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DOES PLANT MORPHOLOGY INFLUENCE FISH FAUNA ASSOCIATED WITH SEAGRASS MEADOWS?

by

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This thesis is submitted for the award of
Bachelor of Science (Environmental Management) with Honours
at the School of Natural Sciences, Edith Cowan University, Joondalup,
Western Australia.

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Supervisor: Dr Glenn HYNDES, Edith Cowan University

USE OF THESIS

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief, incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; contain any material previously published or written by another person except where due reference is made in the text; or contain any defamatory material.

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ABSTRACT

Three distinct seagrass habitats were sampled to determine whether fish assemblages differed between meadows comprising of different seagrass species with different morphological characteristics and whether plant morphology influences species assemblages. Three seagrass habitats consisting of *Posidonia sinuosa, Posidonia coriacea* and meadows of a mixture of *P. coriacea* and *Heterozostera tasmanica* in the Success Bank region, off the coast of Fremantle, Western Australia were selected. For each habitat, sampling was carried out using a 1m wide beam trawl over a distance of 50m at six replicated locations, on three occasions between June and September 2002. Seagrass samples were collected at each location. On each sampling, occasion a $0.025m^2$ quadrat was used to collect data on leaf area index (LAI), seagrass density and biomass, leaf width and length, and epiphytic algal biomass.

MDS ordinations and ANOSIM showed that *P. sinuosa* habitats contain a significantly different composition of fish species to *P. coriacea* habitats (with or without *H. tasmanica*). Species composition was similar in *P. coriacea* on its own or mixed with *H. tasmanica*. SIMPER showed that the differences between *P. sinuosa* and the *P. coriacea* habitats reflected the greater abundances of *Stigmatopora argus, Siphonognathus radiatus* and *Scobinichthys granulatus*, whereas *Stigmatopora nigra* was restricted to the *P. coriacea* habitats only. ANOVA demonstrated that total densities and biomass of fish and species richness were greatest in *P. sinuosa*, while little difference occurred for those variables between the two *P. coriacea* habitats. ANOVA indicated that densities of *S. argus* and *Siphamia cephalotes* did not differ between habitats, while densities of *S. radiatus* and *S. nigra* differed between *P. sinuosa* and the *P. coriacea* habitats. Densities of *S. granulatus* differed only between *P. sinuosa* and *P. coriacea* with *H. tasmanica.*

Seagrass leaf density, leaf area index (LAI), leaf width, dry seagrass biomass and dry epiphytic biomass differed significantly among the three habitats, where as leaf length did not differ between these habitats. Regression analysis indicated that leaf area index influenced species richness, fish abundance and biomass, while leaf width influenced the abundance of *S. argus* and *S. radiatus,* and leaf density influenced the abundances of *S. nigra* and *S. granulatus.* BIOENV revealed that leaf width, leaf density and LAI influenced the fish composition in the seagrass meadows. Specific plant features appear to influence the fish assemblages associated with these habitats. Plant morphology also separated size-classes of an abundant seagrass species supporting the "nursery habitat" theory.

Artificial seagrass and live animals were used in laboratory experiments to evaluate habitat preference of the most abundant seagrass-associated fish species in the absence of predators and food, and to determine whether juvenile and/or adult-sized fish exhibit a preference for a particular seagrass morphology, corresponding to those of *P. sinuosa, P. coriacea* and *H. tasmanica.* Habitat preference experiments were conducted separately for each size class in three experimental aquaria containing artificial seagrass to simulate three different seagrass habitats. Each aquarium contained two different seagrass habitats and ten fish of the same size class. Habitat preference observations were made at hourly intervals over a 10-hour period. Three replicates were conducted for each experiment. The laboratory experiments showed that both juvenile and adult-sized *S. argus* had a strong preference towards the narrow leaves of *P. coriacea* and particularly *H. tasmanica.* However, the preference was more pronounced for the juvenile fish. Thus, seagrass morphology, specifically leaf width, appears to play a significant role in the habitat selection of *S. argus*. However, the ability to avoid predation is equally dependant on their body shape, size and ability to mimic their surroundings.

The findings described in this study have shown that plant morphology appears to play a significant role in influencing fish faunal assemblages associated with seagrass meadows. The results of this study have clear implications for the environmental management of coastal marine ecosystems, highlighting the need to conserve seagrass meadows of different plant morphology to maintain the biodiversity of the fish assemblages in those regions.

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Although my name is on the cover of this thesis, it's contents would not have been possible without the generous help and support from a number of people.

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CHAPTER 1: INTRODUCTION

1.1 THE INFLUENCE OF HABITAT PREFERENCE ON FAUNAL DISTRIBUTION

Rosenweig (cited in Edwards *et al,* 2002) stated that habitat preference in animals has been extensively studied over the past 75 years and shown that many species occupy specific habitats. For example, in terrestrial environments, Edwards *et al.* (2002) indicate that high densities of feral cats in central Australian mulga woodlands are the result of dense understorey that increases their predation success rates while hunting. In aquatic environments, Johnsson *et al.* (2002) found that brown trout (*Salmo trutta*) are very protective of their gravel-based habitats, while Tanner & Deakin (2001) showed that juvenile western king prawns (*Melicertus latisulcatus*) exhibit a clear preference to bare sand over vegetative cover.

Animals display a preference for particular habitats if they provide appropriate food, protection from predation and/or contain like-wise species for reproduction (Brewer, 1994). Svärdson and Hildén (cited in Brewer, 1994) proposed that habitat selection is conducted on a two-stage basis, where an animal visits an area on basic appearance, structure or landscape (first stage). If the habitat is unsuitable upon closer inspection (second stage), the animal returns to the first stage of visiting superficially suitable habitats. Although, this model may be representative of terrestrial habitat selection, it may not represent aquatic habitat selection, specifically for settlement-sized fish and invertebrates, where environmental variables play a significant role in faunal distribution (Bell *et al.*, 1987; Jenkins & Sutherland, 1997; Jenkins & Wheatley, 1998).

The habitat selection of both aquatic and terrestrial animals is influenced by the complexity of the habitat and its ability to provide protection from predators, an abundance of food and suitable mates for reproduction (Brewer, 1994). In coastal, marine and estuarine regions, many different environments provide complex habitats. Of these habitats, seagrass meadows produce an extensive ecosystem in temperate coastal regions of the world.

1.2 SEAGRASS MEADOWS PRODUCE COMPLEX ECOSYSTEMS

Seagrass meadows are a dominant habitat in coastal regions worldwide and due to their physical, chemical and biological effects on habitats, play a significant role in the processes and resources of near-shore coastal ecosystems (Walker & McComb, 1992). These roles include: a reduction in water movement and sediment stabilisation (Fonseca *et al.*, 1982); the collection and binding of organic detritus in sediments (Scoffin, 1970; Walker & McComb, 1985); high rates of primary production (Hillman *et al.*, 1989); contribution of calcium carbonate by epiphytic deposition to sediments (Walker & Woelkering, 1988); and play essential roles in the trapping and recycling of nutrients (Hemminga *et al.*, 1991). As a result of these roles, invertebrate densities and secondary production within seagrass meadows (along with algal reefs) are often significantly greater than adjacent unvegetated habitats (Orth & Heck, 1980; Heck *et al.*, 1989; Ferrell & Bell, 1994; Jenkins *et al.*, 1997; MacArthur & Hyndes, 2001).

1.3 THE FAUNAL ASSEMBLAGES OF SEAGRASS MEADOWS

Seagrass meadows are known to support large and differing faunal assemblages (Heck & Orth, 1980; Kikuchi, 1980; Bell & Pollard, 1989; Howard *et al.*, 1989) which can be divided into four main groups: infauna, motile epifauna, sessile epifauna and epibenthic fauna (Kikuchi, 1980; Howard *et al.*, 1989). The infauna consists of animals living in the sediment and amongst the seagrass rhizomes e.g.

polychaetes and nematodes; motile epifauna are those small, mobile animals associated with the sediment surface or amongst seagrass stems or leaves e.g. amphipods and gastropods, and sessile epifauna comprises permanently attached animals living on the seagrass leaves or stems e.g. bivalves and sponges (Kikuchi, 1980; Howard *et al.*, 1989). Epibenthic fauna incorporates the larger, more mobile animals that are associated with seagrass meadows rather than individual seagrass plants e.g. fish and cephalopods (Kikuchi, 1980; Howard *et al.*, 1989).

Numerous studies have shown that seagrass meadows, support greater fish species richness and abundance than bare substrate (Kirkman *et al.*, 1991; Connolly, 1994; Edgar *et al.*, 1994; Edgar & Shaw, 1995a; Jenkins *et al.*, 1997; Gray *et al.*, 1998; Jenkins & Wheatley, 1998; Hindell *et al.*, 2000a). Fish are closely associated with seagrass meadows for two key reasons. Firstly they provide suitable protection from predators; and secondly, they provide substantial amounts of food (Heck & Orth, 1980; Kikuchi, 1980; Bell & Pollard, 1989; Howard *et al.*, 1989). Numerous fish species, including many that are economically important, use seagrass meadows during the juvenile stage of their life cycle, before migrating to other habitats before the onset of maturity (Pollard, 1984; Bell & Pollard, 1989). This finding has led researchers to conclude that seagrass meadows are extremely important as nursery habitats for juvenile fish (Heck & Orth, 1980; Jenkins *et al.*, 1997; Hindell *et al.*, 2000a). The utilisation of seagrass meadows by juveniles is considered to increase the growth rates and survival of the early life stages of many fish species (Heck & Orth, 1980; Jenkins *et al.*, 1997; Hindell *et al.*, 2000b).

1.4 THE INFLUENCE OF SEAGRASS COMPLEXITY ON FISH ASSEMBLAGES

Seagrass complexity has been suggested to influence food abundance and predation levels within seagrass meadows. Heck and Orth (1980) proposed that variations in seagrass complexity (plant surface area), could influence predation rates and therefore influence faunal assemblages. They indicated that, as seagrass complexity increased, the survival rate of fishes (predominantly juveniles) increased through reduced predation success by larger fishes. However, if vegetative complexity becomes too great, faunal movement within the canopy could be impeded and therefore species richness and fish abundance could decrease (Heck & Orth, 1980). To support this, Kendrick and Hyndes (2003) indicated that a species of Syngnathidae (*Stigmatopora argus*) migrates from a narrow-leaf seagrass to a broad-leaf seagrass as it approaches maturity. As the juveniles increase in size and change colour/pattern, their ability to remain camouflaged and avoid predation decreases, making migration to different habitats important for their survival (Steffe *et al.*, 1989; Kendrick & Hyndes, 2003).

Since fish in seagrass consume mainly planktonic and epifaunal crustaceans and molluscs, and invertebrate diversity and abundance can be influenced by seagrass leaf morphology (Edgar & Shaw, 1995b), seagrass structure is likely to influence fish community structures as fish will congregate within meadows with high food abundance (Orth *et al.*, 1984; Worthington *et al.*, 1991). For example, greater invertebrate species richness in narrow-leaf versus wide-leaf seagrass meadows in south-eastern Australia were found to correspond with greater fish abundance in the former habitat (Jenkins & Sutherland, 1997).

In contrast to Heck & Orth (1980), studies by Bell *et al.* (1987) and Jenkins & Sutherland (1997) have shown that juvenile fish do not discriminate between seagrass habitats of varying structural complexity. Bell *et al.* (1987) conducted small-scale habitat preference experiments using artificial seagrass of differing leaf densities in areas of bare sand. The authors concluded that high abundances of juvenile fishes in the artificial seagrass were not due to habitat preference based on meadow complexity of seagrass or predation. Instead, they concluded that juveniles recruited arbitrarily into any shelter regardless of seagrass complexity (Bell *et al.*, 1987).

It is the combination of these conflicting arguments, which indicates that seagrass complexity appears to play an integral part in the habitat preference of fish assemblages and that fish species exhibit a preference for a specific seagrass habitat. However, many of these studies examining fish habitat preference in seagrass meadows, have not separated seagrass species or have only concentrated on one species. Those studies have therefore considered seagrass as a single uniform habitat. Only a few studies have compared fish assemblages in seagrass meadows comprising various seagrass species (Young, 1981; Stoner, 1983; Middleton *et al.*, 1984; Hyndes *et al.*, 1998) and have concluded that specific and distinct seagrass habitats support their own unique suite of fish species.

1.5 WESTERN AUSTRALIA'S SEAGRASS MEADOWS

Extensive seagrass meadows cover much of the West Australian coastal region, which contain 10 genera and 25 individual species of seagrass that contribute to one-third of the global seagrass flora (Kirkman & Walker, 1989; Kirkman & Kirkman, 2000). The Success Bank region, southwest of Fremantle, is characterised by a high diversity of seagrass species that form extensive meadows. These meadows are known to support large faunal assemblages (Hyndes *et al.*, 1998). The sedimentary sands found in Success Bank are mined for their calcium-rich material that is used in commercial lime production by Cockburn Cement Ltd (Lord, 2000). The area is also used for various recreational marine activities including fishing, SCUBA diving and boating activities throughout the year (SMCWS, 1996).

The most abundant species of seagrass within the Success Bank region are *Amphibolis griffithii*, *Posidonia sinuosa*, *Posidonia coriacea* and *Heterozostera tasmanica*. Each species has different plant morphology and meadow structure (Kirkman & Walker, 1989). *Amphibolis griffithii* forms a dense canopy above an open under-storey of woody terete stalks, which support clusters of leaves (Huisman, 2000). *Posidonia sinuosa*, *P. coriacea* and *H. tasmanica* all have strap-like leaves, which differ in their width and length. *Posidonia sinuosa* meadows are characterised by broad leaves, approximately 8-11mm wide and 1200mm in length, which form uniformly dense meadows (up to 2002 shoots per m^2) and produce 75–100% cover (Cambridge, 1999; Kuo & den Hartog, 2001). *Posidonia coriacea* has narrow (approx. 5mm) leaves, approximately 500mm in length which grow in relatively sparse clumps producing 25-50% seagrass cover (Huisman, 2000). In comparison, *H. tasmanica* produces much narrower (1–3mm) and shorter leaves (approximately 100mm), which are razor-like in shape (Huisman, 2000). Monospecific meadows of *H. tasmanica* do not exist within the region as it is considered a colonising species (Kirkman & Kirkman, 2000; Walker *et al.*, 2001). The colonisation generally occurs in "blow-out" areas of bare sand within *Posidonia* spp. meadows caused by extreme storms (Kirkman & Kirkman, 2000). On Success Bank, *H. tasmanica* is found predominantly in association with *P. coriacea* meadows. This association can greatly alter the appearance and leaf cover of a meadow (Kirkman & Kirkman, 2000).

Previous studies examining fish assemblages associated with seagrass habitats within the Success Bank region, have demonstrated that different seagrass habitats contain their own unique suite of fish species (Hyndes *et al.*, 1998; Hyndes, 2000; MacArthur & Hyndes, 2001; Kendrick & Hyndes, 2003). For example, Hyndes (2002) and MacArthur & Hyndes (2001) found that larger bodied odacid species, such as *Odax acroptilus*, were restricted to stands of *A. griffithii*. In contrast, smaller fish, such as *Neoodax balteatus*, were found in stands of *P. sinuosa* (MacArthur & Hyndes, 2001). Kendrick & Hyndes (2003) found that the pipefish species *Stigmatopora nigra* was closely associated with meadows consisting of *P. coriacea* and *H. tasmanica*, while juvenile *S. argus* migrate from *P. coriacea* meadows to *P. sinuosa* prior to reaching maturity. These results would suggest that fish species show a preference to seagrass habitats that provide the greatest amount of protection from predators throughout their life cycle.

1.6 AIMS AND OBJECTIVES OF PROJECT

The overall aim of this project was to determine whether seagrass structure influences fish assemblages associated with seagrass meadows. In order to examine this, the study has focussed on the seagrass species *P. sinuosa*, *P. coriacea* and *H. tasmanica*, which have strap-like leaves, but vary in leaf width and height. These species form three discrete habitats in the Success Bank region: monospecific *P. sinuosa*, monospecific *P. coriacea* and a mixed habitat consisting of *P. coriacea* and *H. tasmanica*.

The first part of this study used field sampling to examine the influence of habitat structure on fish assemblages with the following specific aims to determine:

- whether the species richness, densities, biomass and species composition of fish assemblages differ amongst three specific and distinct seagrass habitats; and
- whether these variables were influenced by seagrass morphological characteristics and/or biomass of epiphytic algae within each habitat.

The second part of this study used artificial seagrass and live animals in laboratory experiments to evaluate habitat preference of an abundant seagrass-associated fish species in the absence of predators and food. Since fish may migrate to different habitats at various stages of their life cycle (MacArthur & Hyndes, 2001; Kendrick & Hyndes, 2003), the experiments have incorporated two size classes of fish. The specific aim of this part of the study was to determine:

- whether juvenile and adult-sized fish exhibit a preference for particular seagrass morphology, corresponding to those of *P. sinuosa*, *P. coriacea* and *H. tasmanica*.

1.7 PROJECT SIGNIFICANCE

An understanding of the variables that influence habitat preference of fish species associated with seagrass meadows is significant to the field of environmental management for various reasons. Large areas of seagrass have been lost through natural and human induced factors including extreme storms, natural die-off, water eutrophication, sand-dredging and increased coastal development (Kirkman *et al.*, 1991). Cockburn Sound in Western Australia has been subjected to intense seagrass removal over the past 30 years, with more than 4,000 ha being lost through shell sand dredging, industrial discharge and the expansion of port facilities (Kendrick *et al.*, 2002). Furthermore, other areas along the coastline of the Perth Metropolitan region have lost seagrass meadows as a consequence of urban development (Kendrick *et al.*, 2002). Since different seagrass species with different plant structures may support different faunal assemblages, the targeted removal of areas of seagrass may have varying, and possibly detrimental effects, on coastal faunal assemblages. The understanding of how seagrass structure influences fish habitat selection will help managers predict the consequences of seagrass loss on biodiversity and secondary production. Furthermore, such understanding will help in the decision-making processes for the types of seagrasses used in seagrass transplanting programmes.

In recent years, studies have been conducted to examine the faunal assemblages associated with seagrass meadows and unvegetated areas (Connolly, 1994; Edgar *et al.*, 19[illegible] Edgar & Shaw, 1995a; Jenkins *et al.*, 1997). While many of them have used artificial seagrass to determine possible influences of habitat preference (Heck & Thoman, 1981; Bell & Westoby, 1986a, 1986c, 1986b), there are numerous confounding factors associated carrying out experiments in the natural environment. To fully understand the underlying factors that may influence fish habitat selection, a laboratory experimental approach needs to be considered to eliminate some of the confounding factors seen in natural environment. A small number of marine-based studies have been conducted in this manner (Magnhagen, 1988; Gill & Humphries, 1995; Tanner & Deakin, 2001), however, even these only compared seagrass meadows versus bare sand habitat preferences. The approach used in the present study uses laboratory experiments to examine the habitat preference of fish associated within seagrass meadows that contain strap-like leaves with differing leaf width and height. The selection of this specific plant morphology type is significant as a large proportion of seagrass meadows surrounding the West Australian coastline, consists of species with strap-like leaves (Kirkman & Walker, 1989).

1.8 THESIS COMPOSITION

This thesis will be divided into four main chapters. The current chapter (Introduction) has introduced the major components of this study. It has provided a general summary on the faunal assemblages in seagrass, habitat preferences of fishes, and the various factors that may influence their diversity and abundances within seagrass meadows. The significance and specific aims of this study have also been described. Chapter 2 (Methods and Materials) will detail the sampling techniques used in the field sampling and the experimental design used for the laboratory experiments. The chapter will also describe the statistical procedures used to analyse the data. Chapter 3 (Results) will present the findings of the fish and seagrass field sampling and the laboratory experiments. Finally, Chapter 4 (Discussion) will discuss each of the study's components, in light of previous research and their relevance to fisheries and seagrass management.

