha) of the bay had been filled, reducing its area by 20%. Sediments in undisturbed areas of the bay were firm and averaged 94% sand and shell and supported luxuriant beds of sea grass, primarily turtle grass. In contrast, the sediments in dredged canals averaged 92% silt and clay. Light penetration was highest in the southern bay away from the land fills, lowest in the bay near fill areas, and increased again in the dredged canals. The canals, however, were sufficiently deep that adequate light for sea grass photosynthesis did not reach the bottom.

The soft sediment of the canals is generally unsuitable for most macro fauna as well as for sea grasses. A variety of studies (Phillips, 1960; Springer and Woodburn, 1960; Taylor and Saloman, 1968) listed nearly 700 species of marine plants and animals from Boca Ciega Bay. Taylor and Saloman (1968) found the deeply dredged canals contained less than 20% of the species recorded from the bay and these remaining species were nearly all fishes which were highly motile and not restricted to the canals. Thus, in ten years following the disturbance of the bay bottom recolonization of the sediments by plants and animals was negligible. Using conservative and incomplete figures, Taylor and Saloman (1968) estimated an annual loss in fisheries and water sports of about \$1.4 million per year from the bayfill operations.

Godcharles (1971) studied the effects of a commercial hydraulic clam

dredge on the benthic communities in the estuarine areas of Tampa and Tarpon Springs, Florida. He found the hydraulic dredge sampled clams effectively, but uprooted or severed the rhizomes of all sea grasses in its path. The dredged areas filled with fine-grained sediment, and at one station some recovery of *Halodule beaudettei* (*Diplanthera wrightii*) occurred, but no regrowth of *Thalassia testudinum* or *Syringodium filiforme* was ever observed.

Odum (1963) found that the chlorophyll *a* and productivity of turtle grass beds diminished following dredging operations in Redfish Bay, Texas. The year following dredging operations, chlorophyll *a* and productivity increased except where the communities had been covered with soft silt.

In addition, Odum reported that the spill from dredging destroyed grass beds when discharged into areas only 0.5 m deep as it caused the bottom to shoal critically to a point where plants could no longer survive. Odum attributed the increased productivity to the release of nutrients from the displaced sediments.

In Lindbergh Bay, St. Thomas, Virgin Islands, increased turbidity brought about by dredging resulted in a marked reduction in the distribution and abundance of benthic sea grasses (Van Eepoel et al., 1971). In 1968, "benthic grasses could be easily seen from the surface in water 10 meters in depth; the *Thalassia* community was lush, covering the major portion of the bay bottom". By 1971 *Thalassia* along with *Syringodium*, the second most common sea grass in the bay, had become extremely sparse throughout, with "only very few plants being found deeper than 2.5 meters. In the most turbid portions of the bay they were limited to 1.5 meters in depth." Similar destruction of seagrass beds by sedimentation and turbidity caused by dredging in Brewers Bay, St. Thomas, is described by Grigg et al. (1971). The light compensation point for *Thalassia testudinum* in clear waters is reported to be about 40 m (Pomeroy, 1960; Marmelstein et al., 1968; Gessner, 1971), although this figure may not be reliable due to oxygen storage problems.

Eutrophication

The input of sewage or other nutrient-enriched substances into water near sea grass beds produces a number of effects. Sea grasses may have the ability to take up nutrients through the leaves as well as through the roots, and moderate amounts of excess nutrients could stimulate growth. Enrichment also fosters the development of epiphytic algae and phytoplankton. One of the most luxuriant growths of turtle grass and assorted epiphytic algae this author has observed was just inshore of the outfall of the Miami sewage plant on Virginia Key, Florida. Sea grasses are known to have a high light requirement, and the excessive growth of epiphytic algae and phytoplankton decrease the light energy available to the plants.

Taylor et al. (1973) found that significant portions of Hillsborough Bay, Florida, had been damaged by dredging and domestic and industrial efflu-

ents, particularly phosphorus and nitrogen compounds and suspended solids. This resulted in heavy growths of phytoplankton and filamentous algae, marked fluctuations in oxygen concentration, and high turbidity. This resulted in low light transmission which reduced the density and coverage of the sea grass beds, primarily *Thalassia*. Catches of fish and crustaceans were low compared with other areas where environmental conditions were more natural and extensive beds of sea grasses persisted.

