



CHAPTER I

INTRODUCTION

Seagrasses are marine angiosperms which are completely adapted to life in the marine environment. They are widely distributed along the coasts of temperate and tropical seas, and may be considered a conspicuous feature of the shore. They can achieve both vegetative and generative cycle in a saline medium, whilst completely submerged and still firmly anchored the substratum (den Hartog, 1970). The presence of roots, a vascular systems, and the ability to flower distinguish seagrasses from the seaweeds (Lanyon, 1986).

Although the importance of seagrass beds to shallow coastal ecosystems was demonstrated over 70 years ago by the pioneering work of Petersen. Yet, the true importance of the seagrass beds to the ecosystems of marine coastal waters is not yet fully understood and may be underestimated. There are several key features of seagrass ecosystems. The key position is obviously held by the seagrasses themselves as primary producers. Few species feed directly upon the seagrasses. Seagrass production is mainly utilized through the detritus food chain. Other significant functions of the seagrass bed are : stabilizing the bottom; providing substratum for epiphytes and epizoa; and providing food, shelter and nursery grounds for fish and numerous invertebrates (Kikuchi, 1966, 1980; and Zieman, 1982).

Most research works on seagrass communities have been carried out on the temperate species *Zostera marina*, and the tropical representative, *Thalassia testudinum* which occurs in Florida and Caribbean (Kikuchi 1966, 1974, 1980; Kikuchi and Peres, 1977; Zieman, 1982; Phillips, 1984; and Thayer, Kenworthy and Fonseca, 1984).

Very few research work on seagrass communities have been carried out in Thailand. Sudara and Nateekanjanalarp (1989) and Poovachiranon (1989) quantitatively studied the seagrass communities in the Gulf of Thailand and the Andaman Sea, respectively. To date, the knowledge on seagrass communities both of plants and animals is still very limited. However, there have been reports on the importance of seagrass beds as nursery ground for juvenile decapods and fishes such as shrimps, crabs and groupers (Sudara et al., 1989a). The slowly disappearance of dugongs in Thai waters was also related among other things to condition of the seagrass beds as well. Thus, researches on this valuable resource must be encouraged in order to conserve and manage these resources to their highest potential before it is too late.

In this study, various seagrass communities with emphasis on the plant and animal community structure, and their related environmental factors are studied. After preliminary survey of various sites around the Gulf of Thailand, Koh Samui is chosen as the study site because this island consisted of the 4 types of seagrass beds. From a quiet coconut production island, since 1980, Koh Samui became an international tourist attraction spot. In 1986, more than 300,000 tourists visit this wonderful island and its vicinities (Sudara et al., 1989b). This sudden growth of tourism is causing a strong change

in environment quality which might impact on the seagrass beds.

The objectives of this study are as follow :

1. To investigate the type and the distribution of seagrasses at Koh Samui.
2. To study various seagrass community structures found at Koh Samui, both of the plants and animals.
3. To determine certain environmental parameters relating to the seagrass communities.

The findings from this study are expecting to contribute to the following benefits:

1. To contribute to the knowledge of some seagrasses taxonomy and ecology of seagrass beds in Thailand and to add to the knowledge of the Southeast Asian region as well.
2. To demonstrate the importance of seagrass communities with emphasis on some economic important species of decapods and fishes.
3. To provide solid data and information which can be use to formulate effective management plan of this valuable resources as well as to provide more informations for certain fisheries development potential.
4. To provide informations which might help in formulating the conservation plan for the "endanger mammal", the "dugongs", in the Thai waters.

Literature Review

Seagrass is a term that collectively refers to approximately 50 species classified into 12 genera of angiosperms or flowering plants (order Helobiae) that have colonized the sea. They can achieve both their vegetative and generative cycle in a saline medium, which completely adapted to life in the marine environment. They possess five indispensable properties which enable them to survive (den Hartog, 1970, 1977) : (1) ability to survive in a saline medium, (2) ability to grow when completely submerged, (3) an anchoring system sufficient to withstand wave action and tidal current, (4) ability to complete their generative cycle in a saline medium (hydrophilous pollination), and (5) ability to compete with other organisms under more or less stable condition of the marine environment.

Seagrass have evolved distinctive morphological adaptations to the marine environment. These include well-developed rhizomes (horizontal stems) which is typically buried in the substrate ; the rhizome system may be very extensive. Leaves are produced on erect branches and usually only the leafy part of the plant emerges from the substrate ; the leaves are generally green. The stems, roots and leaves of seagrasses contain lignified conducting tissue (veins) and air channels. Seagrasses are flowering plants and as such produce flowers, seeds and fruits, though these do not necessarily resemble their terrestrial counterparts (Lanyon, 1986).

Importance of seagrasses

Seagrass beds seem to have numerous important functions in the nearshore marine environment. However, the importance of seagrass communities is poorly understood, and consequently underestimated. It was Wood and his colleagues who first enumerated their significant roles in the marine environment in 1969. Since then, the importance of seagrass beds have been demonstrated by various authors (Thayer, Wolf and Williams, 1975; Zieman, 1982; Menez, Phillips and Columpong, 1983; Phillips, 1984) which include :

1. High production and growth.

The ability of seagrasses to exert a major influence on the marine seascape is due in large part to their extremely rapid growth and high net productivity. The leaves grow at the rate typically 5.5 mm. per day, but in certain condition it was reported even up to 10.0 mm. per day.

2. Food and Feeding pathways.

The photosynthetically fixed energy from the seagrasses may follow three general pathways : (1) Direct grazing of organisms on the living plant material (or feed on the other organisms which live on the seagrasses), (2) Seagrasses as a food source, which are digested by a very restricted number of organisms ; among the invertebrates, the grazers are restricted to some fishes (Scaridae, Acanthuridae), turtles, and Sirenias, while geese and ducks graze on beds which become exposed during low tides (den Hartog, 1977) and (3) Utilization

of detritus from decaying seagrass material or wash away primary leaves; When seagrasses are washed ashore and begin to decomposed, they are eaten by several insects (larvae), and Taitridae (Amphipod) (Kikuchi and Peres, 1977; Klumpp and van der Valk, 1984). The export of seagrass material, both living and detrital to a location some distance from seagrass bed allows for further distribution of energy away from its original source into the coastal waters.

