Bermuda's Coastal Seagrass Beds as Habitat for Fish

A dissertation presented to satisfy the requirements for the degree of Master of Science in Marine Biology of the University of Glasgow.

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DECLARATION

I declare that this thesis represents work carried out by myself, except where note is made to the contrary.

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4-10-99

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Abstract:

Tropical seagrass communities throughout the world are known to be highly productive centres of biodiversity. Along with coral reefs and mangrove forests, seagrasses are recognised as forming critical habitats for a wide variety of marine organisms. Not only are these habitats important as discrete entities, they act synergistically to promote the stability and productivity of tropical coral reef ecosystems. In particular, seagrass meadows are noted for stabilising sediments, thereby reducing turbidity, and serving as important nurseries and foraging grounds for a variety of economically important fish and crustaceans.

Located at 32°N 65°W, the remote oceanic islands of Bermuda support the northernmost coral reef ecosystem in the world. Populated by humans since 1609, and with over 3,500 scientific publications describing its natural history, Bermuda is arguably one of the most carefully studied of all oceanic islands. Despite this wealth of knowledge, the extent of the island's seagrass meadows, the vigour of this important resource and the composition of the local seagrass-associated communities remain poorly documented.

In 1990 the use of seine nets over seagrass beds was banned in certain coastal areas to protect the juvenile fish living there. This action was taken in absence of any documented information on the distribution and seasonality of fish inhabiting Bermuda's coastal seagrasses. However, this measure was taken in response to anecdotal information that large numbers of juvenile fish were being destroyed as bycatch in the local bait fishery and reflects the management agency's sensitivity to the protection of inshore nurseries.

To address this lack of information the objectives of the current study were:
1) to document the area covered by Bermuda's coastal seagrass beds and to examine recent trends in the spatial extent of these habitats through the examination of photographic aerial surveys spanning the period 1962-1997,
2) to use samples taken by means of a standard Bermuda bait net to describe the composition and seasonality of the fish communities inhabiting three inshore seagrass habitats, and to compare these three communities,
3) to describe the planktonic, epifaunal and infaunal components of the local seagrass-associated micro-invertebrate community, and
4) to document the feeding patterns and food preferences of the dominant members of the fish community found in these seagrass beds.

The coastal seagrass meadows were found to occupy approximately 500Ha in 1981. Since 1962 substantial changes, both expansions and contractions, in the seagrass beds have occurred. The largest declines happened in seagrass beds well removed from any apparent anthropogenic input. The causes and implications of these changes remain unclear.

Forty-two species of fish were identified from the three sampling sites. Large numbers of a few common species often dominated the samples. Both site and season were found to have significant effects on the species diversity of the seagrass-associated fish communities captured by bait net. Species that were common at one site were sometimes rare or absent at others. Observations of seasonal recruitment pulses and

modal progression analysis revealed patterns of residence and growth of fish within this habitat.

The seagrass-associated invertebrate community was found to be both abundant and diverse. A significant difference was found between the extremely abundant microfauna dwelling upon and between the seagrass blades and the less numerous organisms of the adjacent water column. Samples of the infauna revealed far fewer organisms than did epifaunal samples.

Direct diver observations of the feeding behaviour of fish over and within seagrass beds largely confirmed the feeding strategies inferred from analysis of gut contents. The epibiota coating the grass blades formed the primary food source for the majority of seagrass-associated fish. Ontogenetic changes in feeding strategies were observed in a number of fish species.

The results of these investigations indicate that Bermuda's inshore seagrasses are important to local fish production and that the magnitude of this resource is in a state of flux. While indicating that site-specific information is required to assess the importance of particular seagrass meadows, the available information supports management efforts aimed at protecting these habitats.

Chapter 1: Introduction to Bermuda and the Biological Importance of Tropical Seagrass Communities

1.1 An Introduction to Bermuda:

1.1.1 Geology:

The Bermuda Rise consists of a group of three steep-sided seamounts, the northeasterly member of which supports the $55km^2$ land mass of Bermuda. The others rise to approximately 100m depth to form the Argus and Challenger Banks. Originating through volcanic activity along the mid-Atlantic ridge some 110 million years ago, the Bermuda pedestal subsequently migrated approximately 1,000km to the northwest to enter a second phase of volcanic activity about 30-50 million years ago (Vacher, 1986). Since that period it has continued its drift a further 800km to Bermuda's present location. Currently in a phase of volcanic inactivity, these mounts rise from depths of about 4,000m to form a total platform area of about $1,000km^2$.

A limestone cap, which rarely exceeds 100m in thickness, covers the volcanic rock extending down the slopes of the rise to approximately 200m depth. Whilst this limestone is exposed in many locations, much of the land is covered by a layer of soil or sand. The reddish soil, termed paleosol, which accumulates in depressions and flatter locations is a mixture of calcareous particles and fine material accumulated from thousands of years of atmospheric fallout (Vacher, 1986).

Windblown dunes of sand derived from calcareous skeletons of marine algae, foraminifera, molluscs, corals, etc. contribute 90% of Bermudian limestones (Morris et al., 1977). The topography of Bermuda is thus dominated by rolling hills of poorly consolidated sandstones which follow the southern rim of the Bermuda Rise. Percolating rainwater has played a significant role in the cementation of sands to form new limestones while episodes of rising and falling sea level during the Pleistocene resulted in the re-working of deposits on a cyclical basis and the laying down of a series of limestone formations of different ages (Vacher, 1986).

1.1.2 Geography/Climate:

Bermuda is located at 32°20'N and 64°50'W, approximately 960km southeast of the nearest point of land, Cape Hatteras, North Carolina (See Fig. 1.1). The platform resembles an atoll, in that a peripheral annular reef tract and islands, forming a 26km by 52km ellipse, surround a shallow central lagoon (Thomas, 1992a). Darwin (1842) commented on the differences between Bermuda and the typical Pacific atoll citing Bermuda's submerged fringing reef, wide tract of gradually shoaling water to the seaward of this reef, and the size, height and "extraordinary" form of the islands.

The waters covering the platform can be sub-divided into three regions; the North Lagoon to the north and east, the Western Reef Flats, and the waters off the South Shore (See Fig. 1.2). The average depth is 10-15m with a maximum depth of 25m near Three Hills Shoal. There are also four main inland water basins; Great Sound/Hamilton Harbour, St. George Harbour, Castle Harbour and Harrington Sound.

The island's climate is generally described as sub-tropical with the only recognisable seasons, summer and winter, reflecting the two major weather patterns affecting the area. In summer the presence of the Bermuda/Azores high, an area of high pressure over the Atlantic, deflects low pressure systems towards the north thereby maintaining Bermuda in an area of mild southerly breezes. However, during the winter this high moves further south providing little or no protection from the frontal systems associated with the westerlies that dominate at this latitude. Northwesterly gales become frequent and would cause dramatic drops in air temperature were it not for the warming effect of the Gulf Stream to the north and west.

While surface ocean temperatures range from 18°C in January to 28°C in August, the water mass surrounding Bermuda between the depths of 200 and 500m is consistently about 18°C. Inshore temperatures may vary from 15°C to 30°C.

Rainfall is not highly seasonal with a mean annual accumulation of approximately 150cm being distributed throughout the year. October is the wettest month with an average of 16cm, and April the driest at 10cm. Temperatures show marked seasonality with mean monthly air temperatures ranging from 18.5°C in February to 29.6°C in August.

Figure 1.1 – The Location of Bermuda within the Western Atlantic (from Sterrer, 1986)

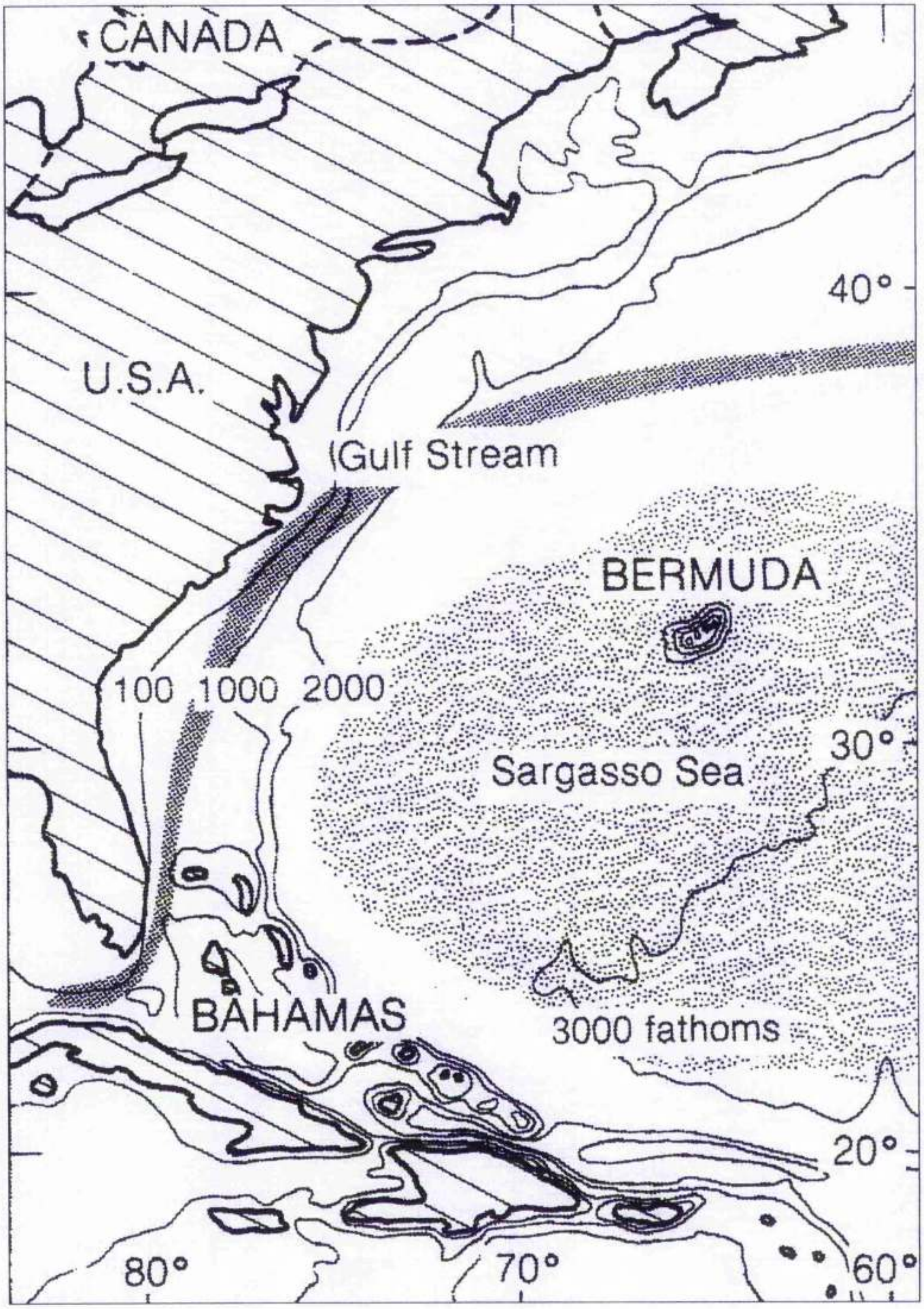
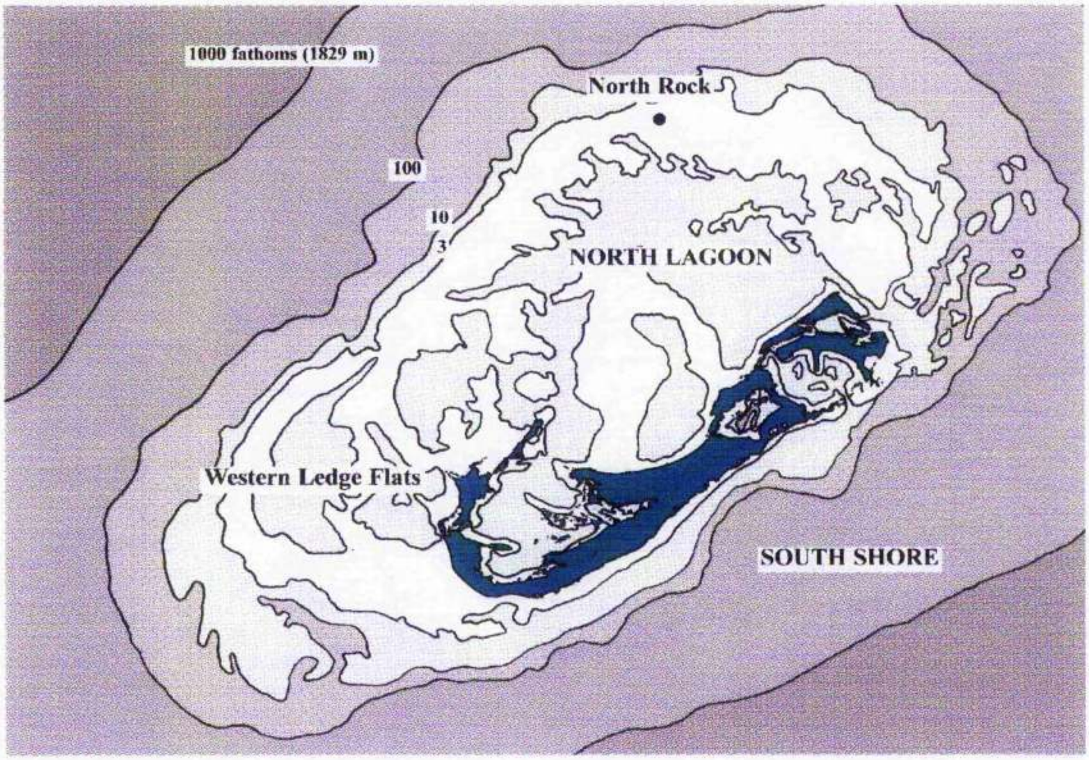


Figure 1.2 – The Bermuda Platform



1.1.3 Marine Communities:

Bermuda supports the most northerly coral reef system in the world, a phenomenon which can be attributed to the warming influence of the Gulf Stream which transports water north from the Caribbean Sea. Although Bermuda lies to the east of the path of the Gulf Stream's northerly flow, spin-offs bring warm water to the islands. These eddies are not predictable but are believed to provide sporadic pulses of larval transport of tropical species to the islands (Glasspool, 1994). That virtually all stony corals and gorgonians found at Bermuda have been recorded from Jamaica emphasises the Caribbean affinity of Bermuda's marine fauna. However, low winter water temperatures (Liddell and Ohlhorst, 1988) and limited larval duration (Glynn, 1973; Glasspool, 1994) apparently restrict recruitment. This high latitude outpost of Caribbean species supports only about one third of the shallow-water stony corals recorded from Jamaica (Logan, 1992).

There are two main reef building communities at Bermuda; the coral reefs which are dominated by stony corals and cover most of the shallow hard substrates of the platform, and the algal-vermetid cup reefs which are principally found on the South Shore and are composed of an intergrowth of crustose coraline algae and vermetid gastropods. Logan (1988) described a great variety of morphological reef types from Bermuda which can be placed in three major reef biotypes:

The platform margin reefs. Located from 5-50m depth on the outer parts of the platform and characterised by large colonies of *Diploria, Montastrea* and *Porites.* Live coral coverage is high, ranging from approximately 20% to 50% with optimum conditions for corals existing in 15-25m (Logan, 1992).

The lagoonal patch reefs. Occurring within the relatively protected waters of the North Lagoon are also dominated by the *Diploria, Montastrea, Porites* assemblage. Although live coral coverage is lower than on the Platform Margin (approximately 16%; Logan, 1992), the calmer conditions on these reefs allow for the growth of a wider range of delicate sessile organisms. Particularly striking is the increase in abundance of branching growth forms of corals and *Millipora alcicornis.*

The inshore reefs. Contained within the enclosed harbours, these have suffered from heavy sedimentation from ship traffic or, particularly in Castle Harbour, from dredging for coastal construction. Live coral coverage is low (approximately 9%; Logan, 1992) and much of the substratum is covered by algae.

Within the shelter of lagoonal and inshore waters calcareous sediments derived from skeletal material of the indigenous biota largely cover the bottom. Dominant lagoon sediment producers include the alga, *Halimeda*, along with numerous infaunal bivalves. Upchurch (1970) characterised the 3 major soft bottom biotopes of the Bermuda Platform as:

The nearshore-sandy substratum, which occurs extensively on the sandy flats of the central lagoon, along the north shore of the island, and in some of the shallow flats of the inshore waters. Beds of seagrasses (*Thalassia testudinum* and *Syringodium filiforme*) and algae (*Halimeda, Penicillus, Padina*), animals such as the echinoids *Lytechinus variegatus*, bivalve molluscs (*Codakia, Gouldia*) and a few solitary coral colonies (*Isophyllia, Porites, Siderastrea*) are scattered through this biotope.

The nearshore-muddy substratum, which is confined to the smaller lagoon basins and the protected inshore basins. Fine sand and silt prevail with seasonal anoxia occurring in the deepest locations. The alga *Penicillus* is abundant and the holothurian *Isostichopus badionotus*, the coral, *Oculina*, and turriform gastropods are also common elements.

The basin centre biotope, which extends throughout the deeper regions of the central lagoon. It is similar to the nearshore-sandy biotope, but seagrasses and corals are rare. *Halimeda* and *Penicillus* are the dominant algae.

1.2 The Biological Importance of Tropical Seagrass Communities:

Seagrass beds have long been regarded as unique and important coastal ecosystems. Much of the justification for the perceived value of seagrass beds lies in their function as a nurturing habitat for fauna. Dense shelter in the form of the seagrass canopy, and food chains fueled by high *in situ* primary productivity, are held to provide the basis for very high faunal productivity.

Seagrass communities extend from the Equator to subpolar waters. Early research suggested that the gross productivity of seagrass communities ranks amongst the highest recorded for natural communities (McRoy and McMillan, 1977). More recent studies set a lower limit, whilst still acknowledging that seagrasses are amongst the most productive of submerged aquatic systems (Larkum and West, 1983). In addition to their own photosynthetic production, seagrass blades serve as substrata for an abundant epiphytic algal flora, the most important of which are the filamentous and crustose coralline red algae (Ogden, 1980). This epiphytic flora contributes substantively to the productivity of seagrass beds; Jones (1968) for example, found that the epiphytes on *Thalassia testudinum* contributed about 25-33% of the community primary productivity. The trophic value of epiphytes is further enhanced by certain qualitative attributes, foremost of which are their high nutritional value and ability to sustain high rates of grazing (Klump, Howard and Pollard, 1989).

Being rooted angiosperms, seagrasses have a marked influence on the chemical and microbiological characteristics of the sediments. Rhizomes, which may form 60-80% of seagrass biomass release organic matter that supports a much greater biomass of aerobic micro- and macrofauna than areas of unconsolidated sediment. Decomposition of seagrass roots, rhizomes and exuded organic matter is usually rapid and complete with little or no increase in the organic matter in the sediment (Moriaty and Boon; 1989).

Seagrasses increase sedimentation and encourage the settlement of the larvae of benthic organisms by providing a physical baffle to hydrographic flow (Fonesca and Fisher, 1986; Eckman, 1983). When calcareous algal epiphytes are abundant in seagrass meadows, the production of calcareous material further contributes to local sedimentation (Zieman, 1983). The roots and rhizomes form a complex matrix which binds sediments and impedes erosion. Seagrasses with dense root masses may create and stabilise short, near vertical sediment walls (Clarke and Kirkman, 1989), greatly reduce storm surges (Whitaker, Reid and Vastano, 1973), and in some instances seem hardly affected by hurricanes which severely damage nearby mangroves and coral reefs (Hartog, 1977).

The action of seagrass beds in promoting sedimentation and reducing resuspension serves to protect adjacent communities by reducing turbidity. Coastal seagrass beds also function to reduce offshore transport of terrigenous sediments thereby minimizing the impact of terrestrial runoff on nearshore reef communities.

McRoy (1983) and Wiebe (1987) have reviewed nutrient dynamics in tropical seagrass beds. Although both reviews demonstrate how little is really known, some interesting facts emerge. First, nitrogen fixation on the shoots and roots of *Thalassia spp.* varies from negligible to 100% of the nitrogen required for production. This variation may be related to the ambient levels of inorganic nitrogen or advection of particulate detritus among sites. Secondly, at least in the Caribbean, the depth of the sediment layer determines the efficiency of nutrient recycling; deeper sediments allow for greater root development and *in situ* recycling of nutrients within the seagrass bed.

Comparatively few tropical animals consume seagrasses directly. Noteworthy among these are green turtles, certain sea urchins, plus acanthurid and scarid fish (Ogden, 1980; Zieman, 1983; McGlathery, 1992). Herbivores usually consume 10-15% of tropical seagrass productivity (Zieman, 1983; Ogden, 1987). The remainder supports a detritus food chain, either *in situ*, or after being transported elsewhere by currents (Zieman *et al.*, 1979; Klug 1980; Zieman, 1983). Some nutrients are directly released into seawater in dissolved form (both organic and inorganic), for use by bacteria and plankton. Estimates of dissolved organic material release by living seagrass range from 6 to 28% of carbon fixed by photosynthesis exuded into the sediment and 1-2% into the water column within 6 hours (Moriaty and Boon, 1989).

The leaves are host to a diverse attached fauna that includes suspension feeders, herbivores, carnivores and bacteria, the latter acting as the primary food source for much of the food web. Food webs in seagrass beds are complex and not fully understood. There are often numerous trophic interactions among the epibiota before material in the food chain becomes available to fish (Young and Young, 1977; Heck and Thoman, 1981; Heck and Wilson, 1987). In most seagrass-fish communities so far studied, the majority of the fish species present are primarily carnivorous, feeding principally on small, mainly detritivorous, seagrass-associated crustaceans (Klumpp, Howard and Pollard, 1989).

Seagrass beds are widely recognised to be important nurseries for many fish species. Experimental manipulations of seagrass density and predator abundance have indicated that the firm relationship observed between seagrass biomass and abundance and diversity of animals (Stoner, 1980a) is the result of both an active choice of dense patches of seagrass by most species and higher rates of predation in sparse patches (Stoner, 1982; Leber, 1985; Bell and Westoby, 1986).

Bell and Westoby (1986b) developed a model to explain these patterns of abundance which holds that; i) competent fish larvae are distributed patchily when ready to settle, ii) they do not discriminate between grass beds when they settle, and iii) they do not leave the grass bed soon after settling, but redistribute within the bed to microhabitats that favour survival. These workers argued that there should be selection for larvae that settle in the first bed that they encounter, to escape the high rate of predation experienced in the plankton.

Further support for this model was provided by Bell et al., (1987). In the course of testing whether fish settling out of the plankton discriminated between seagrass of different density they found that simple predator exclusion cages supported as many newly recruited fish as did more complicated habitats. They took this to be evidence that detailed structure is not important to fish larvae settling in seagrass beds and that seagrasses are important recruitment sites principally because they provide shelter, not because of their biological production.

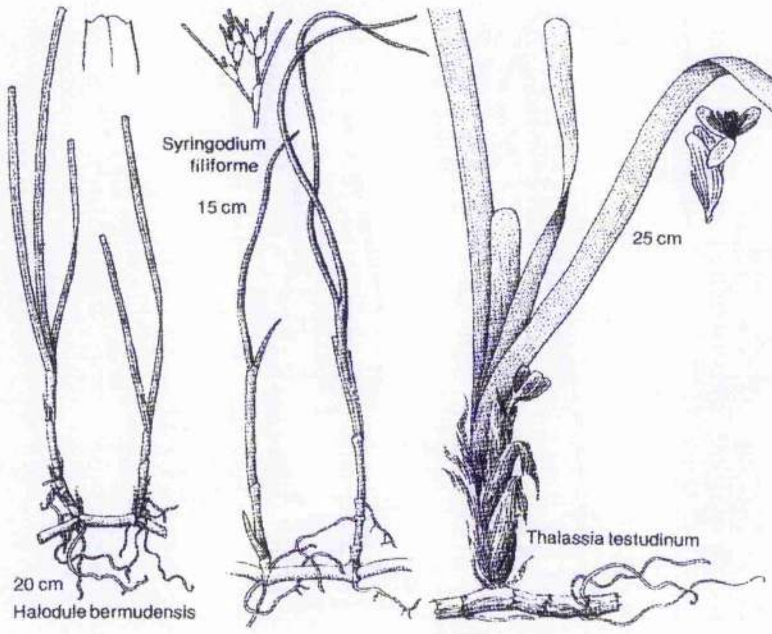
1.3 Seagrasses in Bermuda:

Seagrasses occur as underwater meadows, in some of the marine ponds, inshore waters, coastal bays, nearshore waters and reefal sand channels in Bermuda. However, their areal distribution is rarely extensive and often patchy. Logan and Cook (1992) summarised local seagrass literature, noting that although seagrasses and their associated communities are recognised to be important components of the marine system, they have not been the subject of extensive research in Bermuda. They opined that apparent fluctuations in areal extent of local seagrasses in recent years indicate an urgent need to document quantitatively their spatial and temporal changes.

Although Bermuda has one of the best studied marine environments in the world, documented in more than 3,000 publications, the seagrass communities remain largely unstudied. Sterrer (1986) produced a systematic guide to the identification of Bermuda's marine organisms in which the known occurrence and distribution of the local marine biota is summarised. Working largely from this reference, Logan and Cook (1992) assembled a list of species present in Bermuda's seagrass beds. The poor documentation of Bermuda's seagrass communities is emphasised by comparing the 113 species of epiphytic algae listed by Humm (1964) from *T. testudinum* in Florida, with the total of 2 plant epiphytes recorded from Bermudian seagrasses (Sterrer, 1986).

Three species dominate Bermudian seagrass beds; *Thalassia testudinum, Syringodium filiforme,* and *Halodule bermudensis* (See Fig. 1.3). These three species may occur in mixed stands or in a successional sequence from *Halodule* to *Syringodium* to *Thalassia.* (Williams, 1990). A fourth species, *Halophila decipiens* is reported from Bermuda (Sterrer, 1986) but Thomas (pers. comm.) advises that this may be an erroneous record.

Figure 1.3 – The Seagrasses of Bermuda (from Sterrer, 1986):



Thalassia testudinum is the dominant seagrass of Bermuda, and occurs in many coastal and reefal sand channels and in the anchialine pools of Evans Pond and Lovers Lake (Thomas *et al.*,1992). It is characterised by wide ribbon-like leaves, 15-30cm long and up to 1.5cm wide (Sterrer, 1986). These originate from short roots which normally occur alternately on either side of a horizontal spreading rhizome. The rhizomes, which in this species are structurally the most developed of all Bermudian seagrasses (Zieman, 1987), may be found from 1-25cm under the sediment surface, but are generally found at a depth of 3-10cm. Roots radiate from the rhizomes and occasionally from the short vertical shoots.

The next most common seagrass species in Bermuda, *Syringodium filiforme*, is characterised by thin, round leaves of 0.8-1.8mm in diameter and up to 30cm in length (Sterrer, 1986). This species is unique amongst seagrasses in having round, rather than flattened, leaves (Logan and Cook, 1992). It is common in shallow protected waters (Bernatowitz, 1952), is the dominant seagrass in Harrington Sound (Rupp, 1978), and is also present in Evans Pond (Thomas, *et al.*, 1992). Although there is little published information on this species from Bermuda, Rupp (1978) reported 2,800 leaves per square meter in Harrington Sound, while South (1983) reported 1,500 leaves and 600 shoots per square meter in a pure stand from Ferry Reach. Where *T. testudinum* and *S. filiforme* occur together, the latter is a weak competitor (Logan and Cook, 1992).

Halodule bermudensis is less common than either *T. testudinum* or *S. filiforme.* Its narrow leaf is flattened, about 2mm wide and 2.5-5cm long, with a prominent mid-rib and 2-3 points on the leaf tip (Sterrer, 1986). This species prefers quiet inshore waters and is recorded from Evans Pond (Thomas, 1992b), although it occasionally occurs in mixed stands with *T. testudinum* or *S. filiforme*, as in Whalebone Bay and off St. Catherine's Point (Logan and Cook, 1992).

Enrichment of the water column can favour the rapid growth of mat-forming algae such as *Cladophora prolifera* and *Spyridia aculeata*, a process which has been implicated in causing the overgrowth and displacement of established seagrass beds in local waters (Rupp, 1978). McGlathery (1992) also found that the dominance of seagrasses in Baileys Bay diminished near to the shoreline where seepage of nutrient rich ground waters promoted success of the red alga *S. aculeata*. Pitt (1991) found that water column enrichment did not stimulate the productivity of *Thalassia testudinum* in Bermuda waters, a result which she attributed to increased light attenuation by phytoplankton. The dual ability of seagrasses to extract nutrients from the sediment and create a favourable environment for nitrogen fixation allows seagrasses to dominate in nutrient poor environments. In Bermuda, significant nitrogen fixation in seagrass habitats has been associated with the rhizosphere (O'Neil, 1987).

Other than the seagrasses themselves, the most obvious plants growing in seagrass beds in Bermuda are the macroalgae, most notably *Penicillus capitatus, Udotea flabellum, Turbinaria turbinata, Laurencia obtusa* and several species of *Halimeda* and *Padina* (Logan and Cook, 1992). Blooms of seagrass epiphytes occur periodically in Bermuda, one of which was well documented by McGlathery (1992). In 1990, the seagrass beds of Whalebone Bay were overgrown with a variety of algae, apparently in response to elevated nutrient levels from a rich production of detritus resulting from an extensive seagrass die-off in the summer of 1989. Such blooms are usually short lived, resulting in minimal long-term effect on seagrass beds.

Logan and Cook (1992) list the most common epiphytic animals of Bermudian seagrasses to be protozoans (principally foraminifera), anemones, the calcareous polychaete *Spirorbis formosus*, arthropods, gastropods and the ascidian *Botrylloides nigrum*. Suspension feeders include the anemone *Bunodeopsis antilliensis*, *Spirorbus formosus*, bryozoans and the sponge *Halisarca dujardinu*, while detritus feeders include amphipods and a variety of small gastropods. Probable carnivores include the amphipod *Caprella equilibria*, and the turbellarian *Amphiscolops bermudensis*.

Sessile macrofauna associated with seagrass beds include the fire sponge *Tedania ignis* and the stony corals *Siderastrea radians*, *Isophyllia sinuosa* and *Stephanocoenia michelinii*. Motile epifauna include the sea urchins *Lytechinus variegatus*, *Tripneustes ventricosus* and *Diadema antillarum* which feed on grass blades, detritus and epiphytes (Ogden, 1976). Prior to a massive die-off of *D. antillarum* in 1983 (Lessios, Robertson and Cubit, 1984), this species was also observed to feed on roots of *Thalassia testudinum* that had been exposed by heavy surge action (Logan and Cook, 1992). The sediment-ingesting holothurian *Isostichopus badionotus* and the herbivorous Harbour Conch *Strombus costatus* are also common inhabitants of nearshore seagrass environments. The Queen Conch, *S. gigas*, now rare in nearshore waters, is commonly associated with inter-reefal seagrass beds.

The infauna of grassbeds and nearby soft-bottom habitats in Bermuda includes a variety of bivalves, crustaceans and scavenging and bottom feeding worms. Orth (1971) determined that the infauna of *Thalassia testudinum* beds in Whalebone Bay, Bermuda is four times as abundant and more diverse (55 species) than that of adjacent bare sand (22 species). He attributed this to the greater stability of the sediments, greater variability of microhabitats and the increased availability of food in the form of seagrass-derived detritus.

In Bermuda there have been no substantive studies of the use of seagrass beds by fish. Logan and Cook (1992) cite parrotfishes (Scaridae) as the main group of grazers of seagrasses and note that the juveniles of other species use the grass beds as nurseries, while more permanent residents include eels, wrasses, razor fishes, pipe fishes and cow fishes. These workers note that scooped-out patches of sand in grass beds mark areas where the Spotted Eagle Ray, *Aeteobatus narinari* has foraged for infaunal bivalves. In Bailey's Bay McGlathery (1992) found the Bucktooth Parrotfish *Sparisoma radians* and the Ocean Surgeonfish *Acanthurus bahianus* to be the principal grazers of *Thalassia testudinum*.

Juvenile Green Turtles, *Chelonia mydas,* are abundant over the Bermuda platform where they feed on seagrass and algae. Personal observations of the abundance, size, distribution and behaviour of local Green Turtles suggest that this species is probably a more significant local grazer of *T. testudinum* than are the parrotfishes.

Despite the absence of substantive research into the importance of seagrasses in the Bermuda marine environment, resource managers have extrapolated from overseas research and placed high value on seagrass habitats as juvenile habitat for commercially important species. The protection of seagrasses is a consideration in coastal development applications and several seagrass meadows have been closed to net fishing to limit the bycatch of juvenile fishes. However, considerable threats to the health of local grass beds remain. These include: the proliferation of moorings with resultant scouring of seagrasses, dredging and shoreline development which increases sedimentation and surface runoff, physical destruction by motorboats and trampling by swimmers.

In light of the current lack of knowledge of local seagrass resources, this study seeks to investigate the use of inshore seagrass beds by fish and to examine trends in the aerial extent and distribution of these seagrass beds.

Chapter 2: The Distribution of Bermuda's Nearshore Seagrass Habitats

2.1 Introduction:

2.1.1 General Background:

In Bermuda there is a general recognition of the importance of seagrass meadows and ongoing efforts to protect these by local resource managers. For instance, the Marine Resources Board, an advisory body charged with advising the Minister of the Environment on issues pertaining to the use of marine resources, has a policy of rejecting any foreshore development plan or dredging project that impinges directly on seagrass habitats. Additionally there are seagrass meadows over which the use of nets is banned in order to provide protection for juvenile fish living in them. Despite this enlightened attitude, there is limited hard information upon which to base sound management decisions as there are no published records specifically documenting the area, or trends in distribution of these habitats and no monitoring programme is in place to detect changes.

Seagrass beds are known to be ephemeral, expanding and contracting over time. Aerial photographic surveys provide a means of documenting conspicuous benthic features in areas where water clarity is sufficiently high. As seagrass beds are generally confined to shallow sandy banks in areas of low turbidity, they are well suited to mapping efforts supported by aerial photography. This method has been used extensively for mapping and assessing seagrass meadows in tropical and subtropical areas (Kelly, 1980) from southeastern Australia (West, et al., 1989) to Florida (Sargent, et al., 1995). In the current study aerial photographic surveys taken over the period 1962 – 1997 were examined with the aim of mapping nearshore seagrass beds and assessing trends in extension or contraction of these habitats.

2.1.2 Photographic Resources:

Periodic aerial surveys of the islands of Bermuda have been commissioned by the Bermuda Government to support terrestrial mapping and development planning. A number of the photographic series resulting from these surveys are archived by the Department of Lands and Surveys. Access to photographs from aerial surveys conducted in 1973, 1981 and 1997 was kindly provided by this department whilst another series, from 1962, was loaned by Dr. Alan Logan of the University of New Brunswick, Canada.

Documentation of the survey contracts for all surveys other than that of 1997 are incomplete or unavailable. Thus, particulars of the aircraft and photographic equipment employed are unknown. All of these surveys were flown at 5,000 feet and photographs provided at a scale of 1:10,000. It is believed that these were photographed with 60% forward overlap and either 10% or 20% lateral overlap.

The 1997 survey was conducted in two phases; a terrestrial survey flown at 5,000 feet and a marine survey covering the entire platform to the 20m depth contour and flown at 15,000 feet, providing photographs at 1:10,000 and 1:30,000 scale respectively. The aircraft used for this work was a Piper Aztec PA-23/250 Model F equipped with a Zeiss Jena LMK photogrammetric survey camera with forward motion compensation. This camera was equipped with real time data projectors to print geographic position, time and project data on the side of each exposure. The aircraft was also equipped with an Accuphoto GPS flight management system to provide accurate geo-referencing of those marine photographs which lack control points of known location and elevation. An interface was used which sent the mid-point of exposure signal to the GPS event marker logger, allowing for precise location of the perspective centre at the instant of exposure. This survey was conducted with 80% forward and 30% lateral overlap and although the images available for examination were an incomplete series they still provided full coverage of the islands at 60% forward overlap.

Due to advances in photographic technology, the quality of the images improves along the available time series with the 1962 series being limited to black and white, as are the majority of the 1973 photographs. The 1962 series is incomplete, with significant gaps in the coverage of the western part of the island. Glare from sunlight reflected off the water makes many of the 1997 1:10,000 scale photographs useless for marine mapping purposes. Although irrelevant to terrestrial mapping exercises, the presence of substantial glare on the water obscures all subterranean features. Whenever glare posed problems with interpretation of benthic features the 1:30,000 scale photographs were used.

The 1981 photographic series provides the most complete coverage of inshore marine features at 1:10,000 scale. For this reason this series was selected for mapping local seagrass meadows and to provide a reference point against which earlier and later extensions of these habitats can be compared.

2.1.3 Algal Blooms:

The interpretation of aerial photographs is ideally supported by substantial ground-truthing exercises in which features identified on the photographs are confirmed *in-situ*. Unfortunately it is not possible to do this when interpreting transient conditions in archived material. The interpretation of the historical extension of seagrass beds in Bermuda's protected inshore harbours and bays was compromised by the occurrence of extensive mats of *Cladophora prolifera*. This unattached, highly branched alga has a spherical growth form of approximately 3cm in diameter. Distributed by wave and current action, this alga covered much of the shallow sandy zone from the early 1970's to the early 1990's. Forming thick mats and creating anoxic conditions at the sediment interface, this species effectively smothered much of the biota formerly resident in these areas (Morris, et al., 1977). Presumably as a result of its unattached growth form, this alga was not recorded from those exposed areas where wave action regularly extends to the sea floor.

The Bermuda Inshore Waters Investigation recorded the extent of this algal bloom over the period 1975-1980. Extensive beds were observed in Harrington Sound, Hamilton Harbour, the Little and Great Sounds and Ely's Harbour (Morris et al., 1977; Barnes and Bodungen, 1978; Bodungen et al., 1982). While detailed maps of the beds were produced for Harrington Sound, the extent of beds of the alga in other areas was poorly documented. Other than an ecological survey of the benthos of Harrington Sound conducted in 1994 (Thomas, unpub.), no extensive survey has been conducted since that period. Thomas (1994) found that although the *C. prolifera* beds in the shallow waters of Harrington Sound had disappeared, large beds persisted in deeper water. Personal observations supported by cursory examinations of the 1997 aerial survey indicate that, while this alga persists in some areas to the present day, dramatic reductions in its extent have occurred throughout Bermuda's waters.