CHAPTER 2: METHODS and MATERIALS

2.1 THE INFLUENCE OF SEAGRASS HABITAT AND STRUCTURE ON FISH ASSEMBLAGES

The aims of this part of the study were to determine whether the composition of fish assemblages differed amongst three seagrass habitats and whether they were influenced by seagrass morphological characteristics and the biomass of epiphytic algae within each habitat.

2.1.1 Environmental Setting

Field sampling was conducted within the Success Bank region of Western Australia (32° 5' S, 115° 42' E) (Figure 2.1). Success Bank is an open expanse of water extending from the northern side of Mewstone Rock to just south of Fremantle Harbour. The area is composed of unconsolidated carbonate sands and has been formed predominantly from the onshore transportation of sands over the past 7,500 years (Lord, 2000). Monthly ocean temperatures in the region range between 17°C in winter to 22°C in summer (Hyndes & Potter, 1996; Cambridge, 1999), while daylight hours range from 11.0 hours in June to 15.2 hours in December (Hyndes & Potter, 1996) (Figure 2.2).

The Success Bank region has a diverse range of seagrass species, although it is dominated by *P. coriacea*, *P. sinuosa* and *A. griffithii* meadows (Lord, 2000). *Heterozostera tasmanica* also occurs in extensive patches, particularly in association with *P. coriacea* meadows (Lord, 2000). The meadows within Success Bank are separated by large expanses of unvegetated coarse shell-sand (Lord, 2000).

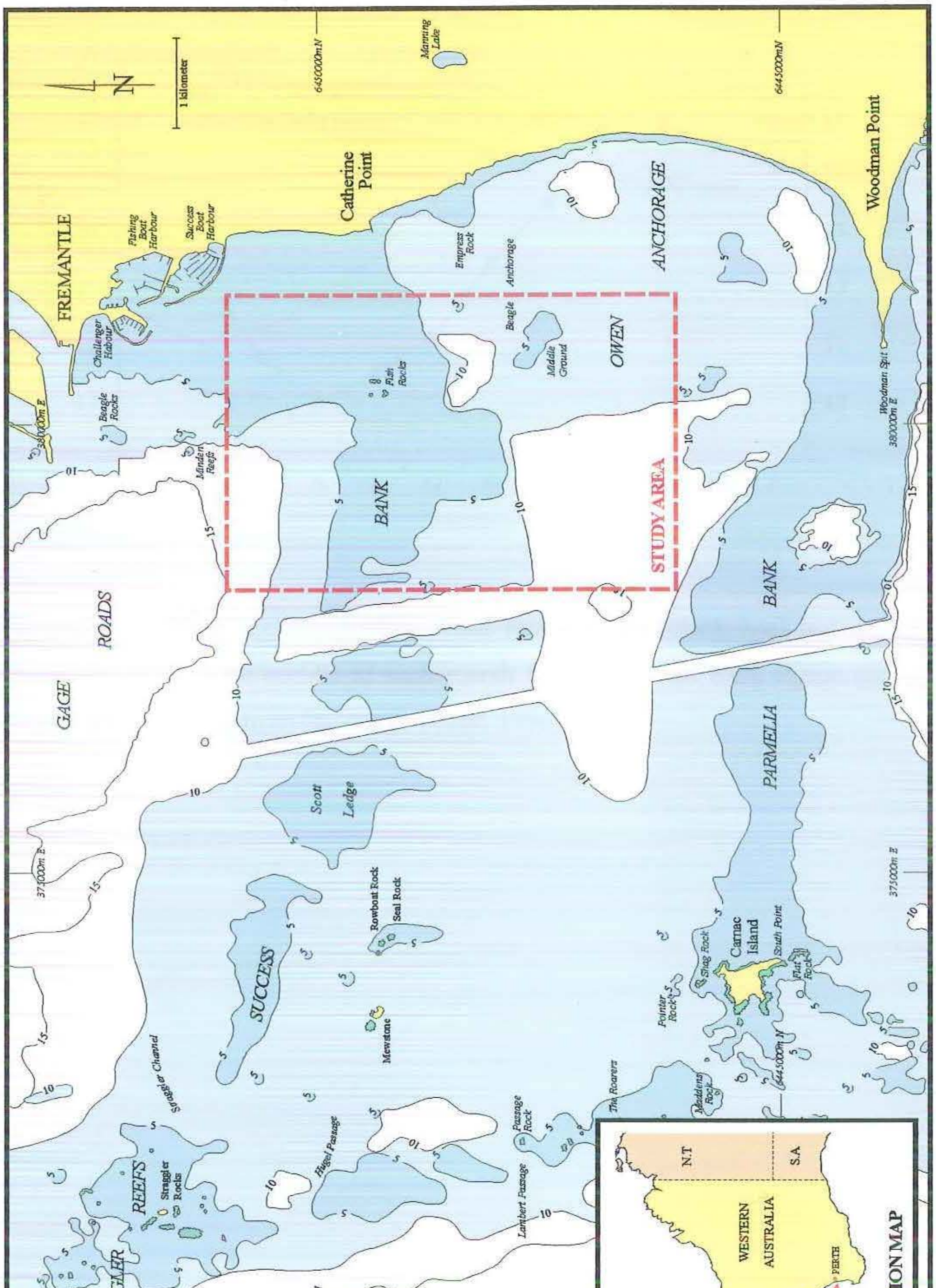


Figure 2.1 Map of the Success Bank region and the limits of the study area.

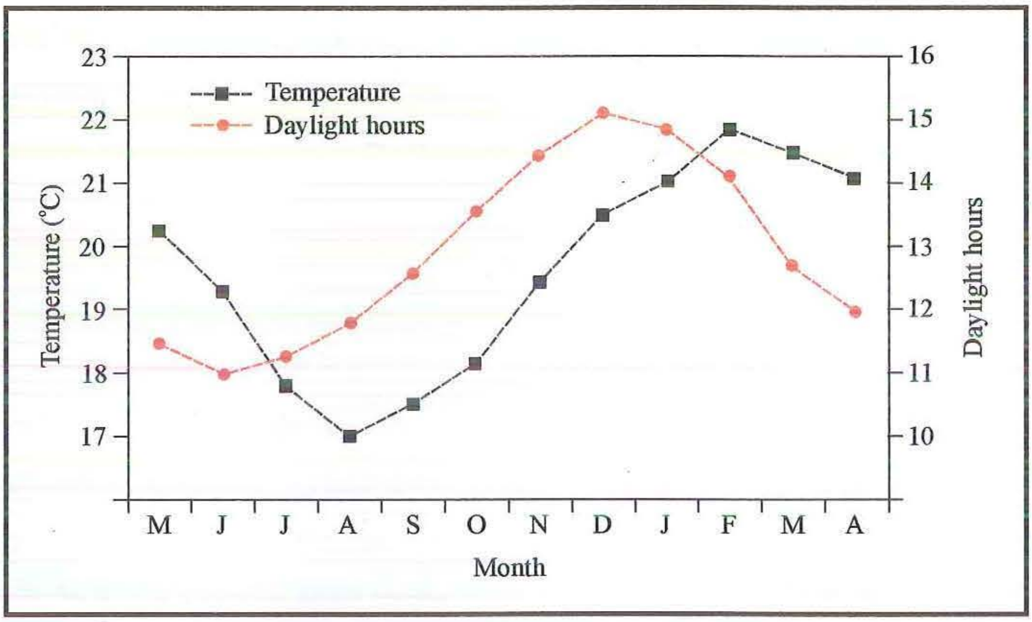


Figure 2.2 Mean monthly surface water temperatures (black line) and daylight hours (red line) in the middle of each month for the Success Bank region and the project area (adapted from Hyndes & Potter, 1996)

The area has seen extensive seagrass removal through shell sand dredging over the past 20 years (Lord, 2000). Apart from commercial sand dredging, the area is used for various recreational purposes such as fishing, SCUBA diving and boating activities (SMCWS, 1996).

2.1.2 Seagrass Habitat Selection

Three seagrass habitat types were chosen on the basis that they comprised one or more of the three seagrass species: *Posidonia sinuosa*, *Posidonia coriacea* and *Heterozostera tasmanica* (Plate 2.1). These three species of seagrass produce extensive meadows within the Success Bank region and throughout larger areas of Western Australia's coastal areas (Kirkman & Kirkman, 2000). Meadows of pure *P. sinuosa* and *P. coriacea* are common in the region (Kendrick *et al.*, 2002) and were considered as two distinct habitats. Since preliminary observations indicated that *H. tasmanica* occurs almost entirely in association with *P. coriacea*, a separate habitat containing these two seagrass species was sampled. Thus, the three seagrass habitats chosen were meadows consisting of pure *P. sinuosa*, meadows of pure *P. coriacea* and meadows of both *P. coriacea* and *H. tasmanica*, to be referred to as the mixed habitat throughout this thesis.

Suitable sample sites were identified through a combination of SCUBA divers and towing two swimmers behind a vessel to examine seagrass habitats. Areas representing the three habitats were marked with a GPS. The suitability of sampling sites was based on whether they were representative of each seagrass habitat, i.e. meadows of pure *P. sinuosa* and *P. coriacea* and mixed meadows of both *P. coriacea* and *H. tasmanica*. Suitable sites needed to greater than 50m long and 5m wide and clear of submerged objects, such as rocks. The six sampling sites chosen for each seagrass habitat were used for both the fish trawling and seagrass sampling.

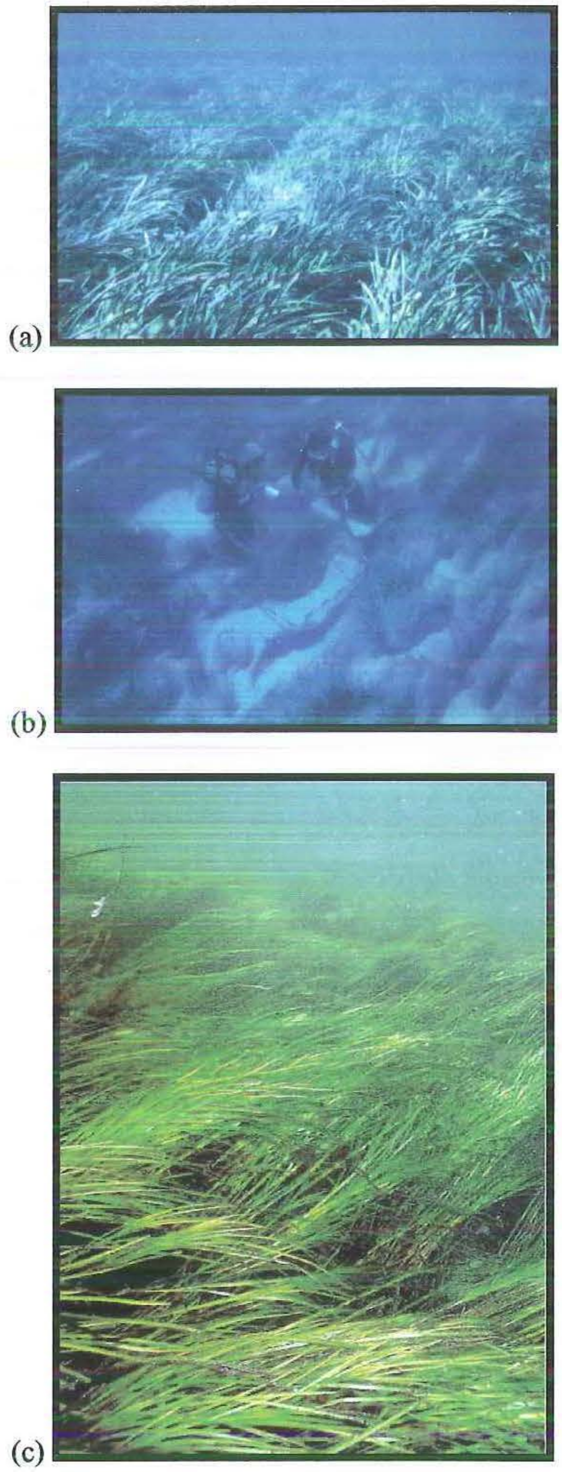


Plate 2.1 The morphological characteristics of (a) *Posidonia sinuosa* (D. Walker), (b) *Posidonia coriacea* (G. Kendrick) and (c) *Heterozostera tasmanica* (Edgar, 2002), the three seagrass species examined in this study.

The majority of suitable sampling sites for the *P. coriacea* and mixed habitats were located in the area around Fish Rock, a fully submerged rock outcrop (32° 04' 45"S, 115° 43' 50"E) (Figure 2.3). This area was found to have extensive areas of pure *P. coriacea* meadows and meadows of mixed *P. coriacea* and *H. tasmanica.* Sites selected for the *P. sinuosa* sampling were located south of Fish Rock (Figure 2.3).

2.1.3 Field Sampling for Fish

Fish in each of the three seagrass habitats were sampled using a beam trawl on the 21st of June, 13th of August and 27th of September 2002. The three sampling occasions were separated by approximately six weeks. On each sampling occasion, all habitats were sampled between 08:00 and 17:00 hours, with the sequence of sampling randomly chosen. All trawls were orientated north to south, except three, which had an east to west orientation (Appendix 1). Six replicate samples from each habitat were taken on each sampling occasion.

Sampling was conducted using a 1m wide by 0.5m high beam trawl consisting of 2.5mm mesh in the body and 1.0mm in the cod-end (Plate 2.2). The trawl was attached to a rope bridle, with its length set at four times the vertical water depth. Before the commencement of sampling, the effectiveness of the trawl to sample the benthic region was determined by placing dots of white paint on the running skis. Appropriate adjustments were made to the configuration of the trawl to ensure it was sampling effectively. Each trawl was towed over a 50m distance behind a 5m vessel with marker buoys identifying the start and finish of each trawl. Following retrieval, the net was emptied and all fish were placed into a bucket of "ice slurry". The fish remained on ice for transportation back to the laboratory and frozen for subsequent processing.

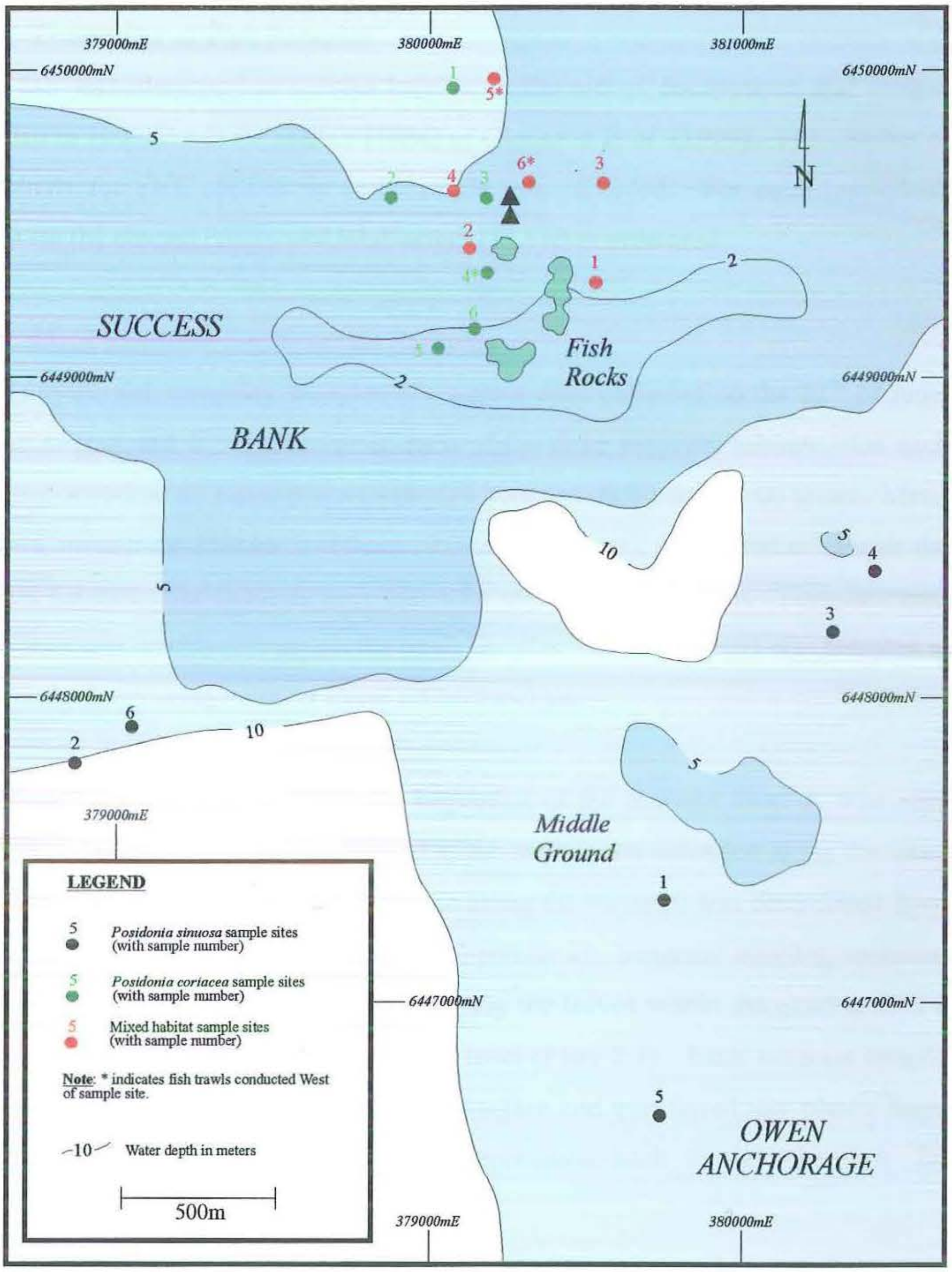


Figure 2.3 Map showing the sampling locations for each seagrass habitat. Both fish and seagrass samples were collected from the same location between June and September 2002.

2.1.4 Processing of Fish Samples

Each fish was identified to species level with the aid of descriptions and images provided in Hutchins & Swainston (1986) or Gommon *et al.* (1994). The number of individuals for each species in each sample was recorded. For each individual, weight (to the nearest 0.01g) and total length (TL) were measured.

2.1.5 Field Sampling for Seagrass Samples

Similar to the fish sampling, samples of seagrass were collected on the 22nd of June, 22nd of August and 2nd of October in each of the three seagrass habitats. On each sampling occasion, all habitats were sampled between 08:00 and 17:00 hours. Metal quadrats, measuring 250mm x 250mm ($0.0625m^2$ in area), were used to sample the seagrass habitats. Six quadrats were taken for each seagrass habitat. The placement of quadrats was stratified to match the trawl samples, i.e. one quadrat was sampled at a randomly determined location along a 50m trawl line.

The vessel's anchor was placed at the beginning of the transect line. A 50m rope (marked at 5m increments) was attached to the anchor and extended along the trawl line. The location of each sample (distance along the transect) was determined from random number tables to the nearest 5m (Appendix 2). Seagrass samples, collected using SCUBA divers, were removed by cutting the leaves within the quadrat with a pruning saw or metal scissors, at sediment level (Plate 2.3). Each seagrass sample was placed into a mesh bag, returned to the surface and transferred into plastic bags. Samples were then placed on ice for transportation back to the laboratory for processing.