Concomitant with increasing sewage pollution and dredging in Christiansted Harbor, St. Croix, Virgin Islands, extensive beds of *Thalassia testudinum* have been overgrown and replaced by *Enteromorpha* (Dong et al., 1972). Over a 17-year period Nichols et al. (1972) documented a 66% reduction in grass beds in the bay.

McNulty (1970) found a lack of sea grasses in an area polluted by sewage effluents in Biscayne Bay, Florida. Only *Halophila decipiens* and *Halodule beaudettei* (*Diplanthera wrightii*) existed in low quantities within 1 km of the outfall. Past this point *Thalassia testudinum* began to occur in sparse quantities. Four years after the abatement of the sewage input the sea grasses had actually declined further, but the area had continued to be disturbed by heavy hydraulic dredging and the resultant increased turbidity, to which sea grasses are especially susceptible.

Sewage effluents (and suspended sediments) reduce dissolved oxygen levels. Hammer (1972a) reports that anaerobiosis depresses photosynthesis in *Thalassia testudinum* and *Halophila decipiens*. After 24 hours exposure to anaerobic conditions *Thalassia* recovered fully while *Halophila* did not. The greater tolerance of *Thalassia* is probably related to its greater ability to store oxygen in its tissues.

Temperature and salinity

Raising the temperature regime of tropical sea grasses can have far greater effects than a similar modification in a temperate environment since organisms in tropical waters live much closer to their thermal death point (Biehl, 1962; see also Zieman and Wood, Chapter 5).

Phillips (1960) reported that *Thalassia testudinum* preferred 20–30°C temperatures in south Florida. Zieman (1975) found that this species has an optimum temperature of between 28 and 30°C and net photosynthesis sharply declines on either side of this range.

Glynn (1968) observed that the leaves of *Thalassia* were killed in Puerto Rico by temperatures of 35–40°C, but that the rhizomes apparently were not affected.

Thorhaug and Stearns (1972) reported that *Thalassia* growing at artificially elevated temperatures produced flowers but no observed fruit. They also produced more new shoots than plants growing at normal temperatures.

Halodule beaudettei (*Diplanthera wrightii*) is an earlier successional

species than *Thalassia* in the Caribbean. It is usually the first sea grass colonizer in disturbed areas, as it is able to establish and spread rapidly.

Phillips (1960) found *Halodule beaudettei* to prefer temperatures of 20–30°C, as does *Thalassia*, but that *Halodule* is a more eurythermal tropical species. Manatee grass, *Syringodium filiforme*, is generally less abundant than *Thalassia* or *Halodule*, and its ecological position is less well defined. Phillips (1960) considers *Syringodium* a tropical plant but not a stenothermal one, although leaves of *Syringodium* begin to die at temperatures below 20°C.

Zieman (1970) found that sea grasses tend to be more resistant to thermal pollution stress than do the algae. The sea grasses tend to be more resistant to periodic acute temperature increases, and even if the leaves are killed off, rapid regeneration is often experienced from the horizontal rhizomes which lie several centimeters below the surface of the sediments. This regeneration occurs in various species because the rhizomes contain large starch reserves and are injured only if the temperature of the sediment reaches lethal levels for extensive periods of time. Phillips (1960) however, points out that frequent removal of leaves may so debilitate rhizomes that the capacity for recovery is impaired.

There is considerable variation in the observed salinity ranges of the Caribbean sea grasses. *Thalassia* has been found to tolerate salinities as low as 3.5‰ (Sculthorpe, 1967) and as high as 60‰ (McMillan and Moseley, 1967) for short periods of time, but usually undergoes defoliation at these extremes. Optimum salinities for *Thalassia* are in the range of 24–35‰ (Phillips 1960; McMillan and Moseley, 1967; Zieman, 1975). McMillan and Moseley (1967) found that *Halodule beaudettei* (*Diplanthera wrightii*) showed the greatest resistance to high-salinity conditions, *Thalassia* was intermediate, and *Syringodium* was the least resistant. This agreed with the observations of Phillips (1960) who found *Halodule* existing in freshwater for short periods of time. He found *Halodule* to be the most euryhaline species, but that it was outcompeted by *Thalassia* and *Syringodium* whenever they were present.