In aerial photographs the shallow water beds of *C. prolifera* show up as very dark patches whilst deeper beds present a less intense image. Although these can usually be distinguished from most seagrass beds, there is a fairly wide range of intensity in the image that a seagrass bed presents. For instance, the short stubble of heavily grazed *Thalassia* presents a light greenish-grey image that is indistinguishable from the open growth form of most *Syringodium* stands. This contrasts dramatically with many inshore *Thalassia* beds which support longer, more dense stands that appear as dark patches on aerial photographs, very similar to those of *Cladophora* beds. In the absence of supporting documentation confirming benthic conditions, the use of photographs taken during the *Cladophora* bloom to map seagrass beds in areas known to have also supported extensive algal mats cannot be conducted with confidence. For this reason the inner portions of the Great Sound (bounded to seaward by an imaginary line running from Bluck's Point to Cavello Point), the Little Sound, Hamilton Harbour and Harrington Sound are not included in the analysis of the 1981 aerial survey (See Fig. 2.1).

2.2 Methods:

2.2.1 Photographic Interpretation:

The interpretation of aerial photographs inevitably requires a degree of subjective judgement. In this regard personal experience is valuable. For this reason initial interpretation was limited to areas with which the author has substantial local knowledge. Photographs of areas known to support seagrass meadows were examined to assist the development of a search image for grass beds. Characteristics of known beds were noted and key attributes identified. Key parameters in the discrimination of seagrasses from adjacent habitats include:

- Colour – seagrasses usually show up as a light to dark greenish-grey. Where these colours are present in predominantly shallow sandy areas it usually indicates the presence of seagrasses.
- Depth – in Bermuda seagrasses are usually found in depths of less that 10m (Logan and Cook, 1992). The deeper margins of seagrass beds occurring on

sloping bottoms are difficult to discern as the colour of the image grades from greenish-grey to deeper blue. Knowledge of the bottom contours assists in judging where the seagrass bed ends.

- Halos – the presence of reefs within a seagrass bed provides a diagnostic feature - a halo of clear sand around the reef. This feature was described by Ogden (1976) and attributed to the grazing action of reef dwellers, principally urchins. Additionally a clear sandy border usually separates seagrasses from the shoreline. The chains of boat moorings similarly create diagnostic halos whenever they are placed within a grass bed (pers. obs).
- Crescent-shaped sand holes- in high-energy areas crescent-shaped sand holes commonly occur near the seaward margins of seagrass beds. These are indicative of damage caused by heavy weather (Clarke and Kirkman, 1989).

In areas where, after close examination of a photograph, confusion over the interpretation of the image persisted, earlier and later photographs of the same location were consulted. Features found on these other photographs often proved helpful in resolving issues. In some cases site visits were required to confirm benthic features.

2.2.2 Mapping:

It was determined that, on a light table illuminated by 4x40 watt flourescent tubes, seagrass beds could be traced directly onto a 1:10,560 scale map (Series E8110, Edition 2-Bda 1975, published by the Public Works Department, Bermuda) placed over the corresponding 1:10,000 scale photograph. The forward overlap provided in these photographic series ensures that any given feature is captured in two adjacent photographs. As the image projected through the map was rarely distinct, regular referral to adjacent photographs was found to be important in facilitating interpretation.

To map the grass beds, photographs that best displayed these features were selected and individually taped to the light table with the corresponding map placed on top and oriented so that prominent geographical features lined up. The map was then also taped in place and the boundaries of the grass beds were drawn directly onto the map in pencil. The resultant vector diagram was compared with the original image and corrected where necessary. Once the relevant information had been extracted from a photograph, another was selected that provided information on adjacent seagrass features. The process was repeated until the seagrasses adjacent to the entire shoreline depicted on the map had been drawn. This process was repeated for each of the 6 maps in the series, providing an assessment of the extent of the nearshore seagrasses of Bermuda in 1981.

It was found that most of Bermuda's coastal grass beds do not extend more than 300m offshore and all of these were included in the mapping exercise. Exceptions to this are the large seagrass meadows that occur to the northwest of Mangrove Bay, Somerset. Because these extend for approximately 1.5km from the coast onto lagoonal sand flats, an imaginary line from Commissioner's Point to Daniel's Island was used as a seaward boundary for mapping (See Fig. 2.1).

2.2.3 Estimation of Areas:

Once the outlines of the seagrass beds had been drawn, a planimeter (Keuffel and Esser Co., model 62002) was employed to estimate the areas of these irregular-shaped objects. The result is provided in an analogue form in $inches^2$, with a vernier scale allowing readings to .01 $inches^2$. The measurement of areas requires the manual tracing of the perimeter of the grass bed with the planimeter, a process during which errors can occur. As the perimeter to area ratio generally declines with size, it is expected that the percentage error in area estimates from planimetry will similarly decline with increasing size of the grass bed. Two grass beds, one medium size and one small, were selected randomly and measured 3 times on the map and 3 times directly from the photograph. This was done in order to assess 1) the precision with which these areas are measured 2) the effect of small grass beds 3) the accuracy of tracing the grass bed on the map. The results of this exercise are presented in Table 2.3.1 (see end of chapter). All of the seagrass beds mapped around the islands were measured using planimetry and the areas summed. This result was transformed into km^2 using the conversion factor of 14.04 $inches^2 = 1km^2$.

2.2.4 Changes in Seagrass Beds:

Comparisons of the mapped seagrass beds compiled from the 1981 aerial survey with photographs from 1962 and 1997 were conducted visually. For those areas where substantive changes were noted to have taken place, photographic time series were compiled, measured and changes in areas calculated. To facilitate measurement of the areas of the seagrass beds in 1997, the relevant photographs from the 1997 survey were enlarged by 300% using a Xerox 5765 digital colour photocopier. This transformed the 1:30,000 scale to 1:10,000 allowing for measurement and area calculations as previously described.

2.3 Results:

2.3.1 Overview of Results:

The coastal seagrass beds of Bermuda that could be mapped from the 1981 aerial survey cover an area of approximately 500Ha and are illustrated in Figure 2.1. Dramatic changes in the extent of many of the major seagrass beds have occurred during the period examined. A large increase in the seagrass bed of Grotto Bay occurred during the period 1962 – 1981 and a substantial expansion of the coastal beds running from Bailey's Bay west along the North Shore to Spanish Point was noted from comparisons of the surveys of 1981 and 1997. During the period 1981 – 1997 very large declines occurred in Castle Harbour, along the east coast near Fort St. Catherine's, in the Great Sound at Spanish Point and along the western shoreline between Pompano Beach and Wreck Hill. These changes are individually examined in detail in section 2.3.4.

2.3.2 Estimation of Precision and Accuracy of Mapping:

The results of the exercise to examine the accuracy and precision of the seagrass mapping are presented in Table 2.3.1 (see end of chapter). No significant differences between the areas estimated by the different methods were observed although the average variance between measurements increased from a low of 0.4% (Mapped, medium bed) to a high of 9.5% (Direct, small bed). This is in keeping with the expectation that both precision and accuracy will tend to decline with diminishing size of the object measured. This effect can be attributed to both the increased significance of manual errors in tracing objects with high surface to area ratios and the increased proportion of the area which must be interpreted through reading of the vernier scale. These results indicate that errors in the estimation of the areas covered with seagrass are more likely to come from inappropriate interpretation of photographic images than through tracing and measuring methodologies.

2.3.3 Distribution of Bermuda's Coastal Seagrass Beds:

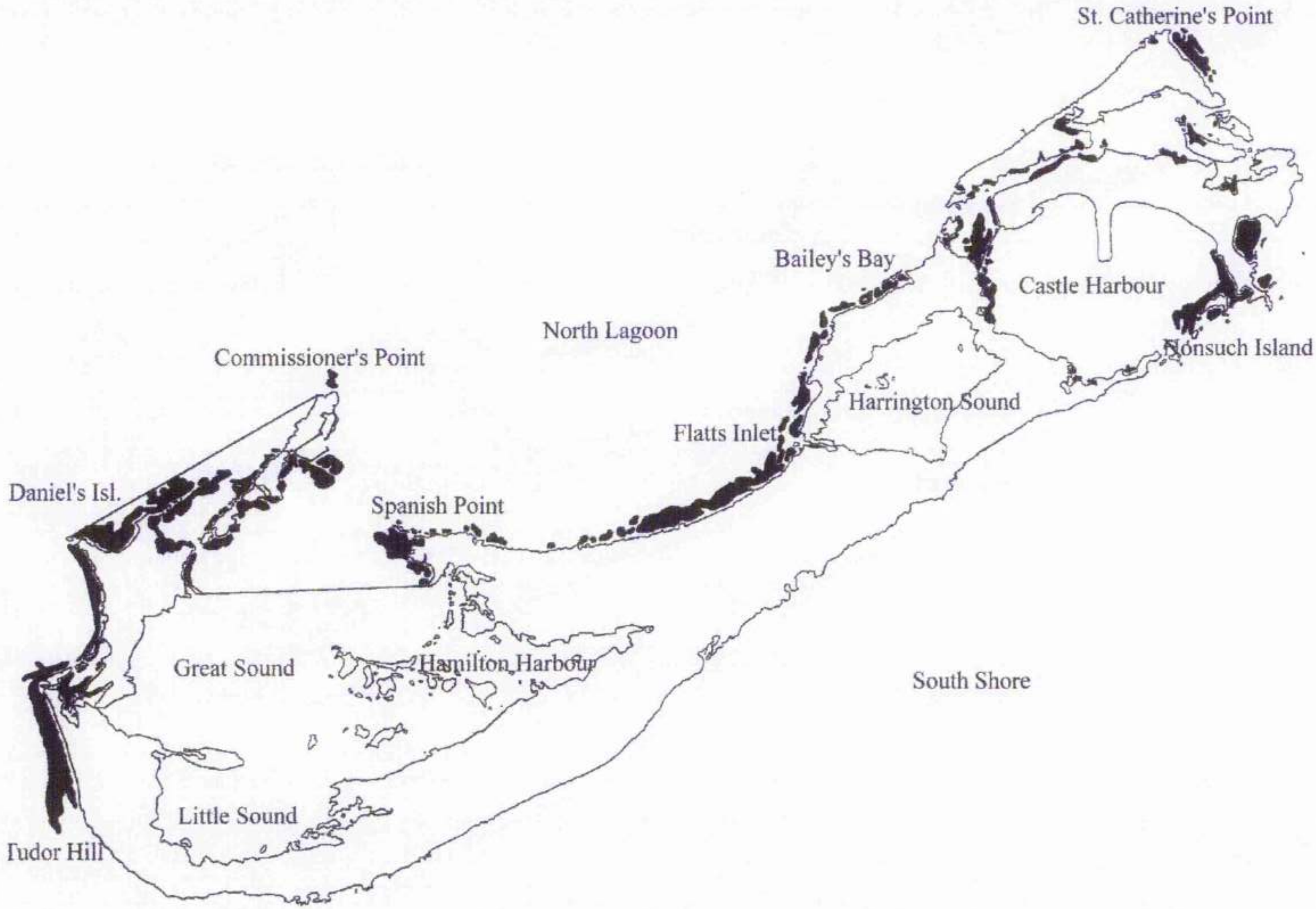
It is notable that, with one exception, no seagrass beds are found along the South Shore, where heavy surf regularly causes large-scale movements of sediment. During the period 1962-'81 one South Shore seagrass bed existed in the south bay at Nonsuch Island where substantial fringing reefs appear to provide sufficient protection for the growth of seagrasses (See Section 2.3.4.6). All the larger seagrass meadows are found in lagoonal waters and inshore harbours where they are afforded protection from heavy surf (See Fig. 2.1).

In 1981 the largest *Thalassia* meadows were found to occur at the NE and SW ends of the islands and near the entrances to the inshore harbours and sounds. These are all areas of substantial current flow, where oceanic waters flood the platform and ebb with tidal cycles. Other than the beds in Grotto Bay and those of the northwestern shoreline between Daniel's Island and Commissioner's Point, large reductions in the extent of these habitats have occurred.

The patchy seagrass beds observed along the North Shore in 1981 have coalesced into an extensive band of approximately 250m in width and 12km long. Field confirmation in August 1998 conducted at 7 locations within this area revealed that this tract of seagrass is composed primarily of *Syringodium*, with a minor component of *Thalassia* that occasionally dominates along the nearshore margin.

Figure 2.1 - Map of Bermuda Showing the Coastal Seagrass Beds - From 1981 Photographic Survey.

Note: Straight lines indicate seaward margin of mapping (Commissioner's Pt. – Daniel's Isl.) and shoreward limit of mapping in Great Sound (Bluck's Pt. – Cavello Pt.). Mapping was not attempted in the inner portions of the Great Sound, Little Sound, Hamilton Harbour, or Harrington Sound.



2.3.4 Changes in the Extent of Major Seagrass Beds – Case Studies:

2.3.4.1 Tudor Hill:

A large portion of the extensive *Thalassia* bed off the western shoreline at Tudor Hill (See Fig. 2.2) has declined dramatically. This area is not covered in the available photographs from 1962. However, in the photographs from 1973 and '81 this bed shows up very clearly, extending from Pompano Beach to Wreck Hill and encompassing essentially all of the area bounded on the seaward side by a line of patch reefs. Although it remained essentially unchanged from 1973 to 1981, today much of the southern part of this area is devoid of seagrasses and the seaward extension of the bed is also much reduced. It is estimated that in 1981 the area of this seagrass bed was 53.2Ha or approximately 10.6% of the coastal seagrass beds of Bermuda at that time. By 1997 this had declined by approximately 40% to 31.9Ha.

Located at the extreme SW corner of the Bermuda islands, this area is protected from ocean swells by a narrow tract of rim reef. To the south of this seagrass bed there is a break in these barrier reefs through which there is a navigable channel for small boats. Although calm seas predominate over this protected sandbank, the area is relatively exposed to the effects of any extreme storm surges that may breach the barrier reef. Given its location it is appealing to assume a cause-effect relationship between the decline of this seagrass bed and the increased hurricane activity experienced in the western North Atlantic during the late 1980s and '90s. However, anecdotal reports from researchers working at an air quality monitoring station overlooking this area indicate that this decline occurred gradually. Furthermore, it occurred after the locally significant hurricanes of 1987 (Emily) and 1988 (Dean), and before the extreme surge conditions experienced with the passage of Felix and other major storms during 1995 (Glasspool, pers. comm.). Given these reports, it appears unlikely that storm surges have caused the decline in the seagrass beds at this location.

Figure 2.2 – Aerial Photographic Series of the Tudor Hill Seagrass Beds

A) 1973

B) 1981

C) 1997

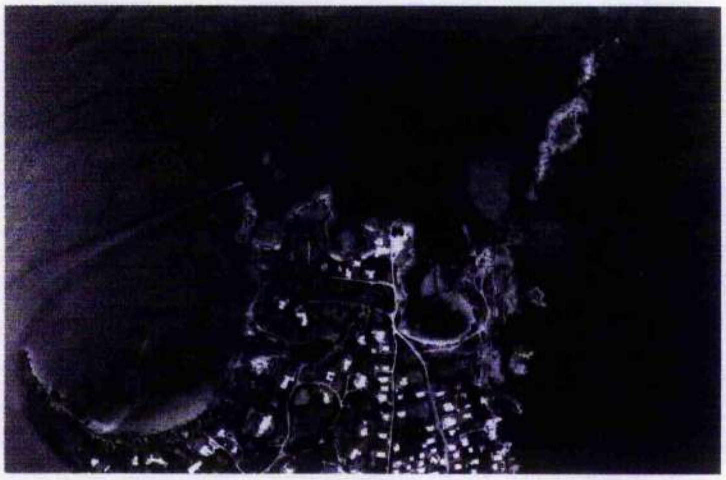
2.3.4.2 Spanish Point:

From the 1981 photographs a 26Ha seagrass bed was mapped in the Great Sound at Spanish Point (See Fig. 2.3). Interpretation of this image was compromised by knowledge that *Cladophora* blooms had been widespread in inshore waters at that point in time. However, the moderate currents recorded from this location (maximum velocity – 0.6 knots, Morris et. al., 1977) may have prevented the formation of *Cladophora* beds over much of this area. Referring to the 1962 photographs it is clear that in excess of 30Ha of seagrass beds had existed in the area at that time. Although the boundaries of these beds are not entirely clear, portions of them do coincide with the image presented on the 1981 photographs. Further the 1997 photographs supported by field observations reveals that a much smaller seagrass bed (7.7Ha) persists within the area of the 1981 bed. Thus, although it cannot be confirmed, it appears that a 26Ha seagrass bed existed at this location in 1981 and that this bed has declined by approximately 70%.

Although protected from heavy seas, this site is proximal to Bermuda's most heavily transited shipping channel, a major source of sediment loading. This area is also part of the channel through which tidal exchange for Hamilton Harbour occurs and is thus potentially susceptible to industrial contaminants originating there. However, whilst Hamilton is the centre of local commerce, it does not support heavy industry. Furthermore, Shepherd et al. (1989) reviewed the causes of declines of coastal seagrass meadows throughout Australia and found little evidence of the effects of industrial chemicals. It is difficult to conceive that either of these potential stressors would cause the decline of this seagrass bed during the same time period in which the seagrass beds immediately to seaward expanded (See Section 2.3.4.3). It appears more likely that there was, in fact, an invasion of the grass bed by *Cladophora*, and that this alga created an environment that compromised the health of the seagrass bed prior to declining itself.

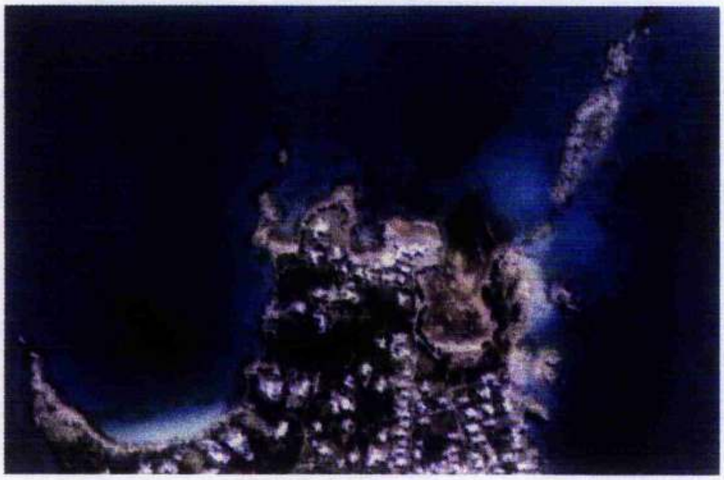
Figure 2.3 – Aerial Photographic Series of the Spanish Point Seagrass Beds

A) 1962



B) 1981

C) 1997



2.3.4.3 North Shore Coastal Seagrass Beds:

The most dramatic increase in the extent of seagrass coverage occurred along the North Shore between 1981 and 1997. The formerly patchy seagrass beds of this region have now coalesced into an essentially continuous swath of approximately 250m x 12km which extends from Spanish Point to Baileys Bay (See Fig. 2.1). In the same area that in 1981 supported approximately 96Ha of seagrass there is now an extensive meadow of 316Ha, an increase of about 229%. Diver observations confirmed that this bed is primarily *Syringodium* with *Thalassia, Halimeda* and *Penicillus* forming minor components.

Although it is clear that seagrass coverage was not extensive in this area when the 1962 photographs were taken, the series of photographs does not provide sufficient resolution to estimate the extent of seagrasses at that time.

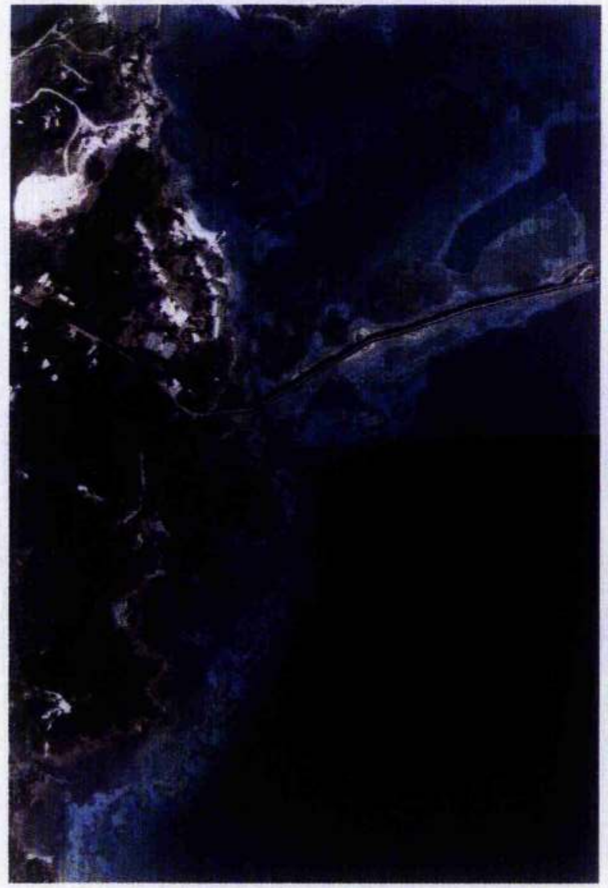
2.3.4.4 Grotto Bay/Walsingham Bay Seagrass Beds:

A dramatic increase in the extent of the inshore seagrass beds that run from Walsingham Bay through to Grotto Bay (See Fig. 2.4) occurred between 1962 and 1981. Due largely to expansion in the Grotto Bay area, the 14.7Ha beds of 1962 grew to cover 33Ha by 1981. From 1981 to 1997 there was a reduction of approximately 24% to 25Ha.

Figure 2.4 – Aerial Photographic Series of the Walsingham/Grotto Bay Seagrass Beds

A) 1973

B) 1981



C) 1997

2.3.4.5 St. Catherine's Point:

The grass beds along the shoreline adjacent to St. Catherine's Point (See Fig. 2.5) provide an interesting comparison with those of Tudor Hill (See Fig. 2.2). Whilst St. Catherine's is less protected from wave action, similarities between these locations include close proximity to the open ocean and exposure to tidal flow around the ends of the island. Unlike those of Tudor Hill, the photographs of the St. Catherine's grass bed from 1962, '81 and '97 all show some evidence of crescent shaped blowout holes, presumable the result of periodic heavy wave action at this site. Ginsburg and Garrett (1969) also mapped the presence of blowouts at this site, while Logan and Cook (1992) reported that erosional action of waves had exposed roots and rhizomes at this site. Although the seaward boundaries of the St. Catherine's beds are difficult to resolve from the 1962 photographs, it is clear that they were far more extensive at that time, approaching 20Ha in area. Having declined to 11.8Ha by 1981, the St. Catherine's grass beds have displayed a further 39% reduction in area to the present 7.2Ha. This is remarkably similar to the estimated 40% decline in seagrass area at Tudor Hill during the same period.

Figure 2.5 – Aerial Photographic Survey of the St. Catherine's Point Seagrass Beds

A) 1962

B) 1981

C) 1997

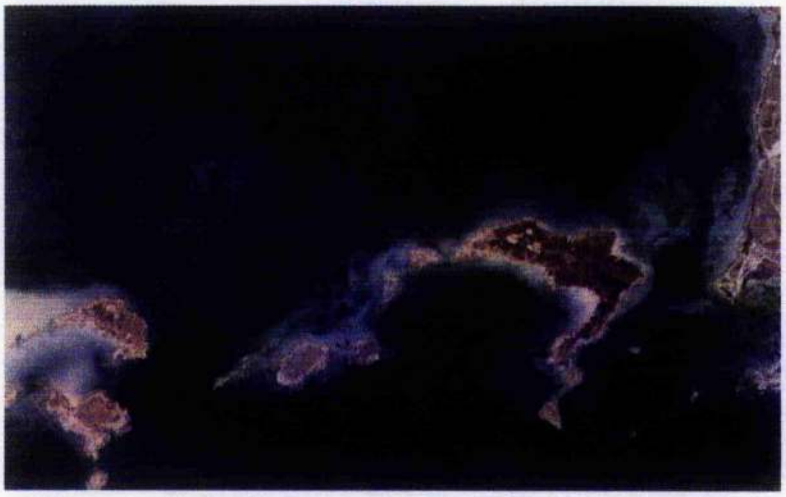
2.3.4.6 Nonsuch Island:

A most dramatic change in the extent of seagrasses has occurred near Nonsuch Island during the period 1981- '97 (See Fig. 2.6). Extensive grass beds existed in this area from 1962 through 1981 at which point in time the area of seagrass coverage was estimated at 46.7Ha. In 1997 this had declined to approximately 6.3Ha, a reduction of 87%. Located predominantly in the lee of the Castle Harbour islands and in an area of moderate current flow (Estimated mean flow - 0.29 knots, Morris et al, 1977) these grass beds would normally be afforded substantial protection from heavy seas. The 1962 and '81 photographs show extensive "blow-outs" in the more exposed portions of these grass beds.

Extreme storm conditions such as those created by the passage of Hurricane Felix in 1995 could affect much of the area formerly covered by seagrasses. Indeed it is believed that this storm was responsible for eliminating seagrasses from much of the most exposed areas around Nonsuch Island (Wingate, pers. comm.). Although it might be expected that storm-inflicted damage would leave telltale blowout scars over the remnants of the seagrass beds, the increased sedimentation also associated with such extreme weather may mask these scars. Kenyon and Poiner (1987) reported such an effect noting that cyclones in Northern Australia involved washouts of large portions of shallow seagrass beds whilst deeper beds, which were protected from direct wave action, were smothered by a thick layer of fine mud. However, such an effect is unlikely to occur in areas that frequently experience substantive wave action (Shepherd et al., 1989). As the area in question regularly experiences a gentle surge and moderate current, it is likely that any fine particulate matter would have been dispersed into deeper water rather than deposited upon adjacent grasses.

Figure 2.6 – Aerial Photographic Series of the Nonsuch Seagrass Beds

A) 1973



B) 1981

C) 1997

2.3.5 The Effects of Moorings:

Bermuda is an ideal location for watersports. With its high population density, beautiful coral reefs and wealthy populace, there are a large number of recreational vessels creating the demand for moorings in sheltered harbours and bays. As these locations are often prime locations for the development of seagrass beds, there are inevitable conflicts between the demand for moorings and the need to preserve seagrass habitat. The mooring systems used in Bermuda typically consist of a heavy iron weight to which a short length of ship's chain is attached as ground chain to absorb the shock loading of heavy waves and a riding chain to which the boat is secured. As the wind changes direction, the ground chain is dragged across the bottom, usually destroying any attached benthic life it contacts. The result is commonly a halo, devoid of life, surrounding the mooring weight and radiating out a distance equaling the length of the ground chain.

Moorings placed in seagrass beds are particularly damaging. They affect not only the blades but, through repeated scouring of the bottom, promote erosion of the sediments and subsequently crush the rhizomes and roots. The result is invariably a circular depression in the sediment surrounded by seagrass. This effect is clearly visible in the aerial photographs of several sites around Bermuda. Figure 2.7 shows the effects of the many moorings that have been placed within the seagrass beds of Mangrove Bay.

Figure 2.7: Mooring-Induced Halos within the Seagrass Bed of the Inner Portion of Mangrove Bay (1997 Photograph)

2.3.6 Discussion:

Through this review of the available photo-documentation of Bermuda's inshore waters it is clear that large changes in the distribution of local seagrass meadows have occurred. In several areas there have been recent, and relatively large-scale, reductions in nearshore seagrass beds whilst expansions elsewhere have been similarly dramatic. Although the ecological implications of these changes are unknown, the instability of seagrass systems has been documented in many locations.

The greatest instability of any seagrass system shown so far is the decline in the North Atlantic beds of *Zostera marina* in the 1930s (Rasmussen, 1977). The cause was believed to be the wasting disease of *Zostera* brought about by *Labrinthula macrocystis*, an organism of dubious taxonomic state. However, a recent theory suggests that wasting disease was actually a side effect and that the real cause was a rise in sea temperatures during the decline (Rasmussen, 1977). According to the temperature theory *Z. marina* occurs as a number of races over a wide geographical area with each adapted to a narrow temperature range. Where high temperatures occurred, a large decline in the *Zostera* occurred too. Den Hartog (1987) reviewed this theory and came to the conclusion that it too failed to account for all the facts and suggested that several factors may have combined in a cyclical fashion to have caused the extensive die-back of these times. He reported (den Hartog, 1994) that light and temperature in combination triggered the decline in *Zostera* by causing the Labrinthulids to attack young plants rather than the aged plant parts that they normally consume.

Whilst Labrinthulids have not been recorded to have affected Bermuda's seagrasses and no record of large-scale declines of seagrasses during the 1930s-1950s exists, this may be more a reflection of a lack of research than the absence of this potential pathogen. In recent years Bermuda has experienced periods of inordinately high seawater temperatures (30-31°C) associated with unprecedented and highly conspicuous coral bleaching events (Cook et al., 1990). It is possible that this stress may also have caused less obvious effects on local seagrass meadows.

Although the shallow water limit to seagrass development is commonly determined by wave energy (Shepherd, et al., 1989), occasional periods of extreme heavy weather can lead to the destruction of otherwise stable seagrass beds. High wave energy has been associated with large changes to seagrass communities in South Australia (Shepherd and Womersley, 1981), and in Western Australia (Kirkman, 1985). Cyclones have also been observed to cause long-term changes to seagrass communities in northern Queensland (Birch and Birch, 1985) and to have wide-scale effects in the north of Australia (Poiner, Walker and Coles, 1989).

The heavy weather associated with hurricanes is clearly a persistent threat to the more exposed seagrasses of Bermuda and it is likely that the declines of the beds at Nonsuch and St. Catherine's Point were, to some extent, associated with such extreme wave action. With the predicted increased frequency of hurricanes arising from the effects of global warming, the impacts of wave action may become more important in structuring Bermuda's seagrass communities.

Blowouts caused by wave action are common dynamic features of seagrass beds (Clarke and Kirkman, 1989). They are characterised by a zone of seagrass to seaward that is gradually being eroded (often with a conspicuous erosion scarp), a central unvegetated depression with high sediment mobility into which vegetation is colonizing, and shoreward of this colonizing edge, further seagrass which continues until the next blowout is encountered. As long as the rate of erosion does not exceed the rate of colonization the blowout will not expand. It may either migrate to seaward if the rates of colonization and erosion are similar, or disappear entirely if the colonization exceeds erosion. Recognising this, Patriquin (1975) reported that whilst wave-erosion regularly causes large-scale damage to seagrass communities in the Bahamas, the system appears to be in a dynamic state of equilibrium.

Based on their review of Australian research, Shepherd et al.(1989) proposed that the underlying cause of man-induced declines in seagrasses is a reduction in the amount of light reaching seagrass chloroplasts that precludes effective photosynthesis. This hypothesis is based on the premise that seagrass meadows occur between an upper limit imposed by exposure to desiccation or wave energy and a lower limit imposed by light penetrating at an intensity which allows photosynthesis to significantly exceed losses to respiration. They noted three prime factors associated with seagrass declines:

1. Increased turbidity: a) a direct impact by man injecting or stirring up fine materials that cloud the water column or b) an indirect impact caused by enhancing nutrient levels through inputs of sewage or fertilizer which cause phytoplankton blooms with subsequent decreases in light transmission.
2. Epiphytic overgrowth: the nutrient enrichment induced proliferation of micro and macroalgal epiphytes that shade out the slower growing seagrasses.

3. Sedimentation: the settlement of fine particles on leaf surfaces to the point where light transmission is severely diminished.

The Australian experience also demonstrates that the demise of seagrass beds can release large volumes of fine sediment. Larkum (1976) referred to this process as "auto-catalytic", where small losses lead to sediment destabilization, which in turn leads to increased turbidity and further losses.

The larger declines of Bermuda's seagrass beds that have come to light through the review of aerial photographs do not appear to be directly associated with human activities. The waters in which local declines have occurred do not display substantive increases in turbidity, nor are there new and dramatic nutrient inputs occurring at these locations. Indeed the sites in question could be described as generally well-flushed locations which communicate directly with low turbidity, nutrient-starved, oceanic waters. Moreover, those declines that have occurred have been largely offset by the dramatic expansion of those seagrass beds which extend along the North Shore, and the causes of these changes are unknown.

Although pollution and enrichment effects on the seagrasses of Bermuda have not been demonstrated, the widespread damage of seagrasses in inshore bays as a result of mooring proliferation in seagrass habitat gives cause for concern. Formerly continuous meadows of seagrass have become peppered with halos, which undoubtedly destabilize the habitat, and reduce its value as shelter. Research into alternate mooring systems for this habitat is required if boats are to be secured over seagrass beds without compromising the seagrass community.

Table 2.3.1 Repetitive Measures of Grass Beds to Estimate Precision and Accuracy of Area Estimates

Area Measured* - Medium Size Grass Bed		Area Measured* - Small Grass Bed	
From Mapped Bed	Direct From Photograph	From Mapped Bed	Direct From Photograph
3.09	3.05	0.14	0.12
3.07	3.08	0.12	0.14
3.05	3.13	0.14	0.10
Mean = 3.07 ± 0.04	Mean = 3.09 ± 0.07	Mean = 0.13 ± 0.02	Mean = 0.12 ± 0.04

**Unconverted data, in square inches*

Chapter 3: Local Seagrass-Associated Fish Assemblages

3.1 Introduction:

Armed with the strong belief that seagrass habitats are important for the health of Bermuda's fish stocks, and prompted by anecdotal reports of large numbers of reef fish being taken as bycatch in the bait fishery, action was taken in 1990 to protect fish in seagrass beds. Despite a total absence of information on the resident ichthyofauna, four inshore seagrass areas were closed to netting with the intent of protecting juvenile fish. Without challenging the assumed importance of local seagrass beds, it is clear that an improved understanding of the distribution and seasonality of occurrence of the fish assemblages of Bermuda's seagrass beds is required to promote optimal resource management. This study was undertaken to address the lack of information.

The two key parameters to which this study was directed were seasonality and site-specificity of information. Specifically for fisheries management purposes, the questions posed were:

1) Are there seasons during which the harvest of bait fishes over a seagrass bed is not particularly harmful?

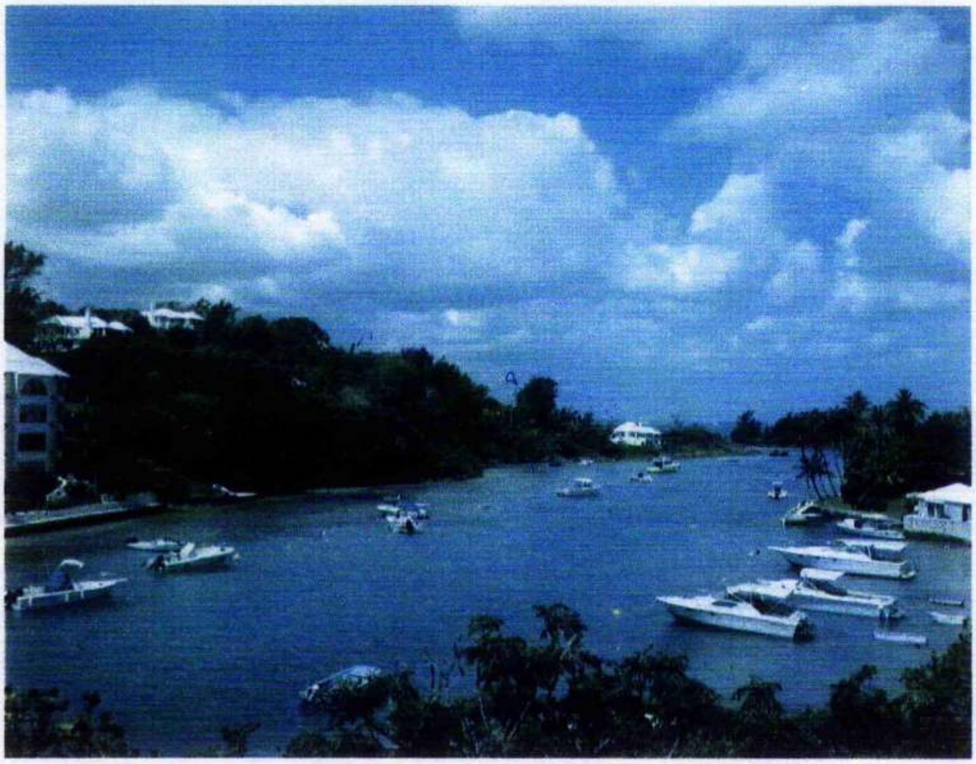
2) Can information gathered at one site be used to predict fish assemblages at other sites? Or does the management of seagrass-associated fish require site-specific information?

The fishing gear used in this study is the standard bait net of the local fishing industry. In addition to being readily available, this gear allows for the estimation of the bycatch that can be expected from the local bait fishery. Three study sites were selected: Flatts Inlet, Bay Island and Walsingham Bay. These sites were chosen because they all support healthy grass beds, are readily accessible, and are located in substantively different environments.

3.1.1 Flatts Inlet:

The study site at Flatts Inlet is located on a shallow sand bank on the south side of a narrow channel which forms the only surface connection between the North Lagoon and Harrington Sound, a $4.8km^2$ tidal basin. The strong current that funnels through this inlet passes through a 4m deep dredged channel which defines the northern boundary of the sand bank (See Fig. 3.1). While currents of 8.7 knots have been recorded at Flatts Bridge during peak flow (Morris et al., 1977), currents over the grass bed are reduced to around 3 knots. Covering approximately 0.5Ha, this mixed stand extends to a depth of about 3.8m at high tide and is dominated by *Thalassia testudinum* with patches of *Syringodium filiforme* and small amounts of *Halodule bermudensis* (Gillis, 1997). During periods of extreme low tide the shallowest portions of this bank are exposed to the air. As this site is well protected from wave action, the margins of this bed are probably controlled by periodic desiccation on the shoreline and by scouring from currents on the banks of the channel. This site is substantively removed from reefal and mangrove habitats.