2.1.6 Processing of Seagrass Samples

The total weight and number of leaves within each sample was recorded. The leaf length of 20 randomly selected leaves was measured to the nearest 1.0mm. Leaf width was measured at 50mm intervals along the length of each leaf (to the nearest 0.5mm). This would enable a mean width to be calculated for each of the 20 leaves selected. Where more than one seagrass species was present, 20 leaves from each species were selected. All leaves in the sample were then scraped to remove epiphytic material on both sides of the leaf using double-sided razorblades. After all epiphytic material had been removed, each sample of seagrass was re-weighed and the weight recorded.

The seagrass leaves were then placed into oven-dried, pre-weighed brown paper bags for drying. Each sample of scraped epiphytic material was transferred into oven-dried, pre-weighed crucibles. All crucibles and paper bags were placed into a drying oven, set at 60°C for 48 hours to determine dry weight. After drying, both the crucibles and paper bags were placed into a desiccator for 24 hours to cool, after which, dry weights for both epiphytic material and seagrass leaves were recorded.

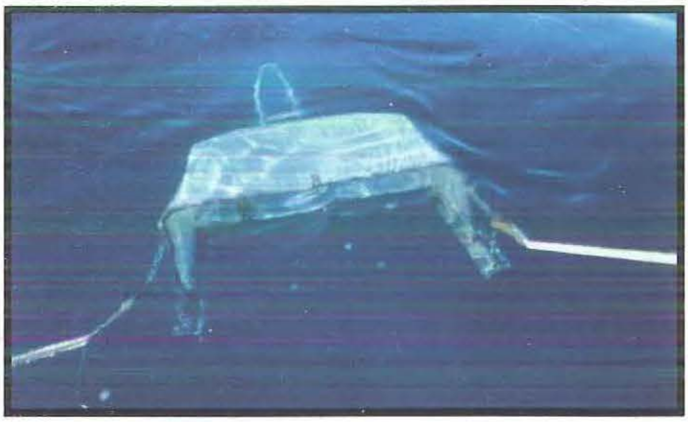


Plate 2.2 The beam trawl used to collect fish samples from each of the three seagrass habitats (G. Hyndes).

Plate 2.3 SCUBA diver collecting seagrass samples (R. Kenna)

2.1.7 Statistical Analysis

Data were initially tested for homogeneity using Levene's Test within SPSS. When the test showed that variances between variables were heterogeneous, data were transformed using Log_{10} (x+1) (Table 2.1). If data remained heteroscedatic after transformation, significance was accepted at the 0.01 probability level to minimise Type 1 errors (Sokal & Rohlf, 1995).

Difference in the species richness, total abundance and total biomass of fish between habitats and months and were examined using a two-way analysis of variance (ANOVA). ANOVAs were also conducted on densities of the five most abundant fish species collected during the sampling, as well as the seagrass variables (seagrass density, leaf width, leaf length, leaf area index, dry seagrass biomass and dry epiphytic biomass). Habitat was considered a fixed variable, while the month was considered a random variable. Further analysis was conducted using one-way ANOVAs and Tukey's test where there were significant habitat affects. Where significant interactions occurred between the main effects, one-way ANOVAs were carried out for each sampling occasion. Since the study was concerned mainly with differences between habitats, emphasis has been placed on this effect in the ANOVA results.

Table 2.1 Results of Levene's Homogeneity of Variance tests for each of the fish and seagrass variables.

	Untransformed Data			
	df1 (df2)	F Value	P Value	Variance Homogeneous
Fish Species Richness	8 (45)	2.054	0.061	Yes
Total Fish Abundance	8 (45)	3.517	0.003	No
Total Fish Biomass	8 (45)	3.640	0.002	No
Leaf Length	8 (45)	3.947	0.003	No
Leaf Width	8 (45)	2.847	0.012	No
Leaf Area Index	8 (45)	1.851	0.092	Yes
Leaf Density	8 (45)	0.854	0.561	Yes
Total Seagrass Biomass (Dry)	8 (45)	1.095	0.384	Yes
Total Epiphytic Biomass (Dry)	8 (45)	4.085	0.001	No

	Transformed Data - Log 10 (x+1)			
	df1 (df2)	F Value	P Value	Variance Homogeneous
Fish Species Richness	Data not re-tested			
Total Fish Abundance	8 (45)	1.525	0.176	Yes
Total Fish Biomass	8 (45)	1.579	0.158	Yes
Leaf Length	8 (45)	3.251	0.000	No
Leaf Width	8 (45)	1.367	0.000	No
Leaf Area Index	Data not re-tested			
Leaf Density	Data not re-tested			
Total Seagrass Biomass (Dry)	Data not re-tested			
Total Epiphytic Biomass (Dry)	8 (45)	2.286	0.038	Yes

Multiple step-wise regression analyses were conducted on data to determine relationships between the fish variables (species richness, total fish abundance, total fish biomass), densities of the most abundant fish species and the seagrass variables (seagrass density, leaf width, leaf length, leaf area index, dry seagrass biomass and dry epiphytic biomass). The fish variables were considered the dependent variables, while the seagrass variables were considered independent variables (Sokal & Rohlf, 1995; Fowler *et al.*, 1998).

Non-metric multidimensional scaling (nMDS) analyses were conducted using the PRIMER (Plymouth Routines in Multivariate Ecology Research) statistical package (Clarke & Warwick, 1994). The total abundance calculated for each species in each replicate were square-root transformed prior to the construction of a similarity matrix using the Bray-Curtis co-efficient (Clarke & Gorley, 2001). The Bray-Curtis co-efficient is regarded as the most robust and appropriate measure for ecological species abundance analysis (Clarke & Warwick, 1994).

Ordination plots were produced from these matrices to provide a visual representation of the patterns of similarity amongst the replicates for each habitat on each sampling occasion. Points that were close together represent samples that are (very) similar in composition, while points further apart represent less similar assemblages (Clarke & Gorley, 2001). Two-way crossed Analysis of Similarities (ANOSIM) was used to determine whether there was a significant difference in the species composition among habitats and months (Clarke & Warwick, 1994).

Where a significant difference occurred between seagrass habitats, a SIMPER analysis was conducted to identify the fish species that contributed most to the possible dissimilarity between those seagrass habitats. The analysis calculates the average dissimilarity betweens all pairs of grouped samples and then breaks down the average into the separate contributions made by each species (Clarke & Warwick, 1994).

Biota and/or Environmental matching (BIOENV) analyses were conducted using the PRIMER statistical package (Clarke & Warwick, 1994). BIOENV selects the environmental variables (in this case, the seagrass variables) which best explains community patterns (the species composition of fish), by maximising a rank correlation between their respective similarity matrices (Clarke & Gorley, 2001). Fish data collected during August were not analysed due to the low fish abundances. Bubble plots overlaying the MDS plots of species composition for June and September, were produced for each of the six seagrass variables.

2.2 THE EVALUATION OF HABITAT PREFERENCE OF AN ABUNDANT SEAGRASS FISH SPECIES

The second part of this study was conducted using laboratory experiments. The aim of the experiment was to assess whether dominant fish species exhibit a preference for particular seagrass leaf widths, represented by *Posidonia sinuosa, Posidonia coriacea* and *Heterozostera tasmanica.*

Artificial seagrasses have been used in a number of habitat preference studies in both natural and laboratory situations as they can reduce variability of habitat structure (Bell *et al.*, 1985). Significant studies using artificial seagrass beds to assess habitat preference include Worthington *et al.* (1991), who used artificial seagrass to investigate fish larvae settlement, Gill and Humphries (1995), who used artificial seagrass to examine habitat choice by members of the Gobiidae (goby) family and by Lee *et al.* (2001), who examined the importance of seagrass canopy to associated fauna by comparing assemblages in both natural and artificial seagrass meadows. In the present study, a series of experimental aquaria containing artificial seagrass were used to simulate three different seagrass habitats. The habitat preference of a specific fish species was monitored over a determined time-period.

2.2.1 Construction of Artificial Seagrass Units

The artificial seagrass units were designed to resemble the natural characteristics of the three seagrass species sampled in the field: *P. coriacea*, *P. sinuosa* and *H. tasmanica*. The artificial seagrass blades were constructed from 425mm lengths of olive-green curling ribbon cut to produce three distinct widths: 2.0mm (*H. tasmanica*), 4.0mm (*P. coriacea*) and 7.0mm (*P. sinuosa*). The leaf width was based on the mean leaf width of the three species collected during the June and August field sampling. Two blades were joined together to represent a single shoot and then attached to a plastic frame, measuring 350 x 400mm, with a 50 x 50mm aperture. Sixty-four shoots (128 leaves) were attached to each plastic frame to produce a seagrass unit that simulated a bed of dense seagrass (Plate 2.4). This density was derived from the average shoot density determined from the June and August field sampling of the three seagrass habitats.

2.2.2 Set-Up of Experimental Fish Aquaria

The experiments were conducted in three rectangular glass aquaria measuring 0.90m long, 0.46m high and 0.35m wide with a capacity of 145 litres. Two seagrass units (one representing each seagrass species) were placed on the bottom of each aquarium, one at each end. Sieved beach sediment was placed on the bottom of each aquarium to a depth of 25mm, covering the mesh frames (Plate 2.5). Three aquaria were set up, with each aquarium containing one of the three pair-wise combinations of seagrass: *P. coriacea* versus *H. tasmanica*, *P. sinuosa* versus *P. coriacea* and *P. sinuosa* versus *H. tasmanica*. Seawater (35 ppt salinity) was added to the aquaria to a depth of 0.39m and was kept at a constant temperature of 20°C throughout the experiment. Water was oxygenated using one air stone at each end of the tank to reduce possible oxygen related influences in fish distributions. Each aquarium had overhead light supplied by a single fluorescent tube.

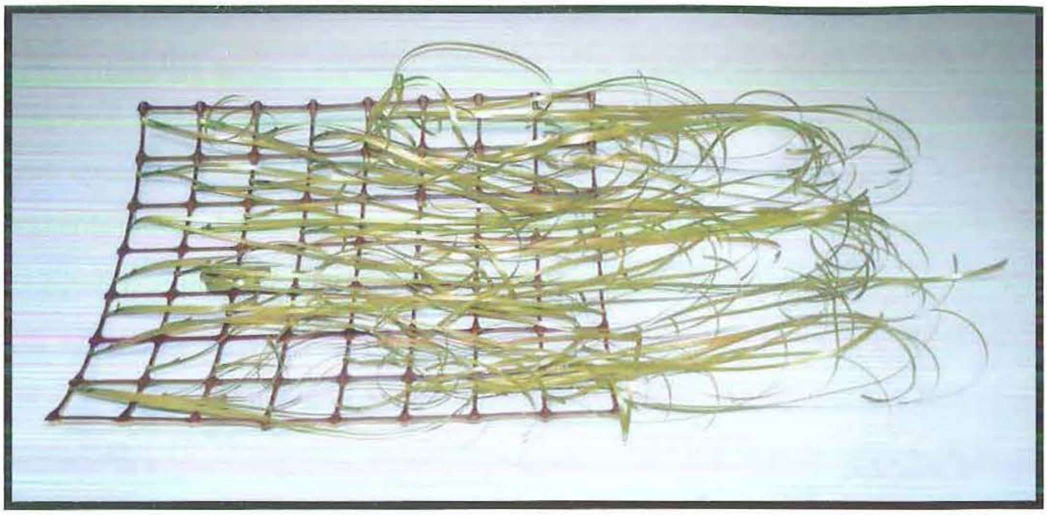


Plate 2.4 An example artificial seagrass units, in this case *Posidonia sinuosa* used in the laboratory experiments to examine habitat preference of an abundant seagrass fish species.

Plate 2.5 One of the three experimental aquaria; complete with *Posidonia sinuosa* (left) and *Posidonia coriacea* (right) artificial seagrass, used in the laboratory experiments to examine habitat preference of an abundant seagrass fish species.

2.2.3 Justification for Species Used in Experiment

The selection of the spotted pipefish, *Stigmatopora argus,* was based on the results from the June and August field sampling, which showed *S. argus* to be the most abundant species collected. The large abundances of this species in seagrass environments have also been recorded by Hyndes *et al.* (1998) and Kendrick & Hyndes (2003). This latter study indicated that adult and juvenile *S. argus* occupy different seagrass habitats (Kendrick & Hyndes, 2003). The authors indicate that juvenile *S. argus* occur predominantly in meadows comprising the narrow leaves of *P. coriacea* and *H. tasmanica* meadows before exhibiting a size-related shift to meadows consisting of the wider leaves of the *P. sinuosa* meadows.

Stigmatopora argus (Plate 2.6) belongs to the Syngnathidae family. These fish are characterised by bony plates or scutes along their bodies (Gommon *et al.*, 1994; Kuiter, 1999; Edgar, 2000). Most species in this family are slow moving, relying considerably on camouflage for survival among seagrass meadows and seaweed in which they live. The species has a long snout and long thin prehensile tail, which it often uses to wrap around objects (Gommon *et al.*, 1994). Body colouration for both males and females varies between bright green and grey with small dark ocelli (spots) covering the length of the back (Gommon *et al.*, 1994; Edgar, 2000). This species can grow to a maximum size of 260mm (Kuiter, 1999) and reaches maturity at 120mm in length (Kendrick & Hyndes, 2003).

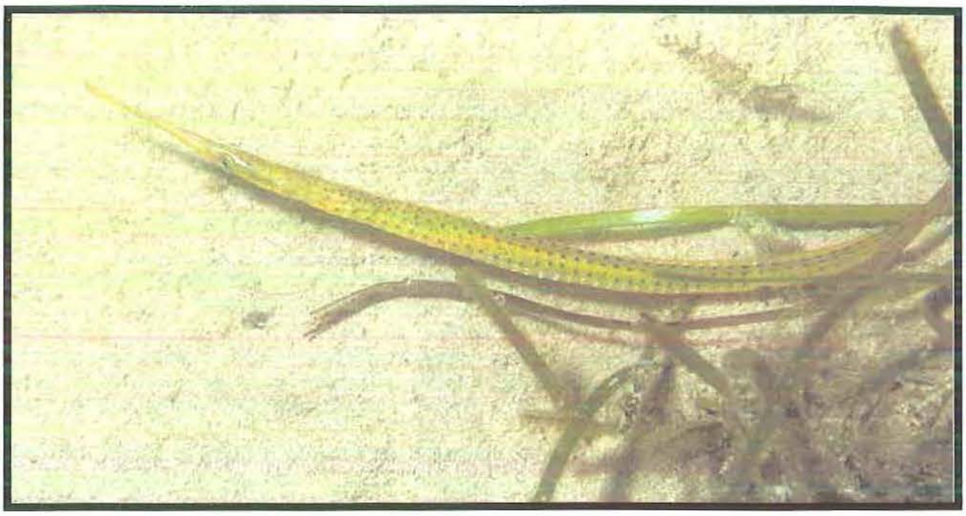


Plate 2.6 Adult *Stigmatopora argus* (spotted pipefish) (Edgar, 2000).

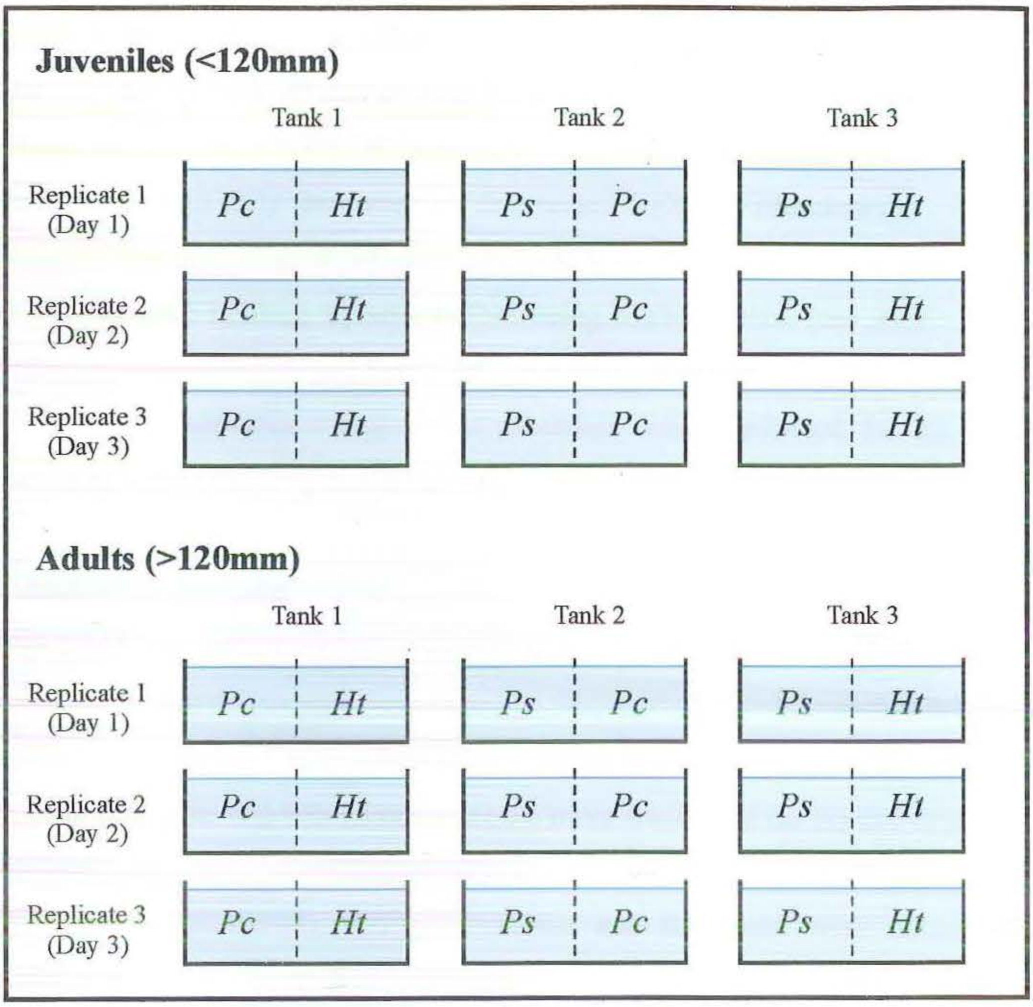
2.2.4 Animal Capture and Maintenance

Fish used in the experiment were caught using a beam trawl towed behind a vessel as described in section 2.1.3, although the distance of each trawl was increased to approximately 200m. Of the fish captured, 150 juveniles (<120mm) and 150 adults (>120mm) were retained for the experiment. All fish were kept alive in covered and aerated, plastic bins and subsequently transferred into holding tanks in the laboratory. Fish were fed twice daily on a combination of live juvenile *Artemia* spp. (brine shrimp) and copepods (Payne *et al* 1998; V. Mosk, University of Western Australia. pers. comm.). Each holding tank was drained to 50% of water depth every second day and refilled with fresh seawater.

2.2.5 Experimental Design and Procedure

Each experimental component consisted of the following treatments: *P. coriacea* versus *H. tasmanica* (Tank 1), *P. sinuosa* versus *P. coriacea* (Tank 2) and *P. sinuosa* versus *H. tasmanica* (Tank 3) (Figure 2.4). A pair-wise comparison design was employed for the habitat preference experiments. Habitat preference experiments were conducted separately for each size class for small (<120mm) and large (>120mm) *S. argus* (Ryer, 1988).

The three replicates for each pair-wise comparison were conducted over a seven-day period. A replicate for each comparison was conducted over a day, with a "day off" between each run. Each replicate commenced at 08:00 and was terminated at 18:00 hours, representing the approximate 10-hour natural light regime during the early spring (September) period when the experiment was conducted. Ten fish were placed into the centre of each experimental aquarium the night before the commencement of the replicate. This enabled the fish to adapt to the controlled aquaria conditions.