3. Nurseries and Shelters.

Seagrass beds serve as a nursery ground, that is a place of both food and shelter, for the juveniles of many organisms. den Hartog (1977) reported that these were quite a number of species which were restricted to the seagrass beds although they do not have a trophic relation with the seagrass itself. However, among the forms which spend only a part of their life in the seagrass beds were several economically important fishes and shrimps. It was well known that dredging in the area of seagrass beds in Florida have caused the disappearance of the economically shrimp, *Peneaus duorarum* (Zieman, 1982).

The leaf canopy produces a shading effect which develops a shaded microenvironment at the base. When intertidal seagrasses are exposed, their cover protect the other inhabitants against strong sunlight, temperature, and salinity fluctuations (den Hartog, 1970; Kikuchi and Peres, 1977).



4. Habitat stabilization.

Seagrasses stabilized the sediment in two ways; (a) the leaves slow and retard current flow to reduce water velocity near the sediment-water interface, a process which promotes sedimentation of particles as well as inhibiting resuspension of both organic and inorganic material; (b) rhizome and root form a complex, interlocking matrix, which bonds sediment and retard erosion. So the dense vegetation can offer a calm underwater space within it (den Hartog, 1977; Kikuchi and Peres, 1977; Fonseca et al., 1982). Thus seagrass beds act as sediment traps. This capability depends on prevailing hydrodynamic conditions, the seagrass species, growth forms and topographical situations.

5. Nutrient effects.

The production of detritus and the promotion of sedimentation by the leaves of seagrasses provide organic matter for the sediment and maintain an active environment for nutrient recycling. Epiphytic algae on the leaves of seagrasses have been shown to fix nitrogen, thus adding to the nutrient pool of the region. In addition, seagrasses have been shown to absorb nutrients from the sediment, transporting them through the plant and releasing the nutrients into the water column through the leaves, thus acting as a nutrient pump from the sediment.

Seagrass community

A community is characterized by its species composition and related features (den Hartog, 1980). The community can be described as a structural framework in which to study plant and animal interrelationships, while the ecosystem is a functional framework in which the interrelationships are viewed as process and in which the effects of the abiotic environment are integrated.

The seagrass community composed of both plant and animal community structures. As for the plant community, the literature reviewed dealt with the seagrass composition (taxonomy and distribution) and biomass. On the other hand, the animal community structure would be emphasized on the zooplankton, benthic fauna (epifauna and infauna) and the nekton (juveniles of shrimp, crabs and fishes).

Among seagrass researches, the term epiphyte mean any organism living on a plant surface, not just a plant living on a plant (Harlin, 1980). It includes both sessile and mobile plants and animals, as well as animals that may crawl onto the leaves from the sediment. Epibenthic organisms are those organism that live on the surface of the sediment; in its broadest sense, this includes motile organisms such as large gastropods and sea urchin, as well as sessile forms such as sponge and sea anemone or macroalgae. Infaunal organisms are those organisms that live burried in the sediment. Nektonic organisms, the highly mobile organisms living in or above the plant canopy, are largely fishes and squids.

Plant community structure

Seagrass taxonomy and distribution

The most authoritative account on the taxonomy and distribution of seagrasses in the world was made by den Hartog (1970). The number of species listed is extremely small, 50. They are grouped in a genera 12 , 9 of which belong to the Potamogetonaceae and the other 3 to Hydrocharitaceae. The taxonomic comparison of the group is shown in Table 1.

Table 1 Taxomonical comparison of the group of the seagrasses
(After den Hartog, 1977).

Families and subfamilies	Genera	Number of species
Potamogetonaceae		
Zosterioideae	<i>Zostera</i>	11
	<i>Phyllospadix</i>	5
	<i>Heterozostera</i>	1
Posidonioideae	<i>Posidonia</i>	3
Cymodoceoideae	<i>Halodule</i>	8
	<i>Cymodocea</i>	4
	<i>Syringodium</i>	2
	<i>Amphibolis</i>	2
	<i>Thalassodendron</i>	2

Table 1 (continue).

Families and subfamilies	Genera	Number of species
Hydrocharitaceae		
Hydrocharitoideae	<i>Enhalus</i>	1
Thalassioideae	<i>Thalassia</i>	2
Halophiloideae	<i>Halophila</i>	8

In Indonesia, Dutch and local scientists have investigated the distribution and structure of seagrass communities at the Flores strait, Jakarta Bay, and Seribu Island. Soegiarto and Polunin (1982) reported that the information on the sources of exploited algal production give some idea of the distribution of major seagrass areas in Indonesia. Interestingly, there is a high coincidence between the areas in Indonesia where dugong and turtle sightings have been made and those where seagrasses are reported.

In Malaysia, 10 species of seagrasses were recorded (Mui and Rajagopal, 1989 and Shafeei, 1990). In the Philippines, Menez et al. (1983) made a comprehensive account on the local seagrass flora. The work of Fortes (1986) is the latest work on the taxonomy and ecology of Philippines seagrasses, adding three new taxa to the list of the species.



Hsu and Chou (1989) reported only four of the 11 species of seagrasses reported by den Hartog (1970) from Singapore. They were found during coral reef and benthic surveys at Palau Semakau, Palau Tekong, Terembu Jarat, Labrador beach, and Cyrene reef.

With the exception of *E. acoroides*, *H. ovalis*, *H. decipiens* and *T. hemprichii*, no other seagrasses have been reported from Brunei. The exposure and substrate conditions of the coasts appear unfavorable for seagrass growth (Chou, de Silva and White, 1987 cited by Fortes, 1990).

In Thailand, the distribution of seagrass areas from the Thai waters are compiled from literatures available so far, including the latest informations observed or gathered during this study, and they are presented in Figure 1. Leumanomont (1979) reported 3 species of seagrasses, *Halophila sp.*, *Enhalus sp.* and *Cymodocea sp.* found within the mangrove areas. Srیمانonbhas (1980) found 2 species of seagrasses, *Halophila decipiens* and *H. minor* at Khram Island, Chonburi province. In the Gulf of Thailand, 9 species of seagrasses were found ; *Halophila ovalis*, *H. ovata*, *H. decipiens*, *Halodule uninervis* (wide leaf), *Halodule uninervis* (narrow leaf), *H. pinifolia*, *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, and *C. serrulata*. Comparing the dominant species between the east and west coast of the Gulf of Thailand, it is obvious that *E. acoroides*, *H. uninervis* (wide leaf) and *H. ovalis* are dominant of the west coast, while at the east coast; *H. pinifolia* and *H. ovalis* are dominant (Sudara and Nateekanjanaarp, 1989).