Chesher (Chapter 6) reports that, although the effluent of heated brine from the Key West desalination plant caused a marked reduction in biotic diversity in the vicinity of the discharge, nearby beds of *Thalassia* were unaffected.

Halodule beaudettei is more euryhaline than *Syringodium filiforme*, and tolerates salinities of 9–52.5‰, whereas *Syringodium* only survives to 35‰ (McMahan, 1968).

Hammer (1968) found the photosynthesis of sea grasses, including *Thalassia* and *Syringodium*, to reach a maximum in full strength seawater, and to decrease as the salinity decreased. Hammer ascribed part of the decrease to direct salinity effects, but pointed out that, with dilution, the available carbon supply was diluted and may also have become limiting.

Zieman (1970, 1974b) found that the seasonality of *Thalassia* could be ascribed largely to temperature and salinity effects. When temperature and salinity vary together, the combination of high temperature and low salinities was found to cause the greatest decline in the plant populations.

Tabb et al. (1962) state: "Most of the effects of man-made changes on plant and animal populations in Florida estuaries (and in many particulars in estuaries in adjacent regions of the Gulf of Mexico and South Atlantic) are a result of alterations in salinity and turbidity. . . High salinities (30–40 ppt) favor the survival of certain species like sea trout, redfish and other marine fishes, and therefore improve angling for these species. On the other hand these higher salinities reduce survival of the young stages of such important species as commercial penaeid shrimp, menhaden, oysters and others. It seems clear that the balance favors the low to moderate salinity situation over the high salinity. Therefore, control in southern estuaries should be in the direction of maintaining the supply of sufficient quantities of fresh water which would result in estuarine salinities of 18 to 30 ppt."

Wind and sea stress

Sea grasses occurring in the tropical marine environment are periodically subject to severe stress from tropical hurricanes and typhoons. Although man cannot generate the extreme winds and resultant wave stress on the beds as a major tropical cyclonic storm, man can influence the manner in which the waves interact with sea grasses by means of his modification of the nearshore sea bottom.

Of all marine communities which are affected by the storm-generated winds, subtidal sea grass beds appear to be among the least susceptible to severe damage by the storms.

Thomas et al. (1961) found that following Hurricane Donna in 1960, large quantities of *Thalassia testudinum* washed onshore. However, there was little quantifiable loss within the beds, although Tabb and Jones (1962) observed heavy mortality of fishes and invertebrates from the same storm in North Florida Bay. Mortalities were caused by mud suffocation, by stranding as the water retreated, and by severe oxygen depletion due to decomposition of suspended organic matter.

In Texas, Oppenheimer (1963) found that inshore turtle grass flats and bottom flora were undamaged, although major erosion occurred as Hurricane Carla passed near Port Aransas, Texas, in 1961.

Glynn et al. (1964) recorded that following Hurricane Edith, a relatively mild storm in September 1963, *Thalassia* beds were not noticeably damaged, although mangroves and beds of *Syringodium* suffered some effects and the coral reef community was severely disturbed.

Population explosions and overgrazing

Overgrazing of sea grasses occurs commonly in the immediate vicinity of patch reefs, leading to the formation of bare "halos" surrounding Caribbean patch reefs. These halos have been attributed to grazing reef fish, primarily surgeon fish (Acanthuridae) and parrot fish (Scaridae) (Randall, 1965) and more recently to the echinoid *Diadema antillarum* (Ogden, 1972). The grazing is localized and presents no threat to the overall grass beds, as the small grazers generally do not venture far from the shelter of the nearby patch reef (Mathison et al., 1971).

However, Camp et al. (1973) have observed dense concentrations of the regular urchin *Lythechinus variegatus* causing massive destruction of mixed sea grass beds, primarily composed of *Thalassia*, on the west coast of Florida. During these outbreaks, areas hundreds of meters long and meters across are completely denuded by the migrations of these urchins. It is doubtful if these outbreaks are of severe consequence compared to the grazing pressure exerted formerly during seasonal migrations of large numbers of sea turtles.