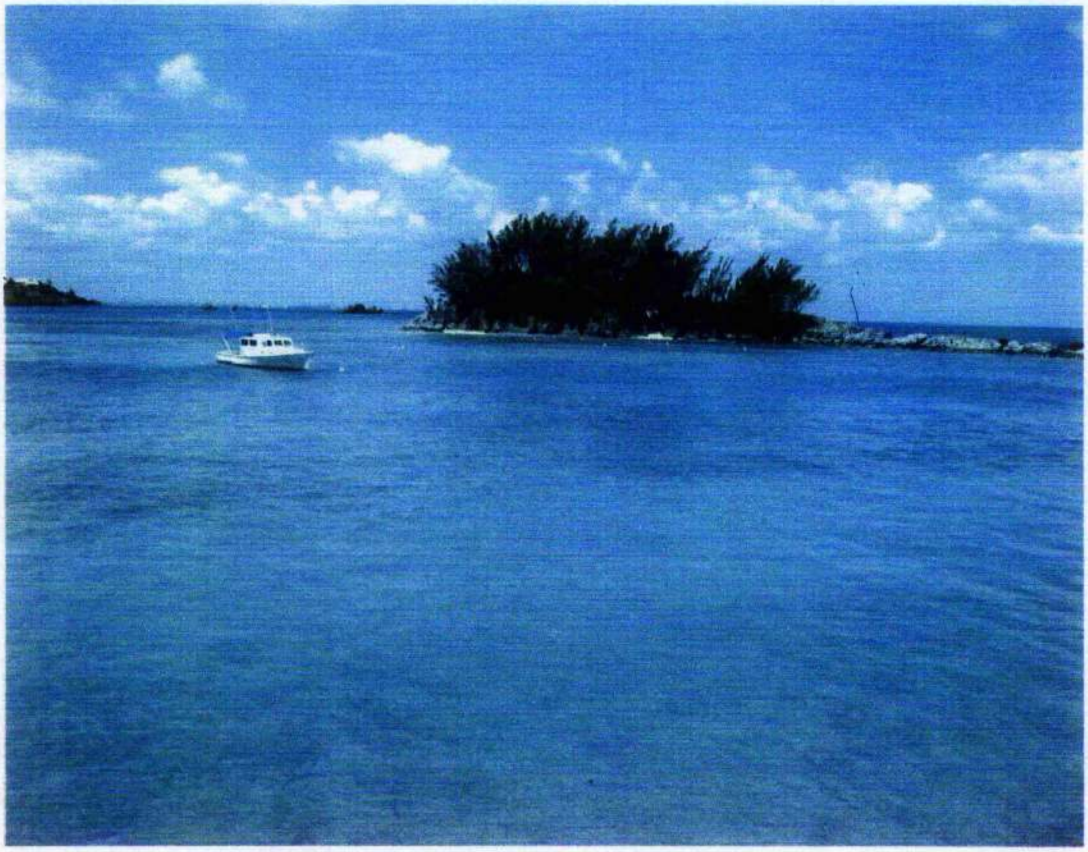
Figure 3.1 - Flatts Inlet, Looking West



3.1.2 Bay Island:

The Bay Island study site is protected from the wave action of the North Lagoon by the island itself and a series of emergent rocks and reefs which form a barrier running parallel to the shoreline for approximately 800m (See Fig. 3.2). The enclosed shallow sandbanks of Bailey's Bay support an 8Ha tract of seagrass meadow. Both current and wave action at this site is minimal. Sampling was conducted adjacent to the small beach on the southeast of the island. This area supports all three common seagrass species with *T. testudinum* dominating, in similar densities to Flatts Inlet. At points this species is found in mixed stands with *H. bermudensis* whilst small, monospecific patches of *H. bermudensis* and *S. filiforme* occur, scattered throughout the bed (Gillis, 1997). Several moorings have been placed within this grass bed creating bare depressions where the chain abrades the seafloor.

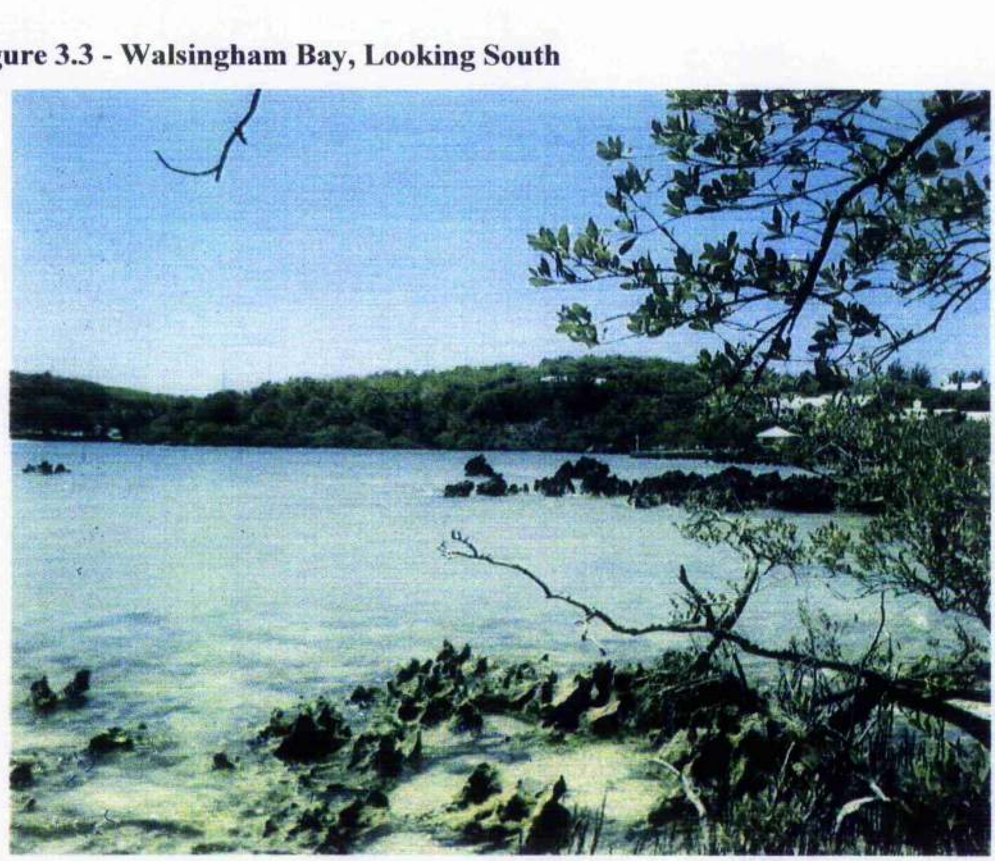
Figure 3.2 - Bay Island, Looking Southwest



3.1.3 Walsingham Bay:

Located on the southwestern shoreline of Castle Harbour beside the entrance to Walsingham Bay, this study site is enclosed by a ring of reefs to the north and is adjacent to one of Bermuda's few remaining stands of mangrove forest (See Fig 3.3). Immediately to the northwest lies a marine protected area that encompasses mangrove, seagrass and reef habitats. The reefs of Castle Harbour remain heavily impacted by the construction of the airport in the 1940's, supporting few live corals which compete with thriving algal communities (Logan, 1992). With the prevailing winds being from the southwest, this site is calm for most of the year whilst the fringing reefs and limited fetch prevent excessive wave action during those periods when the winds shift to the north and east. This area supports a monospecific stand of *T. testudinum* with the highest blade density (480 to 1810 shoots/m^2) and growth rate of this species within the three study sites (Gillis, 1997). This lush meadow extends from near the shoreline to the fringing reef. After the narrow channel into Walsingham Bay, the seagrasses continue to the north into the protected area, forming part of a 25Ha seagrass complex (See also Section 3.2.4.4).

Figure 3.3 - Walsingham Bay, Looking South



3.2 Methods:

3.2.1 Sampling:

A total of 90 net sets were made; 33 at Bay Island, 32 at Flatts, and 25 at Walsingham, during the period April 1995 to July 1997. A Bermuda standard commercial bait net: 45m long, 3.6m deep and made of 32mm mesh was used to collect specimens. With a small boat this beach seine was paid out from the shoreline in an arc so as to return to shore and encompass an area of shallow seagrass habitat. The net was carefully pursed in with the weighted lead line pulled ahead of the float line to drive fish from within the grasses up and into the bunt of the net. Because the strong currents encountered at the Flatts Inlet station compromised this approach by driving the float line downstream ahead of the lead line, sampling at this site was largely confined to slack tide.

The catch was transferred to a seawater-filled tub from which individuals were removed for measurement and subsequent release. Species and total length (or fork length in species with deeply forked tails) was recorded to the nearest mm for each specimen. For abundant species, only the first 100 fish caught at a station during any given month were measured after which the total number caught was estimated. The average depth of the area fished, along with the date and time of the set were also recorded.

Large numbers of small clupeids, engraulids and atherinids were regularly caught. These fish die quickly in the net and holding tub, fouling the water and causing massive mortality amongst any other species with which they are held. In order to minimize the environmental impact of this study, and to allow repeated sampling within these relatively small study sites, these fish were immediately released during netting and hence unreported in this work. This decision was also taken as these fish are pelagic planktivores that are regularly found in all inshore habitats (Sterrer, 1986), form dense schools which move in response to pelagic predators, and do not appear to be specifically associated with seagrass habitats. The surface feeding Bermuda Halfbeak, *Hemiramphus bermudensis*, was also commonly caught and released without recording its presence. Although not strictly a resident of seagrass beds, this inshore, pelagic species is loosely associated with seagrasses being commonly seen at the surface grazing on drifting pieces of *Syringodium filiforme*.

3.2.2 Data Analysis:

3.2.2.1 Between Site and Season Comparisons of Fish Communities:

In order to determine whether the communities differed by site and season, the data were manipulated using an Excel® spreadsheet to calculate a Shannon's Diversity Index for each site and season. Then *t* tests were used to test for differences in diversity as described by Magurran (1988). For this purpose seasons were divided into: Winter (Jan-Feb-Mar), Spring (Apr-May-Jun), Summer (Jul-Aug-Sep) and Fall (Oct-Nov-Dec).

3.2.2.2 Patterns of Recruitment of Selected Species:

Early juveniles of several species that apparently recruit directly to seagrass beds were observed seasonally. For these species the seasonality of occurrence of postlarval or newly settled juvenile fish is presented.

3.2.2.3 Assessing Temporal Patterns of Residence of Selected Species:

Those species that were commonly caught in large numbers provided an opportunity to study temporal patterns of residence within the seagrass habitat. This was done by reviewing their size-frequency of occurrence. Species which depend on this habitat for a short window in their life cycle will be represented in the samples by a restricted range of sizes whilst long-term residents will occur over a wider size range. Monthly size-frequency distributions were constructed for these abundant species.

3.3 Results:

3.3.1 The Ichthyofauna:

Approximately 45 species were observed in the catches (See Table 3.3.1 at the end of this chapter). Of these, 42 were identified to species level whilst difficulty in identifying species within 3 families, the Sygnathidae, Gerreidae and Gobiidae compromised the production of a complete species list. Fortunately, other than some members of the Gerreidae, those species that proved difficult to identify comprised less than 1% of the catch.

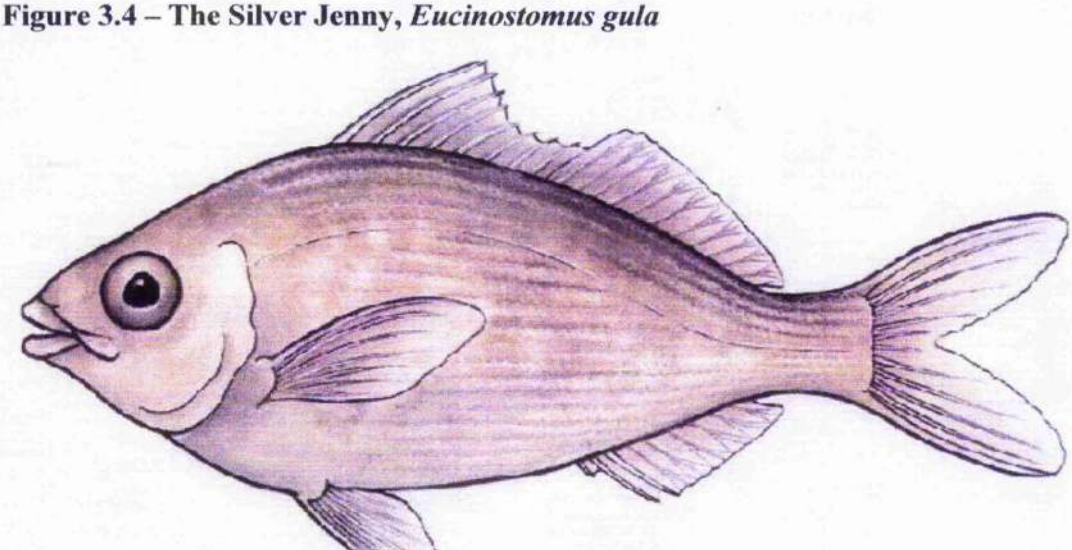
3.3.2 Commonly Observed Species; Patterns of Recruitment and Seasonality of Residence:

The vast majority of the catch was comprised of a relatively small number of species. Brief descriptions of a selection of the more common species are provided here with notes on their documented distribution, habits and use. Sources include: Sterrer, 1986; Humann, 1994; Smith-Vaniz et al., in prep and personal observations. These descriptions are followed by observations of the species patterns of recruitment and residence as determined during this study.

3.3.2.1 The Silver Jenny, *Eucinostomus gula* (Cuvier):

Of the 7 members of the Gerreidae reported from Bermuda, the Silver Jenny is the most distinctive in appearance. This deep-bodied species is uniformly silver with a dusky tip on its dorsal fin. Growing to 20cm the species is often found, singly or in small schools, hovering over the bottom in a variety of shallow inshore habitats including areas of gravel and rubble, seagrass beds and sandy banks. It is occasionally used for bait.

Figure 3.4 – The Silver Jenny, *Eucinostomus gula*



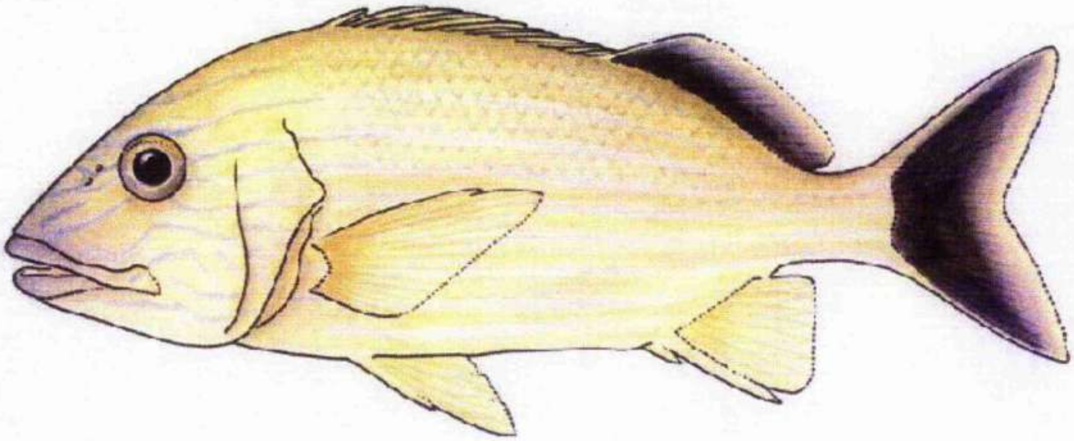
During this study the Silver Jenny was commonly represented in the catch at all sites, occurring in numbers of up to 200 and sizes ranging from 19 to 174mm FL. It was particularly abundant at Walsingham where it comprised approximately 22% of the catch. It was present throughout the year at all sites and was observed to recruit to seagrass beds in summer, with 61 individuals of less that 30mm FL being recorded from Flatts and Bay Island during July and September 1995. This seasonality of recruitment is further highlighted by the observation that of the 115 specimens recorded of less than 45mm FL, only one occurred outside of this July/September period. Although the sample size is limited, a review of the modal progression of size-frequency of this species in the samples (See Appendix 3.2), suggests that new recruits remain in the grass beds for approximately one year during which time they grow to about 85mm FL. Only 14% of the 682 specimens examined were larger than 90mm FL suggesting a migration of larger fish out of this habitat after the first year of life.

3.3.2.2 The Blue-Striped Grunt, *Haemulon sciurus* (Shaw):

Growing to 40cm, *H. sciurus* is one of the most abundant and larger of the 7 grunts recorded from Bermuda. Found both inshore and throughout the North Lagoon in large numbers, and occasionally on offshore reefs to 30m depth, this species is commonly marketed by fishermen. Often seen digging in the sediment for prey, the species is reported to feed mostly at night on invertebrates that it finds in grass beds and sand banks.

The Blue-Striped Grunt was present at all sites throughout this study. Sizes ranged from recruits of 17mm FL to adults of 325 mm FL. Recruitment pulses of up to several hundred individuals were observed from Flatts and Bay Island during September of 1995, at all sites during July/August of 1996 and again, from an isolated sample taken at Bay Island in July 1997. Although a wide range of sizes were represented in the samples throughout the year, less than 7% were of 150mm or greater and specimens of greater than 250mm FL were captured infrequently. This suggests that while seagrasses provide important habitat for juveniles, larger individuals may not be residents but rather visitors using these areas as foraging grounds. Examination of the size-frequency of this species' occurrence in the samples throughout the seasons, and as a composite histogram (See Appendix 3.3), suggests that the Blue-Striped Grunt remains resident within the study sites for up to two years, attaining a length of approximately 80mm in the first year.

Figure 3.5 – The Blue-Striped Grunt, *Haemulon sciurus*

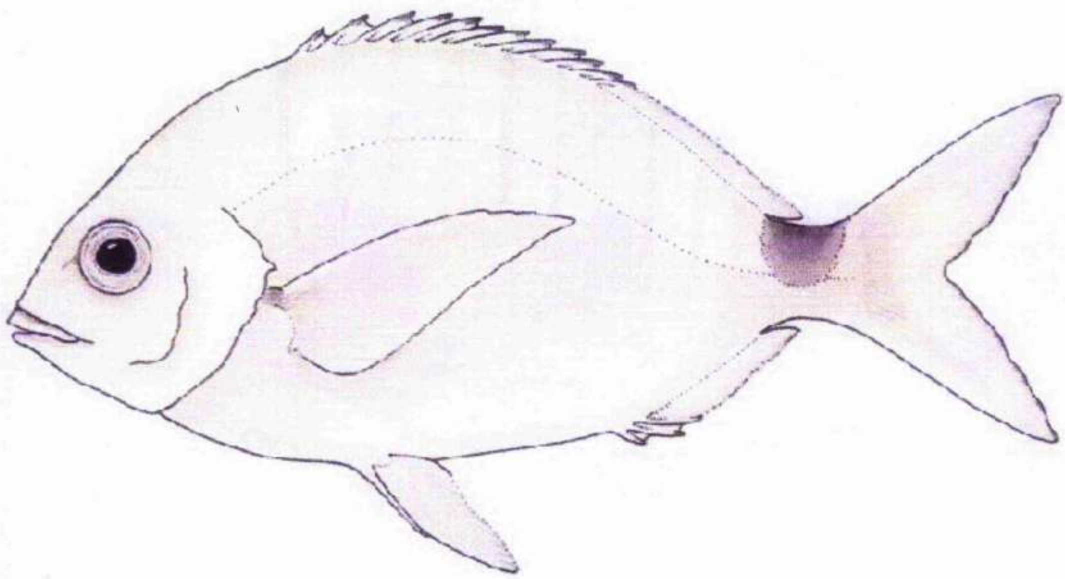


3.3.2.3 The Bermuda Bream, *Diplodus bermudensis* (Caldwell):

The most abundant of the four species of Sparidae from Bermuda, the Bermuda Bream is an endemic species that is remarkable amongst local fish in that it spawns inshore during the winter. Large numbers of postlarvae are regularly observed in shallow bays during late winter. It is most abundant inshore but is commonly found in small numbers as far offshore as the fringing reef. Growing to 40cm, this omnivorous species is readily caught by hook and line and is commonly filleted for food.

During this study, *D. bermudensis* was the most abundant species recorded. Although adults were not common in the catch, thousands of new recruits were caught at Flatts and Bay Island each year from February through March. A clear progression of modes in the monthly size-frequency of breams sampled during this study is evident in the data (See Appendix 3.4). The species recruits to the grass beds and remains for approximately one year, growing to about 60mm FL. After attaining this size the species declines rapidly in abundance indicating a migration to other habitats. Although not represented in the samples, larger breams were commonly observed to return to forage over the seagrass beds. This species was far more common at the Flatts site than at the other stations.

Figure 3.6 – The Bermuda Bream, *Diplodus bermudensis*

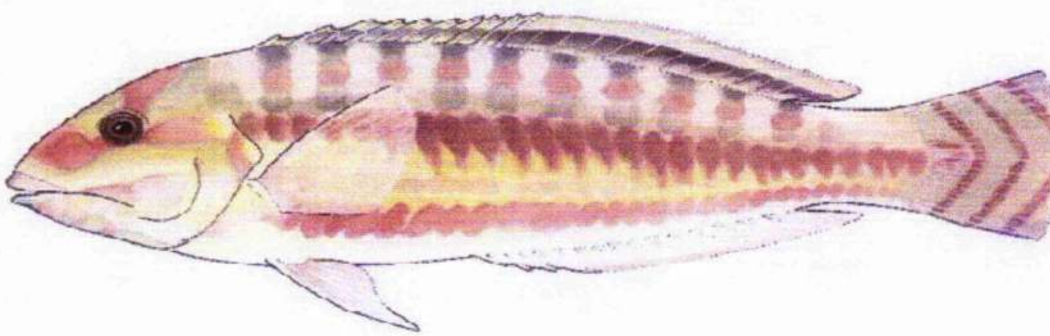


3.3.2.4 The Slippery Dick, *Halichoeres bivittatus* (Bloch):

Named for the slippery mucus which coats this fish and protects it from abrasion as it dives into the sediment to avoid predation, the Slippery Dick is one of the most common of the 16 species of Labridae reported from Bermuda. Particularly abundant inshore, this species inhabits a variety of environments, from rocky and muddy inshore waters to reefs, sand and coral rubble offshore. Growing to 20cm, this predator of benthic invertebrates will readily take a baited hook but, not being considered a food fish, it is generally discarded or used as bait.

Although rarely observed at Flatts Inlet, the Slippery Dick was regularly caught in large numbers at both Bay Island and Walsingham. No clear recruitment events were recorded suggesting that this species either settles out of the plankton in some other habitat, then migrates to seagrass beds, or that new recruits are adept at avoiding capture. With their slender body form, slippery mucous coating and the species' habit of diving into the sediment when threatened, it is entirely possible that they were under-sampled. The observation that specimens were recorded as small as 20mm TL, combined with the fact that all of the individuals of less that 30mm (n=14) occurred in either September 1995 or July 1996, suggests that recruitment to seagrass beds occurs in summer. Although no other information on the recruitment of this species in Bermuda exists, Glasspool (1994) reported that larval labrids were most common in the local plankton during May and June, an observation which indicates that summer recruitment is likely.

Figure 3.7 – The Slippery Dick, *Halichoeres bivittatus*



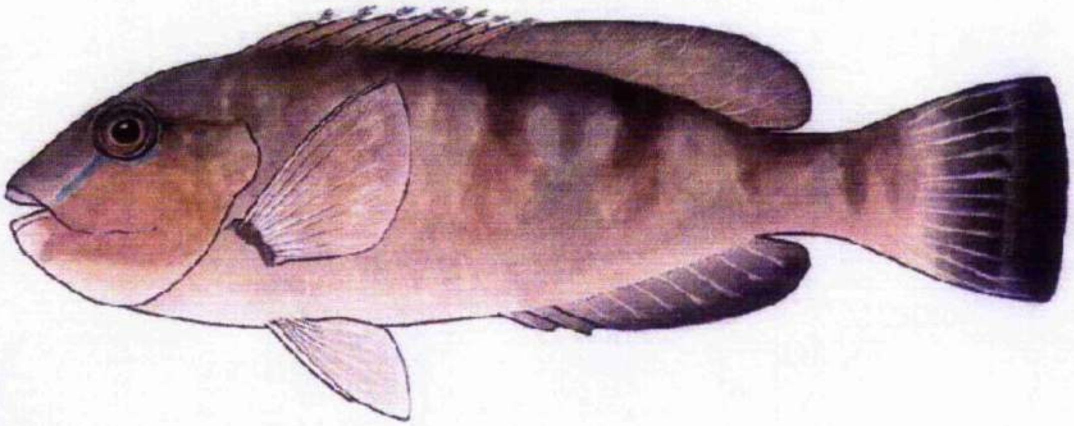
Examination of the progression of modes in the monthly size-frequency histograms constructed from the data (Appendix 3.5) reveals two cohorts. One clear cohort remains in the seagrass bed and grows from approximately 55mm TL in September to 85mm in one year whilst the second, which starts at approximately 85mm TL, disappears by winter. Although specimens of up to 200mm TL were observed during this study, the data indicate that inshore seagrass beds are primarily important to this species as juvenile habitat.

It is remarkable that of approximately 4,000 specimens observed during this study, only 17 came from Flatts Inlet. The relative absence of this species at this site may be indicative of unsuitable environmental conditions at Flatts. This site differs dramatically from the other sites in terms of; current, size and by being much more prone to exposure during periods of extreme low tides.

3.3.2.5 The Bucktooth Parrotfish, *Sparisoma radians* (Valenciennes):

The smallest common parrotfish of 13 species recorded from Bermuda, the Bucktooth is rarely seen far from the shelter of seagrasses, particularly *Thalassia* beds. Unlike most reef-dwelling parrotfish which perform the critical function of grazers within the coral reef community, this fish grazes directly on *Thalassia*, leaving lunate bite marks on the sides of blades. Its mottled colouration allows it to avoid detection by lying motionless between grass blades. Not used by humans, this species is rarely taken, except as bycatch in the bait fishery.

Figure 3.8 – The Bucktooth Parrotfish, *Sparisoma radians*

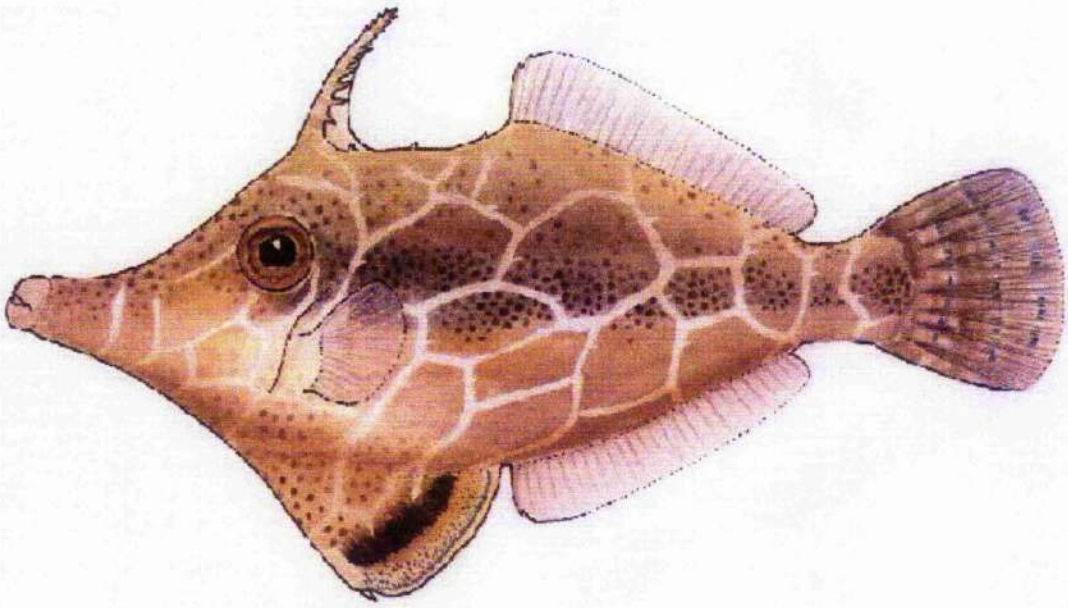


Although rarely caught in large numbers, the Bucktooth Parrotfish was commonly represented in the catch from Bay Island, occasionally from Walsingham and never from Flatts Inlet. Of the 431 specimens observed, 391 were recorded at Bay Island. Whilst no recruitment pulses were detected, one individual of 17mm TL was caught at Bay Island in April 1995. Excluding that one recruit and one large individual of 146mm TL, the species exhibited a size range of 40 – 127mm TL. Insufficient sample size precludes the interpretation of growth of this species through modal progression.

3.3.2.6 The Slender Filefish, *Monacanthus tuckeri* (Bean):

The smallest of 10 species of Balistidae recorded at Bermuda, the Slender Filefish grows to about 8cm. Commonly found in grass beds, coral rubble areas and amongst gorgonians on shallow offshore reefs, it appears to rely heavily on camouflage to avoid predation, adopting the colouration of its background and remaining motionless when approached. It is often observed drifting slowly through seagrass beds with its head down, potentially in search of its preferred prey. Reported to feed on algae and a variety of small invertebrates, this species is not harvested.

Figure 3.9 – The Slender Filefish, *Monacanthus tuckeri*



Of 387 specimens measured, 3 were observed at Flatts Inlet and 2 at Walsingham. The Slender Filefish is a common resident of the Bay Island site where it was found throughout the year and, although usually not very abundant, it did occur in numbers of up to 110 in a single net set. During this study specimens ranged in size from 31-64mm TL. This slow moving, deep-bodied fish has small barbs on its first dorsal spine that makes it highly vulnerable to capture by nets. Judging from the lack of relatively small specimens, it appears as though this species does not recruit directly to the study sites.

3.3.3.1 Between Site Comparisons of Fish Communities:

Between site comparisons using the Shannon Diversity Index revealed significant differences ($p<0.01$) between all locations (See Table 3.3.3.1 at the end of this chapter). Diversity was highest at Walsingham and lowest at Flatts. At Bay Island 35 species were recorded, with 29 species at Flatts, and 23 at Walsingham.

3.3.3.2 Between Seasons Comparisons of Fish Communities:

Comparisons between the fish communities recorded from the seagrass beds during different seasons was conducted both for all stations pooled and for each station individually. The analysis using pooled data yielded significant differences ($p<0.01$) for all 6 possible season combinations. These results are presented in Table 3.3.3.2 (see end of chapter). The results reveal that, while significant ($p<0.01$), the differences between fall and summer and spring and winter are far less marked than are the differences between the other pairings. The seagrass-associated fish communities are substantially more diverse during the summer through fall period than they are during winter and spring. Species richness is highest during the summer and lowest in winter.

3.3.3.2.1 Bay Island:

The results of the comparisons between the fish communities recorded from Bay Island during the different seasons are presented in Table 3.3.3.3 (see end of chapter). At Bay Island only the summer/fall comparison failed to reveal significant differences ($p<0.01$). The diversity indices for these two seasons are similar despite the substantial increase in species occurring at this site during summer.

3.3.3.2.2 Flatts Inlet:

The results of the comparisons between the fish communities recorded from Flatts Inlet during the different seasons are presented in Table 3.3.3.4 (see end of chapter). The only non-significant result ($p<0.01$) revealed from the analysis arose from the comparison of spring and winter. Fall and summer were barely significantly different ($p<0.01$) despite the fact that the large degrees of freedom make this test very sensitive.

3.3.3.2.3 Walsingham:

The results of the comparisons between the fish communities recorded from Walsingham during the different seasons are presented in Table 3.3.3.5 (see end of chapter). In these tests, the only non-significant ($p<0.01$) comparison was between fall and summer. However, it is worthy of note that the calculated t test for the spring and winter couple did not greatly exceed the critical t value.

3.4 Discussion:

The results of this study indicate that there are significant differences between sampling sites and seasons. Thus generalizations based on data collected at one site or season may not be valid for other sites or seasons. Seagrass beds support a variety of fish species throughout the year and, while the total number of species encountered during this study was highest during summer, the increase in species richness during this season was not dramatic. Indeed, at Flatts Inlet the highest species count occurred in winter. Therefore this study failed to identify a season during which the use of bait nets over seagrass beds is substantively less damaging to non-target fish species.

A consistent trend emerged in which the two season couples, summer/fall and winter/spring, differed less than other pairings in all tests. At Walsingham the comparison of fish communities observed during summer and fall failed to yield significant differences as did those for winter/spring for the Flatts Inlet site. This contrasts markedly with the strongly significant results for all other possible season comparisons reflecting the fact that, in large measure, Bermuda has only two clearly recognizable seasons. For consideration of seagrass-associated fish assemblages, combining summer/fall and winter/spring into summer and winter appears to be justifiable.

This study supports the belief that Bermuda's inshore seagrass beds provide important nurseries for fish of several species. While adult fish were caught, the majority of species recorded were present principally as juveniles. Different species utilize this habitat for varying periods of time. Of the abundant species, this period appears to range from approximately one year for *Diplodus bermudensis* and *Eucinostomus gula*, to the entire non-larval life of the *Thalassia*-grazing *Sparisoma radians*.

Although few commercially important species were recorded during this study, indications are that seagrasses are critical to several of the prime target species of the commercial fishery. Newly settled juveniles of the Black Grouper, *Mycteroperca bonaci*, have been found in the seagrasses of both Bay Island (pers. obs.) and Flatts Inlet (Glasspool, pers. comm.) Additionally, commercial fishermen report having caught large numbers of juvenile Lane Snappers, *Lutjanus synagris*, in the seagrasses at Coney Island (Lambe, pers. comm.). It is probable that a larger survey of the fish residing in local seagrass meadows would reveal that juveniles of several more commercially important species inhabit these areas.

The scarcity of Slippery Dicks, *Halichoeres bivittatus*, and the complete absence of the Bucktooth Parrotfish, *Sparisoma radians*, in the catch at Flatts Inlet are of potential interest. The lack of these fish, which were commonly caught at the other sites, may indicate that conditions at Flatts Inlet fail to satisfy their needs. Both of these species appear to be year-round residents of seagrasses. The Flatts Inlet seagrass beds are exposed to strong currents and are small with a large portion that dries out during extreme low tides. While it seems unlikely that currents would preclude these species, the instability of such small seagrass beds, which functionally shrink seasonally, may be unsuitable for year-round habitation.

Table 3.3.1: Fish Species Recorded, Their Occurrence and Relative Abundance within Seine Net Samples

Family	Species	Occurrence/Abundance
Engraulidae	*Anchoa choerostoma*	Occasional/very abundant*
Clupeidae	*Harengula humeralis*	Uncommon/very abundant*
	Jenkinsia lamprotaenia	Common/very abundant*
	Sardinella anchovia	Uncommon/very abundant*
Synodontidae	*Synodus intermedius*	Occasional
Hemiramphidae	*Hemiramphus bermudensis*	Occasional*
Atherinidae	*Allanetta harringtonensis*	Occasional/very abundant*
Holocentridae	*Adioryx vexillarius*	Rare
	Holocentrus rufus	Uncommon
Syngnathidae	*Syngnathus dunckeri*	Rare
	Syngnathus sp.	Rare
	Hippocampus reidi	Rare
Carangidae	*Caranx latus*	Rare
Lutjanidae	*Lutjanus griseus*	Rare
	L. synagris	Rare
	Ocyurus chrysurus	Uncommon
Gerreidae	*Eucinostomus gula*	Common/very abundant
	E. havana	Common/very abundant
	E. lefroyi	Uncommon
Haemulidae	*Haemulon aurolineatum*	Common/abundant
	H. sciurus	Common/very abundant
	H. flavolineatum	Occasional/abundant
	H. carbonarium	Rare
	Orthopristes chrysoptera	Rare

Table 3.3.1(Continued): Fish Species Recorded, Their Occurrence and Relative Abundance within Seine Net Samples

Sparidae	*Diplodus bermudensis*	Common/very abundant
	Calamus calamus	Occasional
	Lagodon rhomboides	Common
Mullidae	*Pseudupeneus maculatus*	Occasional
Chaetodontidae	*Chaetodon capistratus*	Occasional
	C. ocellatus	Rare
Labridae	*Halichoeres bivittatus*	Common/very abundant
	Lachnolaimus maximus	Rare
Scaridae	*Scarus croicensis*	Uncommon
	Sparisoma chrysopterum	Rare
	S. radians	Common/abundant
	S. rubripinne	Rare
Mugilidae	*Mugil liza*	Uncommon
Sphyraenidae	*Sphyraena barracuda*	Uncommon
Gobiidae	Unidentified	Rare
Acanthuridae	*Acanthurus chirurgus*	Rare
	A. bahianus	Rare
Balistidae	*Monacanthus tuckeri*	Occasional/abundant
	M. ciliatus	Rare
Centrolophideae	*Schedophilus ovalis*	Rare
Tetradontidae	*Sphaeroides spengleri*	Common

Key to Abundance Categories: (See also Appendix 3.1)
Rare – less than 10 individuals observed during the study
Uncommon – Present in less than 10% of the net sets
Occasional – Present in more than 10% but less than 30% of the net sets
Common – Present in greater than 30% of the net sets
Abundant – Commonly represented by more than 10 individuals
Very Abundant – Commonly represented by more than 100 individuals
* - Pelagic species, regularly released without enumeration

Table 3.3.3.1: t-Tests Comparing Fish Communities by Station using the Shannon Diversity Index

	Total No. of Fish	Total No. of Species	Sum $p_i(\ln p_i)^2$	Shannon Diversity Index (H')	Evenness (H'/ln S)	Variance of Diversity Index (H')
Bay Isl.	10957	36	4.40	-1.59	-0.44	0.000171
Flatts	13330	29	2.85	-0.91	-0.27	0.000152
Walsingham	3895	23	4.34	-1.86	-0.59	0.000223

Critical t (two-tailed) for df (infinity), (p=0.01) = 2.58

Comparison of Bay Isl. And Flatts	Calculated t	-37.87
	df	23704.78
Comparison of Bay Isl. And Walsingham	Calculated t	13.71
	df	10038.93
Comparison of Flatts and Walsingham	Calculated t	49.16
	df	9685.343

Note – Where the absolute value of the calculated t exceeds the critical t value of 2.58, significant differences exist at p=0.01.

Table 3.3.3.2: *t*-Tests Comparing Fish Communities by Season using the Shannon Diversity Index

	Total No. of Fish	Total No. of Species	Sum $p_i(\ln p_i)^2$	Shannon Diversity Index (H')	Evenness ($H'/\ln S$)	Variance of Diversity Index (H')
Fall	3150	26	5.58	-2.19	-0.67	0.000249
Spring	13340	26	3.15	-1.08	-0.33	0.000149
Summer	4910	31	5.51	-2.10	-0.61	0.000224
Winter	6782	22	3.01	-0.97	-0.31	0.000305

Critical t (two-tailed) for df (infinity), ($p=0.01$) = 2.58

Comparison of Fall and Spring	Calculated t	-55.66
	df	7424
Comparison of Fall and Summer	Calculated t	-4.19
	df	7486
Comparison of Fall and Winter	Calculated t	-51.86
	df	9192
Comparison of Spring and Summer	Calculated t	52.74
	df	11700
Comparison of Spring and Winter	Calculated t	-5.18
	df	13399
Comparison of Summer and Winter	Calculated t	-49.09
	df	11691

Note – Where the absolute value of the calculated t exceeds the critical t value of 2.58, significant differences exist at $p=0.01$.

Table 3.3.3.3: t-Tests Comparing Fish Communities by Season using the Shannon Diversity Index - Bay Island

	Total No. of Fish	Total No. of Species	Sum $p_i(\ln p_i)$	Shannon Diversity Index (H')	Evenness (H'/ln S)	Variance of Diversity Index (H')
Fall	805	19	5.03	-1.99	-0.68	0.001294
Spring	3714	15	2.10	-1.06	-0.39	0.000261
Summer	2837	26	5.17	-2.03	-0.62	0.000369
Winter	3601	19	2.19	-0.71	-0.24	0.000469

Critical t (two-tailed) for df (infinity), (p=0.01) = 2.58

Comparison of Fall and Spring		Calculated t	-23.62
		df	1152
Comparison of Fall and Summer	**Not Significant**	Calculated t	0.88
		df	1299
Comparison of Fall and Winter		Calculated t	-30.64
		df	1451
Comparison of Spring and Summer		Calculated t	38.56
		df	5985
Comparison of Spring and Winter		Calculated t	-13.14
		df	6711
Comparison of Summer and Winter		Calculated t	-45.70
		df	6438

Note – Where the absolute value of the calculated t exceeds the critical t value of 2.58, significant differences exist at p=0.01.