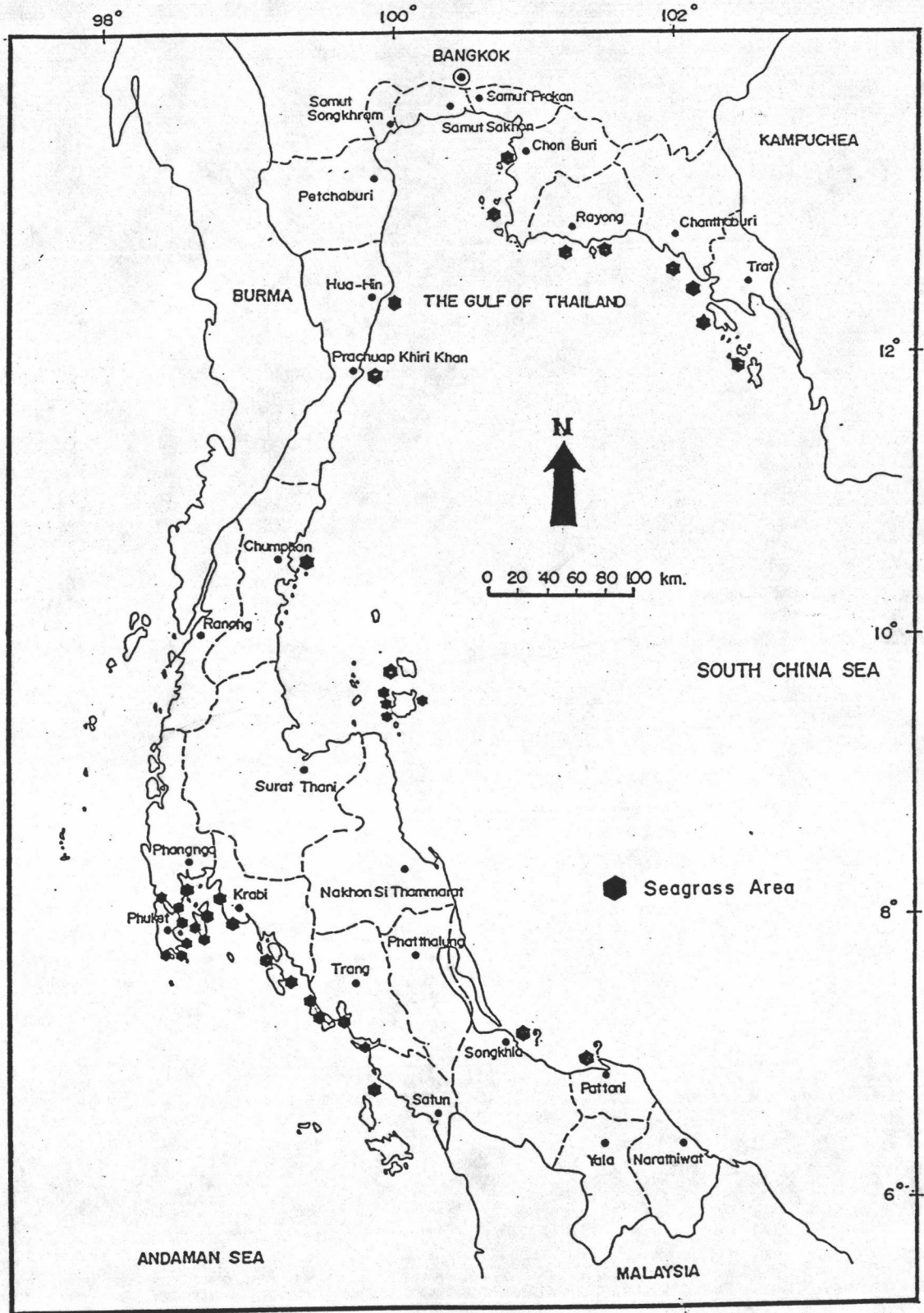


Figure 1 Distribution of seagrasses in Thailand. (Modified from Sudara and Nateekanjanalarp, 1989 and Poovachiranon, 1989).

In the Andaman Sea from Phang-Ngan Bay to Satun province, 9 species of seagrasses were reported; *Halophila beccarii*, *H. ovalis*, *Halodule uninervis*, *H. pinifolia*; *Thalassia hemprichii*, *Syringodium isotifolium*; *Cymodocea rotundata*, *C. serrulata* and *Enhalus acoroides*, with 4 dominant species of *H. ovalis*, *E. acoroides*, *T. hemprichii* and *C. rotundata* (Poovachiranon, 1989).

The Table 2 compiled the available lists the seagrass species and distribution reported from the ASEAN region , mainly based on the works of den Hartog (1970), Fortes (1986) and Fortes (1990).

Table 2 Some species lists of seagrasses from the ASEAN region.

Species	Brunéi	Indo	Malay	Philip	Singa	Thai
		nesia	sia	pires	pore	land
<i>Cymodocea rotundata</i>		●	●	●	●	●
<i>C. serrulata</i>		●	●	●	●	●
<i>E. acoroides</i>	●	●	●	●	●	●
<i>Halodule pinifolia</i>		●		●	●	●
<i>H. uninervis</i>		●		●	●	●
<i>Halophila beccarii</i>			●	●	●	●
<i>H. decipiens</i>	●	●		●		●
<i>H. minor(ovata)</i>		●	●	●	●	●
<i>H. minor, var.nov.</i>				●		
<i>H. ovalis</i>	●	●	●	●	●	●
<i>H. spinulosa</i>		●	●	●	●	
<i>Halophila sp.</i>				●		
<i>Ruppia maritima</i>				●		
<i>Syringodium isoetifolium</i>		●	●	●	●	●
<i>Thalassia hemprichii</i>	●	●	●	●	●	●
<i>Thalassodendron ciliatum</i>		●		●		
Total	4	12	3	16	11	11



Seagrass biomass

Zieman and Wetzel (1980) explained the difference between the terms standing crop and biomass used in seagrass studies that; standing crop refers to the above-sediment material, while biomass refers to the weight of all the living plant material. Both are to be expressed as mass per unit area.