The cause for urchin outbreaks has not been well studied. It is possible that it is due simply to exceptionally successful spawning and recruitment. However, there is the possibility that these outbreaks are due to the reduced predation of the urchins in areas where the normal predators have been overfished.

Oil pollution

As sea grasses are generally subtidal, they are less susceptible to damage from oil than other organisms, especially those in the intertidal zone. Still, shallow beds of sea grasses can suffer destruction from severe oil spills. Diaz-Piferrer (1962) found beds of *Thalassia testudinum* were badly affected by crude oil on the south shore of Puerto Rico. The turtle grass deteriorated over a period of several months, and the normal algal flora was denuded and replaced by blue-green algae. Following the much publicized Santa Barbara oil spill in January 1969, *Phyllospadix torreyi* growing in the intertidal zone was severely damaged (Foster et al., 1971), although subtidal plants and those in the extreme low intertidal zone were largely undamaged as they were, to some degree, protected from direct contact with the oil.

In addition to direct mortality from the contact of the plants with the oil, a second and possibly longer-term damage is caused by the interaction of the sediment and oil. Sea grasses tend to stabilize the fine-grained sediments, but as oil seeps into sediment, it agglomerates into large lumps which offer a greater purchase for waves and currents to act on, and increase the buoyancy of the sediments, thus making removal of the sediments easier. Diaz-Piferrer (1962) recorded the loss of 3,000 m³ of sand from Tamarindo Beach in less than a week due to this effect.

Metals

Thus far metal pollution has not been implicated in the decline or destruction of marine grass beds. As many sea grasses require a reducing environment around the roots (Wood et al., 1969) but an oxidized environment surrounding the leaves, they can pick up metals in a variety of forms.

Many types of metals are found in abundance in polluted sediments where they may become easily mobilized and be taken up by the roots of sea grasses. Parker et al. (1963) found the highest concentrations of cobalt and manganese in Texas bays in sea grasses, the concentrations being over an order of magnitude greater than the concentration in the sediments. Iron was in nearly the same concentration in sea grasses as the sediments, but was more concentrated in sea grasses than in any other plant or animal.

Parker (1962) found the zinc concentration of *Thalassia* and *Halodule beaudetti* (*Diplanthera wrightii*) was 5–10 times the concentration in the sediments. Thus, there is the possibility that excess metals in estuaries will be concentrated in sea grasses and available for passing up the food chain. This is of increasing concern as metals are released into the environment in large quantities from nuclear power plants (e.g. Segar and Pellenbarg, 1973) and desalination plants (e.g. Chesher, Chapter 6), both of which are being constructed at accelerating rates in the tropical inshore regions.

Physical disturbance and recolonization of sea grasses

Physical disturbance of grass beds due to boat traffic on shallow beds has been observed by students of sea grass ecology for quite some time (U.S. Dep. of Int., 1973), although there has been no systematic study of the effects of propeller cuts on grass beds. Phillips (1960) states that "in shallow bays perhaps the most common means of breaking the continuity of growth is the destruction caused by boat propellers". Phillips removed *Thalassia* rhizomes and shoots from two plots in April and May of 1958 in Boca Ciega Bay, and observed no regrowth into the areas after ten months, although the more rapidly growing *Halodule beaudetti* (*Diplanthera wrightii*) recolonized the denuded plots.

Scoffin (1970) also found that *Thalassia* does not spread its rhizome mat rapidly. In a 4-month experiment, he found trenches dug in the sediment were not recolonized.

In attempting to establish the rate of vegetative growth of *Thalassia*, Jones (1968) cut two trenches in grass beds in Bear Cut, Biscayne Bay, Florida, in August 1965. Re-excavation two years later, in August 1967, showed little regrowth into the 1 m X 30 cm X 20 cm deep cuts, although the trenches had filled with sand within a month of cutting. Jones also noted that *Halodule beaudetti* (*Diplanthera wrightii*) had recolonized the upper 2 cm of sediment with 270 cm of rhizome and about 20 growing rhizome tips.

Having heard from local fishermen that propeller cuts were persistent features and sometimes useful in relocating fishing holes and navigation channels, this author used boat tracks in grass beds as station location markers, in areas where it was impractical or imprudent to use marker buoys. Several of these cuts were used reliably for two years (1966–1968) in the Soldier Key region of Biscayne Bay and at least one was recognizable after three years (1966–1969).