Table 3.3.3.4: t-Tests Comparing Fish Communities by Season using the Shannon Diversity Index -Flatts Inlet

	Total No. of Fish	Total No. of Species	Sum $p_i(\ln p_i)^2$	Shannon Diversity Index (H')	Evenness ($H'/\ln S$)	Variance of Diversity Index (H')
Fall	438	12	3.51	-1.58	-0.64	0.002318
Spring	9232	22	2.26	-0.71	-0.23	0.00019
Summer	963	19	4.20	-1.74	-0.59	0.001221
Winter	2697	14	1.89	-0.66	-0.25	0.000537

Critical t (two-tailed) for df (infinity), (p=0.01) = 2.58

Comparison of Fall and Spring		Calculated t	-17.32
		df	513
Comparison of Fall and Summer		Calculated t	2.68
		df	906
Comparison of Fall and Winter		Calculated t	-17.11
		df	659
Comparison of Spring and Summer		Calculated t	27.34
		df	1283
Comparison of Spring and Winter	**Not Significant**	Calculated t	-1.75
		df	4768
Comparison of Summer and Winter		Calculated t	-25.62
		df	1867

Note – Where the absolute value of the calculated t exceeds the critical t value of 2.58, significant differences exist at p=0.01.

Table 3.3.3.5: t-Tests Comparing Fish Communities by Season using the Shannon Diversity Index - Walsingham

	Total No. of Fish	Total No. of Species	Sum $p_i(\ln p_i)^2$	Shannon Diversity Index (H')	Evenness (H'/ln S)	Variance of Diversity Index (H')
Fall	1907	16	3.62	-1.74	-0.63	0.000304
Spring	394	8	1.99	-1.00	-0.48	0.002485
Summer	1110	17	4.12	-1.73	-0.61	0.001019
Winter	484	11	2.69	-1.27	-0.53	0.002227

Critical t (two-tailed) for df (infinity), (p=0.01) = 2.58

Comparison of Fall and Spring		Calculated t	-13.98
		df	494
Comparison of Fall and Summer	**Not Significant**	Calculated t	-0.37
		df	1779
Comparison of Fall and Winter		Calculated t	-9.44
		df	622
Comparison of Spring and Summer		Calculated t	12.24
		df	739
Comparison of Spring and Winter		Calculated t	3.83
		df	856
Comparison of Summer and Winter		Calculated t	-8.10
		df	942

Note – Where the absolute value of the calculated t exceeds the critical t value of 2.58, significant differences exist at p=0.01.

4.2 Infauna:

In this study infauna is defined as those organisms living within the sediment interstices. This excludes organisms living upon the sediment surface which are either members of the macrofauna, and thus probably unavailable as prey to most of the resident fishes, or are species that are also represented in the epifauna of the grass blades and are therefore dealt with separately.

Classically, infaunal studies are conducted by taking grab samples or sediment cores. Grab samples are appropriate in situations where sampling is conducted from the deck of a research vessel and there is no need to discriminate between vertical zones within the sediment. Sediment cores allow slices to be examined thereby revealing the fauna of specific sediment depths. In the current study the organisms living in close proximity to the sediment surface were deemed to be more readily accessible to predation by fish and thus of more interest than those further down. As access to the sediment by diver is readily accomplished in such shallow water, sediment cores were taken.

4.2.1 Methods:

An acrylic cylinder of 3.5cm internal diameter and 12cm in length with the outer wall tapered to produce a circular blade at one end, and two 3.8cm diameter rubber bungs formed the sampling gear (See Fig. 4.1). A diver pushed the sharpened end of the cylinder into the sediment between the grass blades to a depth of approximately 7cm. The exposed end of the cylinder was then plugged with one of the rubber bungs, the cylinder withdrawn, and the bottom end similarly plugged. On 18th May 1998, three sediment cores were taken from between emergent shoots at randomly chosen spots within the grass bed at Bay Island. These were maintained in their original, vertical orientation for transport to the laboratory.

Chapter 4: Seagrass-Associated Invertebrate Communities as Food for Fish

4.1 Introduction:

Sampling of the seagrass community was performed to identify the potential prey available for fish living within the seagrass beds. Whilst an accurate quantitative analysis identifying the many microscopic organisms present and assessing their abundance is beyond the scope of this project, the use of simple methods to identify the dominant members of the microfauna associated with seagrasses was readily accomplished.

Although most of the biomass in this habitat is tied up in the seagrasses themselves, it is recognised that direct grazing on these plants accounts for only 10-15% of tropical seagrass productivity (Zieman, 1983; Ogden, 1987). Earlier examinations of the fish in local seagrass beds confirmed that this habitat is primarily used as a nursery for a number of species, whilst those species which are continuous residents are relatively small fish (See Chapter 3). Though larger fish species visit this habitat and undoubtedly consume the macrofauna, the prey for seagrass-dependent fish are believed to be primarily small, mainly detritivorous, crustaceans (Klumpp, Howard and Pollard, 1989). For this reason efforts were directed toward describing the smaller members of the infauna, epifauna and the plankton associated with grass beds. The widely divergent micro-habitats in which these prey species reside required separate methodologies for their study.

For the study of seagrass communities sampling was conducted at Bay Island (See Fig. 3.2). This site was chosen as it displayed the most diverse ichthyofauna and appears to support the most vigorous seagrass growth of the three sample sites. Preliminary plankton sampling was performed at the Flatts Inlet site (See Fig. 3.1) because of ease of access at night.

Figure 4.1 – Sediment Core Sampling Gear *(with a sediment sample from an inshore seagrass bed and plunger used to extrude samples)*

Within 2 hours, the cores were sectioned to examine the organisms living in the top 2cm. Due to the coarse nature of the surface sediments obtained it was not possible to extrude the core top first as the section of interest readily fell apart when rotated into the horizontal plane. To avoid this problem, a close-fitting plastic rod was fashioned for use as a plunger. This was gently inserted into the top of the core, slowly displacing the seawater covering the sediment. Gentle pressure was applied to force the sediment out through the sharpened end of the corer until only the last 2cm remained. The deeper sediments were cut away and discarded allowing the top 2cm of the sediment core to be examined separately. This portion was washed with filtered seawater and strained through a 63µm sieve. The remaining material was transferred to a Petri dish and examined using a Meiji 7-45X zooming binocular microscope with a fibre optic light source.

4.2.2 Results:

Table 4.2.1 (see end of chapter) presents the result of this work. Visual inspection of the sample prior to sectioning revealed a surface layer with a coating of fine organic mucilage grading into anoxic muds and interrupted at points by roots and rhizomes. Compared with the epifaunal work described below, these samples were found to be relatively poor in biota with small numbers recorded for each of the species' groups represented. Harpacticoid copepods and nematodes consistently dominated in the samples, indicating a relatively uniform distribution of these members of the infauna. Despite this numerical dominance, it was visually apparent that the much larger polychaetes were the principal contributors to the biomass of sample 2. The presence of surface-dwelling organisms such as decapod shrimps and gammarid amphipods suggests the contamination of the infauna with the capture of organisms living at the sediment surface.

4.3 Epifauna:

Seagrass blades form a complex three-dimensional substratum that traps organic debris and provides a rich habitat for micro-invertebrates, algae and protists. As this diverse community includes both sedentary and motile life forms, its study requires collection techniques that provide for the harvest of both the blades and the loosely attached or free-living epibiota.

4.3.1 Methods:

Sampling was conducted at Bay Island on 25th July 1997. A total of 4 samples were taken at random by a diver placing an open plastic bag over a clump of grass blades so as to encompass the blades down to the level of the sediment. Flushing of the sample was limited by avoiding rapid movements and holding the bag tightly closed at the base of the blades. A pair of scissors was then used to cut the grass at the level of the sediment to release the sample which was then sealed in the bag with an elastic band. This process secured a bag full of seawater, seagrass and associated organisms. After transport to the laboratory, the sample was fixed by adding formaldehyde to produce an approximately 10% formalin solution.

The sample was agitated prior to removal of the grass blades. The water was then filtered through a 63μm sieve to reduce the volume. The component retained on the filter was then transferred to a Petri dish, resuspended in a small volume of filtered seawater and examined with a binocular microscope as previously described. The organisms in this filtered fraction were identified, generally to family level, using Sterrer (1986) and the dominant groups were subsequently recorded. The grass blades were similarly inspected and the community adhering to the blades recorded separately. Due to the great abundance of life forms obtained and the difficulty in adequately enumerating these within the organic slime which dominated the samples, this process was limited to producing a strictly qualitative assessment of the principal organisms present in the samples.

4.3.2 Results:

Table 4.3.1 (see end of chapter) summarizes the findings of this work, listing the most common organisms in order of abundance. It was noted that older grass blades were commonly heavily encrusted with coralline algae, bryozoans, hydrozoans and foraminiferans. Young blades contrasted with this, being largely free of fouling other than a coating of organic slime, presumably of bacterial and algal origin. This organic slime in turn supports a diverse community of invertebrate predators that composed the majority of the free-living organisms found in the filtered fraction of the samples. Less common organisms that were observed in the filtered fraction included: decapod shrimps, caprellid and gammarid amphipods, other amphipods and mites.

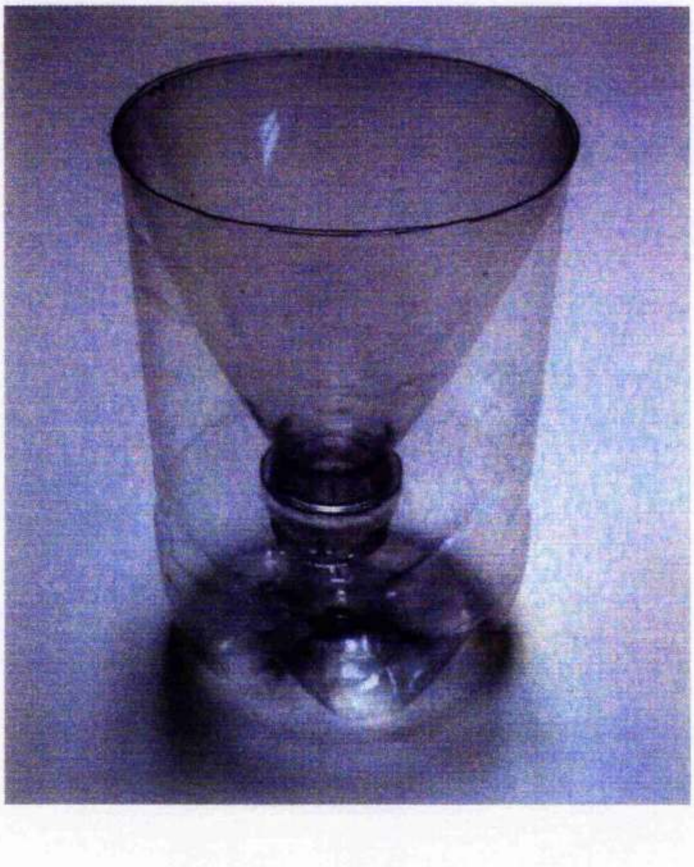
4.4 Plankton:

Two methods were evaluated for sampling the plankton associated with seagrasses. As many of the species living within the grass beds rarely emerge to swim high above the protective canopy, attempts were made to sample specifically within this cover. Traps were deployed to act much as sediment traps do, to collect meiofauna and plankton meiofauna and plankton settling in the beds, and a 100μm mesh plankton net was also dragged through the beds to collect organisms living above and between the grass blades.

4.4.1 Trapping method:

The tapering necks of 1litre plastic soft drink bottles were cut to create a funnel of approximately 8.6cm diameter and 10cm length. This funnel was inverted and pushed into the remainder of the container to form a cylindrical trap approximately 14cm tall and 8.6cm in diameter (See Fig. 4.2). Staples were used to fasten the pieces together and the completed trap was filled with filtered seawater and tied to a steel stake, driven into the sediment within the grass bed so that it was deployed with the funnel opening facing vertically upwards. Four traps were left in place for 24 hours, then retrieved, with the vessels maintained in the vertical orientation for transport to the laboratory. The water contained within the traps was then strained through a 63μm sieve and examined microscopically.

Figure 4.2 – Plankton Trap Design



4.4.1.1 Results:

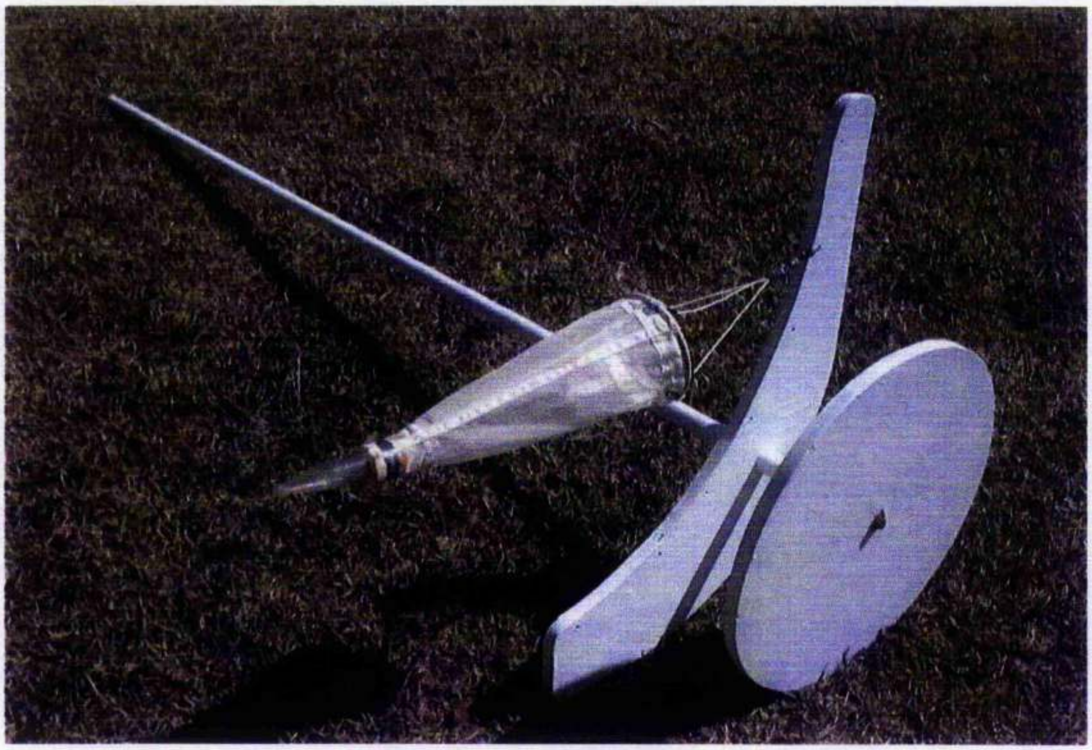
Examination of the catch revealed highly consistent results. Copepods dominated, with the large majority being harpacticoid copepods. Nematodes were also common and small numbers of ostracods were present. The samples also contained small amounts of sediment indicating that wave action had caused some resuspension in the area, or that the disturbance caused during deployment and retrieval of the gear had created some contamination. As only organisms that would be expected to be associated with the epifauna and infauna were collected with this technique, and because more efficient methods for sampling these assemblages are readily available, this method was not pursued further.

4.4.2 Net Sampling Method:

A plankton net of 100μm mesh with a 12cm opening was towed over the seagrass bed using a purpose-built frame to control the depth fished. This apparatus consisted of a 4.5cm diameter pole 2.3m long with a 50cm diameter disk of 2cm thick plywood fastened through the centre to the long axis of the pole to act as a wheel. Also attached to the pole, 15cm in from the wheel and in a fashion that precluded rotation, was a 2cm thick plywood runner drilled at points on the trailing edge to allow for attachment of the net (See Fig. 4.3). The gear was deployed by wading in the grass bed and holding the pole to extend the net away from the operator while pressing down so that the wheel and trailing edge of the runner were in contact with the sea floor. In this position the rig was pushed forward to execute one complete rotation of the net around the operator, thereby sampling in a circular path of 4m diameter. In this fashion the net was towed for approximately 12.6m over the grass bed filtering approximately $0.14m^3$ of seawater at a known height, allowing for assessment of the vertical distribution and abundance of plankton. Sampling was conducted at 10, 30 and 50cm above the substratum both at night and during the day to assess diurnal changes in plankton abundance. Preliminary sampling was conducted at the Flatts Inlet site during May and June of 1997. This site was chosen for study as it was the most accessible site for night-time sampling. Samples were filtered through a 63μm sieve and examined by microscope as previously described.

accessible site for night-time sampling. Samples were filtered through a 63μm sieve and examined by microscope as previously described.

Figure 4.3 Plankton net and Sampling Frame *(with net set to sample at 50cm above substratum)*



Difficulties were encountered in attempting to quantify the organisms present in the 10cm samples due to the large amount of material collected, and in the nocturnal samples from 30 and 50cm due to the large numbers of highly motile animals caught. To address these problems a modified procedure involving subsampling was employed for examining samples collected at Bay Island during July of 1998: -three samples were taken at each of 10, 30 and 50cm during the day on July 19^{th} and again during the night of 20^{th} July. The 10cm samples were filtered through a 63μm sieve and placed in a 97mm diameter Petri dish. Three subsamples (of 2.08% of the sample each) were obtained by isolating portions of the sample with a plastic cylinder of 14mm diameter. These subsamples were drawn off by means of pipette and placed on an 81mm diameter sieve of 63μm mesh that was contained within a second Petri dish to hold seawater during examination.

by counting the contents of 5 fields of view of 33mm diameter each (=5x16.5% of the sample).

4.4.2.1 Results, Flatts Inlet:

It was found that the samples taken at 10cm above the sediment interface, both at night and during the day, contained small amounts of sediment, some grass blades and large numbers of animals that occur as epifauna on the grass blades. As the ring of the net is 12cm in diameter it can be determined that the lower extremity of the net was sampling as low as 4cm above the sediment and that the bulk of the net was passing between the grass blades. In essence it can be deduced that these samples are, in fact, samples of the motile epifauna taken by means of a plankton net. Due to the difficulties encountered in enumerating the 10cm samples, no numerical data are provided for this depth in Table 4.4.3.1 (see end of chapter).

4.4.2.2 Statistical Analysis, Bay Island Plankton:

The experimental design can best described as a 2 by 3 level (day/night by 3 depths) nested, repeated measures design. As varying numbers of 14 taxa were encountered in these samples the model has multiple response variables. To accommodate these characteristics, a multivariate ANOVA was conducted using StatView® version 4.5 software.

The analysis was complicated by the fact that the sampling procedure had produced an unbalanced analytical model with the 30cm and 50cm depths having 5 measures (counts of fields of view) for each of the 3 repeated samples whilst the 10cm samples had been further subsampled 3 times prior to enumerating. In other words whilst there were 5 measures for each of the samples from the 30 and 50cm depths, there were 15 for those from 10cm. This was problematic as repeated measures designs generally call for equal sample size within treatments.

Two methods were employed in order to address this problem. The first approach involved reducing the 15 measures to 5 by averaging sets of 3 measures (1,2,3; 4,5,6; 7,8,9; 10,11,12; 13,14,15) and using these means rather than the original measures as input data. The second approach was to simply work with the first 5 measures in the set of 15. In essence, this latter approach throws out the 2nd and 3rd subsamples from the 10cm samples, confining the analysis to the data derived from the first subsample. As all the subsamples were obtained by randomly extracting a known proportion of the original sample, this approach was taken to be justifiable.

It was found that, despite arriving at the same ultimate result from both approaches, the former method strengthened the analysis. This is probably the result of the averaging process eliminating some of the sample variance, and thereby creating a bias toward the determination of statistical significance. The latter analysis is therefore considered to be more conservative and, as it is free from any systematic bias, is thus reported here.

4.4.2.3 Results, Bay Island:

Table 4.4.3.3 (see end of chapter) presents the results of the ANOVA. As was expected from inspection of the samples, depth was found to have a significant effect ($p<0.05$) on the organisms collected by plankton net. A weaker yet significant depth by time interaction was also determined to exist once sample variance was accounted for.

Figure 4.4 (See end of chapter) presents the abundance of the various taxa as a function of time and depth. The dramatic increase in abundance of organisms at the 10cm level is obviously the most influential effect. The influence of time on the community sampled at various depths, whilst much less pronounced, can also be seen.

4.5 Discussion:

Howard, Edgar and Hutchings (1989) reviewed the literature relating to the faunal assemblages of seagrass beds. They noted that studies of seagrass communities have largely been directed to those species of economic importance, ignoring the lower trophic levels. Citing an absence of published information of seagrass-associated microfaunas, meiofaunas and sessile epifaunas from Australia and the paucity of such information world-wide they cautioned that, despite representing a small proportion of the biomass, the high rate of productivity of the microfauna and meiofauna makes their contribution to community trophic processes disproportionately high. They found that almost all studies of seagrass-associated faunas conducted in Australia prior to 1989 had been descriptive and although this hinders comparisons, these studies do demonstrate that seagrass habitats support communities which are both rich in numbers and species diversity. Classifying the seagrass communities as: infauna, motile epifauna, sessile epifauna, and epibenthic fauna, and further they listed the dominant taxa of each category:

4.5.1 Infauna:

i) Meiofauna: Within the meiofauna they report the dominant taxa to include harpacticoid copepods, ostracods, nematodes and polychaetes. The sediment cores taken from the seagrass bed at Bay Island displayed a fairly small number of organisms with the most common forms being harpacticoids and nematodes. Ostracods, whilst very commonly found as epifauna upon the grass blades, were absent from the sediment samples as were microscopic polychaetes. These results must be viewed with caution. The limited sampling effort in the current study may have failed adequately to describe Bermuda's seagrass infauna for meaningful comparisons.

ii) Macrofauna: Although the methodology employed in the current study clearly undersampled the macrofauna, several of the dominant taxa reported from Australian seagrass-associated sediments are similar to those reported from previous studies at Bermuda. Polychaetes, bivalves and amphipods are abundant in both regions whilst Australian seagrass beds also support large numbers of cumaceans and infaunal holothurians, organisms which are generally not abundant in Bermuda (Sterrer, 1986). Phoronids are abundant in Australian seagrasses and, although Bermuda supports only one species, *Phoronis psammophila*, this organism is reportedly common in local seagrass beds (Sterrer, 1986). Orth (1971), noting that the infauna of Bermudian seagrass beds is 4 times as abundant and far more diverse than that of adjacent bare sand, recorded 55 species including a variety of bivalves, crustaceans and scavenging and deposit feeding worms. Knap et al. (1991) produced a provisional list of the infauna associated with a Bermudian seagrass meadow which included a variety of amphipods, isopods and polychaetes. Logan and Cook (1992) reviewed previous studies reporting 26 species of polychaetes, bivalves, decapods and amphipods from local seagrass-associated sediments. They further noted that their list omits the extensive, but poorly described, intersitial fauna.

4.5.2 Motile epifauna:

i) Meiofauna: Within the meiofauna, the dominant taxa reported by Howard, Edgar and Hutchings (1989) generally corresponded with those observed during this study. They list harpacticoids, ostracods, nematodes and rotifers. During this study the filtered portion of the seagrass bag samples and the plankton tows at 10cm above the seafloor sampled this assemblage. The dominant taxa of the bag samples were polychaetes, harpacticoids, nematodes and ostracods, whilst the plankton tows were heavily dominated by ostracods and harpacticoids with nematodes being fairly common. The dominance of polychaetes in the bag samples and their virtual absence within the plankton samples may indicate that they are better able to cling to the grass blades when disturbed and thus able to avoid capture by net than are the ostracods and harpacticoids. The absence of rotifers reported from the current work may be due to a failure to identify these organisms. However, there are only 3 species known to occur at Bermuda and none of these are reported from seagrass habitats (Sterrer, 1986).

ii) Macrofauna: Whilst the current study was not directed toward the description of the larger members of the motile macrofauna the methods employed did provide information on the smaller members of this group. Turbellarids were common, occasionally occurring in large numbers, particularly *Amphiscolops bermudensis*. Small decapods, gastropods and amphipods were commonly present in relatively small numbers in both the bag and net samples as were larger polychaetes. These groups, along with isopods, pycnogonids echinoderms and nemerteans, were reported to be dominant in the Australian studies. Although the pycnogonid, *Endeis spinosa*, is reportedly common on *Thalassia* in Bermuda (Sterrer, 1986), none were observed during the current study. The absence of isopods from the bag or net samples is puzzling as a number of species are reportedly readily washed from vegetation (Sterrer, 1986). However, Logan and Cook (1992) list none as known to occur in local seagrasses. Large echinoderms, particularly the urchin, *Lytechinus variegatus*, and the holothurian, *Isostichopus badionotus*, are common in Bermudian seagrass beds.

4.5.3 Sessile Epifauna:

Common members of the sessile epifauna of Australian seagrasses include hydroids, bivalves, bryozoans, sponges, ascidians and serpulid polychaetes. Other than bivalves which are rarely found attached to Bermudian seagrasses, and the omission of foramanifera, this list aptly describes the dominant taxa of locally occurring attached epifauna. The dominant sessile epifauna recorded from the bag samples were hydroids, bryozoans and foraminiferans. Sponges and ascidians, although not present in the samples, are commonly found attached to *Thalassia* in Bermuda.

4.5.4 Plankton:

Although perhaps not generally considered to be part of the seagrass community, the planktonic community associated with seagrass beds was investigated. This was largely undertaken in response to behavioural observations of fish, principally *Haemulon* spp., apparently feeding on planktonic organisms both between blades of seagrass and midwater above the beds (See Chapter 5). From these observations it was assumed that planktivory is important to some species of seagrass-associated fish.

A significant depth effect was observed, with a dramatic increase in abundance of organisms found in the samples taken within the seagrass blades. However, as noted in the methods section above, much of this biomass was apparently derived from organisms that live as part of the epifauna rather than associated plankton. Thus, although dragging a plankton net through the grass blades provides a rich sample, it fails to discriminate between plankton and epifauna. As the benefits of a strategy of feeding on plankton within the protective canopy of the grass blades are obvious, and as a relatively large number of juvenile *Haemulon sciurus* were observed to exploit this approach, further work to assess seagrass-associated plankton may be worthwhile. A suction sampling device might prove useful in the selective sampling of this fauna.

Although no significant time effect was detected through this work, a weak time by depth correlation was observed. Figure 4.4, which displays the assemblages sampled by depth and time, suggests that real differences may exist and that further work to clarify these patterns is warranted.

4.6 Conclusions:

These studies revealed a heavy concentration of organisms on the blades of the seagrasses. Diversity and abundance of animals were much less in surface sediments and in the zooplankton around the blades. The greatest concentration of prey for small fishes lay in the microinvertebrate browsers that live within the bacterial/algal slime that coats much of the blade surfaces.

Figure 4.4
The Abundance of Plankters Taken by Net Over Seagrass Beds Presented by Taxon, Time and Depth.

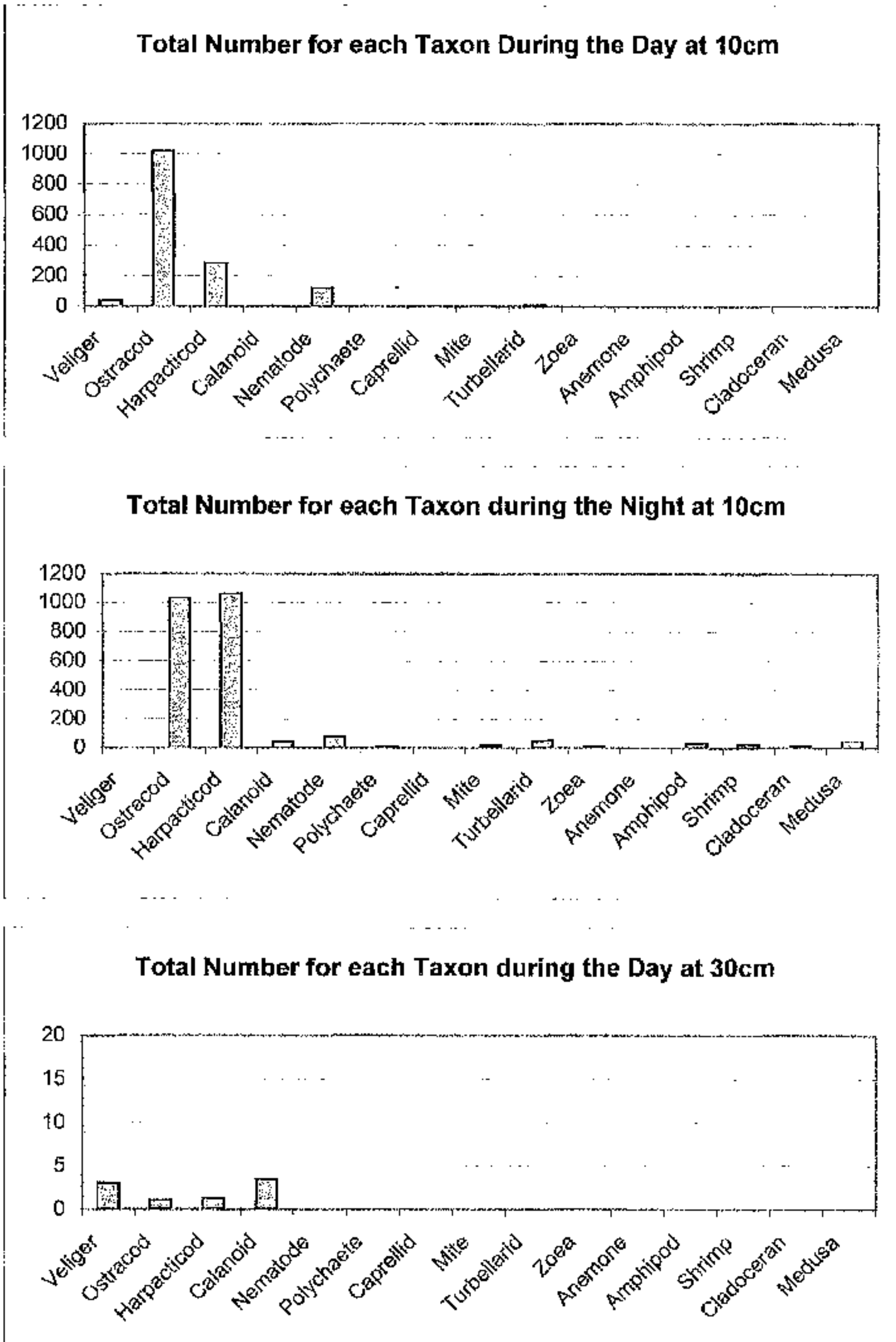
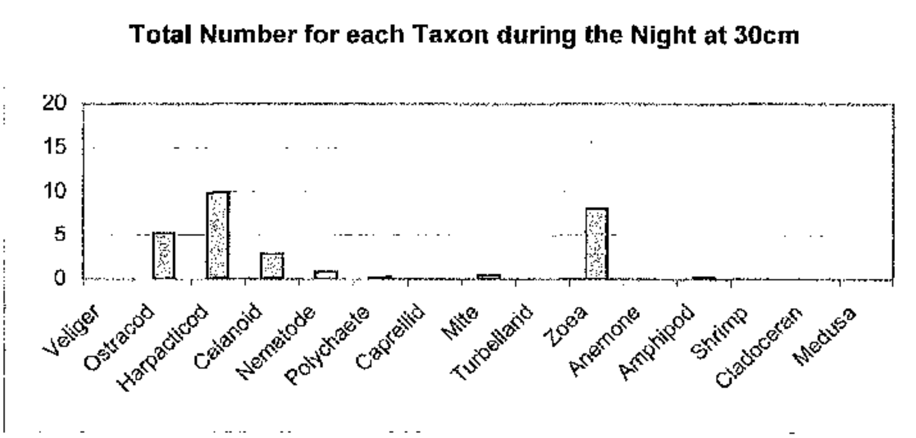
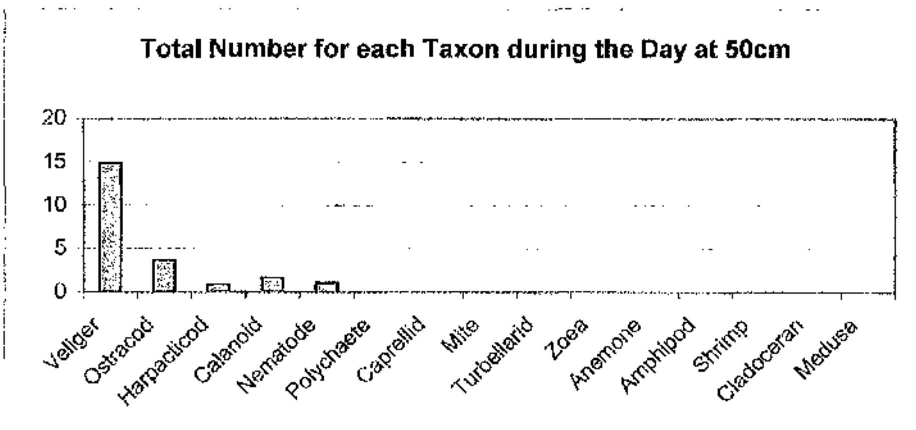


Figure 4.4 (Continued)
The Abundance of Plankters Taken by Net Over Seagrass Beds Presented by Taxon, Time and Depth.





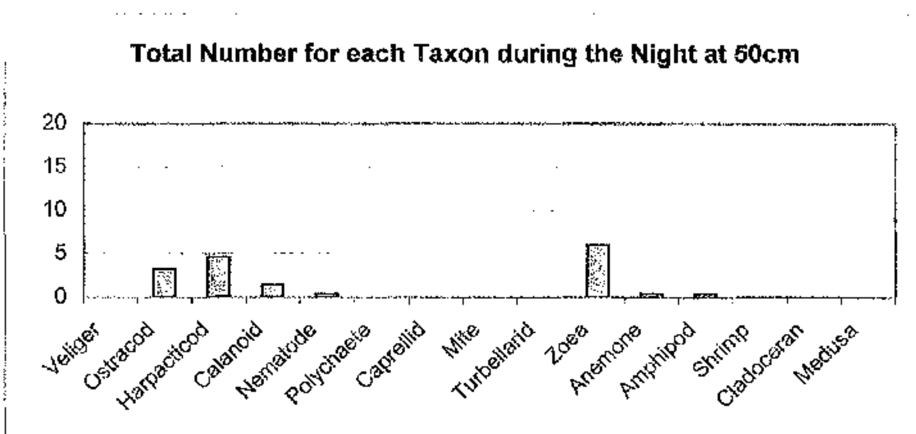


Table 4.2.1 Density of Infaunal Organisms (No./cm^3) Observed in the Top 2cm of Sediment from the Bay Island Seagrass Bed.

Taxonomic Group	Sample 1	Sample 2	Sample 3	Mean	SD
Harpacticoids	0.62	0.53	0.88	0.68	0.18
Gammarids	0.22	0	0.04	0.09	0.12
Shrimp	0.04	0.04	0	0.03	0.02
Nematodes	0.44	0.35	0.44	0.41	0.05
Polychaetes	0	0.18	0	0.06	0.10
Oligochaetes	0	0.04	0	0.01	0.02
Other*	0.09	0.09	0.04	0.07	0.03

* includes: Turbellarians, Foraminifera, Holothurians and Gastropods.

Table 4.3.1 Seagrass Epifauna Ranked in Order of Dominance (top = most abundant, bottom = least dominant)

Sample	1	2	3	4
Attached to Blades	Ostracods Foraminiferans Coralline algae Bryozoans Egg masses - (annelid?)	Foraminiferans Bryozoans Hydrozoans Coralline algae Egg masses – (annelid?)	Coralline algae Bryozoans Hydrozoans Polychaetes Egg masses – (annelid?)	Coralline algae Bryozoans Hydrozoans Polychaetes Foraminiferans Egg mass*
Filtered Portion	Polychaetes Harpacticoids Nematodes Ostracods	Nematodes Harpacticoids Ostracods Polychaetes	Nematodes Ostracods Polychaetes Harpacticoids	Harpacticoids Nematodes Polychaetes Ostracods

Notes: Sample 1(filtered) biomass highly dominated by polychaetes, numbers dominated by harpacticoids.

Sample 2 (blades) older blades heavily encrusted with foraminiferans and bryozoan colonies.

Sample 3 (filtered) large amount of organic slime, biomass dominated by polychaetes, numbers dominated by nematodes, ostracods and harpacticoids.

Sample 4 (blades) *egg case with well-developed embryos – appear to be sabellid polychaetes.

Table 4.4.3.1 Dominant Life Forms Sampled in Seagrass-Associated Plankton – Preliminary Sampling, Flatts Inlet May/June 1997

Height Above Surface (cm)	Day		Night	
	Life Form	**Approximate # /m^3 (Mean, n=3)**	**Life Form**	**Approximate #/m^3 (Mean, n=3)**
10	Harpacticoid		Harpacticoid	
	Ostracod		Ostracod	
	Turbellarian		Turbellarian	
	Nematode		Nematode	
	Polychaete		Polychaete	
	Amphipod		Amphipod	
30	Calanoid	24	Calanoid	1071
	Nematode	7	Cladoceran	571
	Harpacticoid	5	Ostracod	29
			Other	25
50	Calanoid	26	Calanoid	893
	Other	5	Cladoceran	1000
			Ostracod	93
			Other	79

Notes: The numbers recorded here are approximations only. The analysis from which they were derived is not suitable for statistical analysis and the data are included here only to show trends.

Table 4.4.3.3 ANOVA Table for Plankton Tows Conducted at Bay Island.

Source	DF	Sum of Squares	Mean Square	F-Value	P-Value
Depth	2	1425396.252	712698.126	4.477	.0142
Time	1	119700.712	119700.712	.752	.3883
Depth x Time	2	235647.292	117823.646	.740	.4801
Subject	84	13372316.479	159194.244		
Samples	14	50352.405	3596.600	.784	.6876
Samples x Depth	28	99230.799	3543.957	.772	.7964
Samples x Time	14	99666.270	7119.019	1.552	.0864
Samples x Depth x Time	28	197630.497	7058.232	1.538	.0366
Samples x Subject	1176	5395333.716	4587.869		

Chapter 5 Feeding Ecology of Seagrass-Associated Fish

5.1 Introduction:

Sampling was undertaken to describe the foraging behaviour and food preferences of seagrass-associated fish species. Although these habitats are believed to be of prime importance to fish as sources of shelter and food, no systematic study of the feeding ecology of fish in Bermudian seagrass beds has ever been undertaken. Whilst Scarids and Acanthurids have been documented to graze on Bermudian seagrasses (McGlathery, 1992), direct herbivory by fish is believed to be limited to a few species. Molluscs and crustaceans are of extreme importance to fish (Collett et al., 1984; Watson et al., 1984) with crustaceans being one of the main sources of food to fishes in seagrass habitats (Klumpp, et al., 1989). These small invertebrates graze on algae and periphyton, converting this primary production into food for higher consumers. The current study employs the classical strategy of examining gut contents to determine what has been eaten, supplemented with observations of actual feeding behaviour.