Juveniles (<120mm)

	Tank 1	Tank 2	Tank 3
Replicate 1 (Day 1)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*
Replicate 2 (Day 2)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*
Replicate 3 (Day 3)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*

Adults (>120mm)

	Tank 1	Tank 2	Tank 3
Replicate 1 (Day 1)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*
Replicate 2 (Day 2)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*
Replicate 3 (Day 3)	*Pc* | *Ht*	*Ps* | *Pc*	*Ps* | *Ht*

Figure 2.4 Experimental design used for both juvenile (<120mm) and adult (>120mm) fish in the laboratory experiments to examine habitat preference of an abundant seagrass fish species.

Following a disturbance to simulate a predator at the start of each replicate, observations (the number of fish in each habitat) were taken at one-hour intervals throughout the 10-hour period. Fish were observed from a distance of 0.5m in a darkened room, with only the overhead fluorescent light for illumination. At the termination of the replicate, all fish were removed from the experimental aquaria and placed into separate holding aquaria, before being released back into their natural environment. After the fish had been removed, each aquarium was drained and re-filled with clean seawater. The above procedure was conducted for all three replicates with a new batch of fish being used for each replicate.

2.2.6 Statistical Analysis

The results of the laboratory experiments were analysed using a G-statistic to determine significant differences from expected frequencies of fish in each treatment. The results would show if either size-class of fish shows a preference to a specific type of seagrass. This test was chosen over the more traditional chi-square (χ^2), as it is theoretically superior and mathematically simpler than the χ^2 test (Sokal & Rohlf, 1995; Fowler *et al.*, 1998). All observations and replicates were tested for homogeneity using an "interaction" or "homogeneity" G-statistic (Sokal & Rohlf, 1995). If all readings were homogeneous, the results were combined (Gill & Humphries, 1995; Sokal & Rohlf, 1995). The observational results of the three replicates for each experimental tank were combined and tested against the expected frequency of 50:50 using a goodness of fit and a "pooled G-statistic" was calculated (Gill & Humphries, 1995; Sokal & Rohlf, 1995).

CHAPTER 3: RESULTS

3.1 FISH COMMUNITY COMPOSITION BETWEEN SEAGRASS HABITATS

3.1.1 Total Catches and Species Composition of Fish

A total of 548 fish, representing 32 species and 15 families were collected from within the study area between June and September 2002 (Tables 3.1 and 3.2). *Stigmatopora argus* and *Siphonognathus radiatus* were the most abundant species, comprising approximately 35 and 22% of the total catch, respectively (Table 3.2). The next most abundant species were *Stigmatopora nigra* (9%), followed by *Siphamia cephalotes* (6%) and *Scobinichthys granulatus* (5%) (Table 3.2). The majority of the species collected were not economically important and only small numbers of economically important species, which were represented by *Leviprora inops, Leviprora laevigatus* and *Cnidoglanis mactocephalus*, were collected (Table 3.1 and 3.2).

The largest catches of fish were collected from *P. sinuosa* where 277 fish representing 24 out of the 32 species were caught during the study. This was followed by the mixed habitat, with 150 fish representing 19 species and *P. coriacea* with 121 fish representing 16 species (Tables 3.2). Of the 3.06kg of fish caught in the three habitats, 51% was collected from *P. sinuosa*, while 27% and 22% were collected from *P. coriacea* and the mixed habitat, respectively (Table 3.3).

Stigmatopora argus was the most abundant species in each of the seagrass habitats (Table 3.2). Furthermore, this species was most abundant in *P. sinuosa*, where 88 of the 190 fish were caught. Similarly, 78 of the 119 *Siphonognathus radiatus* collected during the study were from *P. sinuosa*. This was

Table 3.1 List of species and families of fish collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. ** indicates commercial and recreational species.

Family	***Species Name***	**Common Name**
Heterodontidae	*Heterodontus portjacksoni* (Meyer, 1793)	Shark, Port Jackson
Plotosidae	*Cnidoglanis macrocephalus* (Valenciennes, 1840)**	Estuarine catfish
Gobiesocidae	*Cochleoceps spatula* (Gunther, 1861)	Clingfish, Spade-nose
	Gobiesocid Gen. C Sp. 1	Clingfish, Glass
Syngnathidae	*Hippocampus breviceps* (Peters, 1869)	Seahorse, Short-headed
	Histiogamphelus cristatus (Macleay, 1882)	Pipefish, Macleay's creseted
	Maroubra perserrata (Whitely, 1948)	Pipefish, Sawtooth
	Phyllopteryx taeniolatus (Lacepede, 1804)	Seadragon, Common
	Pugnaso curtirostris (Castelnau, 1873)	Pipefish, Pug-nose
	Stigmatopora argus (Richardson, 1840)	Pipefish, Spotted
	Stigmatopora nigra (Kaup, 1856)	Pipefish, Wide-body
	Vanacampus poecilolaemus (Peters, 1869)	Pipefish, Long-snout
Scorpaenidae	*Maxillicosta scabriceps* (Whitley, 1935)	Scorpionfish, Little
	Gymnapistes marmoratus (Cuvier, 1829)	Soldierfish
Platycephalidae	*Leviprora inops* (Jenyns, 1840)**	Flathead, Long-headed
	Leviprora laevigatus (Cuvier, 1829)**	Flathead, Rock
Apogonidae	*Siphamia cephalotes* (Castelnau, 1875)	Siphonfish, Wood's
Labridae	*Halichoeres brownfieldi* (Whitley, 1945)	Wrasse, Brownfield's
Odacidae	*Neoodax balteatus* (Valenciennes, 1840)	Weedwhiting, Little
	Odax acroptilus (Richardson, 1850)	Cale, Rainbow
	Siphonognathus radiatus (Quoy & Gaimard, 1834)	Weedwhiting, Long-rayed
	Siphonognathus argyrophanes (Richardson, 1858)	Tubemouth
Clinidae	*Cristiceps australis* (Valenciennes, 1836)	Weedfish, Southern-Crested
	*Heteroclinus roseus (*Gunther, 1861)	Weedfish, Rosy
Callionymidae	*Dactylopus dactylopus* (Valenciennes, 1837)	Dragonet, Fingered
	Synchiropus papilio (Gunther, 1864)	Stinkfish, Painted
Monacanthidae	*Acanthaluteres spilomelanurus* (Quoy & Gaimard, 1824)	Leatherjacket, Bridled
	Brachaluteres jacksonianus (Quoy & Gaimard, 1824)	Leatherjacket, Pygmy
	Scobinichthys granulatus (Shaw, 1790)	Leatherjacket, Rough
Diodontidae	*Diodon nicthemerus* (Cuvier, 1818)	Globefish
Fistulariidae	*Fistularia commersonii* (Ruppell, 1835)	Flutemouth, Smooth
Tetraodontidae	*Torquigener pleurogramma* (Regan, 1903)	Blowfish

Table 3.2 Total abundance and percentage contributions of all fish species collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Fish shown in order of total abundance. ** indicates commercial and recreational species.

Seagrass Habitat	***Posidonia sinuosa***		***Posidonia coriacea***		**Mixed Habitat**		**Total**
	total	**%**	**total**	**%**	**total**	**%**	
Stigmatopora argus	88	31.8	45	35.4	57	38.0	**190**
Siphonognathus radiatus	78	28.2	18	14.2	23	15.3	**119**
Stigmatopora nigra			25	19.7	25	16.7	**50**
Siphamia cephalotes	31	11.2	1	0.8	4	2.7	**36**
Scobinichthys granulatus	18	6.5	9	7.1	3	2.0	**30**
Acanthaluteres spilomelanurus	11	4.0	4	3.1	8	5.3	**23**
Cochleoceps spatula	5	1.8			9	6.0	**14**
Maxillicosta scabriceps	6	2.2	3	2.4	3	2.0	**12**
Halichoeres brownfieldi	8	2.9	1	0.8	2	1.3	**11**
Pugnaso curtirostris	1	0.4	4	3.1	4	2.7	**9**
Neoodax balteatus	5	1.8			2	1.3	**7**
Odax acroptilus	3	1.1	2	1.6	2	1.3	**7**
Hippocampus breviceps	1	0.4	2	1.6	2	1.3	**5**
Torquigener pleurogramma	5	1.8					**5**
Maroubra perserrata			3	2.4			**3**
Dactylopus dactylopus	3	1.1					**3**
Gymnapistes marmoratus	3	1.1					**3**
Histiogamphelus cristatus			1	0.8	1	0.7	**2**
Heterodontus portjacksoni			1	0.8	1	0.7	**2**
Diodon nicthemerus	2	0.7					**2**
*Cnidoglanis macrocephalus***	2	0.7					**2**
Cristiceps australis	1	0.4	1	0.8			**2**
Gobiesocid Gen. C. Sp. 1			1	0.8	1	0.7	**2**
Fistularia commersonii					1	0.7	**1**
*Leviprora inops***					1	0.7	**1**
Brachaluteres jacksonianus	1	0.4					**1**
Siphonognathus argyrophanes	1	0.4					**1**
Vanacampus poecilolaemus	1	0.4					**1**
*Leviprora laevigatus***	1	0.4					**1**
Heteroclinus roseus	1	0.4					**1**
Synchiropus papilio	1	0.4					**1**
Phyllopteryx taeniolatus					1	0.7	**1**
Total catch	**277**		**121**		**150**		**548**

Table 3.3 Total biomass of all each species collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Fish shown in order of total abundance. ** indicates commercial and recreational species.

	Posidonia sinuosa		***Posidonia coriacea***		**Mixed Habitat**		**Total**
Sampling season	**Wt**	**%**	**Wt**	**%**	**Wt**	**%**	
Stigmatopora argus	121.907	7.7	47.939	7.4	66.610	8.0	**236.456**
Siphonognathus radiatus	377.157	23.9	104.180	16.2	135.418	16.2	**616.755**
Stigmatopora nigra			9.814	1.5	5.557	0.7	**15.371**
Siphamia cephalotes	7.613	0.5	0.362	0.1	2.074	0.2	**10.049**
Scobinichthys granulatus	57.632	3.7	35.315	5.5	1.386	0.2	**94.333**
Acanthaluteres spilomelanurus	59.325	3.8	5.292	0.8	4.962	0.6	**69.579**
Cochleoceps spatula	1.430	0.1			2.658	0.3	**4.088**
Maxillicosta scabriceps	54.418	3.4	36.954	5.7	21.205	2.5	**112.577**
Halichoeres brownfieldi	52.868	3.3	1.529	0.2	3.878	0.5	**58.275**
Pugnaso curtirostris	1.037	0.1	5.272	0.8	5.123	0.6	**11.432**
Neoodax balteatus	9.496	0.6			8.658	1.0	**18.154**
Odax acroptilus	40.658	2.6	24.203	3.8	22.386	2.7	**87.247**
Hippocampus breviceps	0.805	0.1	1.354	0.2	1.638	0.2	**3.797**
Torquigener pleurogramma	36.549	2.3					**36.549**
Maroubra perserrata			1.385	0.2			**1.385**
Dactylopus dactylopus	19.013	1.2					**19.013**
Gymnapistes marmoratus	80.447	5.1					**80.447**
Histiogamphelus cristatus			0.729	0.1	1.707	0.2	**2.436**
Heterodontus portjacksoni			364.000	56.6	503.000	60.3	**867.000**
Diodon nicthemerus	14.030	0.9					**14.030**
*Cnidoglanis macrocephalus***	24.630	1.6					**24.630**
Cristiceps australis	5.827	0.4	5.299	0.8			**11.126**
Gobiesocid Gen. C. Sp. 1			0.045	0.0	0.339	0.0	**0.384**
Fistularia commersonii	19.328	1.2			0.371	0.0	**19.699**
*Leviprora inops***					9.918	1.2	**9.918**
Brachaluteres jacksonianus					2.153	0.3	**2.153**
Siphonognathus argyrophanes	3.302	0.2					**3.302**
Vanacampus poecilolaemus	2.720	0.2					**2.720**
*Leviprora laevigatus***	574.200	36.4					**574.200**
Heteroclinus roseus	3.706	0.2					**3.706**
Synchiropus papilio	10.365	0.7					**10.365**
Phyllopteryx taeniolatus					35.700	4.3	**35.700**
Total catch biomass (g)	**1578.463**		**643.672**		**834.741**		**3056.876**

followed by the mixed habitat and *P. coriacea* with 23 and 18 fish, respectively (Table 3.2). In contrast, *Stigmatopora nigra* was absent from *P. sinuosa* and was caught only in *P. coriacea* and the mixed habitat, where 25 individuals were collected from each habitat (Table 3.2). Similar to *S. argus*, *Siphamia cephalotes* was most abundant in *P. sinuosa*, with 86% of the species collected in the habitat (Table 3.2). The species was almost absent from the remaining two habitats, with only four individuals collected in the mixed habitat and a single individual collected from *P. coriacea*. *Scobinichthys granulatus* was found predominantly in *P. sinuosa* where 60% (18 individuals) of the catch was recorded. Nine individuals were collected in *P. coriacea*, while only three were found in the mixed habitat (Table 3.2).

3.1.2 Species Richness, Total Densities and Biomass of Fish

ANOVA showed species richness within the study area differed significantly amongst habitats (p=0.003) and months (p=<0.001) and there was no habitat by month interaction (p=0.441) (Table 3.4). Further analysis, using Tukey's HSD test, revealed that species richness was significantly greater in *P. sinuosa* than in *P. coriacea* (Table 3.5 and Figure 3.1). Furthermore, species richness was almost significantly greater (p=0.051) in the former habitat versus the mixed habitat. No significant difference was evident between *P. coriacea* and the mixed habitat. Mean species richness ranged between 4.0 and 6.5 for *P. sinuosa*, between 2.0 and 5.8 in *P. coriacea* and between 2.3 and 5.0 fish in the mixed habitat (Table 3.5 and Figure 3.1).

Table 3.4 Mean squares, F-values and significance values of the 2-way Analysis of Variance (ANOVA) conducted on species richness, fish abundance and fish biomass collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Shaded boxes indicate significance at p=0.05.

	Independent Variable	**df**	**Mean Squares**	**F Value**	**Sig. Value**	**Observed Powers****
Species Richness	Habitat (H)	2	21.130	6.688	0.003	0.896
	Month (M)	2	40.574	12.843	0.000	0.995
	Interaction (H+M)	4	3.019	0.955	0.441	0.278
Fish Abundance	Habitat (H)	2	0.491	9.825	0.000	0.977
	Month (M)	2	1.330	26.631	0.000	1.000
	Interaction (H+M)	4	0.079	1.572	0.198	0.446
Fish Biomass	Habitat (H)	2	2.018	8.528	0.001	0.956
	Month (M)	2	0.946	3.997	0.025	0.686
	Interaction (H+M)	4	0.125	0.530	0.714	0.166

Table 3.5 Statistical results of pair-wise comparisons conducted for species richness, fish abundance and fish biomass collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Post hoc analysis was conducted using a Tukey's HSD test. Shaded boxes indicate significance at p=0.05

		Mean Difference	**Standard Error**	**Significance**
Species Richness	*P. sinuosa* vs *P. coriacea*	2.000	0.716	0.020
	P. sinuosa vs Mixed	1.720	0.716	0.051
	P. coriacea vs Mixed	0.280	0.716	0.921
Fish Abundance	*P. sinuosa* vs *P. coriacea*	0.328	0.107	0.009
	P. sinuosa vs Mixed	0.198	0.107	0.163
	P. coriacea vs Mixed	0.130	0.107	0.446
Fish Biomass	*P. sinuosa* vs *P. coriacea*	0.641	0.169	0.001
	P. sinuosa vs Mixed	0.490	0.169	0.015
	P. coriacea vs Mixed	0.151	0.169	0.645

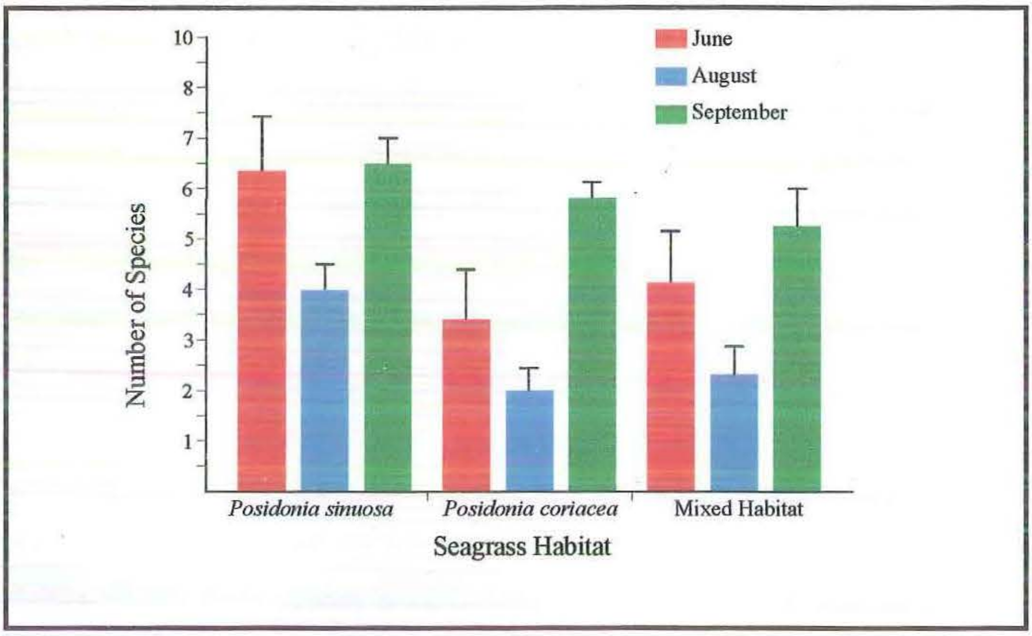


Figure 3.1 Mean species richness (+1S.E) of fish collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

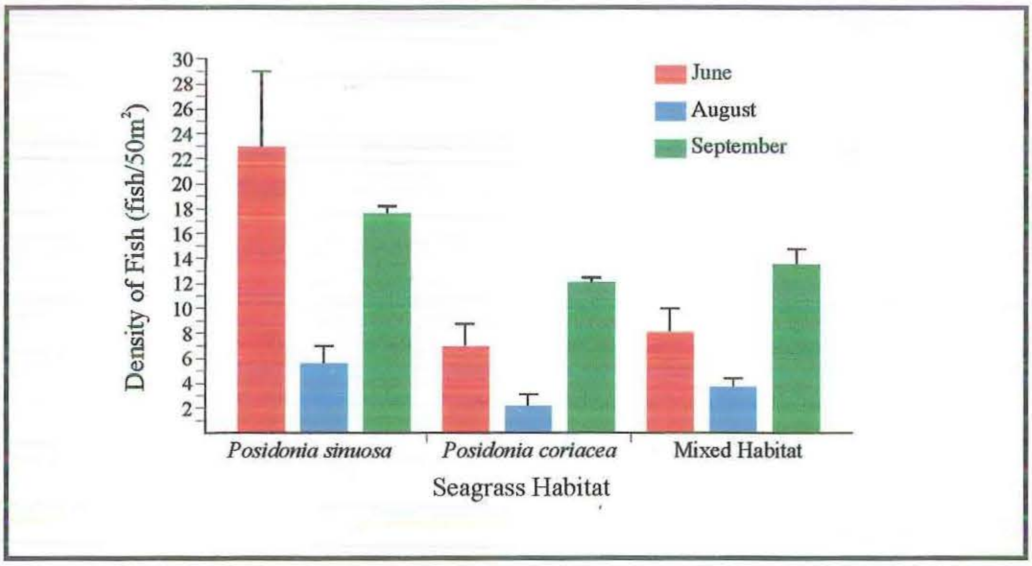


Figure 3.2 Mean fish density (+1S.E) of fish collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

Similar to species richness, ANOVA showed that the total density of fish differed significantly amongst habitats (p=<0.001) and months (p=<0.001) and likewise did not indicate a habitat by month interaction (Table 3.4). Densities were greater in *P. sinuosa* than *P. coriacea*, but no such difference occurred between these two habitats and the mixed habitat (Table 3.5). Mean fish numbers ranged between 5.8 and 23.0 fish per $50m^2$ for *P. sinuosa*, between 2.6 and 12.3 for *P. coriacea* and between 2.6 and 13.6 fish per $50m^2$ for the mixed habitat (Table 3.5 and Figure 3.2).