Fuss and Kelly (1969) and Kelly et al. (1971) studied the survival of transplanted *Thalassia* and the feasibility of recolonizing turtle grass in disturbed areas. They found that sprigs of *Thalassia* require considerable time to initiate growth after disturbance. Fuss and Kelly (1969) found that ten months was required for new rhizome apices to develop, and Kelly et al. found that in a control bed 40% of the transplants had initiated new rhizome growth after thirteen months, whereas in an area with altered sediments only 15–18% of the transplants exhibited new growth.

If only the leaves of *Thalassia* are killed, or removed, regrowth is often rapid because of the starch reserves in the rhizomes. Too frequent leaf destruction will use up these reserves however. Taylor et al. (1973) found that *Thalassia* in Tampa Bay, Florida, tolerated harvesting twice a year. They speculate that this species might tolerate three harvests per year in more tropical areas.

Thorhaug (1974) has reported success in establishing *Thalassia* from seeds in south Florida.

Patriquin (1972) studied the nutrient sources and requirements of *Thalassia* in Barbados, and found that a reduced sediment layer is essential for good growth of turtle grass. Wood (1965) also noted this requirement and found that sea grasses stimulate the development of reducing conditions in the root layer.

Zieman (1974a) found a reduction of the finer components of the sediments in the disturbed *Thalassia* beds due to the lack of the stabilizing effect of the grass blades. This effect is even more pronounced in areas subject to continual boat traffic such as scoured ruts which are used by boaters as channels through the shallow beds and banks. Zieman also found a reduction in the pH and generally in the Eh of the disturbed sediments, yielding a more reducing environment. He suggested that *Thalassia* beds did not recover rapidly from physical disturbances such as boat traffic or dredging because: (1) the disturbed areas, whether sedimented in or scoured open, are not a suitable environment for rhizome growth; (2) when damaged, rhizomes normally require one year just to begin developing active new apices; and (3) rhizome apices, whether arising new from damaged *Thalassia* plants or simply growing from other portions of the grass bed, do not grow rapidly. The particular circumstances at each site determine which of these mechanisms is most important.

Recolonization of disturbed *Halodule beaudetti* (*Diplanthera wrightii*),

shoal grass, is not likely to be a serious problem. This plant does not have a well-developed deep rhizome system, grows well from seeds, and is capable of colonizing a damaged area in a short time. It does not seem as sensitive to sedimentation as *Thalassia*. The author has seen large mats of shoal grass attached to the substrate at only one edge, with the rest of the mat growing floating in the water column with roots and rhizomes unattached. *Halodule* can colonize an area in but a few weeks when conditions are correct, and exists as an annual plant in many estuarine areas. Once *Thalassia* becomes established, however, *Halodule* cannot compete, and is overgrown in all but the upper intertidal zones, or in areas in which turtle grass cannot become established. Den Hartog (1969) reported that in the tropical Indo-Pacific *H. uninervis* and *H. pinifolia* are the first sea grasses to appear following the disturbance of the sea bottom, and that they are gradually replaced by other species.

CONCLUSIONS

As knowledge of the structure and function of sea grass beds increases, it becomes evident that these areas are important components of the nearshore tropical marine ecosystem. A variety of studies have shown how grass beds act as nurseries, food producers, and stabilizers of the sea floor. As increasing development in the tropics begins to encroach upon these valuable resources, careful attention must be given to their fate, as many coastal people depend upon the resources of tropical grass beds for their food and sustenance, from the conch-fishermen of the Bahamas to the turtlers of the western Caribbean. In more developed areas, the grass beds are sources of sport-fishing and other forms of recreation.

Fortunately, recognition of the importance of grass beds to the ecology and ultimately to the economy is beginning to be recognized. The State of Florida, through its Coastal Coordinating Council, has declared grass beds to be preservation areas where no development is permitted. This is in part due to the recognition of the linkage between ecology and economy. An area that is dependent on its income from recreation, and primarily water-oriented recreation, must maintain high water quality standards and esthetic values.

Let us hope that other responsible decisions will result in the continued maintenance of the nearshore tropical marine environment.