5.2 Gut Contents

5.2.1 Methods

Specimens were taken by beach seine in the manner used to sample the fish assemblage, as described in Chapter 3. For each of the more abundant species a representative sample of the sizes occurring in the net set were sacrificed. These were transported in seawater to the lab where they were held in a refrigerator pending examination. All specimens were processed within 24 hours of capture. A Meiji 7-45X zooming binocular microscope with a fibre optic light source was used to examine the dissected gut contents. Sterrer (1986) was used as a reference text for the identification of organisms. Observations of the colour and state of the gut (full or empty) and on the sex and state of maturity of the fish were also recorded.

5.2.2 Results

Table 5.2.2 (see end of chapter) summarises the results of the present gut content studies, providing documented prey items identified by previous workers for comparison.

5.2.3 Discussion

Gut content analysis is often an effective method to characterise the feeding behaviour of fish. However, the difficulty in identifying members of the epiphytic complex which coat the surface of seagrasses and contributes greatly to the nutrition of a large number of species may bias results in favour of those prey items with characteristic, indigestible structures. This epiphytic complex includes a diverse assemblage of diatoms, macroalgae, encrusting algae, bacteria, and fungi (Klumpp, et al., 1989), most of which are virtually indistinguishable using traditional gut analysis methodology. Despite these limitations, the results indicate that gut content analysis gives an indication of the reliance of a given fish species on seagrass communities for food.

Unlike the gut contents of transient species such as the piscivorous *Sphyraena barracuda*, *Caranx latus* and *Synodus intermedius*, the gut content of species that are recognised as resident in seagrass meadows (See Chapter 3) generally revealed a dominance of prey items that are common within that habitat. In large measure these reflect those common members of the epiphytic complex and infauna which have distinctive, indigestible skeletons suggesting that these fish depend upon the seagrass community for a major portion of their nutrition.

Whilst the gut contents of several species closely resembled their documented food preferences, there were some notable differences:

In the present study most specimens of *Sphaeroides spengleri* were found to have consumed *Thalassia* and, in one fish, this contributed approximately 75% of the gut content. This individual contrasts with the results of (Randall, 1967) who found that plant material never exceeded 25% and was usually less than 5% of the gut content.

The small specimen of *Calamus calamus* examined in this study revealed algae and foraminifera, suggesting that this fish was feeding on seagrass epiphytes. From examinations of the gut content of larger specimens, Randall (1967) found the species to feed on a range of animals. The lack of overlap in observed prey items between these studies may arise from the size difference in study animals. These observations of *C. calamus* highlight the fact that differences in gut contents observed in the present study and those recorded elsewhere may be a direct function of the use of seagrasses as juvenile habitat. Ontogenetic changes in feeding strategy may compromise comparisons between studies of fish in juvenile habitat and others based on adult specimens.

5.3 Behavioural Observations

5.3.1 Methods:

Feeding behaviour was observed by snorkelling over shallow (1-2m) grass beds. It was found that when an observer minimises all quick movements and essentially drifts over the grass bed, many species allow close approach. Often the fish appear oblivious of the diver and feed in close proximity (within 1m). Notes were made on feeding behaviour, estimated size, and habitat usage by those species that allowed close approach.

5.3.2 Results:

Observations of feeding by seagrass-associated fish species and notes on size-class specific behaviour including where they were found within this habitat, are provided here and further summarised in Table 5.3.1 (see end of chapter).

Haemulon aurolineatum - Small schools (~20 individuals) of approximately 100mm FL were observed feeding on the epifauna of grass blades by means of a sucking action. Smaller individuals (~50mm) were seen to make darting motions in the water column, presumably feeding on plankton.

Haemulon sciurus - a wide size range of this species was observed feeding in the grass bed. Generally solitary, the mode of feeding varied with size. New recruits (~40mm) were observed making darting motions between grass blades, probably in pursuit of plankton. These small fish remained within the structure of the grass bed. Larger juveniles (>55mm) were observed sucking epiphytic growth from grass blades whilst adults foraged in the sediment between grass blades, presumably taking the larger infauna. Although more wary, large adults were often observed emerging from digging in the sediment with grass blades protruding from their mouths. These were subsequently dropped along with discarded sediment.

Haemulon carbonarium - a narrow size range (~70-110mm) of this species was observed feeding on the epiphytic growth on grass blades. This species appears to be more abundant along the perimeter of grass beds and was commonly seen feeding in the sediment adjacent to the bed.

Halichoeres bivittatus - a wide range of sizes of this species was observed feeding. The juveniles (~50mm) are very cryptic and remain within the structure of the grass bed while larger specimens commonly emerge from between grass blades to swim in the water column. Limited observations suggest that all size classes feed selectively on epiphytic organisms living near the base of grass blades. Adults also commonly follow large *Haemulon sciurus*, presumably to scrounge uneaten food uncovered when these larger fish dig in the sediment.

Diplodus bermudensis - small schools (~15 individuals) of young fish (~50mm) were commonly seen browsing the epiphytic growth from grass blades. These fish appeared remarkably efficient at this mode of feeding, leaving the grazed portion of the blade essentially free of fouling. Large specimens (180-250mm) were seen to graze directly on *Thalassia* blades and also to strip epiphytes from *Syringodium* blades.

Sparisoma radians – usually solitary, specimens (80-120mm) were seen grazing directly on grass blades. A fish that often swims above the grass bed, *S. radians* is wary of approaching swimmers and will commonly retreat or lie motionless between the grass blades to avoid detection.

Chaetodon ocellatus – solitary juveniles of this species (~50mm) were observed foraging on the epifauna of grass blades, concentrating their activity at the base of the blades and moving through the bed without emerging from under the canopy of grass blades.

Eucinostomus gula – solitary individuals of this species (60-110mm) were more common at the edge of grass beds where they were observed feeding in the sediment between grass blades as well as in adjacent sand holes.

Sphaeroides spengleri - Observations of this species were limited as only a few specimens were seen moving slowly over the grass beds. One small individual (~60mm) was observed to consume grass blade epiphytes.

Lagodon rhomboides - This species was found to be quite rare in the predominantly *Thalassia* bed of Bay Island where it was not observed feeding. However, at sites that support mixed stands of *T. testudinum* and *Syringodium filiforme* such as Flatts Inlet, small schools (5-20 individuals) were particularly abundant and were observed feeding primarily in the *Syringodium.* Small specimens (~50mm) feed primarily on epiphytes, medium size ones eat the grass whilst large individuals (>100mm) commonly take blades in their mouths and, with a lateral tug, strip off epiphytes.

Acanthurus bahianus and *A. chirurgus* - mixed schools (3-10 individuals) of juveniles (40-60mm) of these species were observed associated with *D. bermudensis* grazing on the epiphytes on the grass blades. Close examination of blades upon which they had been grazing revealed that they had not eaten the seagrass. Adult *A. bahianus* were observed to graze directly on *Syringodium filiforme.*

Calamus calamus – solitary juveniles (~50mm) were observed moving between the grass blades occasionally taking a bite of the epifauna near the base of the blades.

5.3.3 Discussion:

Comparisons of feeding strategies predicted from the gut contents examinations reported in section 5.1 and those observed in the field yield reasonable agreement. The fish observed feeding within seagrass beds either grazed directly on the blades or consumed the epiphytic community. The only exceptions to this were very young members of the *Haemulon* species which appeared to be planktivorous. Although only juveniles of *H. flavolineatum* and *H. aurolineatum* were observed, it is believed that, similar to the larger *H. sciurus* individuals observed in the grass bed, with age, these fish would graduate from planktivory to grazing on the epiphytic complex.

The common tendency of many fish species to display different feeding strategies at different stages in their life is reinforced by the results of this work. This was most noticeable amongst the most common grunts, *Haemulon sciurus* and *H. aurolineatum*, Pinfish, *Lagodon rhomboides* and the Bermuda Bream, *Diplodus bermudensis*. Stoner (1980) noted that *L. rhomboides*, exhibited planktivory, omnivory, strict carnivory and strict herbivory at different times, places and developmental stages. Similar observations of another sparid, *Diplodus holbrooki*, combined with common differences in external morphology relating to locomotion, mouth dimensions and ontogeny of dentition for both species, led Stoner and Livingston (1984) to assert that "ontogenetic trophic units" rather than taxonomic species are the most useful functional units to use in ecological studies of fish.

Flexibility in feeding strategy within a size class was also observed during the current study. A school of *Diplodus bermudensis* was observed to forage as they moved from a *Thalassia*-dominated bed to a stand of *Syringodium*. In the former they used their terminal, cutting, teeth to graze directly on the tips of the broad *Thalassia* leaves. While in the *Syringodium* they grasped the narrow blades in the middle so that grass projected from both sides of their mouths and, using the side of their mouths, made a lateral pull of their heads to scrape the epiphytic growth off.

McGlathery (1992) reported that the main fish grazers of seagrass in Bermuda's inshore waters are *Sparisoma radians* and *Acanthurus bahianus* and *A. chirurgus*. In the current study *S. radians* was observed to graze almost exclusively on *Thalassia*, juvenile Acanthurids were observed to feed on epiphytes whilst adults were observed feeding directly *Syringodium* blades. However, as adult Acanthurids were rarely encountered, this study failed to confirm their importance as grazers of seagrasses.

During this study the use of diver observation to characterise the feeding behaviour of fish in shallow seagrass beds proved very effective. With minimal effort virtually all the common seagrass residents were observed in the act of feeding, allowing the identification of feeding locations and strategies as well as species interactions and ontogenetic shifts in habitat utilisation.

Table 5.2.2: Summarised Results of Observed and Documented Gut Contents Identifying Major Food Items.

Fish Species	n	Observed Gut Content	Documented Gut Content*
H. aurolineatum	12	Crustaceans, bivalves, gastropods, sand, fish, algal detritus	Shrimp, polychaetes, crustaceans, eggs, hermit crabs, crabs
Haemulon sciurus	8	Polychaetes, crustaceans, ostracods, harpacticoids, amphipods, shrimp.	Crabs, bivalves, shrimp, urchins, ophiuroids, polychaetes, gastropods
H. flavolineatum	0	————	Polychaetes, crabs, sipunculids, chitons, holothurians, isopods, shrimp
Halichoeres bivitattus	6	Bivalves, crustaceans, foraminifera, ostracods	Crabs, urchins, polychaetes, gastropods, ophiuroids, bivalves, shrimp
Diplodus bermudensis	9	Algae, crustaceans, shrimp, fish, gastropods	————
Sparisoma radians	11	*Thalassia*	*Thalassia*, algae
Chaetodon ocellatus	0	————	Polychaetes, crustaceans and zoantharians
Eucinostomus gula	4	Crustaceans, detritus, bivalves, foramanifera, gastropods	————
Spheroides spengleri	6	*Thalassia*, crustaceans, gastropods, bivalves, foramanifera, annelids	Crabs, bivalves, gastropods, polychaetes, urchins, ophiuroids, amphipods, shrimp
Lagodon rhomboides	4	Crustaceans, fish, bivalves, algae, gastropods	————
Acanthurus sp.	0	————	Algae and organic detritus
Calamus calamus	1	Algae, foramanifera	Polychaetes, ophiuroids, bivalves, crustaceans, gastropods
Lachnolaimus maximus	1	Gastropods, bivalves, urchins, hermit crabs	Bivalves, gastropods, crabs, hermit crabs, urchins, amphipods

Table 5.2.2 (Continued): Summarised Results of Observed and Documented Gut Contents Identifying Major Food Items.

Monacanthus tuckeri	8	Amphipods, forams, ostracods, polychaetes, harpacticods, algae.	Unidentified organic matter, copepods, gastropod larvae, crustaceans
Sphyraena barracuda	1	Fish (*Halichoeres bivittatus, Haemulon* sp.)	Fishes, octopus, lobster larvae
Synodus intermedius	6	Fish (*Jenkinsia lamprotaenia*)	Fishes, squid
Caranx latus	1	Fish (*Jenkinsia lamprotaenia*)	Fish (atherinids), pteropods, shrimp, isopods

* Documented gut contents compiled from Randall (1967) and Sterrer (1986) and provided here for comparison. See also Appendix 5.2.

Table 5.3.1: Summary of Visual Observations of the Feeding Behaviour and Habitat Utilisation of Seagrass-Associated Fish.

Species	School size	Length (mm)	Feeding Location	Comments
Haemulon aurolineatum	~20	~100	Grass blades	Sucks epiphytes from grass blades
H. aurolineatum	80-100	~50	Water column	Darting motion – possible planktivore
H. sciurus	solitary	100-300	Sediment	Digs in the sediment between the grass blades
H. sciurus	solitary	60-100	Grass blades	Sucks epiphytes from grass blades
H. sciurus	solitary	40-50	Between blades	Darting motion – possible planktivore
H. carbonarium	Generally solitary	70-110	Grass blades	Sucks epiphytes from grass blades
H. flavolineatum	5-10	~60	Between blades	Darting motion – possible planktivore
Halichoeres bivittatus	Generally solitary	50-150	Between blades	Feeds selectively on epiphytes from the base of grass blades
Diplodus bermudensis	~20	180-250	Grass blades	Direct grazer on *Thalassia*, also takes epiphytes from *Syringodium*
D. bermudensis	~15	~50	Grass blades	Sucks epiphytes from grass blades

Table 5.3.1(Continued): Summary of Visual Observations of the Feeding Behaviour and Habitat Utilisation of Seagrass-Associated Fish.

Species	School size	Length (mm)	Feeding Location	Comments
Sparisoma radians	Generally solitary	80-120	Grass blades	Direct grazer on grass blades
Chaetodon ocellatus	solitary	~40-50	Between blades	Feeds selectively on epiphytes from the base of grass blades
Eucinostomus gula	solitary	60-110	Grass blades and sediment	Feeds on epiphytes on grass blades and in sediment
Sphaeroides spengleri	solitary	60-90	Grass blades	Feeds on epiphytes growing on grass blades
Lagodon rhomboides	Generally solitary	180-200	Grass blades	Feeds on epiphytes growing on *Syringodium* blades
L. rhomboides	~5-20	90-100	Grass blades	Grazes directly on *Syringodium* blades
L. rhomboides	~5-20	~50	Grass blades	Sucks epiphytes from grass blades
Acanthurus bahianus and A. chirurgus	~3-10	40-60	Grass blades	Feeds on epiphytes growing on grass blades
A. bahianus	~3-5	~200	Grass blades	Direct grazer of blades of *Syringodium*
Calamus calamus	solitary	~50	Between blades	Feeds selectively on epiphytes from the base of grass blades

Chapter 6: Conclusions and Recommendations

6.1 Habitat Distribution:

6.1.1 Conclusions:

- Through analysis of aerial photographs, it is estimated that Bermuda's nearshore seagrass beds covered approximately 500 Ha in 1981.
- Comparing the photographic records from 1962 through 1997, it is evident that there have been substantial changes in the extent of seagrass meadows around Bermuda. Unfortunately, lacking a complete high-resolution photographic record with supportive field confirmation, it is impossible to assess accurately these changes. However, it is clear that losses in some areas have been largely compensated for by expansion in others. The ecological implications of these changes are unknown.
- Since 1981 substantive reductions in local seagrass meadows have occurred near the shoreline at Tudor Hill, St. Catherine's Point, and Nonsuch Island. All of these sites are adjacent to the open ocean and experience relatively high water exchange. During this same period, in the more restricted waters along the North Shore, there has been a dramatic increase in nearshore seagrasses. Given these observations it is considered highly unlikely that these changes are directly related to anthropogenic inputs.
- Potentially fruitful areas of investigation into the causes of these changes include the effects of increasing oceanic surface temperatures, surveys to identify existing pathogens of local seagrasses, and the impact of storm-driven waves.
- Many of the prime areas for inshore seagrass development are heavily utilised for recreational boat moorings. In many cases these moorings have eroded existing seagrass beds, undoubtedly destabilising and reducing the value of the habitat as shelter.

6.1.2 Recommendations:

- As shoreline development poses an ongoing threat to coastal seagrass beds their presence should be a criterion when considering projects that might cause direct destruction of seagrasses, increased turbidity or nutrient enrichment.

- The area of seagrass coverage as interpreted from the 1997 photographic survey should be confirmed by field studies for use as a baseline against which future surveys can be compared. As the Ministry of Works and Engineering is planning to repeat their aerial survey every 5 years, the images produced should be studied in order to monitor trends in Bermuda's coastal seagrasses.
- Where declining seagrass meadows are detected they should be studied in order to attempt to determine the cause. Where clearly receding margins are observed these should be the focus for studies.
- There should be a moratorium on the establishment of moorings in seagrass beds and investigations to determine whether a reliable alternate and non-damaging mooring design can be developed for use in these habitats.

6.2 Seagrass-Associated Fish Assemblages:

6.2.1 Conclusions:

- Fishing with bait nets over coastal seagrasses regularly results in the capture of those juvenile fish that spend their early life within this habitat.
- Repeated sampling of seagrass-associated fish assemblages may reveal both recruitment patterns and the early growth rates of the more abundant species.
- Fish species that are rare or absent from one seagrass bed may regularly occur in seagrass beds at another location.
- As seagrass-associated fish communities vary both with season and location, extrapolations from spatially and temporally limited sampling may prove invalid.
- Bermuda's coastal seagrass meadows form important nurseries for many fish species.
- As the killing of non-target juvenile fish is virtually inevitable when bait nets are used in these areas, protection of seagrasses from this gear may prove to be an effective fisheries management strategy.

6.2.2 Recommendations:

- A survey of the use of baitnets over seagrass beds and an assessment of the resulting bycatch should be conducted in order to determine the effect of this activity.

- If the banning of bait-netting in seagrass-dominated areas is to be considered as a fishery management measure, more extensive surveys of the fish inhabiting coastal seagrasses are required to identify areas that form particularly important nurseries for commercial species.

6.3 Seagrass-Associated Invertebrate Communities:

6.3.1 Conclusions:

- Bermuda's seagrasses support a large and diverse microfaunal community that apparently feeds on the abundant periphyton and detritus found upon, and between, the blades of the seagrass.
- The microfauna dwelling upon and between the grass blades was found to be far more abundant and diverse than either the infauna or the planktonic organisms overlying the grass beds.
- The use of a fine-mesh plankton net sampling at controlled heights above the substratum is effective in assessing the vertical distribution of the microfauna associated with seagrasses. When a plankton net is drawn close to the seafloor so that it brushes against seagrass blades, it will sample both the plankton and epifauna.

6.3.2 Recommendations:

- As the methods employed in this study failed to discriminate between the epibiota living upon the seagrass and those planktonic organisms that live between the blades it is not possible to assess the relative values of these components of the seagrass community as food for fish. It is recommended that a suction sampling device be developed to specifically sample the planktonic component of this assemblage to clarify this issue.
- Bermuda's seagrass-associated microfauna has received limited research attention, and remains poorly documented. Further research is recommended to clarify the role of this community.

6.4 Feeding Ecology of Seagrass-Associated Fish:

6.4.1 Conclusions:

- The majority of fish inhabiting coastal seagrass beds feed primarily on the epiphytic community coating the grass blades.
- Direct herbivory on seagrasses is largely restricted to the scarids although the examination of gut contents from the Band-Tailed Puffer, *Sphaeroides spengleri*, and observations of the feeding behaviour of larger Breams, *Diplodus bermudensis*, and Ocean Surgeonfish, *Acanthurus bahianus*, indicate that these species also eat grass blades.
- Ontogenetic changes in feeding strategies were observed in several fish species.
- For the abundant seagrass-associated fish species, the analysis of gut contents revealed a feeding strategy that corresponded well with that determined by direct observations of feeding behaviour.
- Juveniles of most of the species observed were seen foraging upon and between the grass blades, a strategy that takes advantage of both the abundant food and protection from predation that this productive three-dimensional environment provides.

6.4.2 Recommendations:

- In areas where water clarity is sufficiently high for effective direct observations, it is recommended that divers be used to assess the feeding strategies and patterns of habitat utilisation exhibited by seagrass-associated fish.

6.5 Summary Conclusions:

- In recent decades there have been major changes in the extent of local coastal seagrass beds. Although the causes are unknown, it is clear that these changes may have substantial ecological implications. Bermuda's inshore seagrasses have been widely impacted by the establishment of moorings within seagrass beds and the resultant destruction of the seagrasses in the immediate area.

- The fish communities inhabiting local inshore seagrass beds vary significantly between sites and seasons. Extrapolations based on limited spatial and temporal data may prove misleading.

- This study has demonstrated that Bermuda's inshore seagrass beds support a wide diversity of micro-invertebrates. These organisms form the primary food source for many fish species that use this habitat as nurseries. While the link between the productivity of the seagrass community and fish abundance is intuitively obvious, the associated trophic dynamics are poorly understood.

- Recognising that seagrass beds are highly productive centres of marine biodiversity and that Bermuda's seagrass meadows are quite restricted in extent, all reasonable local efforts to minimise anthropogenic impacts should be pursued.

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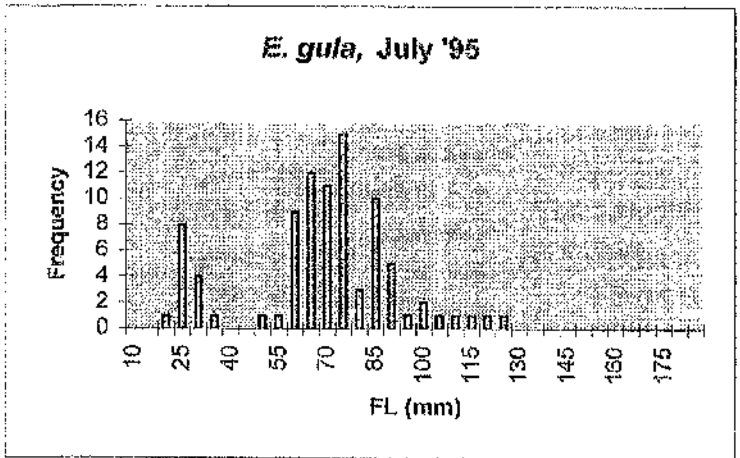
Appendix 3.1 Summary of Fish Observations by Species: Including the Number of Specimens Recorded and the Incidence of Occurrence of the Species in the Catch.

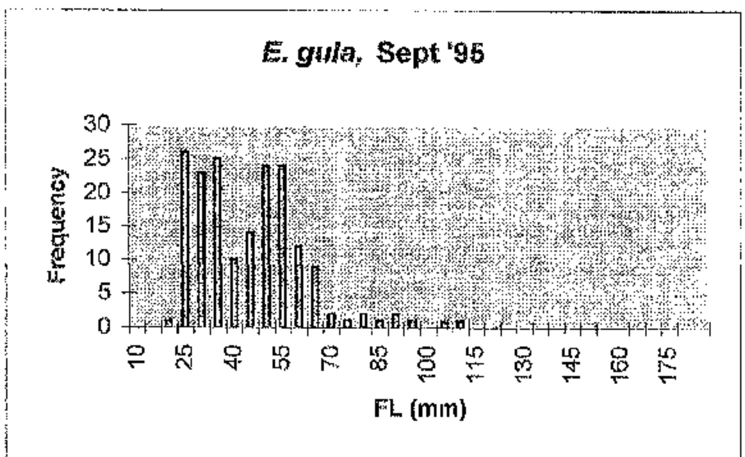
Species	Number of Specimens	Incidence of Occurrence
Synodus intermedius	68	25
Adioryx vexillarius	3	1
Holocentrus rufus	13	8
Syngnathus dunckeri	6	3
Syngnathus sp.	1	1
Hippocanthus reidi	2	2
Caranx latus	7	5
Lutjanus griseus	6	4
L. synagris	1	1
Ocyurus crysurus	16	7
Eucinostomus gula	1194	60
E. havana	1653	55
E. lefroyi	33	8
Haemulon aurolineatum	884	42
H. sciurus	2280	57
H. flavolineatum	322	21
H. carbonarium	9	2
Orthopristes crysopterum	4	3
Diplodus bermudensis	>10,000	58
Calamus calamus	25	9
Lagodon rhomboides	139	40
Pseudupeneus maculatus	178	18
Chaetodon capistratus	13	9
C. ocellatus	1	1
Halichoeres bivittatus	3470	63
Lachnolaimus maximus	1	1
Scarus croicensis	12	5
Sparisoma chrysopterum	5	2
S. radians	462	33
S. rubripinne	3	1
Mugil liza	10	3
Sphyraena barracuda	20	3
Acanthurus chirurgus	2	2
A. bahianus	2	1
Monacanthus tuckeri	430	28
M. ciliatus	6	5
Schedophilus ovalis	1	1
Sphaeroides spengleri	127	44

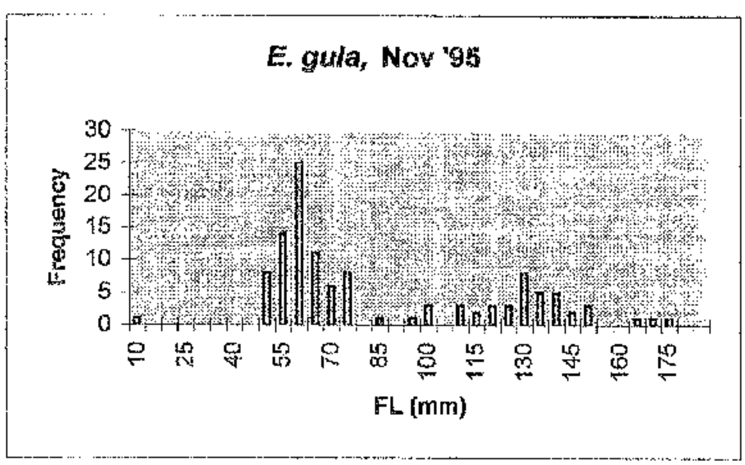
Appendix 3.2
Length Frequency Analysis
Eucinostomus gula

Length (mm)	Jul '95	Sep '95	Nov '95	Feb '96	Mar/Apr '96	Jul '96	Sep '96	Composite
10	0	0	1	0	0	0	0	1
15	0	0	0	0	0	0	0	0
20	1	1	0	0	0	0	0	2
25	8	26	0	0	0	0	0	34
30	4	23	0	0	0	0	0	27
35	1	25	0	0	0	0	0	26
40	0	10	0	0	0	0	0	10
45	0	14	0	0	1	0	0	15
50	1	24	8	1	1	0	0	40
55	1	24	14	16	7	0	0	65
60	9	12	25	13	26	0	1	92
65	12	9	11	16	23	1	0	75
70	11	2	6	24	11	1	2	60
75	15	1	8	8	8	4	3	52
80	3	2	0	3	5	7	7	29
85	10	1	1	2	2	10	2	30
90	5	2	0	1	1	13	3	26
95	1	1	1	0	1	4	2	10
100	2	0	3	7	0	3	3	20
105	1	1	0	4	0	0	1	9
110	1	1	3	3	0	0	2	10
115	1	0	2	0	0	0	0	3
120	1	0	3	2	1	0	0	7
125	1	0	3	0	1	1	0	7
130	0	0	8	2	0	0	0	13
135	0	0	5	0	0	0	0	5
140	0	0	5	0	0	0	0	5
145	0	0	2	0	0	0	0	2
150	0	0	3	0	0	0	1	4
155	0	0	0	0	0	0	0	0
160	0	0	0	0	0	0	0	0
165	0	0	1	0	0	0	0	1
170	0	0	1	0	0	0	0	1
175	0	0	1	0	0	0	0	1
180	0	0	0	0	0	0	0	0
More	0	0	0	0	0	0	0	0

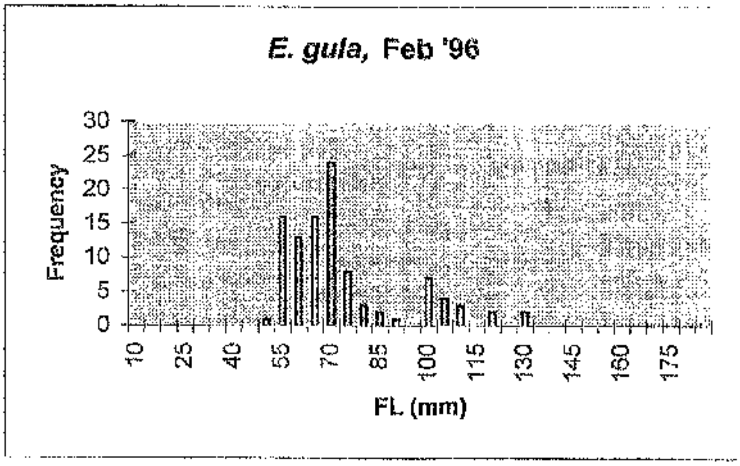
Appendix 3.2 (Continued)
Length Frequency Analysis
Eucinostomus gula

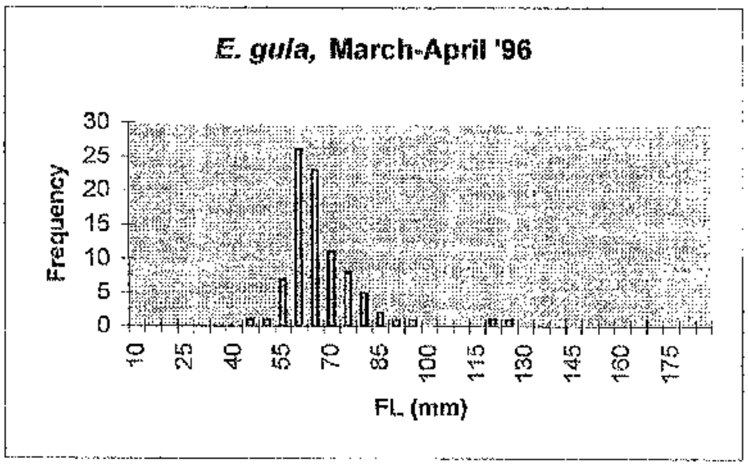


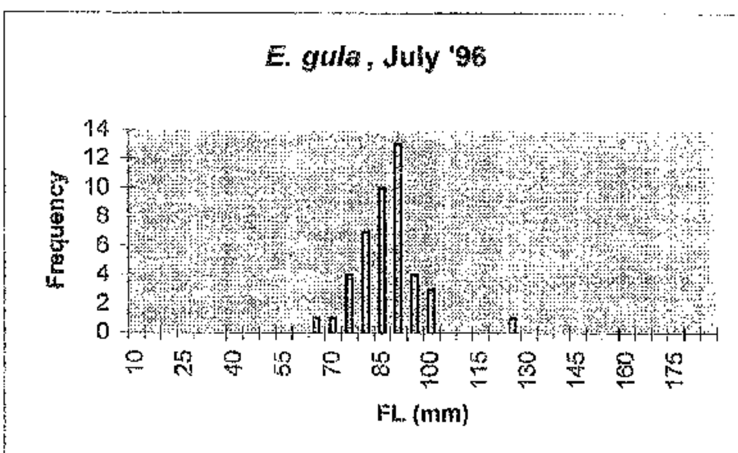




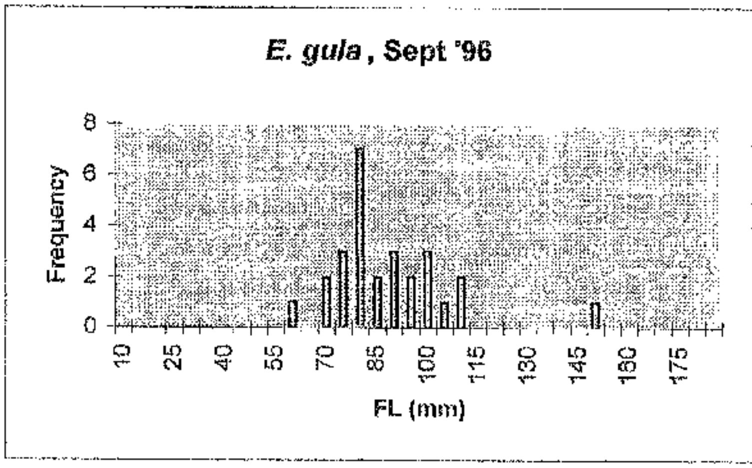
Appendix 3.2 (Continued)
Length Frequency Analysis
Eucinostomus gula

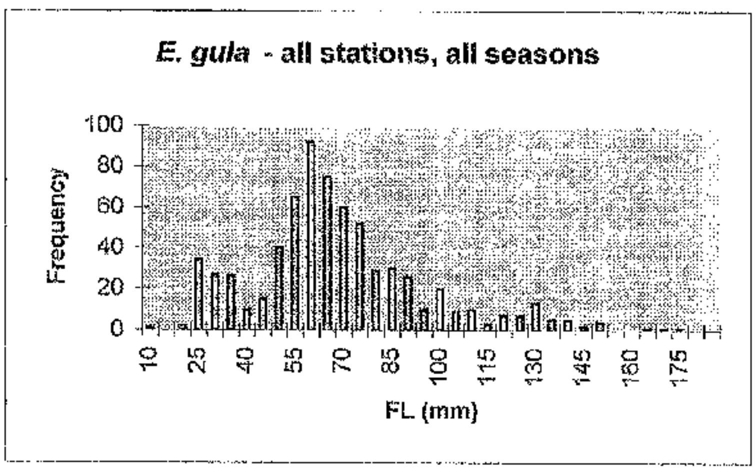






Appendix 3.2 (Continued)
Length Frequency Analysis
Eucinostomus gula





Appendix 3.3
Length Frequency Analysis
Haemulon sciurus

Length (mm)	Apr/May '95	Jul '95	Sep '95	Oct '95	Nov '95	Feb '96	Apr '96	Jul '96	Sept '96	Feb '97	Jun/Jul '97	Composite
10	0	0	0	0	0	1	0	0	0	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	29	0	0	0	29
25	0	0	2	0	0	0	0	53	0	0	18	73
30	0	0	12	3	0	0	0	21	3	0	10	49
35	0	0	13	12	0	0	0	3	11	0	0	45
40	0	0	29	10	0	0	0	6	26	0	0	60
45	0	0	23	20	1	0	0	2	33	0	0	80
50	0	0	33	27	3	6	0	0	38	0	0	111
55	2	0	21	28	8	32	3	1	10	0	0	107
60	5	2	11	15	23	35	14	0	2	0	0	108
65	10	0	9	13	21	20	16	1	1	0	2	93
70	8	3	0	6	35	9	22	2	0	1	0	86
75	9	3	1	4	11	0	19	2	0	4	1	54
80	6	4	0	1	3	0	19	3	1	9	1	47
85	2	12	0	2	0	0	2	2	1	9	0	30
90	1	5	4	3	0	0	1	12	0	3	0	29
95	2	5	4	1	0	0	1	7	0	1	0	21
100	0	3	3	7	3	0	0	1	1	0	0	18
105	2	2	6	8	0	0	0	2	1	1	0	22
110	4	4	5	6	1	0	1	1	3	0	0	28
115	4	0	1	2	2	0	1	2	4	3	0	20
120	6	4	2	2	2	0	2	1	1	3	0	25
125	2	13	0	1	2	0	0	3	1	1	0	24
130	4	7	1	1	1	0	0	3	2	3	1	24
135	2	7	1	2	1	0	0	3	0	3	1	20
140	1	6	0	2	0	0	0	3	3	1	0	16
145	0	6	2	0	1	0	0	4	0	0	0	13

Appendix 3.3 (Continued)
Length Frequency Analysis
Haemulon sciurus

Length (mm)	Apr/May '95	Jul '95	Sep '95	Oct '95	Nov '95	Feb '96	Apr '96	Jul '96	Sept '96	Feb '97	Jun/Jul '97	Composite
150	0	4	0	0	0	0	0	7	1	0	0	12
155	1	0	0	0	0	0	0	1	1	0	0	3
160	0	1	0	2	0	0	0	6	0	0	1	10
165	0	2	1	0	1	0	0	2	1	0	0	9
170	0	2	0	1	1	0	0	2	1	0	0	7
175	0	2	0	0	0	0	0	2	1	0	0	5
180	0	3	0	0	0	0	0	1	0	0	0	5
185	0	1	1	1	0	0	0	5	0	0	0	8
190	1	0	0	0	0	0	0	3	0	0	1	5
195	0	0	1	1	0	0	0	2	0	0	2	6
200	0	2	0	0	0	0	0	6	1	0	0	9
205	0	1	0	0	0	0	0	0	0	0	1	2
210	0	2	0	0	0	0	0	2	0	0	0	4
215	0	0	0	0	0	0	0	4	0	0	0	4
220	0	0	0	0	0	0	0	2	0	0	1	3
225	0	0	0	0	0	0	0	1	0	0	0	1
230	0	0	0	0	0	0	0	0	1	0	0	1
235	0	0	0	0	0	0	0	0	0	0	0	0
240	0	0	0	0	0	0	0	1	0	0	0	2
245	0	0	0	0	0	0	0	0	0	0	0	0
250	0	1	0	0	0	0	0	0	0	0	0	1
255	0	0	0	0	0	0	0	0	0	0	0	0
260	0	0	0	0	0	0	0	0	0	0	0	0
265	0	0	1	0	0	0	0	0	0	0	0	1
270	0	0	0	0	0	0	0	0	0	0	0	0
275	1	0	0	0	1	0	0	0	0	0	0	2
280	0	0	1	0	1	0	0	0	0	0	1	4
285	0	0	0	0	0	0	0	1	0	0	0	1

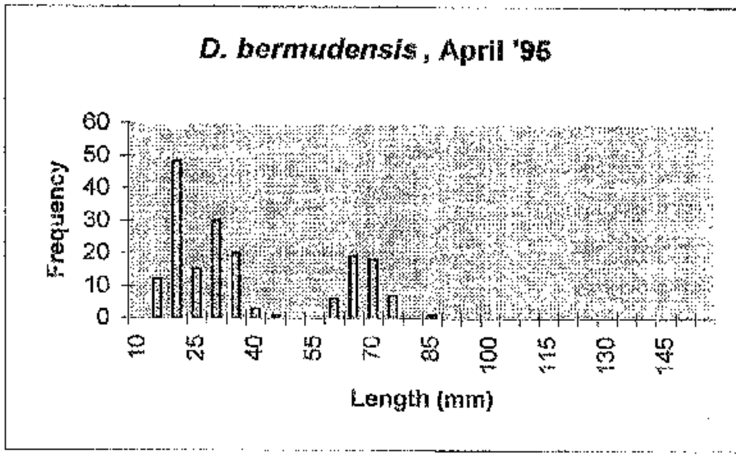
Appendix 3.3 (Continued)
Length Frequency Analysis
Haemulon sciurus