As with the previous two variables, total fish biomass differed significantly amongst habitats (p=0.001) and months (p=0.025) and there was no interaction between these two factors (Table 3.4). Tukey's HSD tests showed that there was significantly greater biomass in *P. sinuosa* than either *P. coriacea* or the mixed habitat, but there were no differences between the two later habitats (Table 3.5). Mean biomass of fish ranged between 44.3 and 128.4g for *P. sinuosa*, between 10 and 87.3g for *P. coriacea* and between 12.3 and 94.6g for the mixed habitat (Table 3.5 and Figure 3.3).

3.1.3 Densities and Length Frequencies of Most Abundant Species

ANOVA identified a significant difference in the densities of *S. argus* among habitats (p=0.023) and months (p=<0.001) (Table 3.6). In addition, there was no interaction between the two factors (p=0.192). Tukey's HSD test further showed that there was no significant difference between the three habitats (Table 3.7). Mean fish densities ranged between 2.2 and 9.2 for *P. sinuosa*, 1.2 and 4.3 for *P. coriacea* and between 1.2 and 6.0 fish per $50m^2$ for the mixed habitat (Figure 3.4). Total lengths (TL) of *S. argus* ranged between 73 and 245mm in the study region (Figure 3.6). Although the length distribution of this species was wide, the majority of the individuals captured were mature-sized fish (TL>120mm). *Posidonia sinuosa* contained the largest number of mature-sized fish (84 individuals), while *P. coriacea* contained the largest number of juvenile-sized fish (17 individuals).

The densities of *S. radiatus* were shown by ANOVA to differ significantly amongst habitats (p=<0.001) and months (p=0.006) (Table 3.6), with no interactions between these two factors. Tukey's HSD test revealed that densities were greater in *P. sinuosa* than in *P. coriacea* and the mixed habitat, while there was no significant difference between *P. coriacea* and the mixed habitat (Table 3.7). Mean densities for the species ranged between 1.4 and 6.0 for *P. sinuosa*, 1.0 and 2.4 for *P. coriacea* and between 2.0 and 2.6 fish per 50m^2 for the mixed habitat (Figure 3.5).

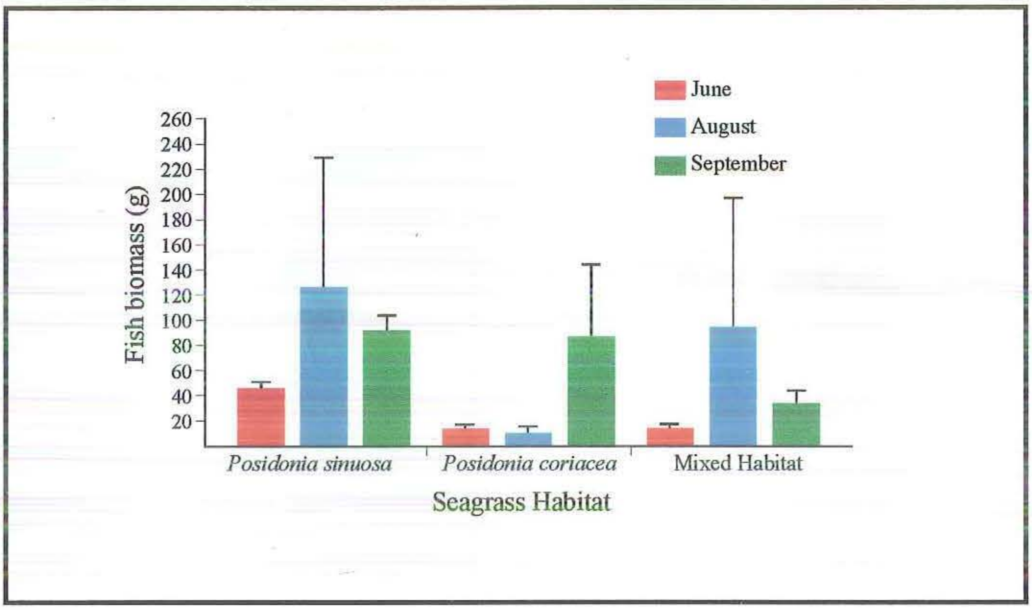


Figure 3.3 Mean fish biomass (+1S.E) of fish collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

Table 3.6 Mean squares, F-values and significance values of the 2-way Analysis of Variance (ANOVA) conducted on the five most abundant fish species collected from the *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Shaded boxes indicate significance at p=0.05.

	Independent Variable	**df**	**Mean Squares**	**F Value**	**Sig. Value**	**Observed Powers****
Stigmatopora argus	Habitat (H)	2	25.389	4.1	0.023	0.698
	Month (M)	2	77.167	12.461	0.000	0.994
	Interaction (H+M)	4	9.889	1.597	0.192	0.453
Siphonognathus radiatus	Habitat (H)	2	58.296	13.051	0.000	0.844
	Month (M)	2	25.685	5.750	0.006	0.996
	Interaction (H+M)	4	11.352	2.541	0.053	0.672
Stigmatopora nigra	Habitat (H)	2	13.722	10.526	0.000	0.984
	Month (M)	2	11.167	8.565	0.001	0.957
	Interaction (H+M)	4	2.889	2.216	0.082	0.604
Siphamia cephalotes	Habitat (H)	2	14.130	1.678	0.198	0.335
	Month (M)	2	8.796	1.045	0.360	0.221
	Interaction (H+M)	4	7.407	0.88	0.484	0.257
Scobinichthys granulatus	Habitat (H)	2	3.167	4.548	0.168	0.745
	Month (M)	2	1.722	2.473	0.096	0.472
	Interaction (H+M)	4	1.556	2.234	0.080	0.608

Table 3.7 Statistical results of pair-wise comparisons conducted for five most abundant fish species collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Post hoc analysis was conducted using a Tukey's HSD test. Shaded boxes indicates significance at p=0.05.

		Mean Difference	**Standard Error**	**Significance**
Stigmatopora argus	*P. sinuosa* vs *P. coriacea*	2.280	1.015	0.073
	P. sinuosa vs Mixed	1.720	1.015	0.216
	P. coriacea vs Mixed	0.560	1.015	0.848
Siphonognathus radiatus	*P. sinuosa* vs *P. coriacea*	3.220	0.805	0.001
	P. sinuosa vs Mixed	3.000	0.805	0.001
	P. coriacea vs Mixed	0.220	0.805	0.959
Stigmatopora nigra	*P. sinuosa* vs *P. coriacea*	1.610	0.449	0.002
	P. sinuosa vs Mixed	1.390	0.449	0.009
	P. coriacea vs Mixed	0.220	0.449	0.874
Siphamia cephalotes	*P. sinuosa* vs *P. coriacea*	1.61	0.963	0.226
	P. sinuosa vs Mixed	1.44	0.963	0.300
	P. coriacea vs Mixed	0.17	0.963	0.984
Scobinichthys granulatus	*P. sinuosa* vs *P. coriacea*	0.5	0.299	0.225
	P. sinuosa vs Mixed	0.83	0.299	0.020
	P. coriacea vs Mixed	0.33	0.299	0.59

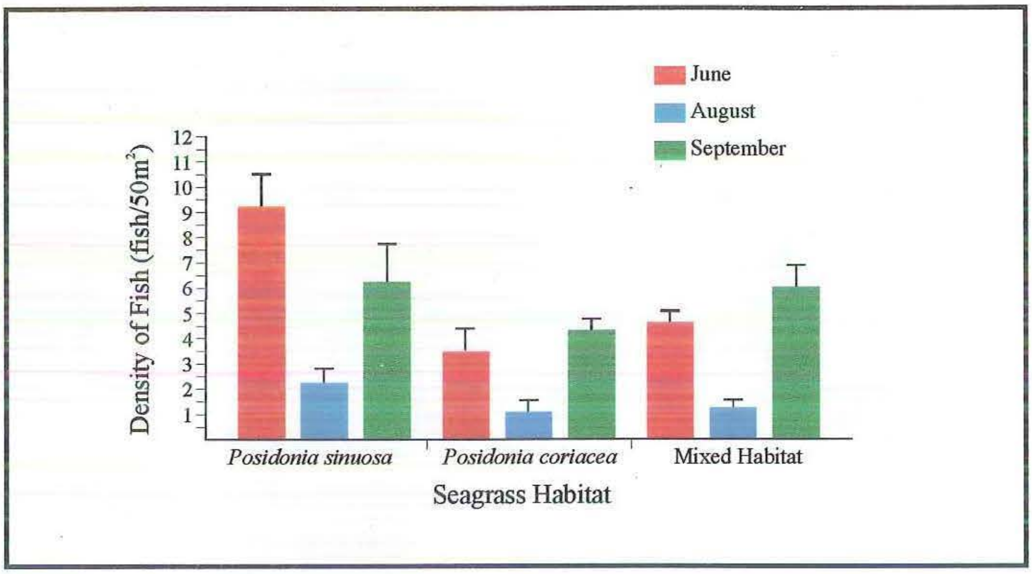


Figure 3.4 Mean fish density (+1S.E) of *Stigmatopora argus* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

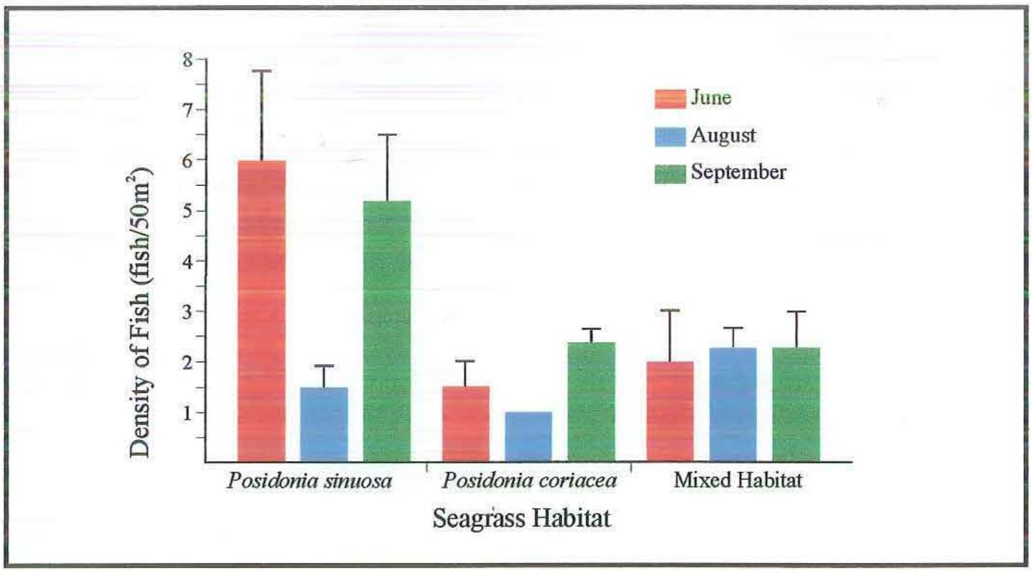


Figure 3.5 Mean fish density (+1S.E) of *Siphonognathus radiatus* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

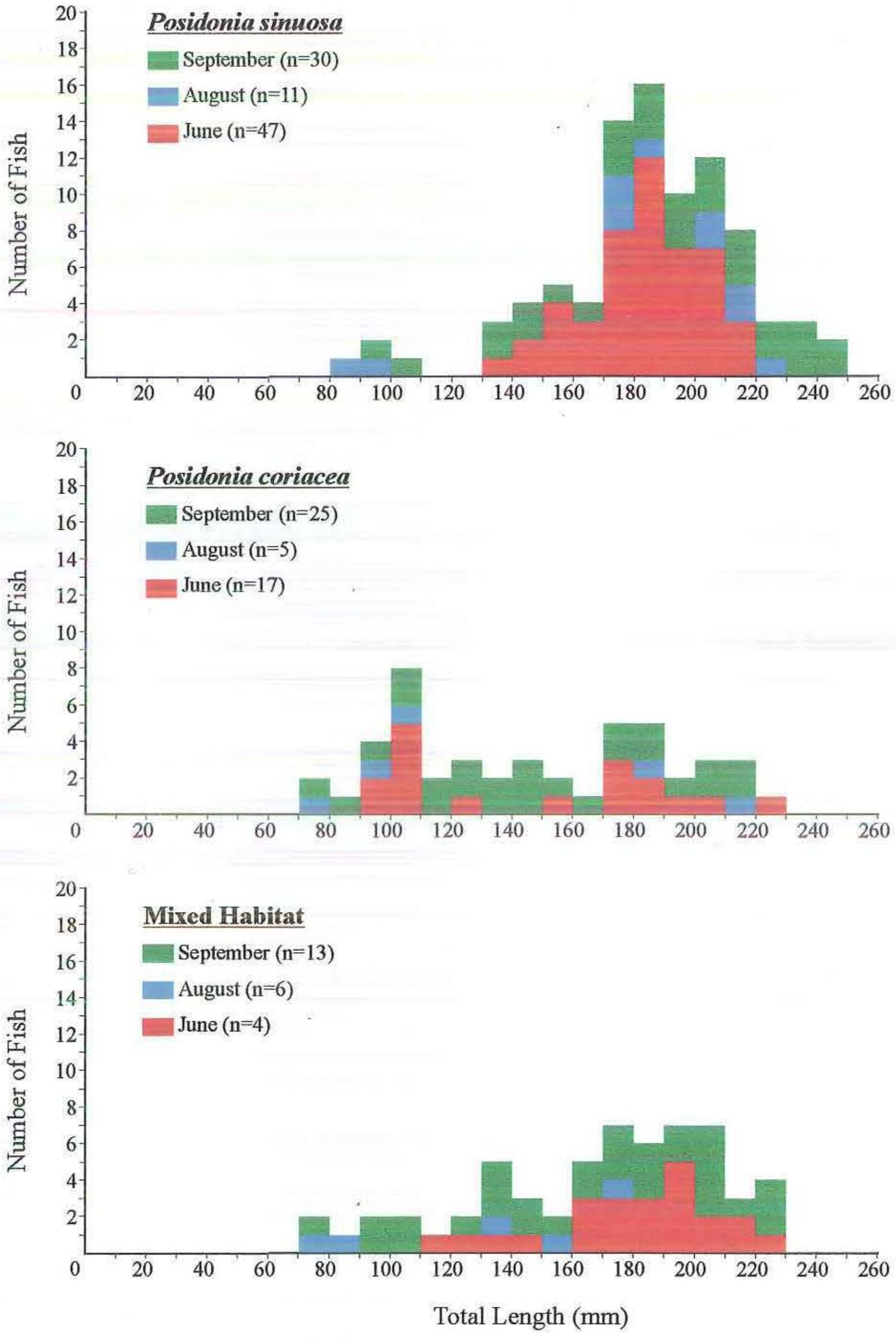


Figure 3.6 Length distribution of *Stigmatopora argus* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

Total lengths of *S. radiatus* were between 55 and 142mm in *P. sinuosa* (Figure 3.6). Greater numbers of fish less than 70mm (TL) were collected in *P. sinuosa* during June. While numbers were lower in the remaining two habitats, the length distributions were similar to those in *P. sinuosa*. Studies have indicated that *S. radiatus* changes sex from female to male at ~130mm in length (Hyndes *et al.*, 1998). From this, the results suggested that ~93% (113 fish) of the catch were females, with 67% (76 fish) of these collected in the *P. sinuosa* habitat (Figure 3.7).

ANOVA results showed that densities of *S. nigra* differed significantly among habitats (p=<0.001) and months (p=0.001) and there was no interaction between these two factors (p=0.82) (Table 3.6). This species was absent from *P. sinuosa* and Tukey's HSD test revealed that densities of this species were similar in *P. coriacea* and the mixed habitat (Table 3.7). Mean densities for *S. nigra* ranged between 1.3 and 3.7 for *P. coriacea* and between 1.2 and 2.5 fish per 50m^2 in the mixed habitat (Figure 3.8). Total lengths of *S. nigra* ranged between 41 and 141mm in *P. coriacea* and mixed habitats, with the largest length distribution occurring during September for both habitats (Figure 3.10).

ANOVA results showed that there was no significant difference between densities of *S. cephalotes* amongst habitats (p=0.198) or months (p=0.360) (Table 3.6). However, 86% of individuals collected during the study were found in *P. sinuosa*. The lack of a significant habitat effect would be due to the high variability that reflects the large numbers of zero catches. Mean densities of this species ranged between 0 and 5.7 for *P. sinuosa*, 0 and 1.0 for *P. coriacea* and between 0 and 1.5 fish per 50m^2 for the mixed habitat (Figure 3.9). Total length of *S. cephalotes* ranged between 18 and 37mm in *P. sinuosa* (Figure 3.11).