Although seagrasses occur with a wide range of densities under optimum conditions, many species can form vast and dense meadows in the shallow coastal seas. Seagrasses have a large standing crop of leaves, but majority of the biomass of the plant is in the sediment and quite difficult to sample adequately because of the depth of penetration of the root system (Zieman, 1972).

Seagrass biomass varies widely depending on the species involved and the local conditions. The biomass of the species *Halophila* is always small, whereas turtle grass, *Thalassia* had been recorded at density exceeding 8 kg. dry weight/m.² (Zieman, 1982).

Data on seagrass biomass are generally available for only eight species and most of them concentrated on two species, *Zostera marina* from temperate zone and *Thalassia testudinum* from the semi-tropical zone.

Of these biomass values, the majority are leaf biomass or standing crop only. Leaves constitute a variable amount of the weight of the plant portion which depending on depth, substrate, nutrient availability, and season (Zieman and Wetzel, 1980). While the standing crop of leaves is significant, the majority of the biomass is in

the sediment, especially for the larger species. Structurally, turtle grass (*Thalassia*) has the most developed root and rhizome system of all the other species. The major problem in determining the total biomass of seagrasses is the collection of root material. Although the majority of root material is found in the upper layers of the sediments, Zieman (1972) found that *Thalassia* roots penetrated to 4 meters to bedrock in South Florida. Shoal grass, *Halodule* and Manatee grass, *Cymodocea* had less well developed root and rhizome systems and consequently would generally have much more of their total biomass in leaves than did turtle grass (Zieman, 1982). Maximum values for the species also vary widely. Biomass measurements for dense stands of shoal grass were typically several hundred grams per square meters; manatee grass reached maximum development at 1,200 to 1,500 g/m², while maximum values for turtle grass were over 8,000 g/m² (Zieman and Wetzel, 1980) .

Table 3 Comparison of biomass distribution for three species of seagrasses from Pine Channel, June 1980. MB indicates station from the central portion of the embayment, while N is from station at the northern end of the channel. (After Zieman, 1982)

Species & Component	MB 2		MB 3		N1	
	g/m. ²	%	g/m. ²	%	g/m. ²	%
<i>Thalassia</i>						
Leaves	206	11	58	15	267	10
Roots & Rhizomes	1669	89	321	85	2346	90
Total biomass	1875		379		2613	
<i>Syringodium</i>						
Leaves	58	24	102	16	28	47
Roots & Rhizomes	182	76	521	84	31	53
Total biomass	240		623		59	
<i>Halodule</i>						
Leaves	54	21	15	11	5	33
Roots & Rhizomes	200	79	120	89	10	67
Total biomass	254		135		15	
All species						
Total biomass	2369		1137		2687	

The ratio of leaves:roots in both *Thalassia* and *Zostera* increased with a change from coarse sand to fine mud substrate. This would show the positive effect of organic muds in the robust development of the plant, or the need for a more well-developed nutrient absorptive in the coarser sediments which generally tend to be lower in nutrients and organic matter.

Zieman and Wetzel (1980) citing Burkholder, Burkholder and Rivero (1959) found a shift from muddy substrate to sandy substrate increased the total biomass and decreased the leaf:root and rhizome ratios. They found leaf:root and rhizome ratios of 1:3 in fine mud, 1:5 in mud and sand, and 1:7 in coarse sand. The highest leaf and biomass weights were found in the coarser sediments.

It was observed also that there was seasonal variations in the biomass, the ratio of leaves:rhizomes of *Z. marina* varied from 1:2 to 1:1 from winter to summer. The biomass of living rhizomes rose from 100 g./m.² in spring to over 200 g/m.² in fall, with the leaf and flowering in biomass increasing from 60 g/m.² to 255 g/m.² during the same period (Sand-Jensen, 1975 cited by Zieman and Wetzel, 1980). The same trend was demonstrated by Penhale (1977) with the *Zostera marina*. having the low biomass during the spring and early summer. The maximum biomass was recorded during late summer and fall, and declined during the winter. This progression was probably due to environmental factors associated with tidal heights.



Animal community structure

Vertical structure

The physical structure of the seagrass system is dominated by the plant cover, which consists of leaves and the belowground network of roots and rhizomes. This ecosystem, with its dense leaf canopy, shallow root-rhizome complex, and locally geographical variable substrate (i.e., particle size distribution), offers various habitats for a wide variety of micro- and macroflora and fauna. The diversity of organisms and overall abundance are higher in eelgrass meadows than in the adjacent unvegetated areas (Summerson and Peterson, 1984).

Kikuchi (1966, 1980) and Kikuchi and Peres (1977) proposed a functionally related classification for the flora and fauna of Japanese eelgrass meadows that can be applied to both temperate and tropical meadows. In this classification, the biotic components are divided into several subunits on the basis of microhabitat structures and mode of existences of the organisms. In the first category are epiphytic organisms that grow on eelgrass blades (Harlin, 1980), including micro- and macroalgae and micro- and meiofauna that are associated with these organisms; sessile fauna attached to the leaves; mobile fauna crawling on the leaves; and swimming fauna which rest on the leaves. In the second category are biota that attach to the blade stems and rhizomes. A third group includes the highly mobile fauna that swim within and over the leaf canopy: decapod crustaceans and fishes that may be either diurnal or seasonal transients or permanent residents. The fourth category includes epibenthic and infaunal

invertebrates which dwell on or within the sediment. Many of these species may display nocturnal vertical migration patterns between the sediment and leaves .

Another category which needed to be considered also are the birds which feed on eelgrass or its epiphytes from the water surface or at low tide.

Organisms also attached themselves on the eelgrass leaves in generally with the peak loads of epiphytes and epibiotas occurring near the center of the leaves (Nagle, 1968). It is also possible that the center of the leaf is the most structurally intact, giving the greatest attachment area, as the leaf ages.