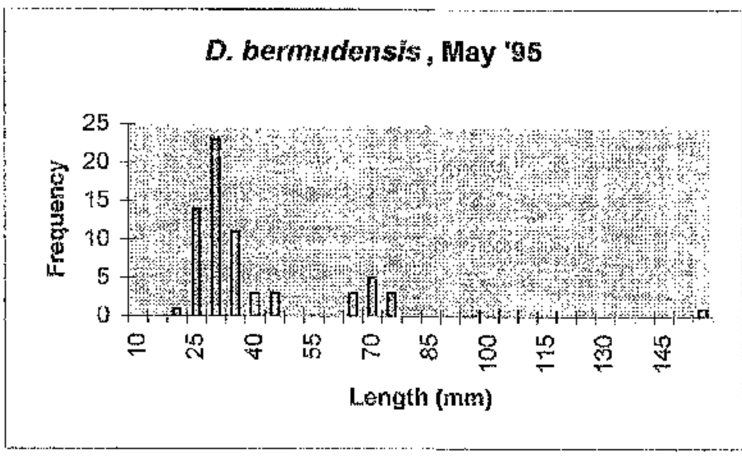
Length (mm)	Apr/May '95	Jul '95	Sep '95	Oct '95	Nov '95	Feb '96	Apr '96	Jul '96	Sept '96	Feb '97	Jun/Jul '97	Composite
290	0	0	0	0	0	0	0	1	0	0	0	1
295	0	1	0	0	0	0	0	0	0	0	2	3
300	0	0	0	0	0	0	0	0	1	0	0	1
305	0	1	0	0	0	0	0	0	0	0	0	1
310	0	0	0	1	0	0	0	1	0	0	0	2
315	0	0	0	0	0	0	0	1	0	0	0	1
320	0	0	0	0	1	0	0	0	0	0	0	1
325	0	0	0	0	0	0	0	0	0	0	1	1

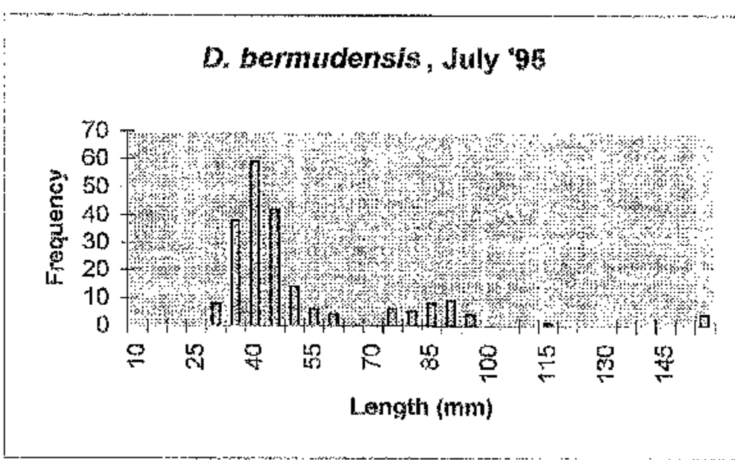
Appendix 3.4
Length Frequency Analysis
Diplodus bermudensis

Length (mm)	April '95	May '95	July '95	Sept '95	Oct '95	Nov/Dec '95	Feb '96	Mar '96	Apr '96	July '96	Composite
10	0	0	0	0	0	0	2	1	0	0	9
15	12	0	0	0	0	0	0	3	0	0	17
20	48	1	0	0	0	0	0	10	1	0	74
25	15	14	0	0	0	0	0	13	45	0	100
30	30	23	8	1	0	0	0	41	41	1	152
35	20	11	38	4	0	0	0	28	20	7	154
40	3	3	59	20	5	0	0	2	18	22	190
45	1	3	42	26	2	8	0	0	8	52	161
50	0	0	14	26	3	12	9	0	0	95	209
55	0	0	6	14	6	35	30	3	0	39	190
60	6	0	4	2	2	33	43	20	0	9	205
65	19	3	0	0	2	13	17	6	0	0	171
70	18	5	0	1	0	5	9	3	0	0	109
75	7	3	6	0	1	1	3	0	0	0	59
80	0	0	5	1	1	1	1	0	0	0	28
85	1	0	8	0	0	2	2	0	0	1	27
90	0	0	9	0	1	0	2	0	0	0	26
95	0	0	4	0	0	0	0	0	0	2	10
100	0	0	0	1	0	0	0	0	0	0	4
105	0	0	0	0	0	0	0	0	0	0	2
110	0	0	0	0	0	2	0	0	0	0	6
115	0	0	1	0	0	0	0	0	0	0	1
120	0	0	0	0	1	0	0	0	0	0	3
125	0	0	0	0	0	1	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	0	1
135	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	1	0	0	0	0	2
145	0	0	0	0	0	1	0	0	0	0	1
150	0	0	0	0	0	0	0	0	0	0	0
> 150mm	0	1	4	0	0	0	0	0	6	1	14

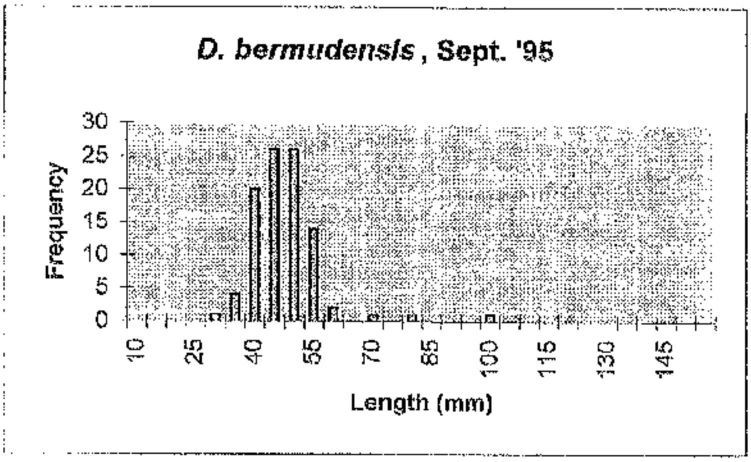
Appendix 3.4 (Continued)
Length Frequency Analysis
Diplodus bermudensis

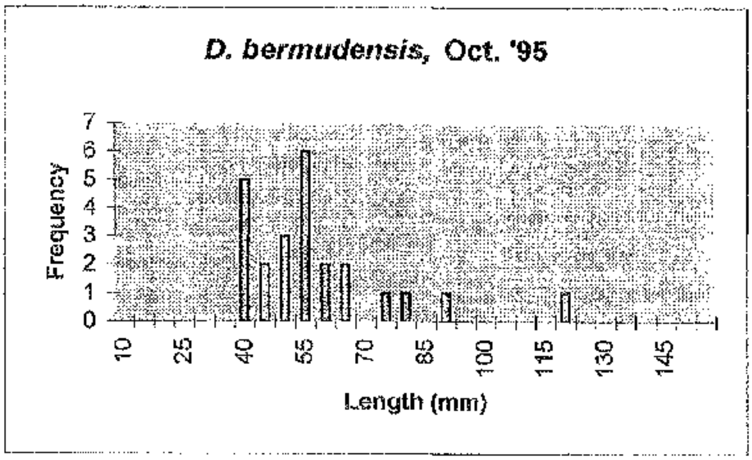


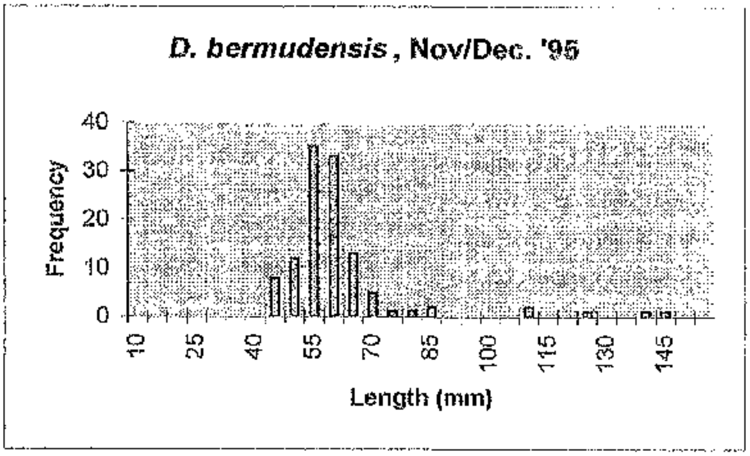




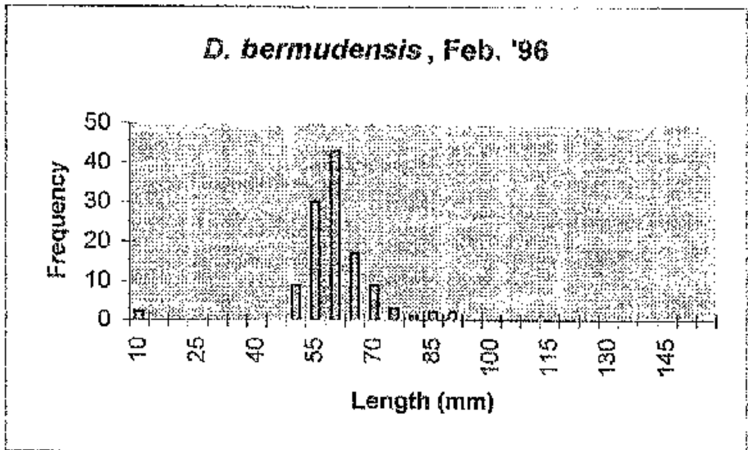
Appendix 3.4 (Continued)
Length Frequency Analysis
Diplodus bermudensis

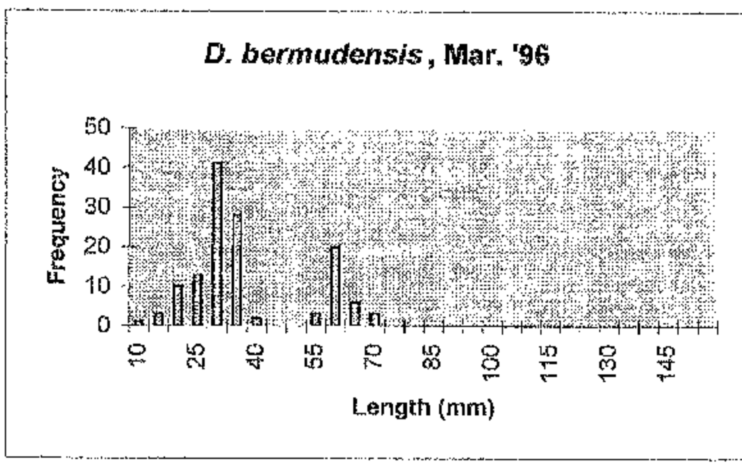


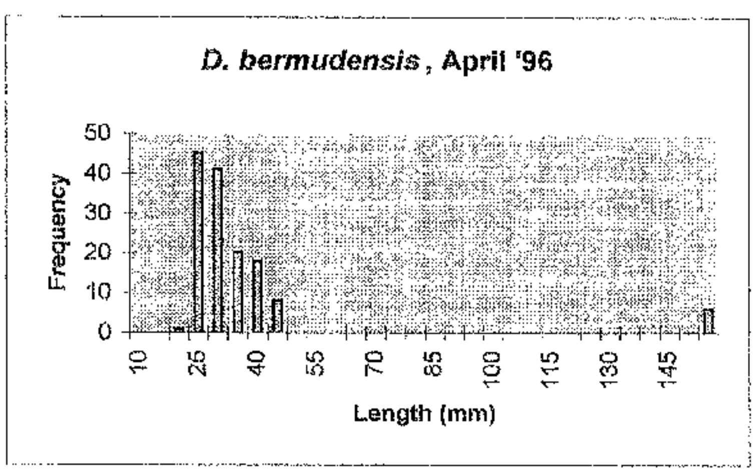




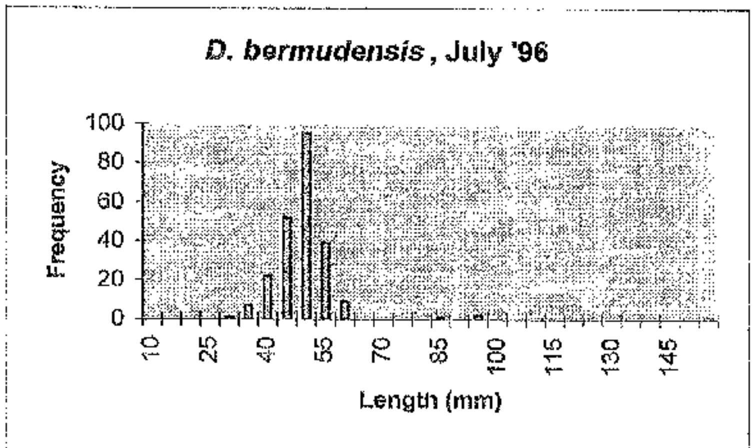
Appendix 3.4 (Continued)
Length Frequency Analysis
Diplodus bermudensis

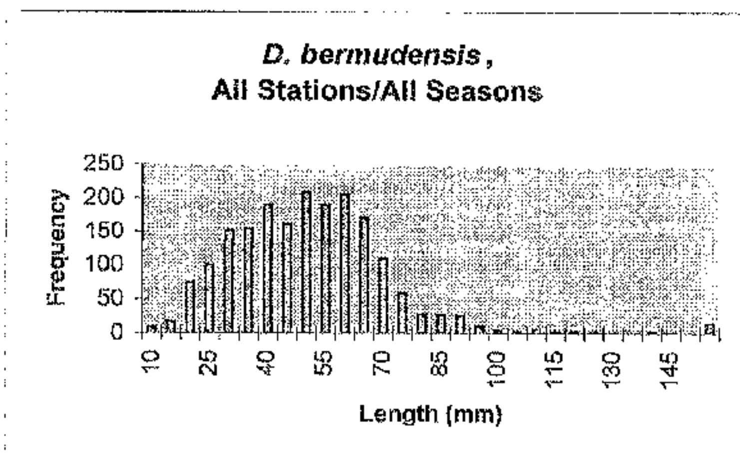






Appendix 3.4 (Continued)
Length Frequency Analysis
Diplodus bermudensis





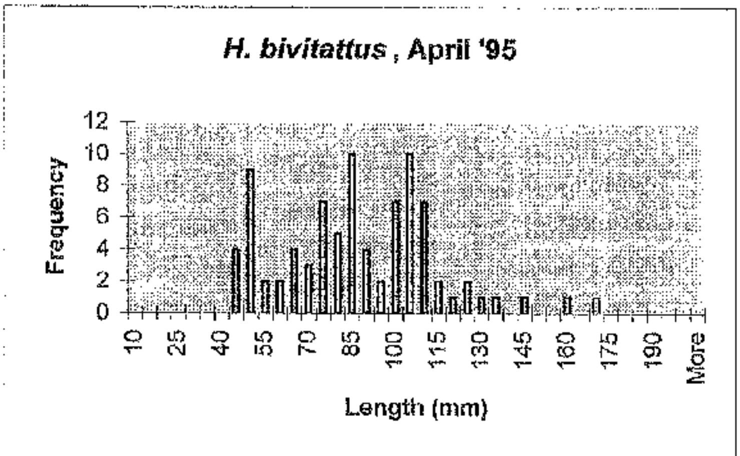
Appendix 3.5
Length Frequency Analysis
Halichoeres bivitattus

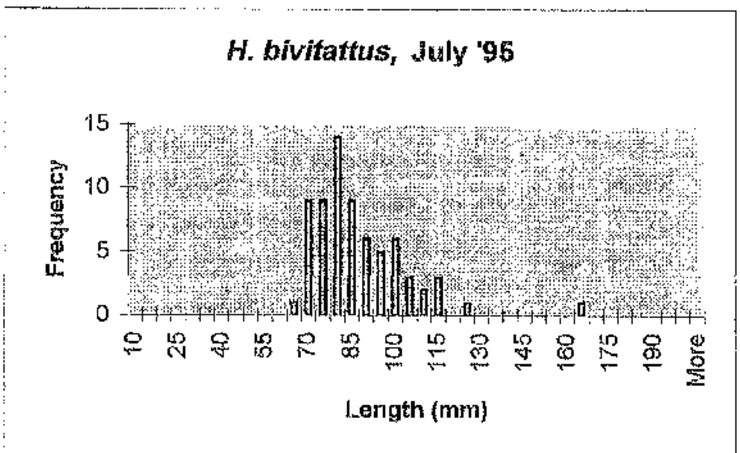
Length (mm)	Apr '95	Jul '95	Sep '95	Oct '95	Nov '95	Mar '96	Apr '96	Jul '96	Sep '96	Jan '97	Feb '97	May '97	Composite
10	0	0	1	1	2	1	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0	0	0	0	1
25	0	0	1	0	0	0	0	3	0	0	0	0	4
30	0	0	7	0	0	0	0	2	0	0	0	0	9
35	0	0	2	0	0	1	0	0	0	1	0	0	4
40	0	0	9	9	5	4	2	0	6	1	3	0	40
45	4	0	10	43	27	2	3	0	6	10	8	0	113
50	9	0	29	32	34	10	6	1	8	8	13	5	157
55	2	0	30	28	46	23	14	0	21	15	30	4	220
60	2	0	24	23	28	33	25	0	21	8	22	10	204
65	4	1	2	30	21	30	34	5	9	10	10	11	172
70	3	9	1	9	15	15	30	24	3	3	6	17	141
75	7	9	1	4	13	12	16	47	1	8	4	13	142
80	5	14	6	0	10	30	17	40	7	11	2	13	160
85	10	9	15	1	2	9	14	41	12	1	0	8	126
90	4	6	7	4	0	7	6	24	12	5	0	4	81
95	2	5	7	5	1	2	4	12	7	5	1	2	53
100	7	6	6	1	3	2	2	13	5	5	0	4	55
105	10	3	8	2	2	3	1	9	4	6	0	2	53
110	7	2	4	2	1	1	1	7	3	0	0	4	33
115	2	3	3	1	1	1	3	0	2	3	0	2	21
120	1	0	1	0	0	0	2	6	3	2	0	0	15
125	2	1	2	0	1	2	1	0	1	2	0	1	13
130	1	0	0	0	0	0	1	4	1	2	0	0	9
135	1	0	3	0	0	2	0	1	2	1	0	0	10
140	0	0	2	0	0	0	0	6	0	1	0	0	9
145	1	0	1	0	0	0	0	1	0	0	0	2	5
150	0	0	1	0	0	0	1	2	1	0	0	1	6

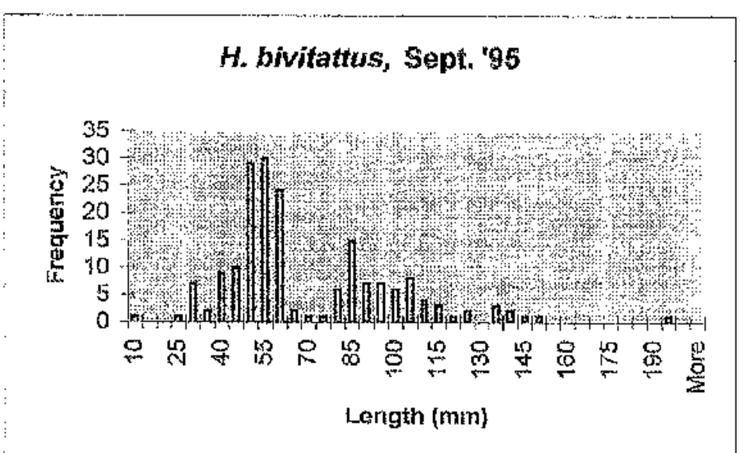
Appendix 3.5 (Continued)
Length Frequency Analysis
Halichoeres bivitattus

Length (mm)	Apr '95	Jul '95	Sep '95	Oct '95	Nov '95	Mar '96	Apr '96	Jul '96	Sep '96	Jan '97	Feb '97	May '97	Composite
155	0	0	0	0	0	0	0	1	0	0	0	0	1
160	1	0	0	1	0	0	0	1	0	1	0	0	4
165	0	1	0	0	0	0	0	0	0	0	0	0	1
170	1	0	0	0	0	0	1	0	0	0	0	0	2
175	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	1	1	0	0	0	0	2
185	0	0	0	0	0	0	0	0	0	0	0	0	0
190	0	0	0	0	0	0	0	0	0	0	0	1	1
195	0	0	1	0	0	0	0	0	0	0	0	0	1
200	0	0	0	0	0	0	0	1	0	0	0	0	1
More	0	0	0	0	0	0	0	0	0	0	0	0	0

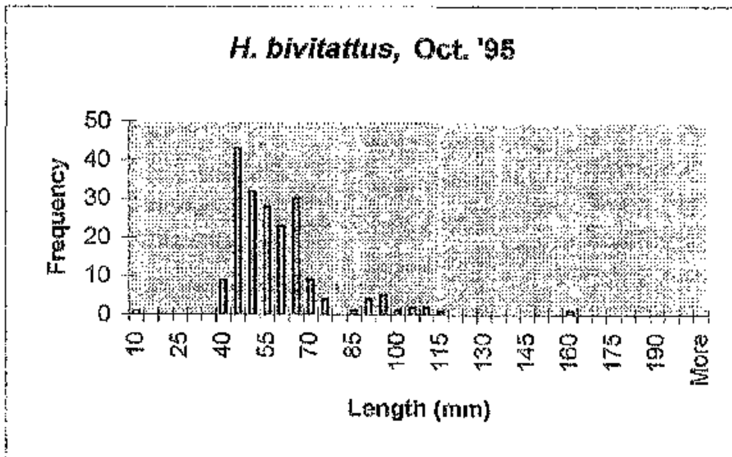
Appendix 3.5 (Continued)
Size Frequency Analysis
Halichoeres bivitattus

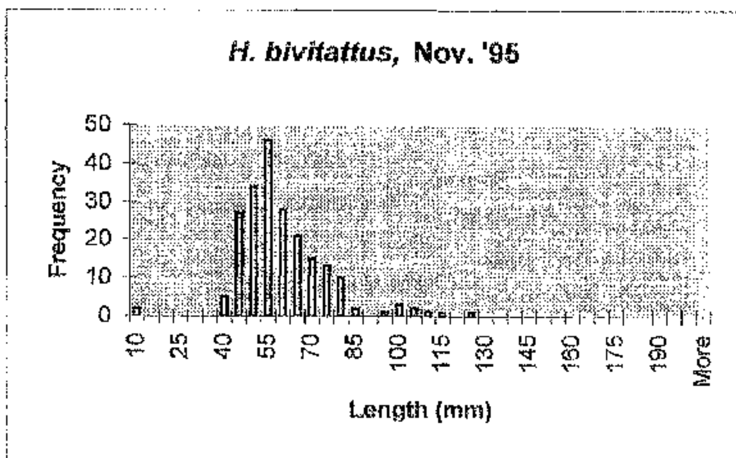


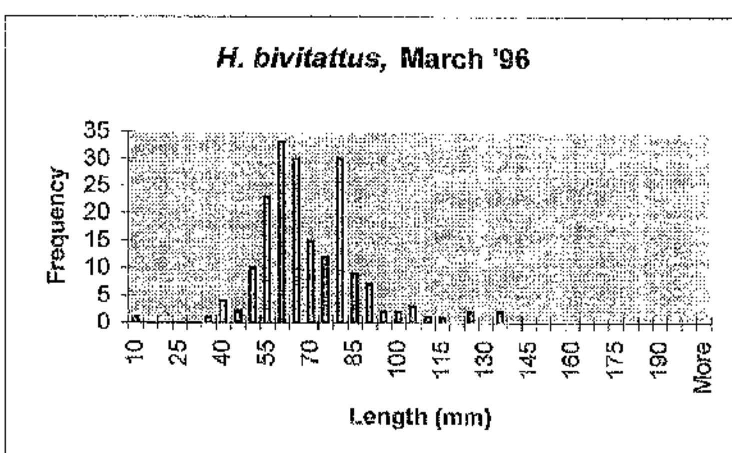




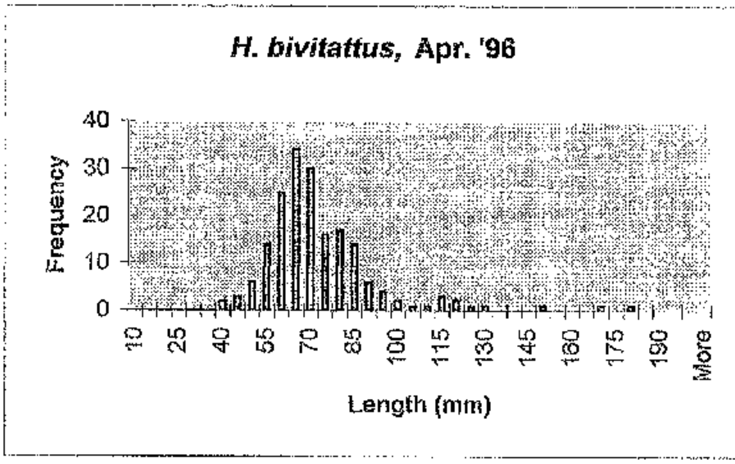
Appendix 3.5 (Continued)
Size Frequency Analysis
Halichoeres bivitattus

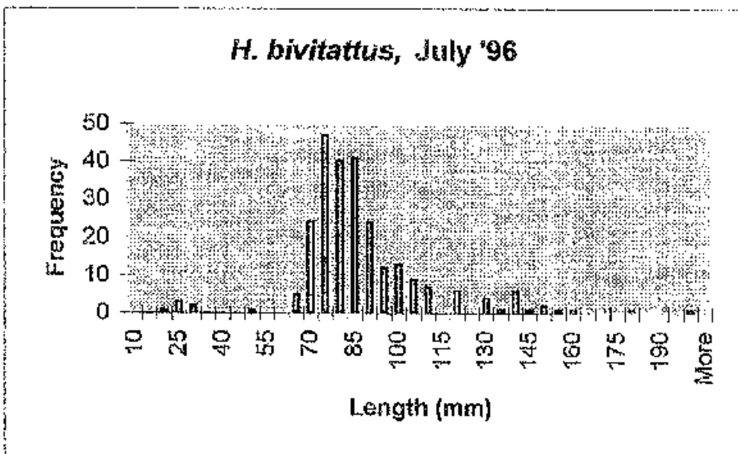


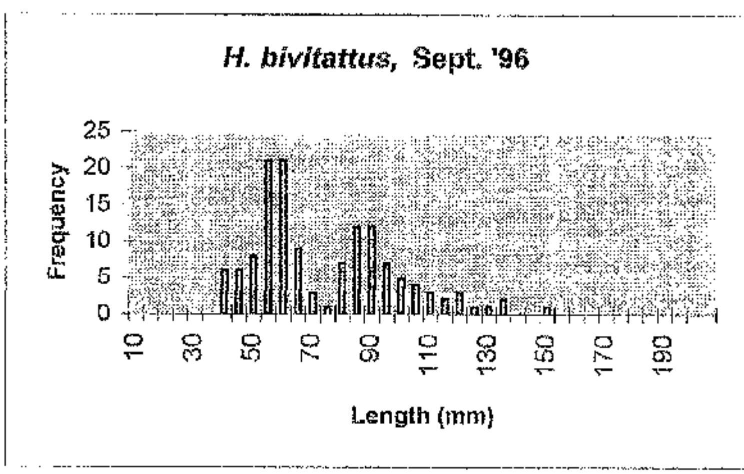




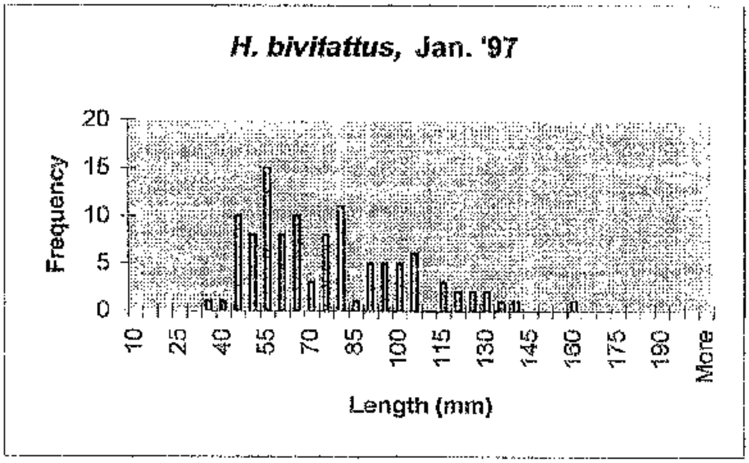
Appendix 3.5 (Continued)
Size Frequency Analysis
Halichoeres bivitattus

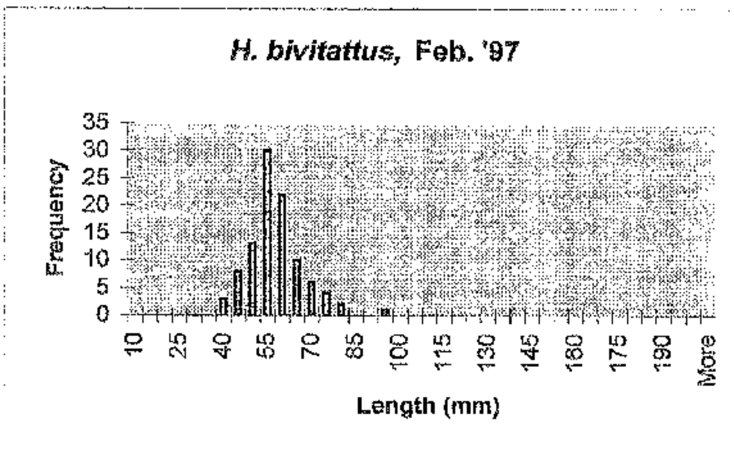


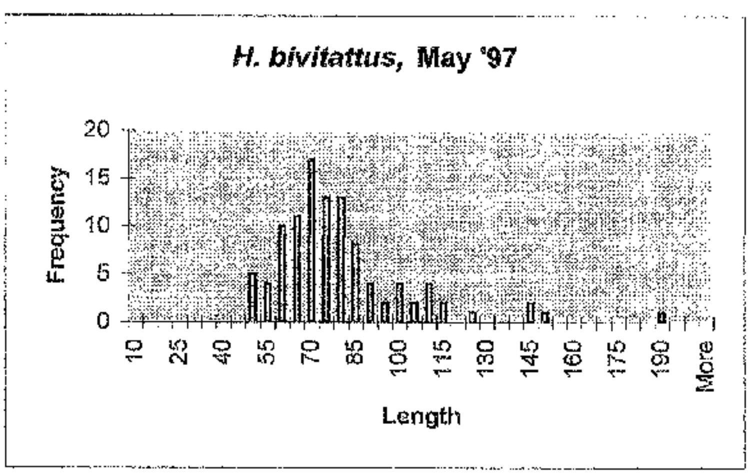




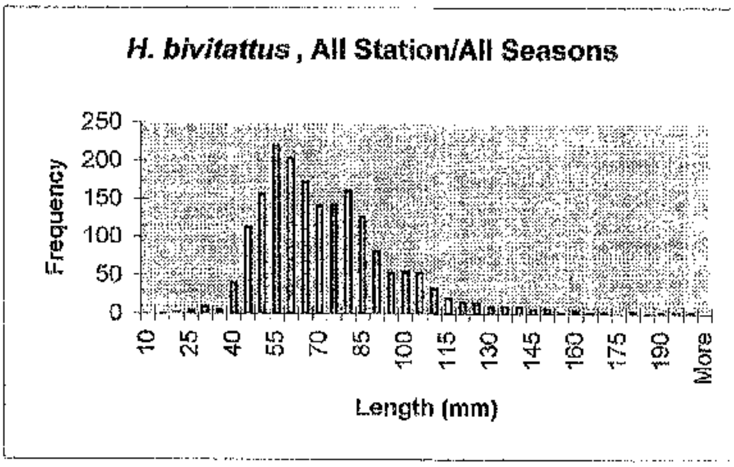
Appendix 3.5 (Continued)
Size Frequency Analysis
Halichoeres bivitattus







Appendix 3.5 (Continued)
Size Frequency Analysis
Halichoeres bivitattus



Appendix 3.6
Total Catch of Fish in Net Sets - Presented by Season
Flatts Inlet

Catch of Fall

Species Observed	No. Caught
Diplodus bermudensis	142
Eucinostomus gula	14
Eucinostomus havana	158
Haemulon aurolineatum	8
Haemulon flavolineatum	5
Haemulon sciurus	80
Holocentrus rufus	3
Lagodon rhomboides	11
Lutjanus synagris	1
Ocyurus chrysurus	7
Sphaeroides spengleri	5
Total Count (N)	434
Number of Species (S)	11

Catch of Spring

Species Observed	No. Caught
Calamus calamus	3
Caranx latus	1
Chaetodon capistratus	1
Diplodus bermudensis	7784
Eucinostomus gula	13
Eucinostomus havana	587
Eucinostomus lefroyi	7
Haemulon aurolineatum	301
Haemulon flavolineatum	194
Haemulon sciurus	143
Halichoeres bivittatus	5
Hemiramphus bermudensis	26
Hippocanthus reidi	1
Lagodon rhomboides	11
Monacanthus tuckeri	3
Ocyurus chrysurus	5
Syngnathus dunckeri	1
Pseudupeneus maculatus	39
Sardinella anchovia	100
Sphaeroides spengleri	1
Synodus intermedius	5
Total Count (N)	9231
Number of Species (S)	21

Catch of Summer

Species Observed	No. Caught
Caranx latus	2
Caranx sp.	1
Chaetodon capistratus	3
Diplodus bermudensis	363
Eucinostomus gula	107
Eucinostomus havana	239
Haemulon aurolineatum	25
Haemulon flavolineatum	27
Haemulon sciurus	147
Halichoeres bivittatus	11
Hemiramphus bermudensis	8
Holocentrus rufus	5
Lagodon rhomboides	3
Lutjanus griseus	4
Mugil liza	2
Scarus croicensis	3
Sphaeroides spengleri	8
Synodus intermedius	3
Total Count (N)	961
Number of Species (S)	18

Catch of Winter

Species Observed	No. Caught
Eucinostomus gula	1
Eucinostomus havana	52
Eucinostomus lefroyi	1
Haemulon aurolineatum	6
Haemulon flavolineatum	56
Haemulon sciurus	259
Halichoeres bivittatus	2
Lagodon rhomboides	35
Monacanthus hispidus	3
Ocyurus chrysurus	3
Syngnathus dunckeri	1
Sphaeroides spengleri	17
Synodus intermedius	1
Total Count (N)	437
Number of Species (S)	13

Appendix 3.6 (Continued)
Total Catch of Fish in Net Sets - Presented by Season
Bay Island

Catch of Fall		Catch of Spring		Catch of Summer		Catch of Winter	
Species Observed	**No. Caught**	**Species Observed**	**No. Caught**	**Species Observed**	**No. Caught**	**Species Observed**	**No. Caught**
Gobiosomus sp.	1	*Calamus calamus*	1	*Acanthurus bahianus*	2	*Acanthurus chirurgus*	1
Chaetodon capistratus	3	*Diplodus bermudensis*	2004	*Calamus calamus*	18	*Calamus calamus*	1
Diplodus bermudensis	8	*Eucinostomus gula*	4	*Caranx latus*	2	*Diplodus bermudensis*	3011
Eucinostomus gula	13	*Eucinostomus havana*	57	*Chaetodon capistratus*	3	*Eucinostomus gula*	10
Eucinostomus havana	18	*Gobiosomus grosvenori*	1	*Diplodus bermudensis*	799	*Eucinostomus havana*	51
Haemulon aurolineatum	24	*Haemulon sciurus*	2	*Eucinostomus gula*	158	*Eucinostomus lefroyi*	2
Haemulon flavolineatum	18	*Halichoeres bivitattus*	1376	*Eucinostomus havana*	13	*Haemulon aurolineatum*	3
Haemulon sciurus	146	*Lagodon rhomboides*	1	*Eucinostomus lefroyi*	4	*Haemulon sciurus*	46
Halichoeres bivitattus	323	*Monacanthus tuckeri*	55	*Haemulon aurolineatum*	306	*Halichoeres bivitattus*	311
Holocentrus rufus	4	*Orthopristis chrysoptera*	2	*Haemulon carbonarium*	9	*Hippocanthus sp.*	2
Lagodon rhomboides	19	*Pseudupeneus maculatus*	114	*Haemulon flavolineatum*	8	*Lagodon rhomboides*	3
Monacanthus tuckeri	197	*Sparisoma radians*	86	*Haemulon sciurus*	355	*Monacanthus hispidus*	1
Monacanthus sp.	1	*Sparisoma rubripinne*	3	*Halichoeres bivitattus*	648	*Monacanthus tuckeri*	105
Syngnathus sp.	1	*Sphaeroides spengleri*	7	*Hemiramphus bermudensis*	13	*Ocyurus crysurus*	1
Pseudupeneus maculatus	2	*Synodus intermedius*	1	*Holocentrus rufus*	1	*Syngnathus dunckeri*	4
Sparisoma radians	4			*Holocentrus vexillarius*	2	*Pseudupeneus maculatus*	11
Sphaeroides spengleri	9	Total No. Caught	3714	*Lachnolaimus maximus*	1	*Sparisoma radians*	17
Synodus intermedius	14	Number of Species	15	*Lagodon rhomboides*	25	*Sphaeroides spengleri*	19
				Monacanthus hispidus	1	*Synodus intermedius*	2
Total No. Caught	805			*Monacanthus tuckeri*	68		
Number of Species	18			*Pseudupeneus maculatus*	10	Total No. Caught	3601
				Scarus croicensis	8	Number of Species	19
				Sparisoma radians	315		
				Sphaeroides spengleri	30		
				Sphyraena barracuda	1		
				Synodus intermedius	37		
				Total No. Caught	2837		
				Number of Species	26		

Appendix 3.6 (Continued)
Total Catch of Fish in Net Sets - Presented by Season
Walsingham Bay

Catch of Fall

Species Observed	No. Caught
Diplodus bermudensis	10
Eucinostomus gula	512
Eucinostomus havana	412
Haemulon aurolineatum	161
Haemulon sciurus	385
Halichoeres bivittatus	355
Lagodon rhomboides	8
Lutjanus griseus	1
Orthopristis chrysoptera	1
Pseudupeneus maculatus	1
Scarus croicensis	1
Sparisoma chrysoperum	1
Sparisoma radians	24
Catch of Fall	15
Sphyraena barracuda	19
Synodus intermedius	1
Total Count (N)	1907
Number of Species (S)	16

Catch of Spring

Species Observed	No. Caught
Diplodus bermudensis	2
Eucinostomus gula	29
Eucinostomus havana	5
Haemulon aurolineatum	2
Haemulon sciurus	253
Halichoeres bivittatus	97
Lagodon rhomboides	4
Sphaeroides spengleri	2
Total Count (N)	394
Number of Species (S)	8

Catch of Summer

Species Observed	No. Caught
Caranx latus	1
Diplodus bermudensis	226
Eucinostomus gula	93
Eucinostomus havana	37
Haemulon aurolineatum	48
Haemulon flavolineatum	14
Haemulon sciurus	464
Halichoeres bivittatus	173
Lagodon rhomboides	17
Lutjanus griseus	1
Monacanthus tuckeri	1
Mugil liza	8
Orthopristis chrysoptera	1
Sparisoma chrysoperum	4
Sparisoma radians	16
Sphaeroides spengleri	3
Synodus intermedius	3
Total Count (N)	1110
Number of Species (S)	17