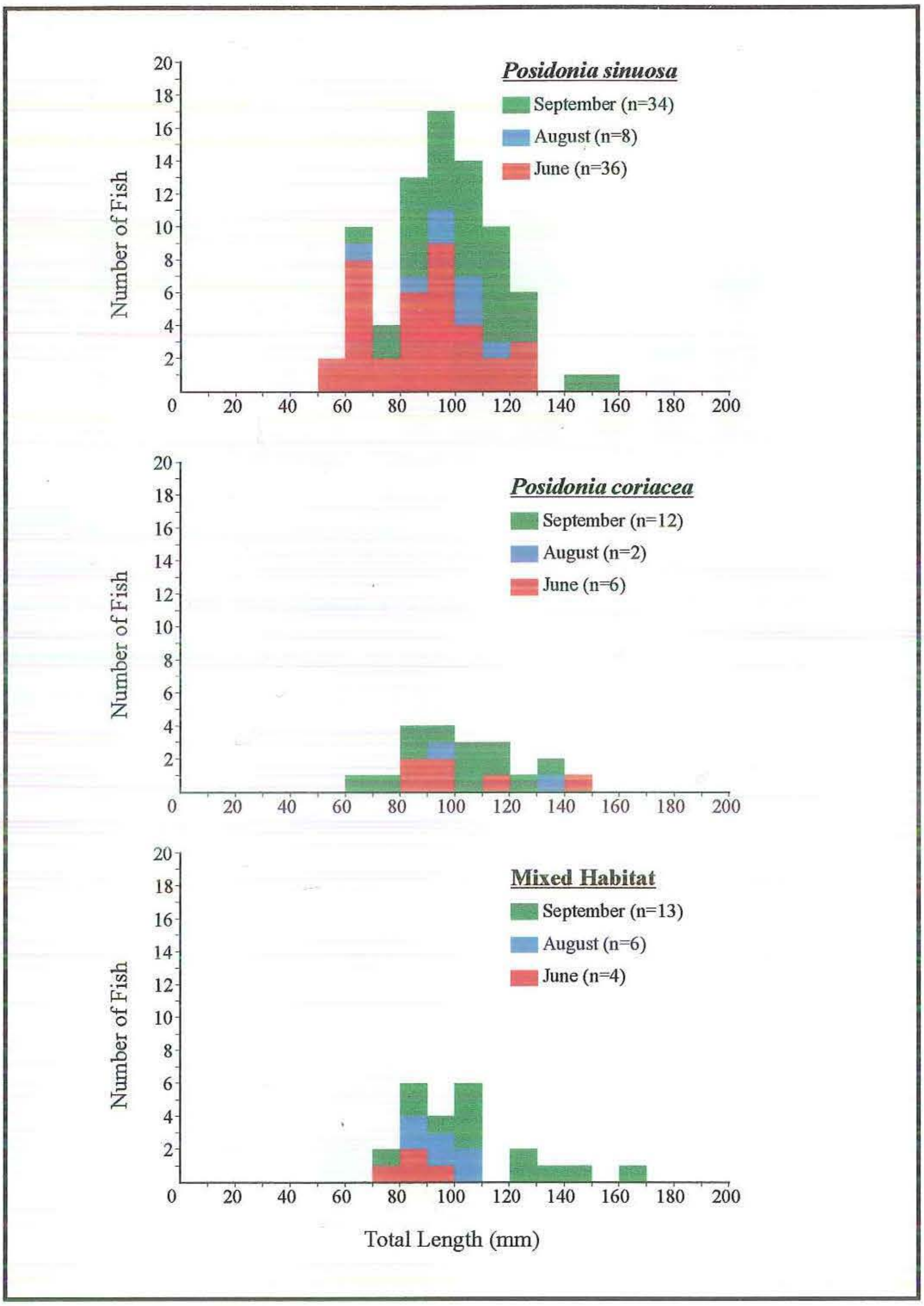


Figure 3.7 Length distribution of *Siphonognathus radiatus* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

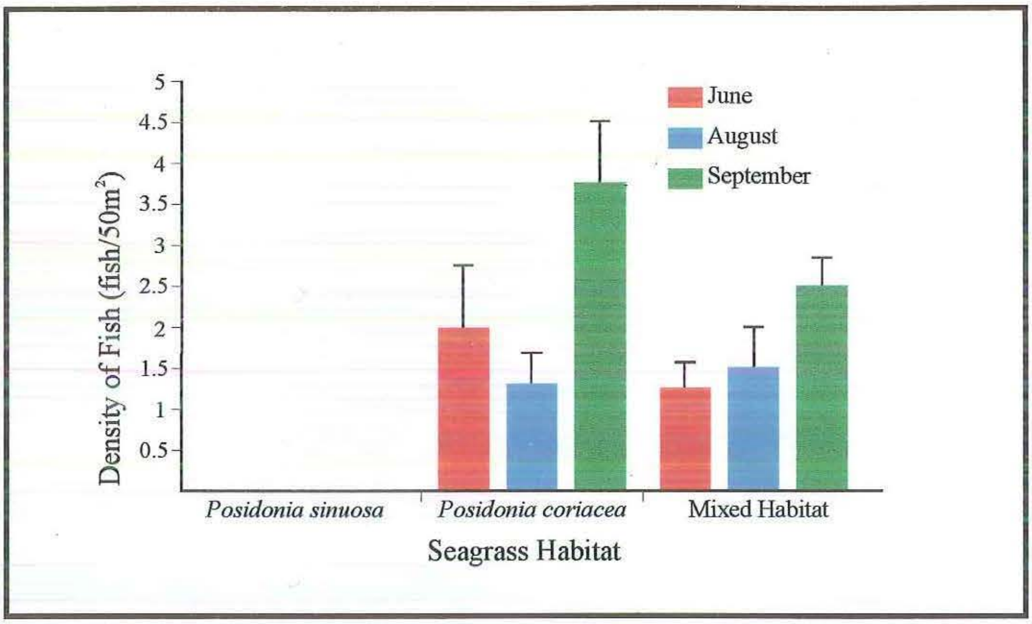


Figure 3.8 Mean fish density (+1S.E) of *Stigmatopora nigra* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

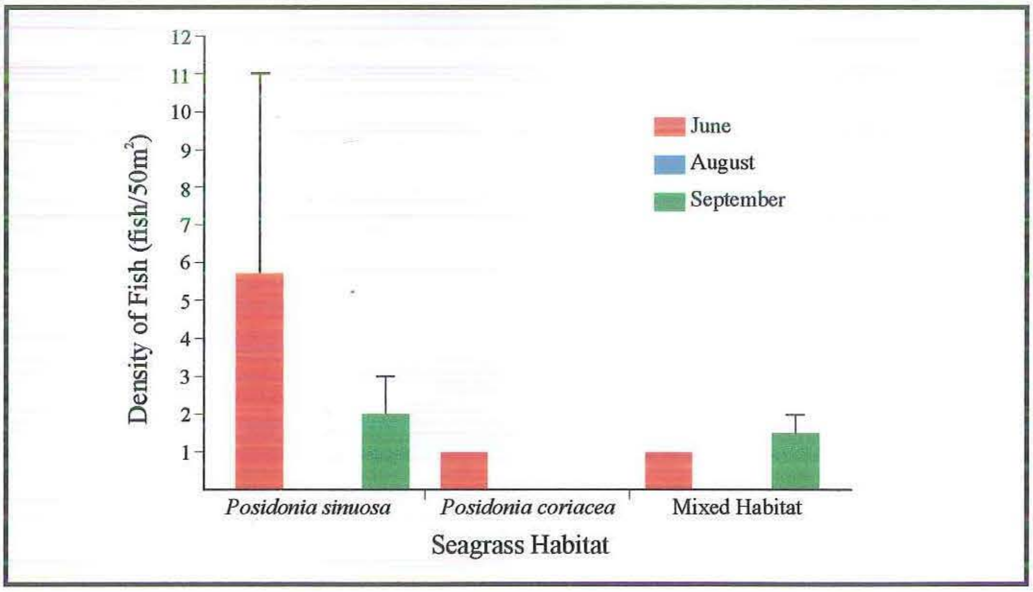


Figure 3.9 Mean fish density (+1S.E) of *Siphamia cephalotes* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

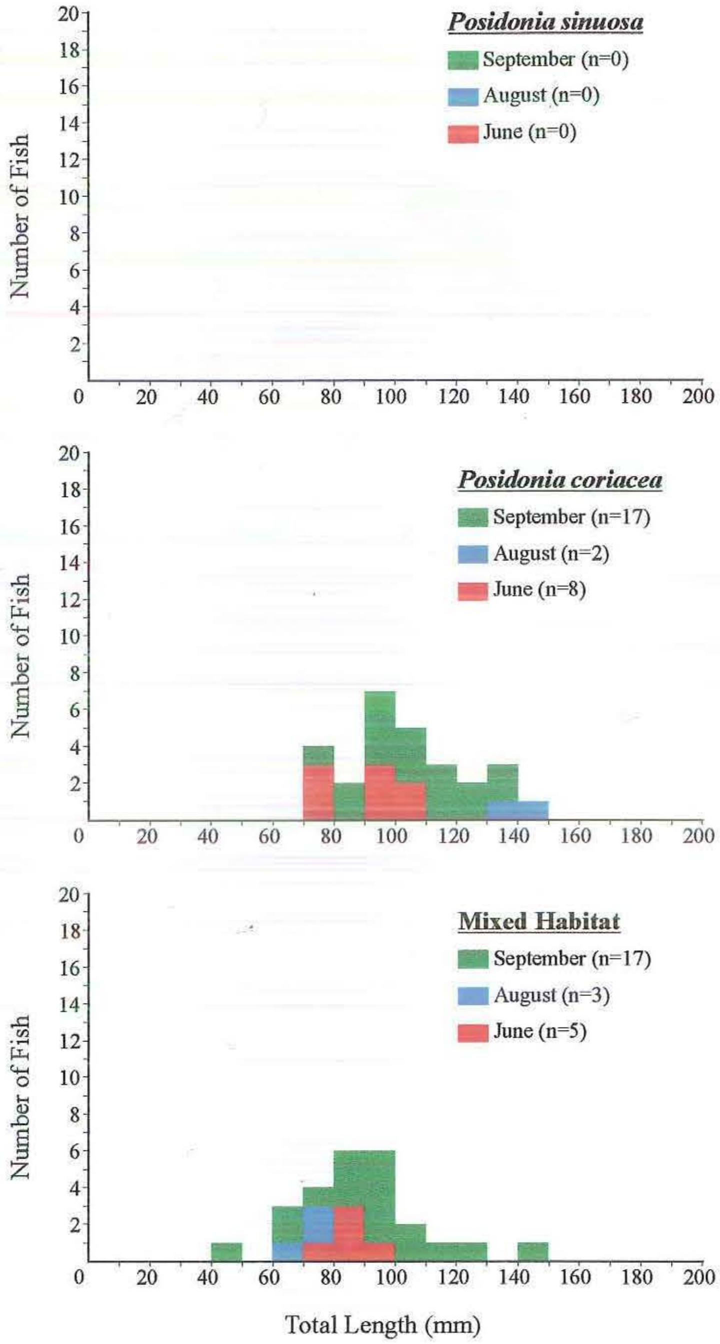


Figure 3.10 Length distribution of *Stigmatopora nigra* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

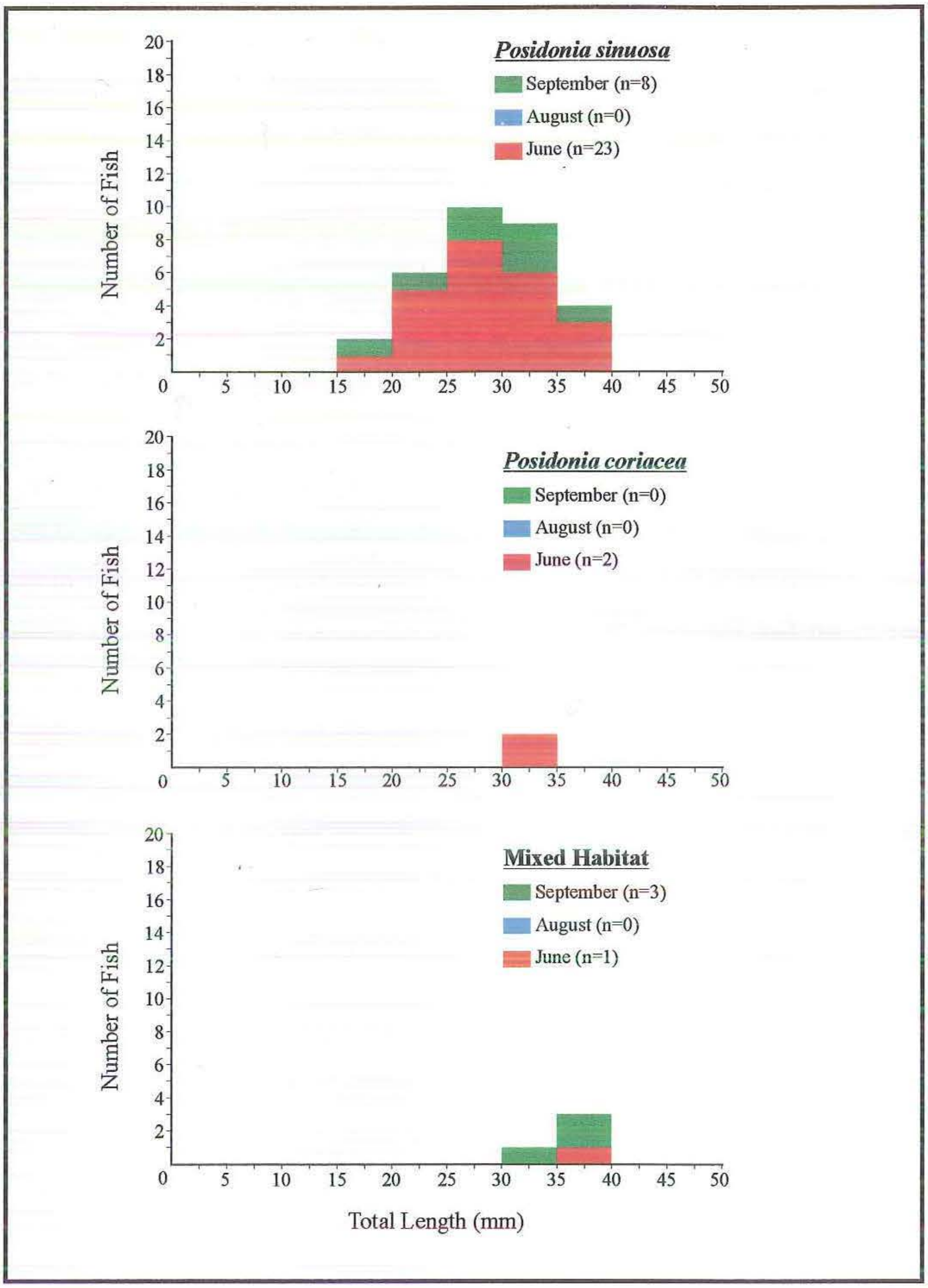


Figure 3.11 Length distribution of *Siphamia cephalotes* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

ANOVA results showed that densities of *S. granulatus* did not differ significantly among habitats (p=0.168) and did differ among months (p=0.096). (Table 3.6) There was no interaction between the two factors (p=0.080). Mean densities of *S. granulatus* ranged from between 1.5 and 2.3 for *P. sinuosa*, 0.0 and 1.5 for *P. coriacea* and between 1.0 and 2.0 fish per 50m^2 for the mixed habitat. (Figure 3.12). Total lengths of *S. granulatus* ranged between 21 and 89mm in *P. sinuosa* and *P. coriacea*. Far fewer fish were found in the mixed habitat, where lengths ranged between 20 and 40mm (Figure 3.13)

3.1.4 Ordinations, Analysis of Similarities (ANOSIM) and SIMPER Analysis

The nMDS plot of species abundance data collected from each habitat examined indicates that the samples from *P. sinuosa* generally lay to the left of the plot forming a relatively discrete group, whereas the samples from *P. coriacea* and the mixed habitat were interspersed on the right hand side of the two-way crossed plot (Figure 3.14). ANOSIM confirmed that the species composition differed between habitats (R-stat=0.270, p=<0.001) and months (R-stat=0.327, p=<0.001). Pair-wise comparisons revealed that species composition differs between *P. sinuosa* (R-stat=0.434, p=<0.001) and the other two habitats, but not between *P. coriacea* and the mixed habitat (R-stat=0.03, p=0.300).

SIMPER indicated that the average dissimilarity and dissimilarity/standard deviation ratio for both *P. sinuosa* versus *P. coriacea* and *P. sinuosa* versus the mixed habitat was greatest for *S. radiatus*, *S. argus*, *S. nigra* and *S. granulatus* (Table 3.8). *Siphonognathus radiatus*, *S. argus* and *S. granulatus* were diagnostic of the *P. sinuosa* habitat, while *S. nigra* was diagnostic of both *P. coriacea* and the mixed habitats.

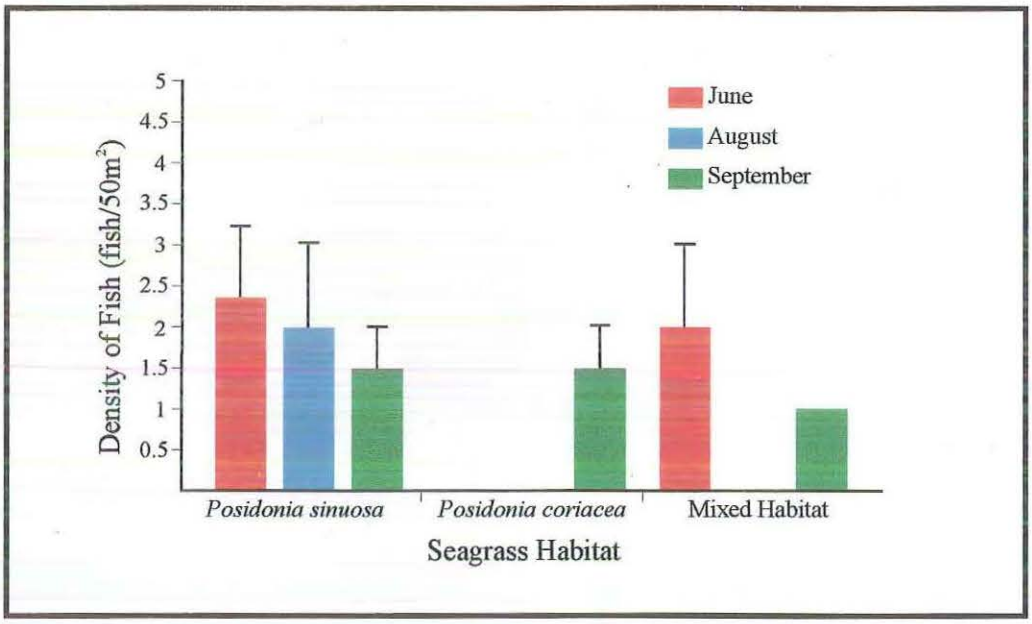


Figure 3.12 Mean fish density (+1S.E) of *Scobinichthys granulatus* collected from *Posidonia sinuosa*, *Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

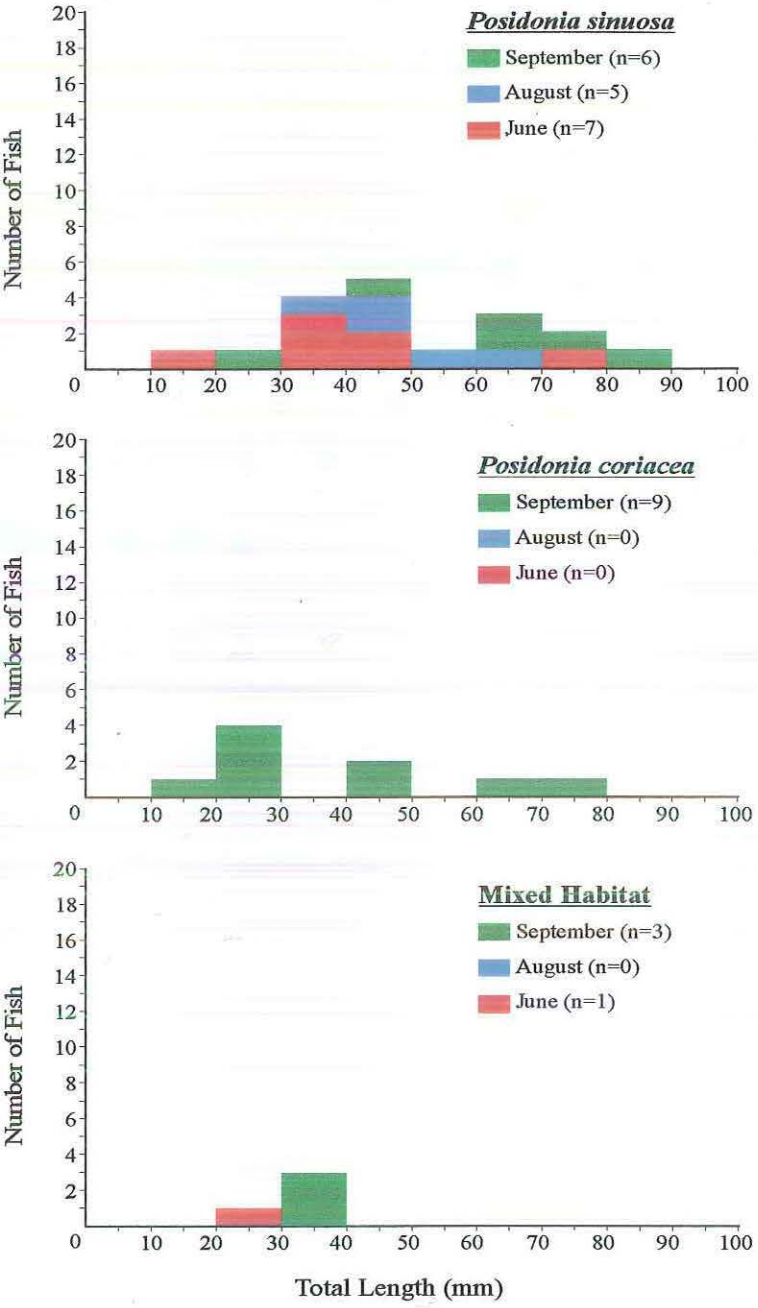


Figure 3.13 Length distribution of *Scobinichthys granulatus* collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