Eelgrass leaves, together with the epiphytic community, form the basis of several heterogeneous trophic pathways. In simplest terms the pathways among the four functional groupings of Kikuchi (1980) are displayed by fauna that (1) feed directly on eelgrass blade; (2) graze primarily on epiphytes; (3) graze both on leaves and the epiphytic community; (4) obtain energy and nutrients from decaying material (detritus) within the meadow. Many are opportunistic species and others display ontogenetic diet shifts.

Horizontal structure

Coupled with vertical and temporal aspects of community variability is a dimension that is less well documented—horizontal gradients in structure. Silt-clay, organic matter, and nitrogen pools were usually lowest outside eelgrass meadows near Beaufort, North

Carolina, and increased in magnitude toward the center of the meadows. Shoot density and standing crop of leaves and of root-rhizomes increased from the edge to the inside. These aspects of eelgrass ecosystems should reflect in the faunal communities along the edge to center gradient, but at present there are few data to support this hypothesis (Thayer, Kenworthy and Fonseca, 1984). In response to chemical conditions, food resources, or protection from predators (all of which are influenced by the hydraulic regime across the meadow), there is evidence that diversity and abundance of infauna and mobile animals are greater within eelgrass meadows than in adjacent unvegetated areas (Kikuchi, 1966 and Middleton et al., 1984). The same results were also found in the tropical seagrass (Dolar, 1989). In one of the few studies that focused on horizontal gradients of fauna in eelgrass beds, some results demonstrated an increase in both density and diversity from the edge to the center. This was probably due to the sediment-stabilizing function of the eelgrass bed (Kenworthy, Zieman and Thayer 1982 cited by Thayer et. al., 1984).

Hydrodynamic regimes may account for the vertical and horizontal gradients in most areas. Differences in meadow forms, sedimentary development, and fluid energy in these different regimes contributed to different adaptive strategies used by plants and animals in order to cope with diverse hydraulic conditions.

Zooplankton

There have been few studies on zooplankton in the seagrass beds, which included the comparison of zooplankton in water overlying seagrass beds and over unvegetated area. The density of epibenthic

harpacticoid copepods, a favorite food of juvenile chum salmon in the Pacific Northwest, was four times as high in a thick stand of eelgrass than nearby in a sandy habitat without eelgrass. Dense schools of juvenile chum salmon were feeding upon and among the eelgrass blades (Simenstad, Kinney and Miller, 1980 cited by Phillips, 1984).

Meyer found no significant differences between vegetated stations relative to unvegetated in zooplankton biomass. Numbers and biomass levels were, however, one to two orders of magnitude higher at night than during the day. Some zooplankters, such as medusae and ctenophores, were more abundant over grass beds, which was concluded that they were concentrated on grass blades. Demersal plankton (benthic organisms that enter the plankton at night) such as amphipods, isopods, harpacticoid copepods, cumaceans, tanaids, mysids, and adult polychaetes, were more abundant over grass beds at night (Meyer, 1982 cited by Thayer et al., 1984).

Meyer suggested that demersal plankton were important forage items for pelagic-feeding planktivorous fishes which resided in the grass beds at night. During the day these same organisms appeared to be important food for diurnal benthic-feeding fishes. Since many planktivorous fishes also use grass beds as refuges. Meyer also suggested that if nondemersal, open-water zooplankton were concentrated in grass beds on flood tides, they would provide more food sources for grass bed fishes. The reason for high zooplankton density in seagrass beds might be related to the swarming behavior of the zooplankton themselves.

Faunal epiphytes

A diverse and complex assemblage of animals, about which little was known until the work of Nagle (1968), is closely associated with seagrass blades. It includes protozoans, nematodes, polychaetes, oligochaetes, hydroids, bryozoans, sponges, molluscs, decapods, and barnacles. Also included in faunal lists are some fishes which are adapted to clinging on grass blades. Zieman (1982), in a survey of the tropical seagrass community of Florida, stated that the diversity and abundance of faunal epiphytes was the evidence of the ability of seagrasses to provide a substrate for attachment. Few of the faunal species appeared to be obligate epiphytes. They often found associated with macroalgae in the meadow, on shells, pilings and rocks, and on or in the substrate. Eelgrass, however, occurs in areas frequently devoid of other surfaces for attachment and, therefore, can form a significant area of attachment.

The complexity of the epiphytic fauna is further evidenced by the four subdivisions described by Kikuchi and Peres (1977) and Kikuchi (1980). One subunit consists of microfauna and meiofauna that dwell within the "felt-like" coating of micro- and small macroalgae: ciliates, flagellates, foraminiferans, nematodes, polychaetes, rotifers, tardigrades, copepods, and ostracods. The second subunit is the sessile fauna: hydrozoans, actinians, bryozoans, tube-building polychaetes, and compound ascidians. The third includes gastropods, polychaetes, turbellarians, nemerteans, crustaceans, and some echinoderms that are free to move over the blades. Swimming animals which rest on the leaves—mysids, hydromedusae, small squids, and

special fishes (*Lepadogaster*, Syngnathid fishes) -- are included in the fourth subunit.

Since Nagle's (1968) publication, there has been increasing awareness in the importance of epiphytic fauna, particularly as food for fishery important organisms.

Unlike microalgae, which tend to increase in density from the leaf base to the tip, faunal epiphytes display a variety of distributional trends: those that decrease in abundance up the stem; those which increase in abundance up the stem; and those which vary with the density of plant epiphytes. Nagle (1968) showed that *Crepidula*, *Littorina*, *Corophium acherusicum*, *Corophium acutum*, and some mites, polychaetes, and nematodes tended to be more abundant at the base of the stem. These species also found abundant in the samples of the adjacent sediment. Nagle concluded that these epiphytic fauna were the spill-over from normal benthic populations. He also found that some snails, caprellid amphipods, copepods, turbellarians, and bryozoans increased in density up the stem, while several species (e.g., *Bittium*, *Cymadusa*, *Microdeutopus*) were most dense on areas of the leaves with dense epiphytes. These distributions appeared to be related either to currents or to their feeding activities. Thayer, Wolfe and Williams (1975) studied in a newly established eelgrass meadow in North Carolina. They found that gastropods represented 72% of the total numbers of epifauna in the system; deposit feeders 77% suspension feeders 18% ; and carnivore-scavengers 5%. There was seasonal variation in numbers with maximum abundance in spring and early summer.