Catch of Winter

Species Observed	No. Caught
Diplodus bermudensis	13
Eucinostomus gula	240
Eucinostomus havana	24
Eucinostomus lefroyi	19
Gobiosomus spp.	3
Halichoeres bivitattus	169
Monacanthus tuckeri	1
Pseudupeneus maculatus	1
Lagodon rhomboides	2
Sphaeroides spengleri	11
Synodus intermedius	1
Total Count (N)	484
Number of Species (S)	11

Appendix 3.7
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
10-Apr-95	1650	Flatts	1	*Eucinostomus havana*	approx 90
10-Apr-95	1650	Flatts	1	*Diplodus bermudensis*	approx 200
10-Apr-95	1650	Flatts	1	*Anchoa choerostoma*	approx 2000
10-Apr-95	1600	Bay Isl.	2	*Sphaeroides spengleri*	2
10-Apr-95	1600	Bay Isl.	2	*Monacanthus tuckeri*	5
10-Apr-95	1600	Bay Isl.	2	*Pseudupeneus maculatus*	1
10-Apr-95	1600	Bay Isl.	2	*Sparisoma radians*	1
10-Apr-95	1600	Bay Isl.	2	*Halichoeres bivittatus*	1
19-Apr-95	1515	Bay Isl.	3	*Haemulon sciurus*	1
19-Apr-95	1515	Bay Isl.	3	*Eucinostomus havana*	approx 40
19-Apr-95	1515	Bay Isl.	3	*Monacanthus tuckeri*	2
19-Apr-95	1515	Bay Isl.	3	*Sparisoma radians*	1
19-Apr-95	1515	Bay Isl.	3	*Halichoeres bivittatus*	45
19-Apr-95	1550	Bay Isl.	4	*Monacanthus tuckeri*	6
19-Apr-95	1550	Bay Isl.	4	*Sparisoma radians*	1
19-Apr-95	1550	Bay Isl.	4	*Pseudupeneus maculatus*	4
19-Apr-95	1550	Bay Isl.	4	*Halichoeres bivittatus*	28
26-Apr-95	1145	Flatts	5	*Eucinostomus havana*	23
26-Apr-95	1145	Flatts	5	*Eucinostomus gula*	7
26-Apr-95	1145	Flatts	5	*Diplodus bermudensis*	1
26-Apr-95	1145	Flatts	5	*Haemulon aurolineatum*	2
26-Apr-95	1145	Flatts	5	*Diplodus bermudensis*	approx. 600
26-Apr-95	1230	Flatts	6	*Haemulon aurolineatum*	158
26-Apr-95	1230	Flatts	1	*Eucinostomus havana*	approx 90
26-Apr-95	1230	Flatts	6	*Haemulon aurolineatum*	158
26-Apr-95	1230	Flatts	6	*Hemiramphus bermudensis*	8
26-Apr-95	1230	Flatts	6	*Pseudupeneus maculatus*	25
26-Apr-95	1230	Flatts	6	*Monacanthus tuckeri*	3
26-Apr-95	1230	Flatts	6	*Haemulon sciurus*	21
26-Apr-95	1230	Flatts	6	*Synodus intermedius*	3
26-Apr-95	1230	Flatts	6	*Haemulon flavolineatum*	12
26-Apr-95	1230	Flatts	6	*Diplodus bermudensis*	74
26-Apr-95	1230	Flatts	6	*Eucinostomus havana*	105
26-Apr-95	1230	Flatts	6	*Eucinostomus gula*	3
26-Apr-95	1230	Flatts	6	*Chaetodon capistratus*	1
26-Apr-95	1230	Flatts	6	*Acanthurus sp. chirurgus*	1
26-Apr-95	1230	Flatts	6	*Syngnathus dunckeri*	1
26-Apr-95	1230	Flatts	6	*Lagodon rhomboides*	1
5-May-95	1530	Walsingham	7	*Halichoeres bivittatus*	2
5-May-95	1600	Walsingham	8	*Eucinostomus havana*	4
17-May-95	1645	Flatts	10	*Hemiramphus bermudensis*	4
17-May-95	1645	Flatts	10	*Synodus intermedius*	1
17-May-95	1645	Flatts	10	*Diplodus bermudensis*	approx. 1000
18-May-95	1420	Flatts	11	*Diplodus bermudensis*	approx. 500
18-May-95	1420	Flatts	11	*Ocyurus chrysurus*	5
18-May-95	1420	Flatts	11	*Synodus intermedius*	1
18-May-95	1420	Flatts	11	*Eucinostomus havana*	23
18-May-95	1420	Flatts	11	*Hemiramphus bermudensis*	4
18-May-95	1420	Flatts	11	*Sardinella anchovia*	100
18-May-95	1420	Flatts	11	*Anchoa choerostoma*	approx. 9000
18-May-95	1420	Flatts	11	*Jenkinsia lamprotaenia*	approx. 5000
18-May-95	1515	Flatts	12	*Haemulon sciurus*	116
18-May-95	1515	Flatts	12	*Calamus calamus*	3

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
18-May-95	1515	Flatts	12	*Eucinostomus havana*	approx 200
18-May-95	1515	Flatts	12	*Diplodus bermudensis*	Approx. 300
18-May-95	1515	Flatts	12	*Hippocampus reidi reidi*	1
18-May-95	1515	Flatts	12	*Haemulon flavolineatum*	182
18-May-95	1515	Flatts	12	*Pseudupeneus maculatus*	14
18-May-95	1515	Flatts	12	*Eucinostomus gula*	1
18-May-95	1515	Flatts	12	*Hemiramphus bermudensis*	10
2-Jul-95	1110	Flatts	13	*Diplodus bermudensis*	5
2-Jul-95	1110	Flatts	13	*Haemulon sciurus*	11
2-Jul-95	1110	Flatts	13	*Eucinostomus havana*	7
2-Jul-95	1110	Flatts	13	*Hemiramphus bermudensis*	7
2-Jul-95	1110	Flatts	13	*Eucinostomus gula.*	2
2-Jul-95	1500	Flatts	14	*Haemulon flavolineatum*	2
2-Jul-95	1500	Flatts	14	*Haemulon sciurus*	11
2-Jul-95	1500	Flatts	14	*Hemiramphus bermudensis*	1
2-Jul-95	1500	Flatts	14	*Diplodus bermudensis*	200
2-Jul-95	1500	Flatts	14	*Eucinostomus havana*	4
2-Jul-95	1500	Flatts	14	*Eucinostomus gula.*	3
2-Jul-95	1500	Flatts	14	*Halichoeres bivittatus*	1
8-Jul-95	1400	Flatts	15	*Mugil liza*	1
8-Jul-95	1400	Flatts	15	*Lutjanus griseus*	3
8-Jul-95	1400	Flatts	15	*Haemulon sciurus*	14
8-Jul-95	1400	Flatts	15	*Diplodus bermudensis*	30
8-Jul-95	1400	Flatts	15	*Diplodus bermudensis*	30
8-Jul-95	1400	Flatts	15	*Calamus calamus*	1
8-Jul-95	1400	Flatts	15	*Haemulon flavolineatum*	5
8-Jul-95	1400	Flatts	15	*Eucinostomus havana*	12
8-Jul-95	1400	Flatts	15	*Eucinostomus gula*	5
8-Jul-95	1400	Flatts	15	*Halichoeres bivittatus*	2
8-Jul-95	1400	Flatts	15	*Sphaeroides spengleri*	1
9-Jul-95	930	Bay Isl.	16	*Eucinostomus havana*	5
9-Jul-95	930	Bay Isl.	16	*Eucinostomus gula*	11
9-Jul-95	930	Bay Isl.	16	*Synodus intermedius*	1
9-Jul-95	930	Bay Isl.	16	*Haemulon sciurus*	13
9-Jul-95	930	Bay Isl.	16	*Haemulon aurolineatum*	2
9-Jul-95	930	Bay Isl.	16	*Haemulon flavolineatum*	1
9-Jul-95	930	Bay Isl.	16	*Hemiramphus bermudensis*	1
9-Jul-95	930	Bay Isl.	16	*Sparisoma radians*	5
9-Jul-95	930	Bay Isl.	16	*Halichoeres bivittatus*	14
9-Jul-95	930	Bay Isl.	16	*Diplodus bermudensis*	50
12-Jul-95	1730	Bay Isl.	17	*Haemulon sciurus*	28
12-Jul-95	1730	Bay Isl.	17	*Eucinostomus gula*	19
12-Jul-95	1730	Bay Isl.	17	*Eucinostomus havana*	1
12-Jul-95	1730	Bay Isl.	17	*Halichoeres bivittatus*	9
12-Jul-95	1730	Bay Isl.	17	*Sparisoma radians*	2
12-Jul-95	1730	Bay Isl.	17	*Diplodus bermudensis*	50
12-Jul-95	1730	Bay Isl.	17	*Monacanthus tuckeri*	1
12-Jul-95	1730	Bay Isl.	17	*Sparisoma radians*	1
12-Jul-95	1730	Bay Isl.	17	*Juvenile grunts*	12
12-Jul-95	1900	Flatts	18	*Haemulon sciurus*	26
12-Jul-95	1900	Flatts	18	*Scarus croicensis*	3
12-Jul-95	1900	Flatts	18	*Calamus calamus*	1
12-Jul-95	1900	Flatts	18	*Eucinostomus havana*	5

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
12-Jul-95	1900	Flatts	18	*Eucinostomus gula*	13
12-Jul-95	1900	Flatts	18	*Haemulon aurolineatum*	18
12-Jul-95	1900	Flatts	18	*Haemulon flavolineatum*	5
12-Jul-95	1900	Flatts	18	*Halichoeres bivittatus*	1
15-Jul-95	1045	Walsingham	19	*Halichoeres bivittatus*	30
15-Jul-95	1045	Walsingham	19	*Diplodus bermudensis*	120
15-Jul-95	1045	Walsingham	19	*Eucinostomus gula*	23
15-Jul-95	1045	Walsingham	19	*Haemulon flavolineatum*	4
15-Jul-95	1045	Walsingham	19	*Juvenile grunt*	25
15-Jul-95	1045	Walsingham	19	*Monacanthus tuckeri*	1
15-Jul-95	1045	Walsingham	19	*Haemulon aurolineatum*	1
15-Jul-95	1045	Walsingham	19	*Haemulon sciurus*	2
15-Jul-95	1045	Walsingham	19	*Lagodon rhomboides*	4
15-Jul-95	1145	Walsingham	20	*Mugil liza*	6
15-Jul-95	1145	Walsingham	20	*Eucinostomus gula*	2
15-Jul-95	1145	Walsingham	20	*Eucinostomus havena*	29
15-Jul-95	1145	Walsingham	20	*Juvenile grunts*	50
15-Jul-95	1145	Walsingham	20	*Lagodon rhomboides*	3
15-Jul-95	1145	Walsingham	20	*Orthopristis chrysoptera*	1
16-Jul-95	1130	Bay Isl.	21	*Juvenile grunt*	2
16-Jul-95	1130	Bay Isl.	21	*Diplodus bermudensis*	100
16-Jul-95	1130	Bay Isl.	21	*Haemulon sciurus*	18
16-Jul-95	1130	Bay Isl.	21	*Eucinostomus gula*	11
16-Jul-95	1130	Bay Isl.	21	*Halichoeres bivittatus*	18
16-Jul-95	1130	Bay Isl.	21	*Haemulon aurolineatum*	9
16-Jul-95	1130	Bay Isl.	21	*Sparisoma radians*	1
2-Sep-95	1430	Bay Isl.	22	*Haemulon sciurus*	1
2-Sep-95	1430	Bay Isl.	22	*Hemiramphus bermudensis*	12
2-Sep-95	1430	Bay Isl.	22	*Anchoa choerostoma*	10000
2-Sep-95	1430	Bay Isl.	22	*Synodus intermedius*	2
2-Sep-95	1430	Bay Isl.	22	*Juvenile grunts*	6
2-Sep-95	1430	Bay Isl.	22	*Halichoeres bivittatus*	9
2-Sep-95	1430	Bay Isl.	22	*Eucinostomus gula*	24
2-Sep-95	1430	Bay Isl.	22	*Monacanthus tuckeri*	7
2-Sep-95	1430	Bay Isl.	22	*Sphaeroides spengleri*	1
2-Sep-95	1430	Bay Isl.	22	*Pseudupeneus maculatus*	1
2-Sep-95	1430	Bay Isl.	22	*Haemulon aurolineatum*	1
2-Sep-95	1545	Flatts	23	*Diplodus bermudensis*	32
2-Sep-95	1545	Flatts	23	*Eucinostomus gula*	66
2-Sep-95	1545	Flatts	23	*Haemulon sciurus*	8
2-Sep-95	1545	Flatts	23	*Haemulon aurolineatum*	2
4-Sep-95	1740	Bay Isl.	24	*Synodus intermedius*	7
4-Sep-95	1740	Bay Isl.	24	*Eucinostomus gula*	32
4-Sep-95	1740	Bay Isl.	24	*Halichoeres bivittatus*	99
4-Sep-95	1740	Bay Isl.	24	*Monacanthus tuckeri*	40
4-Sep-95	1740	Bay Isl.	24	*Sphaeroides spengleri*	4
4-Sep-95	1740	Bay Isl.	24	*Chaetodon capistratus*	2
4-Sep-95	1740	Bay Isl.	24	*Acanthurus sp. bahianus*	2
4-Sep-95	1740	Bay Isl.	24	*Calamus calamus*	1
4-Sep-95	1740	Bay Isl.	24	*Holocentrus vexillarius*	2
4-Sep-95	1740	Bay Isl.	24	*Diplodus bermudensis*	1
4-Sep-95	1740	Bay Isl.	24	*Sparisoma radians*	16
4-Sep-95	1740	Bay Isl.	24	*Haemulon sciurus*	35

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
4-Sep-95	1740	Bay Isl.	24	*Haemulon aurolineatum*	46
4-Sep-95	1740	Bay Isl.	24	*Pseudupeneus maculatus*	2
23-Sep-95	1000	Walsingham	25	*Haemulon sciurus*	12
23-Sep-95	1000	Walsingham	25	*Haemulon aurolineatum*	5
23-Sep-95	1000	Walsingham	25	*Synodus intermedius*	1
23-Sep-95	1000	Walsingham	25	*Halichoeres bivittatus*	8
23-Sep-95	1000	Walsingham	25	*Sparisoma radians*	2
23-Sep-95	1000	Walsingham	25	*Eucinostomus gula*	26
23-Sep-95	1000	Walsingham	25	*Haemulon flavolineatum*	3
23-Sep-95	1050	Walsingham	26	*Sparisoma chrysopterum*	4
23-Sep-95	1050	Walsingham	26	*Halichoeres bivittatus*	25
23-Sep-95	1050	Walsingham	26	*Eucinostomus gula*	19
23-Sep-95	1050	Walsingham	26	*Haemulon sciurus*	29
23-Sep-95	1050	Walsingham	26	*Haemulon aurolineatum*	5
23-Sep-95	1050	Walsingham	26	*Lagodon rhomboides*	1
23-Sep-95	1150	Walsingham	27	*Eucinostomus gula*	17
23-Sep-95	1150	Walsingham	27	*Haemulon sciurus*	33
23-Sep-95	1150	Walsingham	27	*Halichoeres bivittatus*	42
23-Sep-95	1150	Walsingham	27	*Haemulon aurolineatum*	12
23-Sep-95	1150	Walsingham	27	*Haemulon flavolineatum*	7
24-Sep-95	930	Bay Isl.	28	*Synodus intermedius*	2
24-Sep-95	930	Bay Isl.	28	*Sphaeroides spengleri*	3
24-Sep-95	930	Bay Isl.	28	*Eucinostomus gula*	6
24-Sep-95	930	Bay Isl.	28	*Haemulon aurolineatum*	2
24-Sep-95	930	Bay Isl.	28	*Halichoeres bivittatus*	2
24-Sep-95	930	Bay Isl.	28	*Sparisoma radians*	5
24-Sep-95	930	Bay Isl.	28	*Holocentrus rufus*	1
24-Sep-95	930	Bay Isl.	28	*Monacanthus tuckeri*	1
24-Sep-95	930	Bay Isl.	28	*Haemulon sciurus*	4
24-Sep-95	1000	Bay Isl.	29	*Eucinostomus gula*	5
24-Sep-95	1000	Bay Isl.	29	*Pseudupeneus maculatus*	7
24-Sep-95	1000	Bay Isl.	29	*Synodus intermedius*	2
24-Sep-95	1000	Bay Isl.	29	*Halichoeres bivittatus*	35
24-Sep-95	1000	Bay Isl.	29	*Sphaeroides spengleri*	1
24-Sep-95	1000	Bay Isl.	29	*Monacanthus tuckeri*	5
24-Sep-95	1000	Bay Isl.	29	*Lagodon rhomboides*	1
24-Sep-95	1000	Bay Isl.	29	*Haemulon aurolineatum*	1
24-Sep-95	1000	Bay Isl.	29	*Eucinostomus havana*	1
24-Sep-95	1100	Flatts	30	*Haemulon sciurus*	23
24-Sep-95	1100	Flatts	30	*Sphaeroides spengleri*	3
24-Sep-95	1100	Flatts	30	*Diplodus bermudensis*	24
24-Sep-95	1100	Flatts	30	*Diplodus bermudensis*	24
24-Sep-95	1100	Flatts	30	*Haemulon flavolineatum*	2
24-Sep-95	1100	Flatts	30	*Eucinostomus gula*	3
24-Sep-95	1100	Flatts	30	*Eucinostomus havana*	37
24-Sep-95	1100	Flatts	30	*Halichoeres bivittatus*	1
30-Sep-95	1000	Flatts	31	*Mugil liza*	1
30-Sep-95	1000	Flatts	31	*Lutjanus griseus*	1
30-Sep-95	1000	Flatts	31	*Synodus intermedius*	1
30-Sep-95	1000	Flatts	31	*Haemulon flavolineatum*	1
30-Sep-95	1000	Flatts	31	*Caranx latus*	2
30-Sep-95	1000	Flatts	31	*Chaetodon capistratus*	1
30-Sep-95	1000	Flatts	31	*Eucinostomus havana*	55

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
30-Sep-95	1000	Flatts	31	*Diplodus bermudensis*	1
30-Sep-95	1030	Flatts	32	*Haemulon sciurus*	45
30-Sep-95	1030	Flatts	32	*Synodus intermedius*	2
30-Sep-95	1030	Flatts	32	*Diplodus bermudensis*	20
30-Sep-95	1030	Flatts	32	*Holocentrus rufus*	5
30-Sep-95	1030	Flatts	32	*Chaetodon capistratus*	2
30-Sep-95	1030	Flatts	32	*Lagodon rhomboides*	3
30-Sep-95	1030	Flatts	32	*Haemulon flavolineatum*	12
30-Sep-95	1030	Flatts	32	*Eucinostomus havana*	119
30-Sep-95	1030	Flatts	32	*Sphaeroides spengleri*	4
30-Sep-95	1030	Flatts	32	*Haemulon aurolineatum*	5
30-Sep-95	1030	Flatts	32	*Halichoeres bivittatus*	5
30-Sep-95	1030	Flatts	32	*Eucinostomus gula*	2
30-Sep-95	1030	Flatts	32	*Caranx sp.*	1
7-Oct-95	1145	Bay Isl.	33	*Haemulon sciurus*	35
7-Oct-95	1145	Bay Isl.	33	*Halichoeres bivittatus*	85
7-Oct-95	1145	Bay Isl.	33	*Sphaeroides spengleri*	2
7-Oct-95	1145	Bay Isl.	33	*Monacanthus tuckeri*	25
7-Oct-95	1145	Bay Isl.	33	*Haemulon aurolineatum*	14
7-Oct-95	1145	Bay Isl.	33	*Pseudupeneus maculatus*	1
7-Oct-95	1145	Bay Isl.	33	*Lagodon rhomboides*	1
7-Oct-95	1145	Bay Isl.	33	*Sparisoma radians*	1
7-Oct-95	1145	Bay Isl.	33	*Haemulon flavolineatum*	1
7-Oct-95	1145	Bay Isl.	33	*Eucinostomus havana*	3
7-Oct-95	1145	Bay Isl.	33	*Eucinostomus gula*	2
7-Oct-95	1320	Bay Isl.	34	*Synodus intermedius*	6
7-Oct-95	1320	Bay Isl.	34	*Sparisoma radians*	2
7-Oct-95	1320	Bay Isl.	34	*Monacanthus tuckeri*	18
7-Oct-95	1320	Bay Isl.	34	*Haemulon sciurus*	49
7-Oct-95	1320	Bay Isl.	34	*Halichoeres bivittatus*	25
7-Oct-95	1320	Bay Isl.	34	*Sphaeroides spengleri*	1
7-Oct-95	1320	Bay Isl.	34	*Haemulon aurolineatum*	5
7-Oct-95	1320	Bay Isl.	34	*Chaetodon capistratus*	3
7-Oct-95	1320	Bay Isl.	34	*Pseudupeneus maculatus*	1
7-Oct-95	1320	Bay Isl.	34	*Holocentrus rufus*	1
7-Oct-95	1320	Bay Isl.	34	*Haemulon flavolineatum*	1
7-Oct-95	1320	Bay Isl.	34	*Gobiosomus sp.*	1
7-Oct-95	1320	Bay Isl.	34	*Eucinostomus havana*	1
7-Oct-95	1320	Bay Isl.	34	*Lagodon rhomboides*	2
8-Oct-95	845	Walsingham	35	*Haemulon sciurus*	2
8-Oct-95	845	Walsingham	35	*Sphaeroides spengleri*	1
8-Oct-95	845	Walsingham	35	*Eucinostomus gula*	12
8-Oct-95	845	Walsingham	35	*Eucinostomus havana*	8
8-Oct-95	845	Walsingham	35	*Lagodon rhomboides*	1
8-Oct-95	845	Walsingham	35	*Halichoeres bivittatus*	1
8-Oct-95	915	Walsingham	36	*Lutjanus griseus*	1
8-Oct-95	915	Walsingham	36	*Haemulon sciurus*	31
8-Oct-95	915	Walsingham	36	*Sparisoma chrysopterum*	1
8-Oct-95	915	Walsingham	36	*Sparisoma radians*	2
8-Oct-95	915	Walsingham	36	*Lagodon rhomboides*	2
8-Oct-95	915	Walsingham	36	*Halichoeres bivittatus*	55
8-Oct-95	915	Walsingham	36	*Sphaeroides spengleri*	1
8-Oct-95	915	Walsingham	36	*Haemulon aurolineatum*	79

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
8-Oct-95	915	Walsingham	36	*Eucinostomus havana*	14
26-Oct-95	1400	Walsingham	37	*Eucinostomus havana*	60
26-Oct-95	1400	Walsingham	37	*Halichoeres bivittatus*	39
26-Oct-95	1400	Walsingham	37	*Lagodon rhomboides*	1
26-Oct-95	1400	Walsingham	37	*Sphaeroides spengleri*	2
26-Oct-95	1400	Walsingham	37	*Sparisoma radians*	1
26-Oct-95	1400	Walsingham	37	*Haemulon aurolineatum*	1
26-Oct-95	1600	Bay Isl.	38	*Eucinostomus havana*	1
26-Oct-95	1600	Bay Isl.	38	*Haemulon sciurus*	37
26-Oct-95	1600	Bay Isl.	38	*Diplodus bermudensis*	3
26-Oct-95	1600	Bay Isl.	38	*Synodus intermedius*	6
26-Oct-95	1600	Bay Isl.	38	*Sphaeroides spengleri*	2
26-Oct-95	1600	Bay Isl.	38	*Monacanthus tuckeri*	11
26-Oct-95	1600	Bay Isl.	38	*Holocentrus rufus*	1
26-Oct-95	1600	Bay Isl.	38	*Monacanthus sp.*	1
26-Oct-95	1600	Bay Isl.	38	*Halichoeres bivittatus*	37
26-Oct-95	1600	Bay Isl.	38	*Haemulon aurolineatum*	3
29-Oct-95	830	Flatts	39	*Lutjanus synagris*	1
29-Oct-95	830	Flatts	39	*Chaetodon capistratus*	2
29-Oct-95	830	Flatts	39	*Haemulon sciurus*	24
29-Oct-95	830	Flatts	39	*Haemulon flavolineatum*	3
29-Oct-95	830	Flatts	39	*Lagodon rhomboides*	1
29-Oct-95	830	Flatts	39	*Eucinostomus havana*	100
29-Oct-95	830	Flatts	39	*Diplodus bermudensis*	8
29-Oct-95	830	Flatts	39	*Eucinostomus gula.*	1
29-Oct-95	1430	Flatts	40	*Eucinostomus gula*	4
29-Oct-95	1430	Flatts	40	*Haemulon sciurus*	27
29-Oct-95	1430	Flatts	40	*Eucinostomus havana*	55
29-Oct-95	1430	Flatts	40	*Ocyurus chrysurus*	1
29-Oct-95	1430	Flatts	40	*Diplodus bermudensis*	14
29-Oct-95	1430	Flatts	40	*Chaetodon capistratus*	1
16-Nov-95	1540	Bay Isl	41	*Haemulon sciurus*	16
16-Nov-95	1540	Bay Isl	41	*Eucinostomus havana*	12
16-Nov-95	1540	Bay Isl	41	*Monacanthus tuckeri*	110
16-Nov-95	1540	Bay Isl	41	*Halichoeres bivittatus*	200
21-Nov-95	1430	Bay Isl.	42	*Monacanthus tuckeri*	8
21-Nov-95	1430	Bay Isl.	42	*Eucinostomus havana*	1
21-Nov-95	1430	Bay Isl.	42	*Halichoeres bivittatus*	9
21-Nov-95	1430	Bay Isl.	42	*Synodus intermedius*	2
21-Nov-95	1430	Bay Isl.	42	*Holocentrus rufus*	1
21-Nov-95	1430	Bay Isl.	42	*Haemulon flavolineatum*	4
21-Nov-95	1430	Bay Isl.	42	*Eucinostomus gula*	7
21-Nov-95	1430	Bay Isl.	42	*Haemulon sciurus*	4
21-Nov-95	1430	Bay Isl.	42	*Sphaeroides spengleri*	1
21-Nov-95	1430	Bay Isl.	42	*Lagodon rhomboides*	1
21-Nov-95	1430	Bay Isl.	42	*Haemulon aurolineatum*	1
21-Nov-95	1500	Bay Isl.	43	*Monacanthus tuckeri*	25
21-Nov-95	1500	Bay Isl.	43	*Syngnathus dunckerifish*	1
21-Nov-95	1500	Bay Isl.	43	*Halichoeres bivittatus*	3
21-Nov-95	1500	Bay Isl.	43	*Haemulon sciurus*	5
21-Nov-95	1500	Bay Isl.	43	*Holocentrus rufus*	1
21-Nov-95	1500	Bay Isl.	43	*Eucinostomus gula*	2
21-Nov-95	1500	Bay Isl.	43	*Sphaeroides spengleri*	1

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
21-Nov-95	1500	Bay Isl.	43	*Lagodon rhomboides*	1
21-Nov-95	1500	Bay Isl.	43	*Haemulon flavolineatum*	12
25-Nov-95	1200	Walsingham	44	*Eucinostomus gula*	200
25-Nov-95	1200	Walsingham	44	*Haemulon sciurus*	52
25-Nov-95	1200	Walsingham	44	*Sphyraena barracuda*	8
25-Nov-95	1200	Walsingham	44	*Sphaeroides spengleri*	4
25-Nov-95	1200	Walsingham	44	*Sparisoma radians*	2
25-Nov-95	1200	Walsingham	44	*Eucinostomus havana*	30
25-Nov-95	1200	Walsingham	44	*Haemulon aurolineatum*	8
25-Nov-95	1200	Walsingham	44	*Halichoeres bivittatus*	60
25-Nov-95	1200	Walsingham	44	*Lagodon rhomboides*	2
25-Nov-95	1200	Walsingham	44	*Scarus croicensis*	1
26-Nov-95	1415	Walsingham	45	*Eucinostomus havana*	300
26-Nov-95	1415	Walsingham	45	*Eucinostomus gula*	300
26-Nov-95	1415	Walsingham	45	*Sphyraena barracuda*	11
26-Nov-95	1415	Walsingham	45	*Sphaeroides spengleri*	7
26-Nov-95	1415	Walsingham	45	*Haemulon sciurus*	300
26-Nov-95	1415	Walsingham	45	*Haemulon aurolineatum*	73
26-Nov-95	1415	Walsingham	45	*Diplodus bermudensis*	10
26-Nov-95	1415	Walsingham	45	*Sparisoma radians*	19
26-Nov-95	1415	Walsingham	45	*Halichoeres bivittatus*	200
26-Nov-95	1415	Walsingham	45	*Lagodon rhomboides*	2
26-Nov-95	1415	Walsingham	45	*Orthopristis chrysoptera*	1
26-Nov-95	1415	Walsingham	45	*Synodus intermedius*	1
26-Nov-95	1415	Walsingham	45	*Pseudupeneus maculatus*	1
3-Dec-95	1545	Flatts	46	*Lagodon rhomboides*	10
3-Dec-95	1545	Flatts	46	*Haemulon sciurus*	4
3-Dec-95	1545	Flatts	46	*Haemulon flavolineatum*	2
3-Dec-95	1545	Flatts	46	*Holocentrus rufus*	1
3-Dec-95	1545	Flatts	46	*Eucinostomus gula*	3
3-Dec-95	1545	Flatts	46	*Haemulon aurolineatum*	8
3-Dec-95	1520	Flatts	47	*Eucinostomus havana*	3
3-Dec-95	1520	Flatts	47	*Sphaeroides spengleri*	2
3-Dec-95	1520	Flatts	47	*Ocyurus chrysurus*	1
3-Dec-95	1520	Flatts	47	*Diplodus bermudensis*	120
3-Dec-95	1520	Flatts	47	*Haemulon sciurus*	25
3-Dec-95	1520	Flatts	47	*Holocentrus rufus*	2
3-Dec-95	1520	Flatts	47	*Sphaeroides spengleri*	3
3-Dec-95	1520	Flatts	47	*Eucinostomus gula*	3
3-Dec-95	1520	Flatts	47	*Ocyurus chrysurus*	5
3-Dec-95	1520	Flatts	47	*Chaetodon capistratus*	1
3-Feb-96	1700	Flatts	48	*Haemulon sciurus*	150
3-Feb-96	1700	Flatts	48	*Diplodus bermudensis*	250
3-Feb-96	1700	Flatts	48	*Haemulon flavolineatum*	26
3-Feb-96	1700	Flatts	48	*Ocyurus chrysurus*	2
3-Feb-96	1700	Flatts	48	*Haemulon aurolineatum*	4
3-Feb-96	1700	Flatts	48	*Lagodon rhomboides*	2
3-Feb-96	1700	Flatts	48	*Eucinostomus havana*	2
10-Feb-96	1515	Flatts	49	*Diplodus bermudensis*	108
10-Feb-96	1515	Flatts	49	*Sphaeroides spengleri*	1
10-Feb-96	1515	Flatts	49	*Lagodon rhomboides*	6
10-Feb-96	1530	Flatts	50	*Diplodus bermudensis*	286
10-Feb-96	1530	Flatts	50	*Haemulon sciurus*	107

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
10-Feb-96	1530	Flatts	50	*Monacanthus hispidus*	1
10-Feb-96	1530	Flatts	50	*Haemulon flavolineatum*	30
10-Feb-96	1530	Flatts	50	*Lagodon rhomboides*	5
10-Feb-96	1530	Flatts	50	*Halichoeres bivittatus*	1
10-Feb-96	1530	Flatts	50	*Sphaeroides spengleri*	2
10-Feb-96	1530	Flatts	50	*Eucinostomus havana*	2
10-Feb-96	1530	Flatts	50	*Eucinostomus gula*	1
11-Feb-96	1345	Walsingham	51	*Eucinostomus gula*	35
11-Feb-96	1345	Walsingham	51	*Eucinostomus lefroyi*	7
11-Feb-96	1345	Walsingham	51	*Eucinostomus havana*	3
11-Feb-96	1345	Walsingham	51	*Lagodon rhomboides*	2
11-Feb-96	1345	Walsingham	51	*Halichoeres bivittatus*	20
11-Feb-96	1345	Walsingham	51	*Diplodus bermudensis*	9
11-Feb-96	1345	Walsingham	51	*Sphaeroides spengleri*	3
11-Feb-96	1445	Walsingham	52	*Synodus intermedius*	1
11-Feb-96	1445	Walsingham	52	*Sphaeroides spengleri*	2
11-Feb-96	1445	Walsingham	52	*Eucinostomus gula*	1
11-Feb-96	1445	Walsingham	52	*Pseudupeneus maculatus*	1
11-Feb-96	1500	Walsingham	53	*Eucinostomus gula*	160
11-Feb-96	1500	Walsingham	53	*Eucinostomus havana*	21
11-Feb-96	1500	Walsingham	53	*Diplodus bermudensis*	4
11-Feb-96	1500	Walsingham	53	*Sphaeroides spengleri*	5
11-Feb-96	1500	Walsingham	53	*Eucinostomus lefroyi*	10
11-Feb-96	1500	Walsingham	53	*Halichoeres bivittatus*	17
14-Feb-96	1530	Flatts	54	*Eucinostomus havana*	4
14-Feb-96	1530	Flatts	54	*Diplodus bermudensis*	200
27-Mar-96	1245	Walsingham	55	*Eucinostomus lefroyi*	1
27-Mar-96	1245	Walsingham	55	*Halichoeres bivittatus*	80
27-Mar-96	1245	Walsingham	55	*Eucinostomus gula*	4
27-Mar-96	1245	Walsingham	55	*Sphaeroides spengleri*	1
27-Mar-96	1245	Walsingham	55	*Gobiosoma grosvenori*	2
27-Mar-96	1400	Walsingham	56	*Halichoeres bivittatus*	30
27-Mar-96	1400	Walsingham	56	*Eucinostomus lefroyi*	1
27-Mar-96	1400	Walsingham	56	*Eucinostomus gula*	35
27-Mar-96	1415	Walsingham	57	*Halichoeres bivittatus*	22
27-Mar-96	1415	Walsingham	57	*Monacanthus tuckeri*	1
27-Mar-96	1415	Walsingham	57	*Gobiosoma grosvenori*	1
27-Mar-96	1415	Walsingham	57	*Eucinostomus gula*	5
27-Mar-96	1500	Bay Isl.	58	*Eucinostomus lefroyi*	2
27-Mar-96	1500	Bay Isl.	58	*Synodus intermedius*	1
27-Mar-96	1500	Bay Isl.	58	*Monacanthus tuckeri*	10
27-Mar-96	1500	Bay Isl.	58	*Eucinostomus havana*	27
27-Mar-96	1500	Bay Isl.	58	*Eucinostomus gula*	8
27-Mar-96	1500	Bay Isl.	58	*Lagodon rhomboides*	2
27-Mar-96	1500	Bay Isl.	58	*Halichoeres bivittatus*	50
27-Mar-96	1500	Bay Isl.	58	*Haemulon sciurus*	1
27-Mar-96	1500	Bay Isl.	58	*Heemulon aurolineatum*	1
27-Mar-96	1550	Bay Isl.	59	*Eucinostomus havana*	2
27-Mar-96	1550	Bay Isl.	59	*Halichoeres bivittatus*	1
27-Mar-96	1550	Bay Isl.	59	*Monacanthus tuckeri*	4
27-Mar-96	1550	Bay Isl.	59	*Diplodus bermudensis*	10000
27-Mar-96	1620	Bay Isl.	60	*Haemulon sciurus*	1
27-Mar-96	1620	Bay Isl.	60	*Monacanthus tuckeri*	30

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
27-Mar-96	1620	Bay Isl.	60	*Pseudupeneus maculatus*	4
27-Mar-96	1620	Bay Isl.	60	*Halichoeres bivittatus*	38
27-Mar-96	1620	Bay Isl.	60	*Lagodon rhomboides*	1
27-Mar-96	1620	Bay Isl.	60	*Eucinostomus gula*	1
27-Mar-96	1620	Bay Isl.	60	*Sparisoma radians*	1
31-Mar-96	1445	Flatts	61	*Diplodus bermudensis*	200
31-Mar-96	1445	Flatts	61	*Sphaeroides spengleri*	2
31-Mar-96	1445	Flatts	61	*Halichoeres bivittatus*	1
31-Mar-96	1445	Flatts	61	*Lagodon rhomboides*	1
31-Mar-96	1445	Flatts	61	*Monacanthus hispidus*	2
31-Mar-96	1530	Flatts	62	*Diplodus bermudensis*	1000
31-Mar-96	1530	Flatts	62	*Ocyurus chrysurus*	1
31-Mar-96	1530	Flatts	62	*Lagodon rhomboides*	8
31-Mar-96	1530	Flatts	62	*Haemulon sciurus*	1
31-Mar-96	1530	Flatts	62	*Eucinostomus lefroyi*	1
31-Mar-96	1530	Flatts	62	*Haemulon aurolineatum*	1
31-Mar-96	1545	Flatts	63	*Lagodon rhomboides*	13
31-Mar-96	1545	Flatts	63	*Lagodon rhomboides*	13
31-Mar-96	1545	Flatts	63	*Eucinostomus havana*	39
31-Mar-96	1545	Flatts	63	*Haemulon aurolineatum*	1
31-Mar-96	1545	Flatts	63	*Diplodus bermudensis*	30
31-Mar-96	1545	Flatts	63	*Haemulon sciurus*	1
21-Apr-96	1500	Walsingham	64	*Halichoeres bivittatus*	11
21-Apr-96	1500	Walsingham	64	*Eucinostomus gula*	2
21-Apr-96	1500	Walsingham	64	*Sphaeroides spengleri*	2
21-Apr-96	1530	Walsingham	65	*Haemulon sciurus*	96
21-Apr-96	1530	Walsingham	65	*Eucinostomus gula*	16
21-Apr-96	1530	Walsingham	65	*Halichoeres bivittatus*	48
21-Apr-96	1530	Walsingham	65	*Diplodus bermudensis*	1
21-Apr-96	1615	Walsingham	66	*Haemulon sciurus*	81
21-Apr-96	1615	Walsingham	66	*Haemulon aurolineatum*	2
21-Apr-96	1615	Walsingham	66	*Eucinostomus gula*	11
21-Apr-96	1615	Walsingham	66	*Diplodus bermudensis*	1
21-Apr-96	1615	Walsingham	66	*Halichoeres bivittatus*	25
21-Apr-96	1615	Walsingham	66	*Lagodon rhomboides*	4
21-Apr-96	1615	Walsingham	66	*Eucinostomus havana*	1
30-Apr-96	1415	Bay Isl.	67	*Sphaeroides spengleri*	1
30-Apr-96	1415	Bay Isl.	67	*Pseudupeneus maculatus*	1
30-Apr-96	1415	Bay Isl.	67	*Diplodus bermudensis*	2000
30-Apr-96	1415	Bay Isl.	67	*Halichoeres bivittatus*	10
30-Apr-96	1415	Bay Isl.	67	*Eucinostomus gula*	2
30-Apr-96	1415	Bay Isl.	67	*Monacanthus tuckeri*	4
30-Apr-96	1415	Bay Isl.	67	*Sparisoma radians*	2
30-Apr-96	1500	Bay Isl.	68	*Monacanthus tuckeri*	12
30-Apr-96	1500	Bay Isl.	68	*Sparisoma radians*	4
30-Apr-96	1500	Bay Isl.	68	*Halichoeres bivittatus*	20
30-Apr-96	1500	Bay Isl.	68	*Pseudupeneus maculatus*	2
30-Apr-96	1500	Bay Isl.	68	*Eucinostomus gula*	1
30-Apr-96	1500	Bay Isl.	68	*Sphaeroides spengleri*	1
30-Apr-96	1500	Bay Isl.	68	*Haemulon sciurus*	1
1-May-96	1030	Flatts	69	*Diplodus bermudensis*	5000
1-May-96	1030	Flatts	69	*Lagodon rhomboides*	1
1-May-96	1130	Bay Isl.	70	*Monacanthus tuckeri*	19