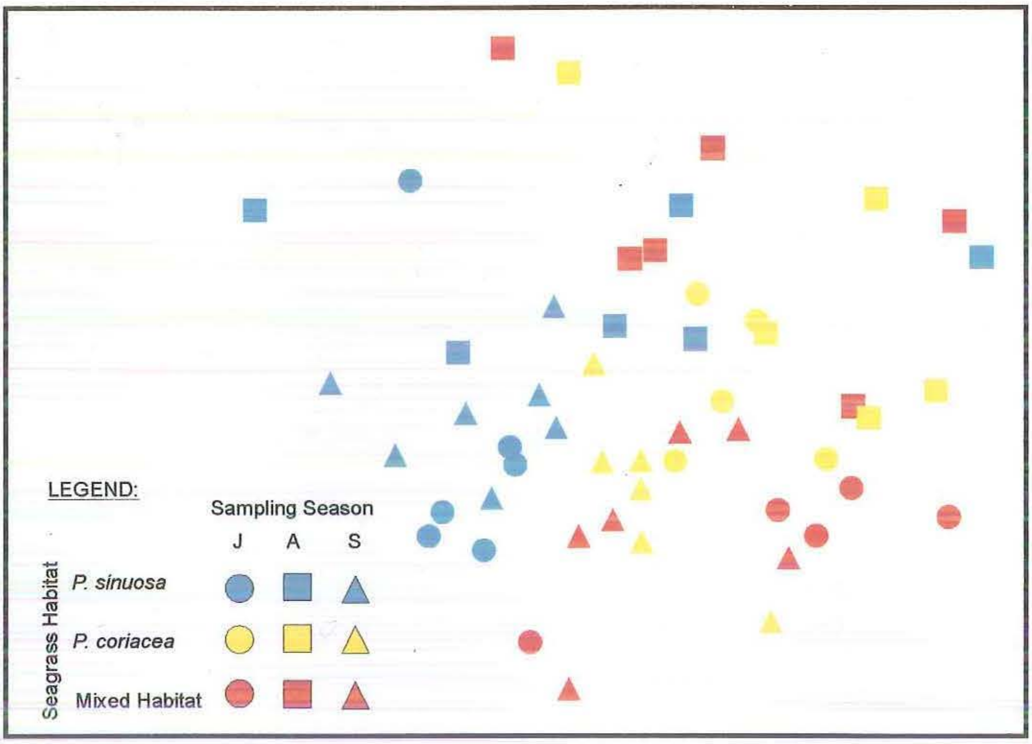


Figure 3.14 MDS ordination plot of species composition of fish collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

Table 3.8 SIMPER results showing dissimilarity of fish species collected from *Posidonia sinuosa*, *Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

	Av. Abundance		**Av. Diss**	**Diss / SD**	**Contrib %**
	P. sinuosa	***P. coriacea***			
Siphonognathus radiatus	4.33	1.25	9.29	1.28	14.28
Stigmatopora argus	4.89	2.94	8.95	1.29	13.75
Stigmatopora nigra	0.00	1.81	8.09	1.24	12.43
Scobinichthys granulatus	1.00	0.56	5.35	1.05	8.22

	Av. Abundance		**Av. Diss**	**Diss / SD**	**Contrib %**
	P. sinuosa	**Mixed**			
Stigmatopora argus	4.89	3.17	10.07	1.32	14.84
Siphonognathus radiatus	4.33	1.33	9.69	1.36	14.27
Stigmatopora nigra	0.00	1.30	7.04	1.16	10.37
Scobinichthys granulatus	1.00	0.17	5.12	1.00	7.55

3.2 MEADOW AND PLANT MORPHOLOGY WITHIN SEAGRASS HABITATS

Two-way ANOVA revealed that leaf density of seagrass differed significantly amongst habitats (p=<0.001) and months (p=0.019) and there was a significant interaction between these two effects (p=0.042) (Table 3.9 and Figure 3.11). Due to this interaction, further analysis using Tukey's HSD test was split by month to examine habitat differences. These tests revealed that seagrass density was greater in *P. sinuosa* than in the mixed habitat in all three months and greater in *P. sinuosa* than in *P. coriacea* in June (p=<0.000) (Table 3.10 and Figure 3.15). There was no significant difference between *P. coriacea* and the mixed habitat for each month (Table 3.10 and Figure 3.15).

Leaf area index differed significantly both among habitats (p=<0.001) and months (p=0.004), but there was no significant interaction between these two factors (p=0.196) (Table 3.9). Tukey's HSD test revealed that leaf area index was greater in *P. sinuosa* than in *P. coriacea* (p=0.005) and the mixed habitat, but there was almost a significant difference between *P. coriacea* and mixed habitats (p=0.052) (Table 3.11 and Figure 3.16).

Dry seagrass biomass was shown by ANOVA to differ significantly among habitats and months, there was also an interaction between these two factors (Table 3.9). For this reason, Tukey's HSD test was split by month, which revealed that seagrass biomass differed significantly only between *P. sinuosa* and the mixed habitat and this only occurred in June (Table 3.12 and Figure 3.17).

Table 3.9 Mean squares, F-values and significance values of the 2-way Analysis of Variance (ANOVA) conducted on seagrass density, leaf area index, dry seagrass biomass, dry epiphytic biomass, leaf length and leaf width collected from the *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002, within the Success Bank region. Shaded boxes indicate significance at p=0.05.

	Independent Variable	**df Value**	**Mean Squares**	**F Value**	**Sig. Value**	**Observed Powers****
Seagrass Density	Habitat (H)	2	11640.352	11.560	0.000	0.991
	Month (M)	2	4386.130	4.356	0.019	0.726
	Interaction (H+M)	4	2721.463	2.703	0.042	0.703
Leaf Area Index	Habitat (H)	2	0.124	20.443	0.000	1.000
	Month (M)	2	0.038	6.338	0.004	0.879
	Interaction (H+M)	4	0.010	1.688	0.169	0.476
Dry Seagrass Biomass	Habitat (H)	2	441.260	12.982	0.000	0.996
	Month (M)	2	118.400	3.483	0.000	0.622
	Interaction (H+M)	4	32.888	0.968	0.039	0.281
Dry Epiphytic Biomass	Habitat (H)	2	1.024	8.245	0.001	0.950
	Month (M)	2	0.033	0.263	0.770	0.089
	Interaction (H+M)	4	0.237	1.906	0.126	0.531
Leaf Length	Habitat (H)	2	21926.161	1.418	0.253	0.288
	Month (M)	2	43321.792	2.803	0.071	0.524
	Interaction (H+M)	4	7768.977	0.503	0.734	0.159
Leaf Width	Habitat (H)	2	65.417	33.224	0.000	1.000
	Month (M)	2	2.898	1.472	0.240	0.298
	Interaction (H+M)	4	2.227	1.131	0.354	0.326

Table 3.10 Results of the Tukey's HSD test conducted on seagrass density collected from the *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Shaded boxes indicate significance at p=0.05.

		Mean Difference	**Standard Error**	**Significance**
June	*P. sinuosa* vs *P. coriacea*	0.180	0.032	0.000
	P. sinuosa vs Mixed	0.225	0.032	0.000
	P. coriacea vs Mixed	0.046	0.032	0.358
August	*P. sinuosa* vs *P. coriacea*	0.029	0.034	0.687
	P. sinuosa vs Mixed	0.102	0.034	0.026
	P. coriacea vs Mixed	0.073	0.034	0.123
September	*P. sinuosa* vs *P. coriacea*	0.077	0.061	0.440
	P. sinuosa vs Mixed	0.168	0.061	0.039
	P. coriacea vs Mixed	0.091	0.061	0.330

Table 3.11 Results of pair-wise comparisons conducted on seagrass density, leaf area index, dry seagrass biomass, dry epiphytic biomass, seagrass leaf length and seagrass leaf width collected from the *Posidonia sinuosa, Posidonia coriacea* and mixed habiats between June and September 2002 within the Success Bank region. Shaded boxes indicate significance at p=0.05

		Mean Difference	**Standard Error**	**Significance**
Leaf Area Index	*P. sinuosa* vs *P. coriacea*	0.095	0.029	0.005
	P. sinuosa vs Mixed	0.165	0.029	0.000
	P. coriacea vs Mixed	0.070	0.029	0.052
Dry Epiphytic Biomass	*P. sinuosa* vs *P. coriacea*	0.069	0.012	0.832
	P. sinuosa vs Mixed	0.443	0.012	0.002
	P. coriacea vs Mixed	0.373	0.012	0.008
Seagrass Width	*P. sinuosa* vs *P. coriacea*	2.494	0.474	0.000
	P. sinuosa vs Mixed	3.744	0.474	0.000
	P. coriacea vs Mixed	1.250	0.474	0.029

Table 3.12 Results of pair-wise comparisons conducted on dry seagrass biomass collected from the *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Shaded boxes indicate significance at p=0.05.

		Mean Difference	**Standard Error**	**Significance**
June	*Posidonia sinuosa* vs *Posidonia coriacea*	3.081	2.450	0.439
	Posidonia sinuosa vs Mixed	8.536	2.450	0.009
	Posidonia coriacea vs Mixed	5.455	2.450	0.990
August	*Posidonia sinuosa* vs *Posidonia coriacea*	4.628	2.524	0.193
	Posidonia sinuosa vs Mixed	0.936	2.524	0.927
	Posidonia coriacea vs Mixed	5.565	2.524	0.103
September	*Posidonia sinuosa* vs *Posidonia coriacea*	1.300	4.649	0.958
	Posidonia sinuosa vs Mixed	2.200	4.649	0.885
	Posidonia coriacea vs Mixed	3.500	4.649	0.737

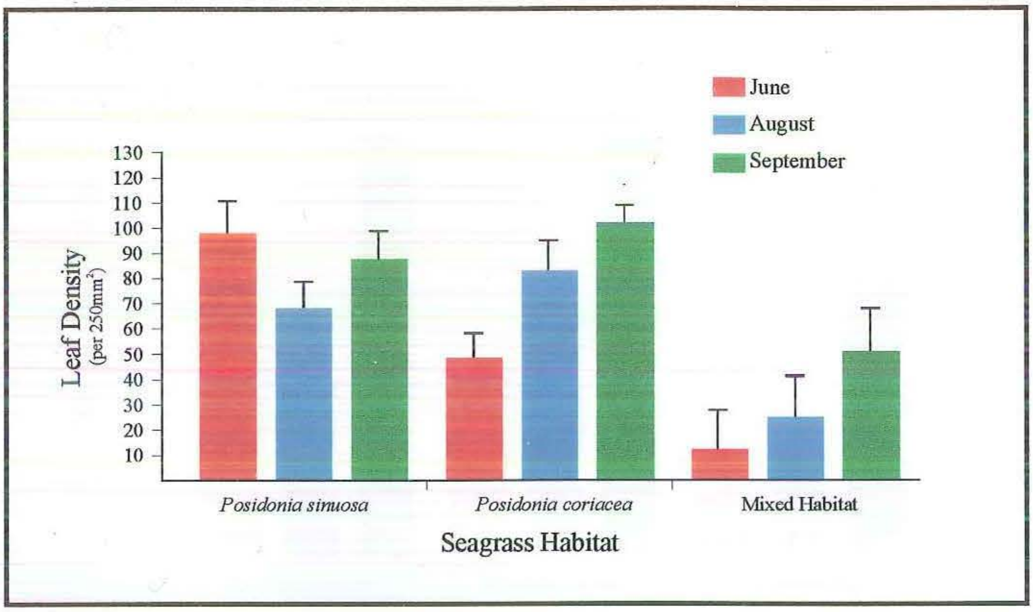


Figure 3.15 Mean seagrass leaf density (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

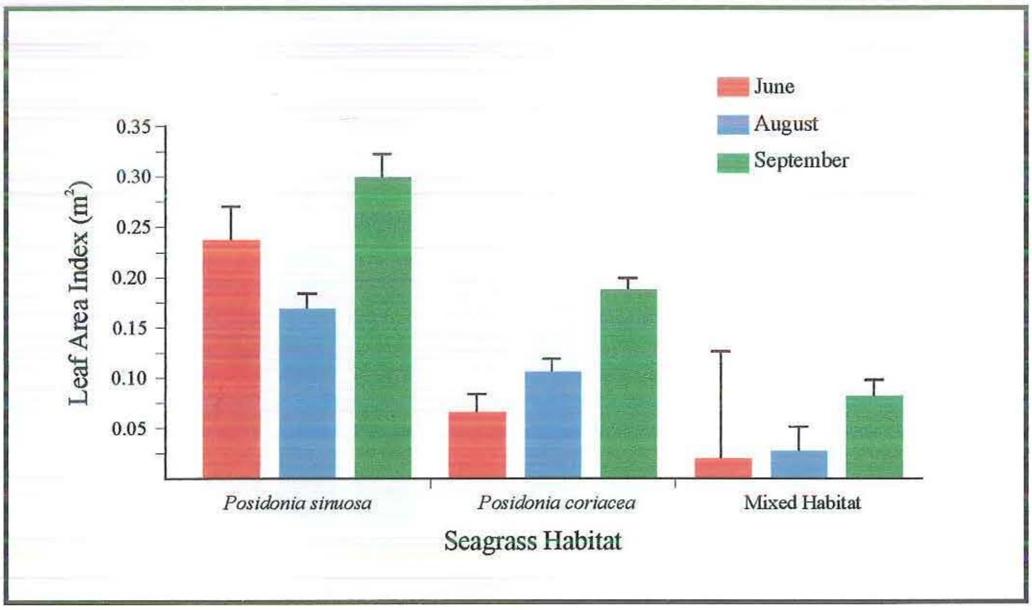


Figure 3.16 Mean seagrass leaf area index (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

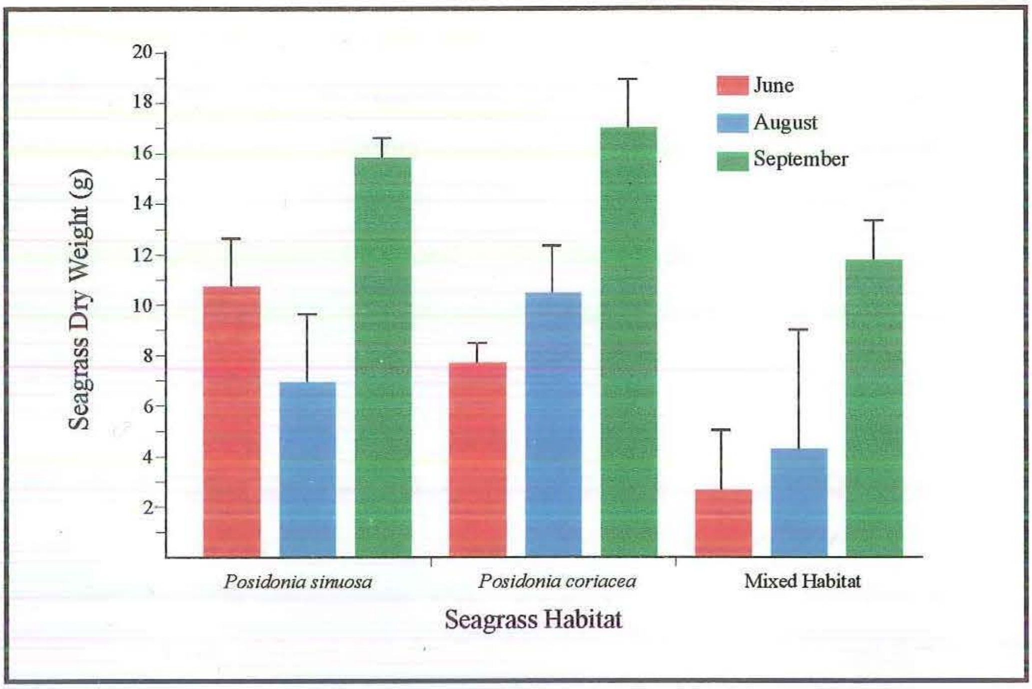


Figure 3.17 Mean dry seagrass biomass (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

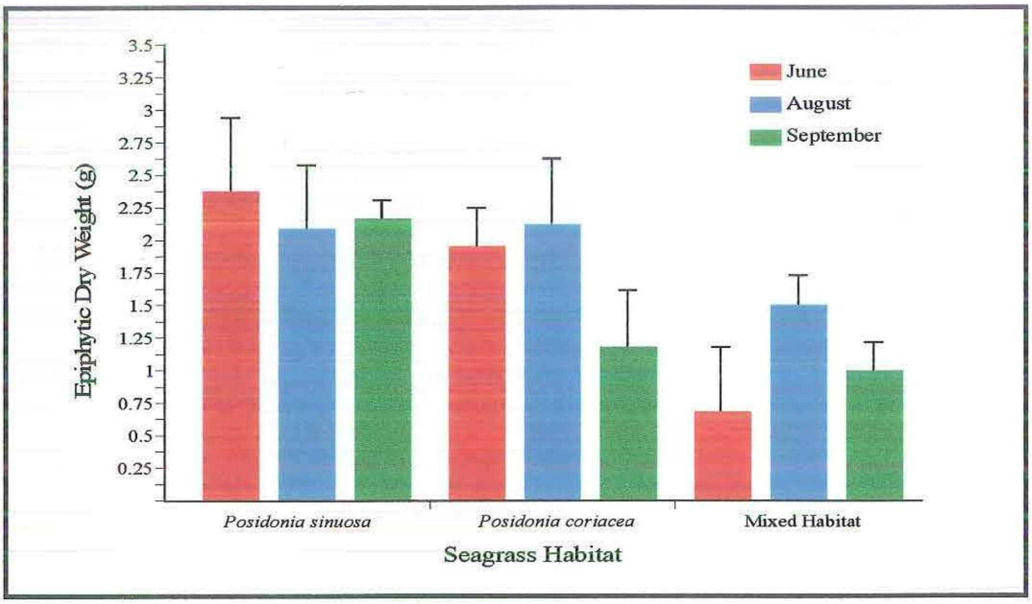


Figure 3.18 Mean dry epiphytic biomass (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

ANOVA indicated that dry epiphytic biomass differed significantly among habitats for (p=0.001), but not between months and there was no interaction between these two factors (Table 3.9). Further analysis indicated epiphytic biomass was significantly higher in both *Posidonia* habitats than the mixed habitat (Table 3.11). Mean values ranged between 0.67 and 1.49g for the mixed habitat compared to between 2.06 and 2.37g for *P. sinuosa* and between 1.2 and 2.13g of dry epiphytic biomass for *P. coriacea* (Table 3.11 and Figure 3.18).

In contrast to the other variables, seagrass leaf length did not differ significantly among habitats (p=0.253) or months (p=0.071) and there was no interaction between these two factors (p=0.734) (Table 3.9). Mean values ranged between 360 and 409mm for *P. sinuosa*, 320 and 439 for *P. coriacea* and between 343 and 408mm for the mixed habitat (Table 3.11 and Figure 3.19).