Nagle (1968), Kikuchi (1966), and Brook (1977, 1978) also indicated that gastropods, amphipods and polychaetes were typically most numerous, while isopods could be important. Some examples of Brook (1977), in a Card Sound, Florida, turtle grass bed, he estimated that amphipod represented 62.2% of all crustaceans.

Heck and Wetstone (1977) studied the habitat complexity in tropical seagrass meadows (*Thalassia testudinum*) in Panama by two potential measurements, plant diversity and above ground plant biomass. They summarized that plant diversity was very weakly related to both invertebrate diversity, whereas above ground plant biomass was significantly related to both these factors. Given that plant biomass reflected the physical complexity, they conceived of four possible explanations : (1) food availability, (2) protection from predators, (3) increased living space and (4) additional habitat. Stoner (1980) reported that the relative abundances of epifaunal amphipods and epifaunal polychaetes were closely related to the mean biomass of macrophytes. Thus, no doubt, is related to increased surface area and habitat complexity above the sediment provided by grass blades and epiphytes.

Infauna

The infauna can be diverse, but are not visually obvious. The rigid pen shell (*Atrina rigida*) is a common filter feeder in many grass beds, along with numerous bivalve molluscs such as *Chione cancellata*, *Codakia orbicularis*, *Tellina radiata*, *Lucina pennsylvanica*, and *Laevicardium laevigatum*. A variety of annelid worms are in the infauna, notably *Arenicola cristata*, *Onuphis magna*, *Terebellides*

stroemi and *Eunice longicerrata* (Zieman, 1982).

Orth (1973) found 117 macroinvertebrate taxa associated with eelgrass (*Zostera marina*) beds in the Chesapeake Bay, Virginia. Not all these were infaunal, many of faunas moved from the sediment and onto the leaves in the summer. The recorded density of infauna was higher from eelgrass than from any other benthic habitat in the Chesapeake Bay system. This similar trend was also found by Kikuchi (1980) in Japan.

Nekton

Seagrass beds have long been considered nursery or feeding areas for a wide variety of nektonic species, many of which are of direct commercial or recreational value, or which are important as food for other fishes and for birds. To be of significance as a nursery, a habitat must provide protection from predators, a substrate for attachment of sessile stages, and/or a plentiful food supply. Seagrass habitats fulfill all of these criteria and, as a consequence, there has been considerable effort to describe both their composition and functional relations to nekton (Thayer et al., 1984).

Few studies have been directed specifically at decapods as a component of the nekton. Heck and Orth (1980a) took monthly trawls in monospecific eelgrass and in mixed eelgrass-widgeon grass meadows in the lower Chesapeake Bay, Virginia, and found a high degree of similarity in the decapod fauna. Six species dominated the fauna, representing 98% of the total numbers: *Palaemonetes vulgaris* (68% of the total), *P. pugio*, *P. intermedius*, *Crangon septemspinosus*,

Callinectes sapidus, and *Penaeus aztecus*. With the exception of *C. septemspinosa*, these species also were important components of eelgrass meadows of North Carolina and of tropical seagrass meadows (Zieman 1982). Differences do exist between meadows in Chesapeake Bay, North Carolina and subtropical systems, for example, caridean shrimps (*Hippolyte*, *Tozeuma*, *Thor*, and *Periclimenes*) are numerous in North Carolina and Florida seagrass areas, but are rare in Chesapeake Bay.

Pink shrimp were distributed throughout Rookery Bay Sanctuary in southwestern Florida, but were most abundant at stations with grass-covered bottoms (shoal grass and turtle grass), and within these stations were most abundant where benthic vegetation was dense. Postlarval pink shrimp with carapace length less than 3 mm. were taken only at stations where shoal grass and turtle grass were present, while other stations without grass always had larger mean size (Zieman, 1982).

The subtropical seagrass system of south Florida appeared to differ from most temperate beds by the presence of relatively large numbers of prominent coral reef fishes over grass at night due to its location in the vicinity of coral reefs. Fishes from families Pomadasyidae, Lutjanidae, and Holocentridae, seek shelter on the reef during the day and moved into adjacent grass beds at night to feed. This situation is typical of Caribbean seagrass meadows. All of the grunts and snappers mentioned above except *Ocyurus chrysurus*, when of appropriate size, will live diurnally on the reef and feed in the grass bed at night. Diel visitors use the grass bed primarily as a

feeding ground (Zieman, 1982).

Zieman, 1982 citing Yokel, 1975 who used a trawl, reported greatest densities of fishes in seagrass meadows as opposed to bare sand and shell bottom, he concluded that 3.5 times as many fishes were captured in grass as in other habitats.

Orth and Heck (1980) reported a different fish community in eelgrass of the Chesapeake Bay (48 species), but noted similarities in seasonal abundances. The numbers of fish species associated with eelgrass was dramatically higher than nearby unvegetated substrates. This was also reported by Kikuchi (1966, 1974) in Japan. In all of these eelgrass beds many species were important food and game fishes

Kikuchi (1966, 1974, 1980) classified the nektonic fauna which appeared in the *Zostera* beds of Tomioka Bay, Southern Japan, into four categories as follows : 1. Permanent residents: small filefish (*Rudarius ercodes*), sea cat fish (*Plotosus anguillaris*), syngnathid fishes, gobies (*Rhinogobius pflaumi*, *Pterogobius zonoleucus*, *Chaenogobius heptacanthus*), sea sculpin (*Pseudoblennius cottoides*), stingfish (*Hypodytes rubripinnis*), blenny (*Enedrias nebulosus*), and hippolytid and palaemonid shrimps. 2. Seasonal residents: a. Juvenile and subadult stage: Japanese sea bass (*Lateolabrax japonicus*), rock fishes (*Sebastes inermis*, *S. oblongus*, *S. marmoratus*), alterids (*Stephanolepis cirrhifer*, *S. japonicus*), gerrids (*Gerres japonicus*, *G. oyena*), sea breams (*Pagrus major*, *Sparus sarba*, *Acanthopagrus schlegeli*), grouper (*Epinephelus fasciatus*), and greenlings (*Hexagrammos otakii*, *Agrammus agrammus*). b. Residents in spawning season: squid (*Sepioteuthis lessoniana*), portunid crabs (*Portunus pelagicus*, *Charybdis*



japonica, *Thalamita sima*), and shrimps (*Processa japonica* and *Sclerocrangon angusticauda*). 3. Transients: puffer (*Fugu niphobles*, *F. pardalis*), *Ditrema temmincki*, *Leiognathus nuchalis*; *Therapon oxyrinchus*, and *Inegocia japonica*. 4. Casual species: *Diodon hystrix*, *Ostracion tuberculatus*, *Paralichthys olivaceus* and others.