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
1-May-96	1130	Bay Isl.	70	*Sparisoma radians*	5
1-May-96	1130	Bay Isl.	70	*Halichoeres bivittatus*	272
1-May-96	1130	Bay Isl.	70	*Pseudupeneus maculatus*	78
1-May-96	1130	Bay Isl.	70	*Lagodon rhomboides*	1
1-May-96	1130	Bay Isl.	70	*Eucinostomus gula*	1
1-May-96	1130	Bay Isl.	70	*Orthopristis chrysopterum*	2
1-May-96	1130	Bay Isl.	70	*Diplodus bermudensis*	3
1-May-96	1610	Flatts	71	*Diplodus bermudensis*	200
1-May-96	1610	Flatts	71	*Eucinostomus havana*	8
1-May-96	1610	Flatts	71	*Eucinostomus gula*	2
1-May-96	1610	Flatts	71	*Eucinostomus lefroyi*	7
1-May-96	1610	Flatts	71	*Sphaeroides spengleri*	1
1-May-96	1610	Flatts	71	*Lagodon rhomboides*	6
1-May-96	1610	Flatts	71	*Halichoeres bivittatus*	1
2-May-96	845	Flatts	72	*Lagodon rhomboides*	3
2-May-96	845	Flatts	72	*Haemulon aurolineatum*	1
3-Jul-96	640	Bay Isl.	73	*Sparisoma radians*	31
3-Jul-96	640	Bay Isl.	73	*Eucinostomus gula*	7
3-Jul-96	640	Bay Isl.	73	*Diplodus bermudensis*	39
3-Jul-96	640	Bay Isl.	73	*Eucinostomus havana*	3
3-Jul-96	640	Bay Isl.	73	*Haemulon sciurus*	55
3-Jul-96	640	Bay Isl.	73	*Haemulon aurolineatum*	39
3-Jul-96	640	Bay Isl.	73	*Halichoeres bivittatus*	150
3-Jul-96	640	Bay Isl.	73	*Lagodon rhomboides*	11
3-Jul-96	640	Bay Isl.	73	*Synodus intermedius*	1
6-Jul-96	1600	Bay Isl.	74	*Lachnolaimus maximus*	1
6-Jul-96	1600	Bay Isl.	74	*Sparisoma radians*	100
6-Jul-96	1600	Bay Isl.	74	*Haemulon aurolineatum*	150
6-Jul-96	1600	Bay Isl.	74	*Haemulon sciurus*	87
6-Jul-96	1600	Bay Isl.	74	*Calamus calamus*	5
6-Jul-96	1600	Bay Isl.	74	*Eucinostomus gula*	12
6-Jul-96	1600	Bay Isl.	74	*Eucinostomus havana*	1
6-Jul-96	1600	Bay Isl.	74	*Haemulon carbonarium*	1
6-Jul-96	1600	Bay Isl.	74	*Diplodus bermudensis*	250
6-Jul-96	1600	Bay Isl.	74	*Scarus croicensis*	1
6-Jul-96	1600	Bay Isl.	74	*Halichoeres bivittatus*	166
6-Jul-96	1600	Bay Isl.	74	*Lagodon rhomboides*	4
6-Jul-96	1720	Bay Isl.	75	*Diplodus bermudensis*	9
6-Jul-96	1720	Bay Isl.	75	*Eucinostomus lefroyi*	4
6-Jul-96	1720	Bay Isl.	75	*Synodus intermedius*	1
30-Jul-96	1130	Bay Isl.	76	*Hemiramphus sp.*	1
30-Jul-96	1130	Bay Isl.	76	*Synodus intermedius*	7
30-Jul-96	1130	Bay Isl.	76	*Scarus croicensis*	6
30-Jul-96	1130	Bay Isl.	76	*Haemulon sciurus*	14
30-Jul-96	1130	Bay Isl.	76	*Halichoeres bivittatus*	54
30-Jul-96	1130	Bay Isl.	76	*Calamus calamus*	3
30-Jul-96	1130	Bay Isl.	76	*Sphaeroides spengleri*	1
30-Jul-96	1130	Bay Isl.	76	*Sparisoma radians*	19
30-Jul-96	1130	Bay Isl.	76	*Eucinostomus gula*	2
30-Jul-96	1130	Bay Isl.	76	*Diplodus bermudensis*	4
30-Jul-96	1130	Bay Isl.	76	*Haemulon aurolineatum*	9
30-Jul-96	1130	Bay Isl.	76	*Lagodon rhomboides*	4
30-Jul-96	1215	Walsingham	77	*Lutjanus griseus*	1

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
30-Jul-96	1215	Walsingham	77	*Haemulon sciurus*	300
30-Jul-96	1215	Walsingham	77	*Eucinostomus gula*	1
30-Jul-96	1215	Walsingham	77	*Halichoeres bivittatus*	23
30-Jul-96	1215	Walsingham	77	*Diplodus bermudensis*	20
30-Jul-96	1215	Walsingham	77	*Eucinostomus havana*	3
30-Jul-96	1215	Walsingham	77	*Haemulon aurolineatum*	6
30-Jul-96	1215	Walsingham	77	*Lagodon rhomboides*	2
30-Jul-96	1215	Walsingham	77	*Sparisoma radians*	2
1-Aug-96	1000	Flatts	78	*Diplodus bermudensis*	51
1-Aug-96	1000	Flatts	78	*Haemulon sciurus*	9
1-Aug-96	1000	Flatts	78	*Eucinostomus gula*	13
1-Aug-96	1000	Flatts	78	*Halichoeres bivittatus*	1
1-Aug-96	1035	Bay Isl.	79	*Sphaeroides spengleri*	2
1-Aug-96	1035	Bay Isl.	79	*Hemiramphus*	23
1-Aug-96	1035	Bay Isl.	79	*Halichoeres bivittatus*	20
1-Aug-96	1035	Bay Isl.	79	*Eucinostomus gula*	9
1-Aug-96	1035	Bay Isl.	79	*Diplodus bermudensis*	50
1-Aug-96	1035	Bay Isl.	79	*Calamus calamus*	9
1-Aug-96	1035	Bay Isl.	79	*Haemulon aurolineatum*	15
1-Aug-96	1035	Bay Isl.	79	*Synodus intermedius*	3
1-Aug-96	1035	Bay Isl.	79	*Haemulon sciurus*	5
1-Aug-96	1035	Bay Isl.	79	*Lagodon rhomboides*	1
1-Aug-96	1035	Bay Isl.	79	*Sparisoma radians*	5
1-Aug-96	1035	Bay Isl.	79	*Eucinostomus havana*	2
20-Sep-96	1230	Walsingham	80	*Haemulon sciurus*	55
20-Sep-96	1230	Walsingham	80	*Diplodus bermudensis*	21
20-Sep-96	1230	Walsingham	80	*Sparisoma radians*	9
20-Sep-96	1230	Walsingham	80	*Sphaeroides spengleri*	1
20-Sep-96	1230	Walsingham	80	*Eucinostomus gula*	4
20-Sep-96	1230	Walsingham	80	*Eucinostomus havana*	4
20-Sep-96	1230	Walsingham	80	*Haemulon aurolineatum*	5
20-Sep-96	1230	Walsingham	80	*Halichoeres bivittatus*	25
20-Sep-96	1230	Walsingham	80	*Lagodon rhomboides*	1
20-Sep-96	1230	Walsingham	80	*Synodus intermedius*	2
20-Sep-96	1315	Walsingham	81	*Haemulon sciurus*	33
20-Sep-96	1315	Walsingham	81	*Halichoeres bivittatus*	20
20-Sep-96	1315	Walsingham	81	*Diplodus bermudensis*	65
20-Sep-96	1315	Walsingham	81	*Lagodon rhomboides*	6
20-Sep-96	1315	Walsingham	81	*Haemulon aurolineatum*	14
20-Sep-96	1315	Walsingham	81	*Sphaeroides spengleri*	2
20-Sep-96	1315	Walsingham	81	*Eucinostomus gula*	1
20-Sep-96	1315	Walsingham	81	*Sparisoma radians*	3
20-Sep-96	1315	Walsingham	81	*Caranx latus*	1
20-Sep-96	1315	Walsingham	81	*Eucinostomus havana*	1
20-Sep-96	1440	Bay Isl.	82	*Haemulon sciurus*	58
20-Sep-96	1440	Bay Isl.	82	*Sphaeroides spengleri*	15
20-Sep-96	1440	Bay Isl.	82	*Sparisoma radians*	100
20-Sep-96	1440	Bay Isl.	82	*Diplodus bermudensis*	96
20-Sep-96	1440	Bay Isl.	82	*Halichoeres bivittatus*	90
20-Sep-96	1440	Bay Isl.	82	*Synodus intermedius*	11
20-Sep-96	1440	Bay Isl.	82	*Monacanthus tuckeri*	11
20-Sep-96	1440	Bay Isl.	82	*Monacanthus sp.*	1
20-Sep-96	1440	Bay Isl.	82	*Caranx latus*	2

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
20-Sep-96	1440	Bay Isl.	82	*Haemulon aurolineatum*	21
20-Sep-96	1440	Bay Isl.	82	*Eucinostomus gula*	9
20-Sep-96	1440	Bay Isl.	82	*Lagodon rhomboides*	3
20-Sep-96	1440	Bay Isl.	82	*Chaetodon capistratus*	1
20-Sep-96	1440	Bay Isl.	82	*Scarus croicensis*	1
20-Sep-96	1440	Bay Isl.	82	*Haemulon flavolineatum*	7
10-Jan-97	1030	Bay Isl.	83	*Halichoeres bivittatus*	81
10-Jan-97	1030	Bay Isl.	83	*Haemulon aurolineatum*	1
10-Jan-97	1030	Bay Isl.	83	*Sparisoma radians*	9
10-Jan-97	1030	Bay Isl.	83	*Monacanthus tuckeri*	8
10-Jan-97	1030	Bay Isl.	83	*Monacanthus sp.*	1
10-Jan-97	1030	Bay Isl.	83	*Sphaeroides spengleri*	6
10-Jan-97	1030	Bay Isl.	83	*Syngnathus dunckerifish*	1
10-Jan-97	1030	Bay Isl.	83	*Acanthurus sp.*	1
10-Jan-97	1030	Bay Isl.	83	*Pseudupeneus maculatus*	1
10-Jan-97	1030	Bay Isl.	83	*Diplodus bermudensis*	1
10-Jan-97	1200	Bay Isl.	83	*Eucinostomus havana*	22
10-Jan-97	1200	Bay Isl.	83	*Diplodus bermudensis*	10
10-Jan-97	1200	Bay Isl.	83	*Sphaeroides spengleri*	10
10-Jan-97	1200	Bay Isl.	83	*Sparisoma radians*	3
10-Jan-97	1200	Bay Isl.	83	*Syngnathus dunckerifish*	1
10-Jan-97	1200	Bay Isl.	83	*Monacanthus tuckeri*	14
10-Jan-97	1200	Bay Isl.	83	*Halichoeres bivittatus*	44
10-Jan-97	1200	Bay Isl.	83	*Eucinostomus gula*	1
8-Feb-97	1215	Flatts	84	*Diplodus bermudensis*	46
8-Feb-97	1215	Flatts	84	*Sphaeroides spengleri*	3
8-Feb-97	1230	Flatts	85	*Synodus intermedius*	1
8-Feb-97	1230	Flatts	85	*Sphaeroides spengleri*	9
8-Feb-97	1230	Flatts	85	*Diplodus bermudensis*	140
8-Feb-97	1230	Flatts	85	*Eucinostomus havana*	5
8-Feb-97	1230	Flatts	85	*Syngnathus dunckerifish*	1
8-Feb-97	1430	Bay Isl.	86	*Hippocampus reidi*	2
8-Feb-97	1430	Bay Isl.	86	*Synodus intermedius*	1
8-Feb-97	1430	Bay Isl.	86	*Ocyurus chrysurus*	1
8-Feb-97	1430	Bay Isl.	86	*Calamus calamus*	1
8-Feb-97	1430	Bay Isl.	86	*Sparisoma radians*	4
8-Feb-97	1430	Bay Isl.	86	*Pseudupeneus maculatus*	6
8-Feb-97	1430	Bay Isl.	86	*Syngnathus dunckerifish*	2
8-Feb-97	1430	Bay Isl.	86	*Haemulon aurolineatum*	1
8-Feb-97	1430	Bay Isl.	86	*Haemulon sciurus*	44
8-Feb-97	1430	Bay Isl.	86	*Halichoeres bivittatus*	97
8-Feb-97	1430	Bay Isl.	86	*Monacanthus tuckeri*	39
8-Feb-97	1430	Bay Isl.	86	*Diplodus bermudensis*	2000
8-Feb-97	1430	Bay Isl.	86	*Sphaeroides spengleri*	3
31-May-97	1600	Bay Isl.	87	*Pseudupeneus maculatus*	28
31-May-97	1600	Bay Isl.	87	*Sparisoma radians*	72
31-May-97	1600	Bay Isl.	87	*Sparisoma rubripinne*	3
31-May-97	1600	Bay Isl.	87	*Calamus calamus*	1
31-May-97	1600	Bay Isl.	87	*Haemulon sciurus*	1
31-May-97	1600	Bay Isl.	87	*Gobiosomus sp.*	1
31-May-97	1600	Bay Isl.	87	*Diplodus bermudensis*	1
31-May-97	1600	Bay Isl.	87	*Sphaeroides spengleri*	3
31-May-97	1600	Bay Isl.	87	*Synodus intermedius*	1

Appendix 3.7 (Continued)
Fish Catch by Net Set

Date	Time	Station	Set #	Species	Total number
31-May-97	1600	Bay Isl.	87	*Halichoeres bivittatus*	1000
31-May-97	1600	Bay Isl.	87	*Monacanthus tuckeri*	7
31-May-97	1600	Bay Isl.	87	*Eucinostomus havana*	17
15-Jun-97	1330	Flatts	88	*Eucinostomus havana*	9
15-Jun-97	1330	Flatts	88	*Haemulon sciurus*	4
15-Jun-97	1330	Flatts	88	*Diplodus bermudensis*	9
15-Jun-97	1330	Flatts	88	*Caranx latus*	1
15-Jun-97	1350	Flatts	89	*Eucinostomus havana*	39
15-Jun-97	1350	Flatts	89	*Haemulon sciurus*	2
15-Jun-97	1350	Flatts	89	*Halichoeres bivittatus*	4
15-Jun-97	1350	Flatts	89	*Diplodus bermudensis*	200
23-Jul-97	1114	Bay Isl.	90	*Sparisoma radians*	30
23-Jul-97	1114	Bay Isl.	90	*Sphyraena barracuda*	1
23-Jul-97	1114	Bay Isl.	90	*Eucinostomus gula*	11
23-Jul-97	1114	Bay Isl.	90	*Sphaeroides spengleri*	3
23-Jul-97	1114	Bay Isl.	90	*Haemulon carbonarium*	8
23-Jul-97	1114	Bay Isl.	90	*Diplodus bermudensis*	150
23-Jul-97	1114	Bay Isl.	90	*Haemulon sciurus*	37
23-Jul-97	1114	Bay Isl.	90	*Monacanthus tuckeri*	3
23-Jul-97	1114	Bay Isl.	90	*Haemulon aurolineatum*	11
23-Jul-97	1114	Bay Isl.	90	*Lagodon rhomboides*	1
				Grand Total of all fish =	43638

Appendix 4.1

Summary of Plankton Data - Abundance of Plankters by Taxon, Depth and Time as Sampled by Net over Seagrass Beds.

Depths 2 and 3

See Key to Codes FollowingTables

Taxon	Depth	Time	S1-a	S1-b	S1-c	S1-d	S1-e	S2-a	S2-b	S2-c	S2-d	S2-e	S3-a	S3-b	S3-c	S3-d	S3-e
1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	2	1	0	3	0	1	3	2	0	0	3	1	2	0	0	0
3	3	2	1	1	4	0	2	2	2	2	0	3	0	2	1	2	1
4	3	2	0	1	1	1	0	0	0	0	0	1	0	1	2	0	0
5	3	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
6	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	3	2	1	1	1	0	4	1	1	2	0	2	3	5	4	3	2
11	3	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
12	3	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
13	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	2	2	1	1	2	2	3	1	0	2	3	5	1	2	1	0
3	2	2	2	2	4	4	6	3	3	3	3	1	8	3	3	3	1
4	2	2	2	2	2	0	1	0	0	0	1	1	1	2	0	0	2
5	2	2	1	0	0	0	0	0	0	0	0	0	2	0	1	0	0
6	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
9	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2	2	3	2	2	2	1	4	3	1	4	4	3	1	3	5	2
11	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
13	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4.1 (Continued)

Summary of Plankton Data - Abundance of Plankters by Taxon, Depth and Time as Sampled by Net over Seagrass Beds.

Depths 2 and 3

See Key to Codes FollowingTables

Taxon	Depth	Time	S1-a	S1-b	S1-c	S1-d	S1-e	S2-a	S2-b	S2-c	S2-d	S2-e	S3-a	S3-b	S3-c	S3-d	S3-e
1	3	1	15	9	8	18	10	1	3	2	3	2	0	1	0	2	0
2	3	1	2	2	0	1	0	2	1	1	1	4	1	0	0	2	1
3	3	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0
4	3	1	0	1	1	1	0	1	1	0	0	0	0	1	2	0	0
5	3	1	0	0	0	1	0	0	0	0	1	1	1	0	1	0	0
6	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	1	0	0	0	1	0	0	0	0	0	2	1	3	2	2	4
2	2	1	0	0	1	0	0	1	0	2	1	0	0	0	0	0	0
3	2	1	0	0	1	0	0	1	0	2	0	1	1	0	0	0	0
4	2	1	0	1	2	0	0	3	2	4	1	2	1	0	0	0	1
5	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4.1 (Continued)

Summary of Plankton Data - Abundance of Plankters by Taxon, Depth and Time as Sampled by Net Over Seagrass Beds.

Depth 1 Only

See Key to Codes Following Tables

Taxon	Time	S1.a1	S1.a2	S1.a3	S1.a4	S1.a5	S1.b1	S1.b2	S1.b3	S1.b4	S1.b5	S1.c1	S1.c2	S1.c3	S1.c4	S1.c5	S2.a1
1	1	0	3	0	0	1	1	1	1	0	1	0	0	0	1	1	0
2	1	6	8	14	22	8	14	3	6	3	13	6	10	1	6	6	21
3	1	2	5	2	3	6	2	4	4	5	2	6	5	1	3	1	4
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	1	2	0	2	0	2	1	0	2	0	2	1	0	2	0	0
6	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	30	7	9	6	5	16	10	15	1	23	13	6	14	5	9	11
3	2	18	8	7	7	14	4	5	8	6	3	4	7	11	4	6	20
4	2	0	2	2	1	2	2	1	0	0	0	0	0	0	0	0	0
5	2	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
6	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
9	2	7	2	2	0	0	0	0	0	0	0	0	1	0	0	1	0
10	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
13	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	1	1	2	1	2	0	0	0	0	0	0	0	0	1	0	0

Appendix 4.1 (Continued)

Summary of Plankton Data - Abundance of Plankters by Taxon, Depth and Time as Sampled by Net Over Seagrass Beds.

Depth 1 Only

See Key to Codes Following Tables

Taxon	Time	S2.a2	S2.a3	S2.a4	S2.a5	S2.b1	S2.b2	S2.b3	S2.b4	S2.b5	S2.c1	S2.c2	S2.c3	S2.c4	S2.c5	S3.a1	S3.a2
1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	1	13	7	9	16	14	13	12	9	11	12	13	2	1	1	3	2
3	1	2	2	6	4	1	1	1	2	0	0	1	1	2	1	0	1
4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5	1	2	0	1	0	4	3	2	2	0	1	1	0	0	0	1	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	10	13	8	10	2	6	1	2	1	1	2	4	2	1	6	3
3	2	17	7	4	26	0	0	1	0	0	1	0	2	0	0	30	18
4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5	2	2	1	0	1	3	1	0	0	0	1	2	1	0	0	1	1
6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
13	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
14	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2

Appendix 4.1 (Continued)

Summary of Plankton Data - Abundance of Plankters by Taxon, Depth and Time as Sampled by Net Over Seagrass Beds.

Depth 1 Only

See Key to Codes Following Tables

Taxon	Time	S3.a3	S3.a4	S3.a5	S3.b1	S3.b2	S3.b3	S3.b4	S3.b5	S3.c1	S3.c2	S3.c3	S3.c4	S3.c5
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	6	4	4	0	2	1	0	1	9	3	0	0	4
3	1	0	0	0	0	2	0	0	0	2	3	0	1	0
4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	1	0	0	0	0	0	1	1	0	1	1
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	1	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	8	6	8	8	3	6	6	4	0	3	1	10	6
3	2	12	25	35	3	3	5	1	1	2	1	2	2	0
4	2	1	0	0	0	0	0	0	0	0	0	0	0	0
5	2	1	0	0	3	0	0	0	0	1	1	0	0	0
6	2	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	0	0	0	0	0	0	0	0	0
9	2	1	0	0	0	0	0	0	0	0	0	0	0	0
10	2	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	1	0	1	0	0	0	0	0	0	0	0	0	0
13	2	0	0	2	0	0	0	0	0	0	0	0	0	0
14	2	0	0	0	0	0	0	0	0	0	0	0	0	0
15	2	0	1	1	1	0	0	0	0	0	0	0	0	0

Appendix 4.1 (Continued)
Key to Plankton Data and Transformations

Key to Plankton Data Codes

Taxon Code –	Depth Code	Time Code
1 – Veliger	1 – 10cm	1 - day
2 – Ostracod	2 – 30cm	2 – night.
3 – Harpacticod	3 – 50cm	
4 – Calanoid		
5 – Nematode		
6 – Polychaete		
7 – Caprellid		
8 – Mite		
9 – Turbellarid		
10 – Zoea		
11 – Anemone		
12 – Amphipod		
13 – Shrimp		
14 – Cladoceran		
15 – Medusa		

Sample code

For depths 2&3, the 5 replicates of Samples 1-3 are coded as S1-a to e, S2 a to e, and S3 a to e. These are presented as headers of the columns of data.
With Depth 1, Sample 1-3 are broken down into 3 subsamples coded a-c, and further to indicate fields of view 1 through 5.

Thus S1.a1 indicates sample 1, subsample a, field of view 1. These are provided as headers of the columns of data.

Transformations

Transformations to #/m3 result from the following sampling parameters.
Three samples were taken at each depth at each sampling time.
i) Each sample represents the catch from filtering 0.14 cubic metres of seawater.
ii) Samples taken at depths 2&3 were subsampled simply by counting the contents of 5 fields – each of which represents 16.5% of the sample.
iii) Samples taken at depth 1 were subsampled 3 times – each of which comprised 2.08% of the sample which were, in turn, subsampled by counting the contents of 5 fields - each of which represents 16.5% of the subsample.

Samples from depth 2&3 can be transformed to #/m3 by multiplying by ((1/0.14)x(1/0.165)) = 43.29

Appendix 5.1: Gut Content and Gonad Development Observations

Bucktooth Parrotfish *(Sparisoma radians)*

Date	Station	Total Length	Gonads*	Gut Contents
3 Jul '96	Bay Isl.	80mm	25%, F - III	Gut full, Green. 90% ground plant material, 5% *Thalassia* blades. Red alga, sand.
3 Jul '96	Bay Isl.	93mm	10%, M - III	Gut full, Green. Mostly ground plant material, some *Thalassia* blades. Red alga, sand.
3 Jul '96	Bay Isl.	91mm	20%, M - IV	Gut full, Green. Mostly ground plant material, some *Thalassia* blades.
3 Jul '96	Bay Isl.	81mm	30%, F – III-IV	Gut full, Green. Mostly well-ground plant material. 5% sand.
3 Jul '96	Bay Isl.	62mm	20%, F - III	Gut full, Green. Mostly ground plant material, 5-10% *Thalassia* pieces, some sand.
3 Jul '96	Bay Isl.	98mm	20%, F - II	Gut full, Green. Mostly ground plant material, 5% *Thalassia* blades. Red alga, sand.
20 Sep '96	Bay Isl.	81mm	10%, M - II	Gut full, Green. 90% finely ground plant material, *Thalassia* pieces, 5% sand.
20 Sep '96	Bay Isl.	115mm	60%, F - IV	Gut full, Green. 80% finely ground plant material, 15% *Thalassia*, some sand.
20 Sep '96	Bay Isl.	108mm	70%, F - IV	Gut full, Green. 50% finely ground plant material, 45% *Thalassia*, some sand.
20 Sep '96	Bay Isl.	94mm	45%, F - IV	Gut half full, Green. 50% finely ground plant material, 50% *Thalassia*.
20 Sep '96	Bay Isl.	74mm	30%, M - III	Gut 30% full, Green. 85% finely ground plant material, 10% *Thalassia*, 5% sand.

Sand Diver *(Synodus intermedius)*

Date	Station	Fork Length	Gonads*	Gut Contents
3 Jul '96	Bay Isl.	88mm	<10%, I	2 fish (*Jenkinsia lamprotaenia?*), 12 digenetic trematodes
20 Sep '96	Bay Isl.	139mm	<10%, I	Gut full, 2 fish (*Jenkinsia lamprotaenia*), approx. 45mm FL, 4 digenetic treamatodes.
20 Sep '96	Bay Isl.	148mm	<10%, I	Gut half full, 2 partially digested fish, 10 digenetic treamatodes.
20 Sep '96	Bay Isl.	115mm	<10%, I	1 freshly-eaten *Jenkinsia lamprotaenia*, numerous digenetic treamatodes.
20 Sep '96	Bay Isl.	127mm	<10%, I	2 *Jenkinsia lamprotaenia*, numerous digenetic treamatodes.
20 Sep '96	Bay Isl.	120mm	<10%, I	Gut empty, some scales in hind gut.
8 Feb '98	Bay Isl.	163mm	10%, F - II	Gut empty, several cestodes
8 Feb '98	Bay Isl.	183mm	15%, F - II	No food, approximately 30 digenetic trematodes, hindgut full of cestodes

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV – ready to spawn, V – spent.

Appendix 5.1: (Continued) Gut Content and Gonad Development Observations

Slippery Dick *(Halichoeres bivittatus)*

Date	Station	Total Length	Gonads*	Gut Contents
3 Jul '96	Bay Isl.	84mm	40%, F, II	Gut empty, 1 trematode.
3 Jul '96	Bay Isl.	95mm	35%, F, II	Gut empty.
3 Jul '96	Bay Isl.	77mm	40%, F, III	Gut empty.
3 Jul '96	Bay Isl.	74mm	40%, F, II	Ostracods, crustacean parts, foraminifera.
3 Jul '96	Bay Isl.	76mm	40%, F, III	Gut almost empty. Crustaceans, foraminifera, some sand and plant debris.
23 Jul '97	Bay Isl.	84mm	30%, F, III	Some sediment, crustacean parts (decapod shrimp?), ostracods, foraminifera.

Tomtate *(Haemulon aurolineatum)*

Date	Station	Fork Length	Gonads*	Gut Contents
3 Jul '96	Bay Isl.	83mm	5%, I	Gut largely empty. Bivalves, gastropods, amphipod crustaceans, crustacean parts.
3 Jul '96	Bay Isl.	74mm	<10%, I	Gut partly full. Bivalves, fish scales, amphipod crustaceans, crustacean parts, sand.
3 Jul '96	Bay Isl.	82mm	5%, I	Gut full. Crustaceans, some bivalves, algal debris, sand.
3 Jul '96	Bay Isl.	81mm	5%, I	Gut partly full. Principally crustacean parts, gastropods, sand, algal debris, copepod.
3 Jul '96	Bay Isl.	76mm	15%, I	Gut partly full. Principally crustacean parts, fish scales, some sand and algae.
20 Sep '96	Bay Isl.	78mm	<15%, I	Gut full. Amphipod and isopod crustaceans, harpacticoid copepods, bivalves, sand.
20 Sep '96	Bay Isl.	98mm	20%, M, III	Gut full. Bivalves, sand, *Thalassia* debris, gastropods, crustacean parts.
20 Sep '96	Bay Isl.	78mm	<15%, I	Gut half full. Crustacean parts, sand.
20 Sep '96	Bay Isl.	78mm	<15%, I	Gut largely empty. Numerous harpacticoid copepods.
20 Sep '96	Bay Isl.	81mm	<15%, I	Gut largely empty. Crustacean parts, gastropods, sand, amphipod crustaceans.
23 Jul '97	Bay Isl.	84mm	5%, I	Gut full. 1 large seed, numerous harpacticoids, crustacean parts, amphipod crustaceans, algae, sand, spicule.
23 Jul '97	Bay Isl.	82mm	5%, I	Fish debris, sediment, bivalves, forams, harpacticoids, crustacean parts.

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV – ready to spawn, V – spent.

Appendix 5.1: (Continued) Gut Content and Gonad Development Observations

Pinfish *(Lagodon rhomboides)*

Date	Station	Fork Length	Gonads*	Gut Contents
3 Jul '96	Bay Isl.	58mm	5%, I	Gut full. 95% crustaceans, bivalve, fish scales.
3 Jul '96	Bay Isl.	55mm	5%, I	Gut mostly empty. Filamentous algae, crustacean debris, sand, bivalve, gastropod.
3 Jul '96	Bay Isl.	48mm	5%, I	Gut mostly empty. Algal debris, fish scales, sand, crustacean parts, 1 bivalve.
20 Sep '96	Bay Isl.	142mm	V	Gut full. 5 *Jenkinsia lamprotaenia.*

Bermuda Bream *(Diplodus bermudensis)*

Date	Station	Fork Length	Gonads*	Gut Contents
6 Jul '96	Bay Isl.	55mm	<5%, I	Branching filamentous algae, fish scales, a few crustacean parts.
6 Jul '96	Bay Isl.	50mm	<5%, I	Crustacean parts, decapod shrimps, fish scales, 1 bivalve.
6 Jul '96	Bay Isl.	45mm	<5%, I	Gut largely empty. Fish scales, crustacean parts.
6 Jul '96	Bay Isl.	48mm	<5%, I	Gut largely empty. 1 decapod shrimp, fish scales.
6 Jul '96	Bay Isl.	43mm	<5%, I	Gut largely empty. 1 decapod shrimp, crustacean parts, sand, algal debris.
8 Feb '98	Flatts	66mm	No data	Gut 20% full, mostly filamentous green algae, gastropods, crustacean parts.
8 Feb '98	Flatts	53mm	No data	Gut almost empty. Some filamentous green algae and several amphipod crustaceans.
8 Feb '98	Flatts	61mm	No data	Gut virtually empty. Some filamentous green algae.
8 Feb '98	Flatts	58mm	No data	Gut 40% full, all filamentous green algae.
8 Feb '98	Bay Isl.	61mm	<5%, I	Gut full, almost all filamentous green algae, harpacticoid copepods.

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV – ready to spawn, V – spent.

Appendix 5.1: (Continued) Gut Content and Gonad Development Observations

Silver Jenny *(Eucinostomus gula)*

Date	Station	Fork Length	Gonads*	Gut Contents
20 Sep '96	Bay Isl.	67mm	<5%, I	Stomach half full. Primarily crustacean parts, with bivalves, gastropods, sand.
20 Sep '96	Bay Isl.	88mm	40%, F, IV	Gut full, greenish brown. Sand, bivalves, foraminifera, gastropods.
20 Sep '96	Bay Isl.	74mm	<5%, I	Gut mostly empty, greenish brown. Lots of sand, bivalves, crustacean parts.
23 Jul '97	Bay Isl.	112mm	35%, F, III	Gut full. Foraminifera, gammaridean amphipods, crustacean parts, bivalves, sand, plant debris.

Band-tailed Puffer *(Spheroides spengleri)*

Date	Station	Total Length	Gonads*	Gut Contents
10 Jan '97	Bay Isl.	65mm	<5%, I	Gut 65% full, Greenish. Lots of sand, bivalves, gastropods, foraminifera, *Thalassia*, crustacean parts, spicules.
10 Jan '97	Bay Isl.	72mm	<5%, I	Gut 50% full, Greenish-brown. Sand, *Thalassia*, algal debris, crustacean parts, spicules, ostracods, gastropods.
10 Jan '97	Bay Isl.	69mm	<5%, I	Gut 70% full, Greenish-brown. Predominantly pieces of fresh *Thalassia* (3-5mm), sand, foraminifera, gastropods, ostracods, harpacticoid copepods.
10 Jan '97	Bay Isl.	58mm	<5%, I	Gut 50% full. Some sand, predominantly consistent sized (approx. 2x2mm), firm, clear cylindrical segments. Possibly the remnants of a segmented worm.
10 Jan '97	Bay Isl.	42mm	<5%, I	Gut 10% full. Sand, foraminifera, crustacean parts.
23 Jul '97	Bay Isl.	62mm	<5%, I	Gut full. Green algal debris, foraminifera, diatoms, sand, crustacean parts, seagrass litter (brown), coraline algae, ostracods.

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV - ready to spawn, V – spent.

Appendix 5.1: (Continued) Gut Content and Gonad Development Observations

Slender Filefish *(Monacanthus tuckeri)*

Date	Station	Total Length	Gonads*	Gut Contents
10 Jan '97	Bay Isl.	52mm	<5%, I	Gut 20% full, greenish. Appears to be dominated with algae, harpacticoid copepods, ostracods. Several unidentified cylindrical structures with minute green "cilia".
10 Jan '97	Bay Isl.	59mm	<5%, I	Gut empty.
10 Jan '97	Bay Isl.	54mm	<5%, I	Gut 5% full, greenish. Many of the unidentified cylindrical structures with minute green "cilia".
10 Jan '97	Bay Isl.	50mm	<5%, I	Gut almost empty. Milky with numerous transparent, ribbon-like structures - apparently remnants of the unidentified cylindrical structures reported above.
10 Jan '97	Bay Isl.	57mm	<5%, I	Gut almost empty. Milky, some foraminifera, several of the unidentified cylindrical structures with minute green "cilia", sand.
8 Feb '98	Bay Isl.	55mm	<5%, I	Gut full. Foraminifera, ostracods, serpulid worm tubes, filamentous algae, *Thalassia*.
8 Feb '98	Bay Isl.	57mm	<5%, I	Harpacticoid copepods, ostracods, foraminifera, red algae, diatoms, polychaetes.
8 Feb '98	Bay Isl.	49mm	<5%, I	Gut full. Foraminifera, ostracods, polychaetes, amphipods, harpacticoid copepods, diatoms, red algae, numerous serpulid worm tubes.

Saucer-eye Porgy *(Calamus calamus)*

Date	Station	Fork Length	Gonads*	Gut Contents
23 Jul '97	Bay Isl.	46mm	<5%, I	Sand, unidentified greenish yellow paste, foraminifera, diatoms.

Fringed Filefish *(Monacanthus ciliatus)*

Date	Station	Total Length	Gonads*	Gut Contents
10 Jan '97	Bay Isl.	59mm	<5%, I	Crustaceans, gastropods, bivalves, foraminifera, algae, sand.

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV – ready to spawn, V – spent.

Appendix 5.1: (Continued) Gut Content and Gonad Development Observations

Hogfish *(Lachnolaimus maximus)*

Date	Station	Fork Length	Gonads*	Gut Contents
23 Jul '97	Bay Isl.	620mm	15%, F, II	Gut full. Gastropods, foraminifera and bivalves, crustacean parts, urchin spines. Some seagrass litter and sediment. Species identified: *Arca zebra*, *Lytechinus variagatus*, *Cerithium* spp., *Anadara notabilis*, *Codakia* sp., *Calcinus verrilli*.

Horse-eye Jack *(Caranx latus)*

Date	Station	Fork Length	Gonads*	Gut Contents
20 Sep '96	Bay Isl.	74mm	<5%, I	Gut full. 2 *Jenkinsia lamprotaenia*.

Blue-striped Grunt *(Haemulon sciurus)*

Date	Station	Total Length	Gonads*	Gut Contents
8 Feb '98	Bay Isl.	113mm	<5%, I	Gut half full, greenish. Amphipod, numerous oligochaete setae, harpacticoid copepods, fish scales, foraminifera.
8 Feb '98	Bay Isl.	108mm	<5%, I	Gut half full. Harpacticoid copepods, amphipods, ostracods, decapod shrimps.
8 Feb '98	Bay Isl.	112mm	<5%, I	Gut almost empty. Stomatopod, harpacticoid copepods, foraminifera, sand.
8 Feb '98	Bay Isl.	53mm	<5%, I	Gut almost empty. Ostracods, amphipods, harpacticoid copepods, caprellid amphipod, oligochaete setae.
8 Feb '98	Bay Isl.	61mm	<5%, I	Gut half full. Ostracods, harpacticoid copepods, nematodes, gastropods, serpulid worm tubes, foraminifera, crustacean parts.
8 Feb '98	Bay Isl.	57mm	<5%, I	Gut almost empty. Several decapod shrimps, foraminifera, crustacean parts.
8 Feb '98	Bay Isl.	78mm	<5%, I	Gut almost empty. Ostracods, decapod crustaceans, foraminifera, harpacticoid copepods, decapod shrimp, sand.
8 Feb '98	Bay Isl.	77mm	<5%, I	Gut almost empty. Ostracods, harpacticoid copepods, foraminifera, sand, serpulid worm tubes, crustacean parts, fish scales, *Thalassia* debris.

* - Includes estimated percentage of gut cavity occupied by gonads, sex (M/F), and state of development coded as: I – immature, II – early gonadal development, III – ripening, IV – ready to spawn, V – spent.