Though the permanent residents were small in size and had no commercial value, they were the most important with respect to total density and biomass. On the other hand, some of the seasonal residents were valuable for the inshore fishery. After a pelagic larval life, juvenile fishes move down to the bottom layer of inshore waters and enter the submerged vegetation (Kikuchi, 1966).

In a study done by Coles et al. (1987) at North-eastern Queensland, juveniles of six commercially important prawn species constituted the trawl catch across seagrass beds in waters between Cape York and Cairns: *Metapenaeus endeavouri*, *Peneaus esculentus*, *P. latisulcatus*, *P. longistylus*, and *M. ensis* of the prawn species important in the commercial trawl fishery.

In the Gulf of Carpentaria, Australia, on the other hand, juveniles of three species of prawns namely, *Peneaus esculentus*, *P. simisulcatus* and *M. endeavouri*, which are of major importance in the penaeid prawn catch in this area, likewise utilize seagrass beds as nursery grounds (Poiner, Staples and Kenyon, 1987).

Middleton et al., 1984 reported that the *Zostera* bed at New South Wales, Australia, supported smaller species and the post larval recruits of several economically important fishes, whereas *Posidonia* supported larger species and the large juveniles of economically

important species. These differences appear to be related to variations in the spatial heterogeneity of the canopies created by the two seagrasses.

Dolar (1989) surveyed the fishes and crustaceans community within the seagrass dominated mainly by *Enhalus acoroides* at North Bais Bay, Philippines. The results showed that there were significantly more fish in terms of species richness, densities and biomass, collected from the seagrass bed than from the sand flats. The catches were represented mainly by juvenile individuals. More fishes and crustaceans were caught at night than during the day sampling.

Sudara et al. (1989a) reported that the seagrass bed both *Halodule pinifolia* and *Enhalus acoroides* at Khung Krabane Bay, Chanthaburi Province, Thailand, served as a good nursery ground for juveniles of many economically important species, i.e., sea bass, grouper, shrimps (*Peneaus spp.* and *Metapeneaus spp.*), crabs (*Portunus pelagicus*) and *Acetes spp.* which are processed locally into shrimp paste or fish sauce. *Mugil sp.* (Mugilidae), *Sphyraena sp.* (Sphyraenidae), *Cephalopholis pachycentron* (Serranidae), *Lutjanus monostigma*, *L. carponotatus*, *L. russelli* (Lutjanidae), these were the example of economically important species of fishes found in the seagrass beds.

Satumanatpan (1990) also studied on the species composition and abundance of seagrass fish fauna at Khung Krabane Bay, Chanthaburi Province, Thailand from June-December 1989 using Beam Trawl. He reported that *Enhalus acoroides* bed had more density per trawl than *Halodule pinifolia* about 2.86 times whereas the diversity and

similarity index was not much different (similarity index = 62.5%). Two categories of fish faunas were found, permanent residents which occurred in the two seasons (winter and rainy) i.e., Gobiidae, and seasonal residents were Lutjanidae (found only in winter or rainy season). He also summarized that most of the fishes were in the juvenile stage.

Environmental factors influencing the seagrass distribution

The most notable feature of seagrass is its ability to grow in a remarkably wide range of coastal habitats. The roots and rhizomes are a well-developed anchoring system that not only help to maintain the plant securely in place, but also gives it access to the interstitial sedimentary environment that is rich in nutrients (Thayer et al., 1984).

Solar radiation, depth and turbidity

Seagrasses require high light intensity for photosynthesis (Zieman and Wetzel, 1980). The maximum depth at which seagrasses are found is correlated with the available light regime, provided that suitable sediments are available. Buesa (1975) reported that maximum depths for tropical seagrasses of the northeast coast of Cuba as follow: turtle grass (*Thalassia*), 14 m. (46 ft.); manatee grass (*Cymodocea*, 16.5 m. (54 ft.); *Halophila decipiens*, 24.3 m. (80 ft.); and *H. englemanni* 14.4 m. (47 ft.).

Light intensity and quality change according to condition of the water. In clear water, light is relatively enriched in blue wavelength with depth. On the contrary, in highly turbid water, blue light is scattered and the enrichment is in the portion of the green wavelength. In both conditions the longer red wavelengths are absorbed in the first few meters of the water column. Buesa (1975) also found that turtle grass responded to the red portion and the blue portion was better for manatee grass.

Seagrasses would grow in less depth when the water is more turbid (Zieman, 1982 and Phillips, 1984). Other interrelated factors such as the available of suitable substrate, current velocity, light penetration and exposure to wave could also limit the depth of seagrasses growth (Thayer et al., 1975).

Zonation

Principle factors determining seagrass distribution are light and pressure at depth and exposure at shallow end of the gradient (Zieman, 1982). A general pattern of seagrass distribution in clear waters of South Florida and the Caribbean, Shoal grass (*Halodule*) usually grows in the shallowest water and tolerates exposure better than other species.

In the eulittoral zone of between mean high-water neap and low-water neap, extensive beds of parvozostera (*Halodule*, *Zostera*) could be found and often accompanied by the halophilid. In the zone between mean low-water neap and mean low-water springs these were replaced by the coarser magnozosterids. In the upper sublittoral the

magnozosterids were replaced by the very coarse enhalids and amphibolids. At the greatest depths in which angiosperms were able to grow, they were represented either by the tiny halophilids or by enhalids. In addition, *Halophila* species behaved as eurybiontic pioneer species, or in where the other seagrasses were absent. The genus seems to have a wide ecological range, but restricted capacity for competition with more specialized forms. The enhalids and amphibolids are large, stenobiont forms, with a good capacity to compete (den Hartog, 1977).

The zonation pattern of seagrass communities in the Philippines were (1) *Halodule uninervis* (narrows-leaf) zone, (2) *Halophila*, *Halodule uninervis* (wide-leaf) zone, (3) *Thalassia*, *Cymodocea* and *Enhalus* zone (Fortes, 1986) closely to approximated that presented by den Hartog (1977) in relation to the zonation of different growth forms of seagrasses. In addition, they agreed remarkably well with that proposed by Johnston (1978a,b), Brouns and Heijs (1985) for the Papua New Guinea seagrass communities.

Sediment and substrate

Seagrasses grow in various sediments from fine mud to coarse sand, depending on the type of source material (den Hartog, 1970, 1977). As roots planted, seagrasses require a sufficient depth of sediment for development. Zieman (1982) pointed out that the single most important sediment characteristic for seagrass growth and development is sufficient depth. Depth requirements also vary among different species. Because of its shallow, surfacial root system, shoal

grass can colonize thin sediment in an area of minimal hydraulic stability. Turtle grass (*Thalassia*) is more robust, requiring 50 cm. (20 inches) of sediment to achieve lush growth, although meadow formation can begin with lesser sediment depth (Zieman, 1982).

Brouns and Heijs (1985) reported that in Papua New Guinea *Thalassia hemprichii* occurred on all types of substrate: mud, muddy sand, sand and coral debris. *Enhalus acoroides* grew on sandy and muddy bottoms. *Cymodocea rotundata* grew on sandy-mud bottoms. *C. serrulata* was found on the coral sand or mud covered coral debris. *Halodule uninervis* with two distinct forms: (1) narrow-leaved form (with leaves up 1 mm. wide) and (2) a wide-leaved form (with leaves from 1 to 4 mm. in width). The narrow-leaved form developed monospecific stands high in the intertidal on exposed, sandy bottoms, while the wide-leaved form occurred in the sheltered muddy localities. *Halodule pinifolia* formed a pure stand on muddy bottoms or mud covered coral debris in the upper sublittoral zone. *Halophila ovata* only occurred on muddy or sandy bottoms while *H. decipiens* found on deep sandy patches. *Syringodium isoetifolium* can be found on sandy bottoms or on coral rubble.

Sudara and Nateekanjanalarp (1989) reported at Koh Samui and Koh Pha-Ngan, that the larger species *Enhalus acoroides* occurred on the coarse sand, medium and coral rubble, whereas *Halodule uninervis* (wide variety) found on the fine-medium coarse sand and coral rubble.



Salinity

Seagrasses tolerate a wide range of salinities of from 6-60 ppt., even in freshwater for short periods. McMillan and Mosely (1967) reported that the turtle grass (dominant seagrass of South Florida) survived in salinity from 3.5 ppt. to 60 ppt., but could tolerate these extremes for only short periods. Following the passage of a hurricane in South Florida in 1960, Zieman (1982) indicated that the damage of the turtle grass came from freshwater run off which have been more severe than the physical effects of the high winds and water surge.

McMillan and Mosely (1967), McMahan (1968) and McMillan (1979) studied salinity tolerance in seagrasses. The result showed shoal grass was the most broadly euryhaline, turtle grass was intermediate, and manatee grass and *Halophila* had the narrowest tolerance ranges. *Halophila* being even more stenohaline than manatee grass.

Oxygen

Most seagrass meadows have sufficient oxygen in the water column for the survival of their associated plants and animals. Dense beds in shallow water with restricted circulation can show extremely reduced oxygen levels or even anoxia late at night on a slack tide (Zieman, 1982). Reported on oxygen changes in the water (Broekhuysen, 1935 cited by Phillips, 1984) over an eelgrass meadow in Holland showed that anoxia conditions prevailed from 1.00 am until 6.00 am. At 3.00 pm there was a 360 % saturation of oxygen in the water. Hence, the animals within the eelgrass meadow must be adapted to the

anoxia conditions and to the lowered pH levels attendant with the low oxygen.

There was a little data to indicate that oxygen was a limiting factor or constituted a stress on the system because the extreme diurnal change. However the anoxic system in the seagrass bed may also resulted from the heavy load of suspended organic sediment that would also consume oxygen. Generally the wind can lead to generate the turbulence which help to aerate the water (Zieman, 1982).

Current velocity

Little work has been done to determine the response of seagrass communities to different current velocity (Zieman, 1982). Seagrass production and biomass are strongly influenced by current velocity. Both turtle grass and eel grass show maximum standing crops where current velocities 0.5 m./sec. (Conover, 1968). Fonseca and Kenworthy (1987) studied the effect of current flow on the enhancement of nutrient uptake at the leaf surface of seagrasses by reducing the diffusion boundary layer, modifying the scale of turbulence within the canopy thus presenting more nutrients to the leaf. Current velocity (together with wave action) creates hydraulic regimes that influence seagrass and seedling distribution. Current and wave have been correlated with meadow configuration, relief and blow out formation and migration, as well as the distribution of seagrass detritus.

Temperature

Seagrass tolerate a wide range of water temperatures, varying from 0 to 40 °C. The optimum temperature for growth and development of a species seems to be a function of its specific site. It is likely that seagrasses form biotypes adapted to a local regime of temperature. The fundamental importance of temperature in controlling seasonal growth in *Z. marina* had been recognized by den Hartog (1970) and Rasmussen (1977). Along latitudinal gradients in North America, the reproductivity of the species is probably controlled primarily by water temperature (Phillips, McMillan and Bridges, 1983).

Shoal grass and manatee grass were more eurythermal than turtle grass (Zieman, 1982). This fitted its ecological role as a pioneer or colonizing species (den Hartog, 1970). Shoal grass was commonly found in shallower water than either turtle grass and manatee grass, where thermal variation would tend to be greater (den Hartog, 1970; Fortes, 1986; Johnstone, 1978a,b; Brouns and Heijs, 1985). McMillan (1979) found that shoal grass had a greater chill tolerance than turtle grass while manatee grass showed less resistance to chilling.