The two-way ANOVA indicated that seagrass leaf width differed significantly among habitats for (p=<0.001) but not among months (p=0.240) and there was no interaction between these two factors (p=0.354) (Table 3.9). Further analyses, using Tukey's HSD test, indicated leaf width was significantly greater in *P. sinuosa* than either *P. coriacea* (p=0.000) or the mixed habitat (p=0.000) (Table 3.11). Leaf width in *P. coriacea* was significantly greater than the mixed habitat (p=0.029) (Table 3.11). Mean leaf widths ranged between 6.7 and 7.2mm for *P. sinuosa*, 3.8 and 4.3 for *P. coriacea* and between 3.2 and 3.9mm in the mixed habitat (Table 3.11 and Figure 3.20).

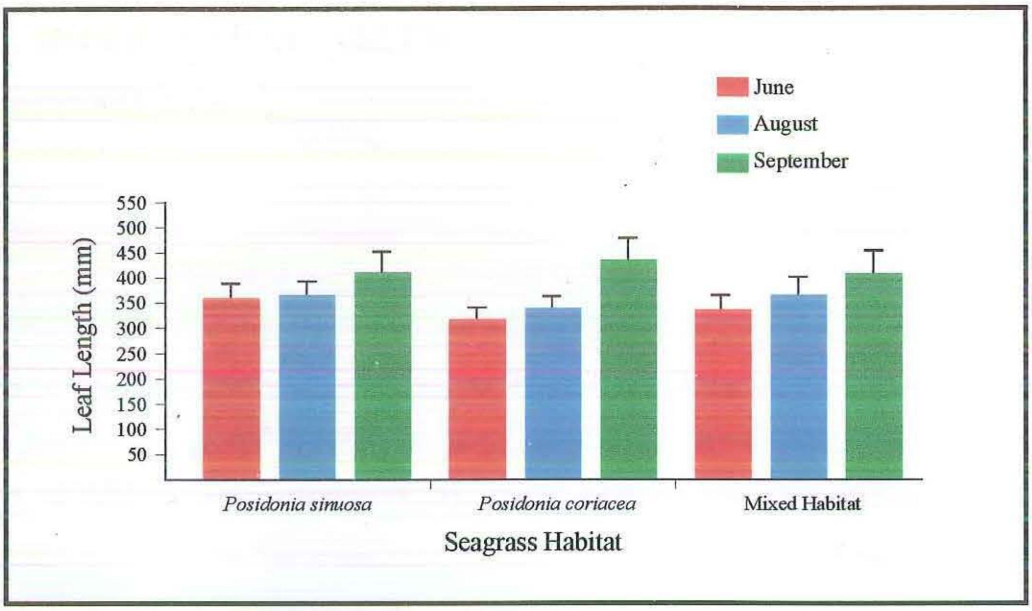


Figure 3.19 Mean seagrass leaf length (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

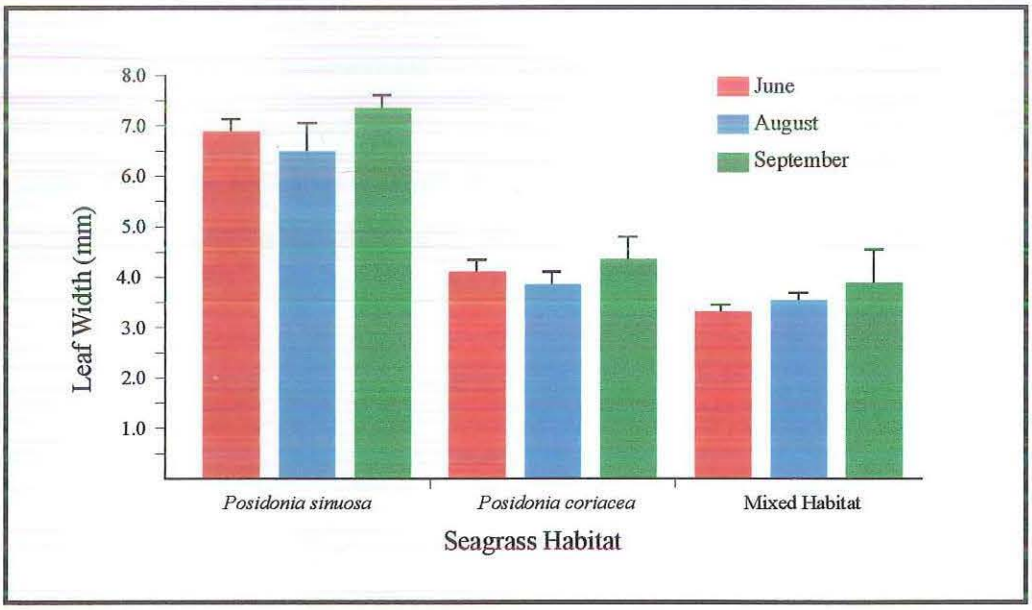


Figure 3.20 Mean seagrass leaf width (+1S.E) from each habitat sample collected from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region.

3.3 INTERACTION BETWEEN FISH AND SEAGRASS HABITATS

Step-wise multiple regressions showed that leaf area index and epiphytic biomass were the only variables that were related to fish species richness, total fish abundance and fish biomass in either June or September (Table 3.13). Species richness was related to leaf area index only during September sampling (R^2=0.335, p=0.012), while fish abundance (R^2=0.309, p=0.017) and biomass (R^2=0.548, p=<0.000) was related to LAI in June (Table 3.13). Dry epiphytic biomass also showed a significant influence on fish abundances during June sampling, with R square values of 0.309 for combined leaf area index and dry epiphytic biomass (Table 3.13).

A similar step-wise regression showed that the abundance levels of the five most abundant fish species collected throughout the sampling, were related to one of the following variables: leaf area index, leaf width and dry epiphyte biomass (Table 3.14). The abundance of *S. argus* (R^2=0.273, p=0.026) and *S. radiatus* (R^2=0.318, p=0.015) were related to leaf width in June, and for the latter species, also September, where it was also related to epiphytic biomass (Table 3.14). The abundances of *S. granulatus* (R^2=0.266, p=0.028) and *S. nigra* (Table 3.14) were related seagrass density in June but not September.

Table 3.13 R square values and p-values of the step-wise regression conducted between the seagrass and fish variables during (a) June and (b) September 2002 from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats between June and September 2002 within the Success Bank region. Shaded boxes indicate no significant relationship between variables.

	Step 1			Step 2		
	Variable	R2	P Value	Variable	R2	P Value
Species Richness	▨	▨	▨	▨	▨	▨
Fish abundance	Leaf area index	0.309	0.017	Dry Epiphytic Biomass	0.503	0.029
Fish Biomass	Leaf area index	0.548	0.000	▨	▨	▨

	Step 1			Step 2		
	Variable	R2	P Value	Variable	R2	P Value
Species Richness	Leaf area index	0.335	0.012	▨	▨	▨
Fish abundance	▨	▨	▨	▨	▨	▨
Fish Biomass	▨	▨	▨	▨	▨	▨

Table 3.14 R square and p values of the step-wise regression conducted between the seagrass variables and the five most abundant fish species collected during (a) June and (b) September 2002 from *Posidonia sinuosa, Posidonia coriacea* and mixed habitats within the Success Bank region. Shaded boxes indicate no significant relationship between variables.

		Step 1			Step 2	
	Variable	R2	P Value	Variable	R2	P Value
Stigmatopora argus	Leaf Width	0.273	0.026			
Siphonognathus radiatus	Leaf Width	0.318	0.015			
Stigmatopora nigra	Seagrass Desnity	0.26	0.031			
Siphemia cephalotes						
Scobinichthys granulatus	Seagrass Desnity	0.266	0.028			

		Step 1			Step 2	
	Variable	R2	P Value	Variable	R2	P Value
Stigmatopora argus						
Siphonognathus radiatus	Epiphytic Biomass	0.500	0.001	Leaf Width	0.648	0.000
Stigmatopora nigra						
Siphemia cephalotes						
Scobinichthys granulatus						

BIOENV indicated that seagrass density; leaf area index (LAI) and seagrass width significantly influenced the fish species composition within the three seagrass habitats. Leaf density, leaf width and LAI showed the greatest influence to fish community patterns in June (R^2=0.453), while leaf width was the most influential in September (R^2=0.461). The separate MDS plot of species abundance data for June and September exhibit a similar separation of samples from *P. sinuosa* and the other two habitats that was shown in Figure 3.14. That is, the samples from *P. sinuosa* generally lay at the top of the plot forming a discrete group, where the samples from *P. coriacea* and the mixed habitats were interspersed at the bottom of the plot. The overlay of the plant variables, where the size of the symbol reflects the magnitude of the plant variable for that sample, shows that for seagrass density, leaf area index and leaf width in June, the larger symbols are located at the top of the overlays and become smaller towards the bottom. A similar tend can be seen in the seagrass density overlay for September, however the distribution pattern is less pronounced. The remaining overlays of leaf length, dry seagrass biomass and dry epiphytic biomass, for both months, do not show the same linear distribution pattern

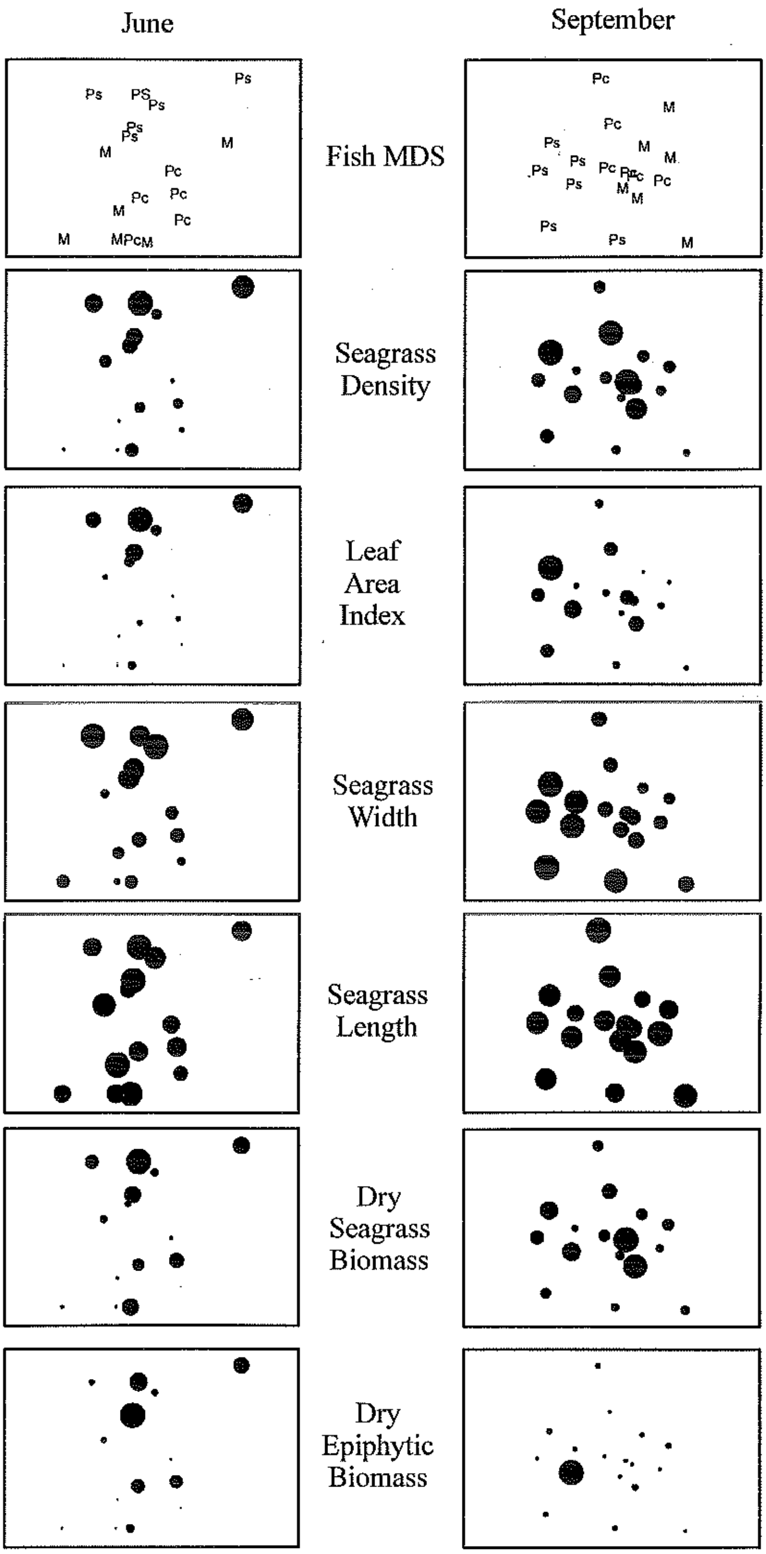


Figure 3.21 BIOENV plots of fish community patterns associated with the seagrass variables collected from *Posidonia sinuosa* (Ps), *Posidonia coriacea* (Pc) and mixed habitats (M) between June and September 2002 within the Success Bank region.

3.4 THE EVALUATION OF HABITAT PREFERENCE OF AN ABUNDANT SEAGRASS FISH SPECIES

G-test analysis showed that juvenile *S. argus* had a significant preference towards seagrass containing thinner leaves (Table 3.15). When fish were given the choice between *P. sinuosa* (leaf width=7mm) and *P. coriacea* (leaf width=4mm), a mean of 76.9% of fish were observed in the thinner leaved habitat (*P. coriacea*). Similarly, 63.6% of fish were observed in *H. tasmanica* when fish were provided with a choice of this thin-leaved habitat (leaf width=2mm) and the wider leaved *P. sinuosa*. When provided with the choice of *P. coriacea* and *H. tasmanica*, 67.5% of juvenile fish were observed in the thinner seagrass habitat (*H. tasmanica*) (Table 3.15a). The mean ratio of fish in each habitat for each pair-wise comparison remained comparatively constant throughout the experimental period for juvenile *Stigmatopora argus* (Figure 3.22)

Similar to the juveniles, adult *S. argus* showed a preference to habitats containing thinner leaves (Table 3.15b). When fish were given the choice between *P. sinuosa* (leaf width=7mm) and *P. coriacea* (leaf width=4mm), a mean of 61% of fish were observed in the thinner leaved habitat (*P. coriacea*). Similarly, 56.3% of fish were observed in *H. tasmanica* when fish were provided with a choice of this thin-leaved habitat (leaf width=2mm) and the wider leaved *P. sinuosa*. When provided with the choice of *P. coriacea* and *H. tasmanica*, 55% of fish were observed in the thinner seagrass habitat (*H. tasmanica*) (Table 3.15b). The mean ratio of fish in each habitat for each pair-wise comparison remained comparatively constant throughout the experimental period (Figure 3.23). The mean ratio of fish in each pair-wise comparison remained comparatively constant throughout the experimental period for adult *Stigmatopora argus* (Figure 3.23).

Table 3.15 Mean number (±1SE) of (a) juvenile and (b) adult *Stigmatopora argus* observed in each seagrass unit for each pair-wise comparison carried out in the laboratory experiments. Seagrass units simulated *Posidonia sinuosa* (7mm), *Posidonia coriacea* (4mm) and *Heterozostera tasmanica* (2mm).

A-Juveniles	***Posidonia coriacea***	***Heterozostera tasmanica***
Posidonia sinuosa	2.31 : 7.69 (0.20 : 0.20)	3.64 : 6.36 (0.15 : 0.15)
Posidonia coriacea		3.25 : 6.75 (0.29 : 0.29)

B - Adults	***Posidonia coriacea***	***Heterozostera tasmanica***
Posidonia sinuosa	3.9 : 6.1 (0.22 : 0.22)	4.36 : 5.63 (0.17 : 0.17)
Posidonia coriacea		4.5 : 5.5 (0.21 : 0.21)

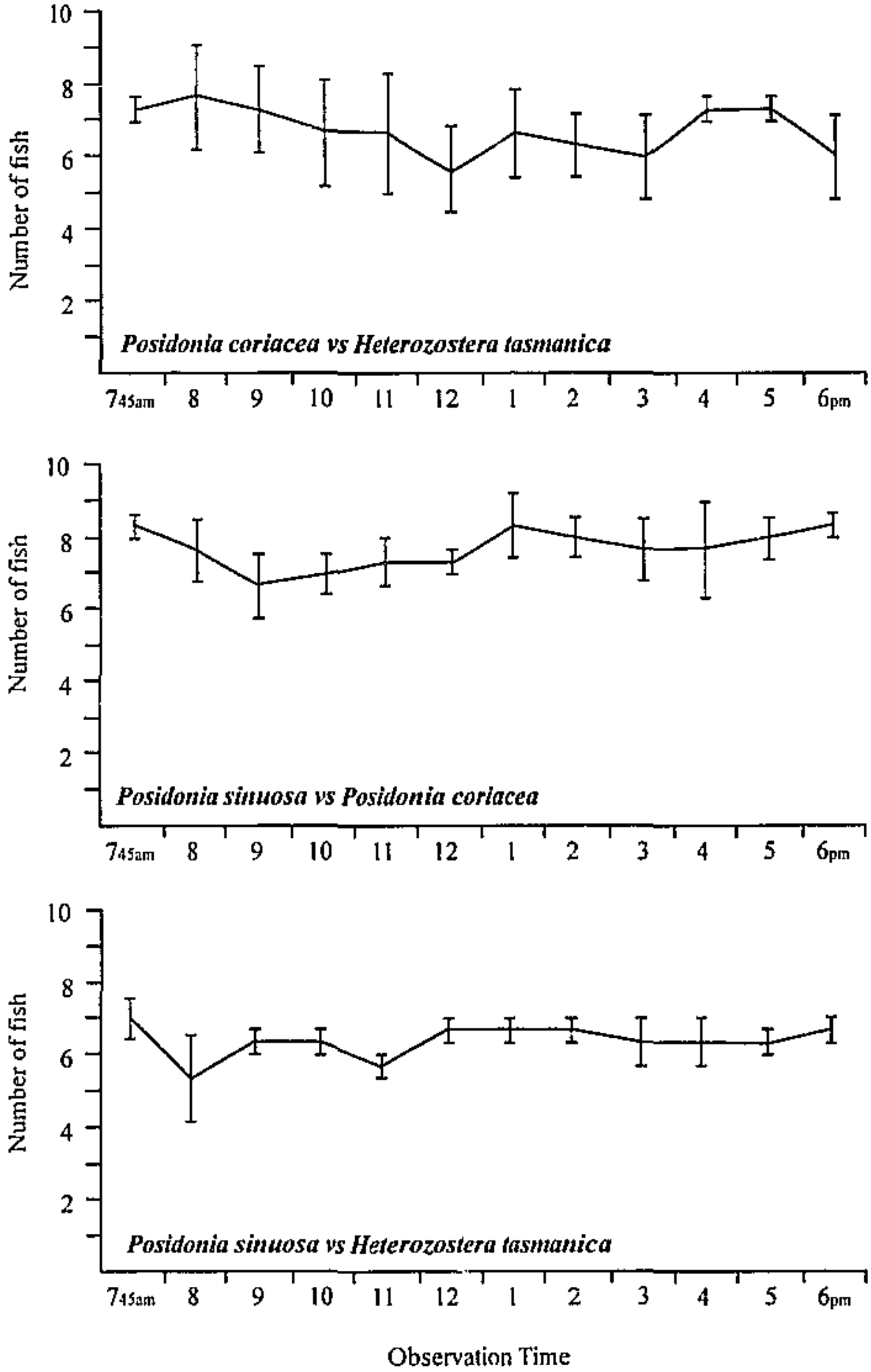


Figure 3.22 Mean numbers (±1S.E) of juvenile *Stigmatopora argus* observed over a 10-hour period in the thinner of the two seagrass species in each pair-wise comparison of the laboratory experiment.

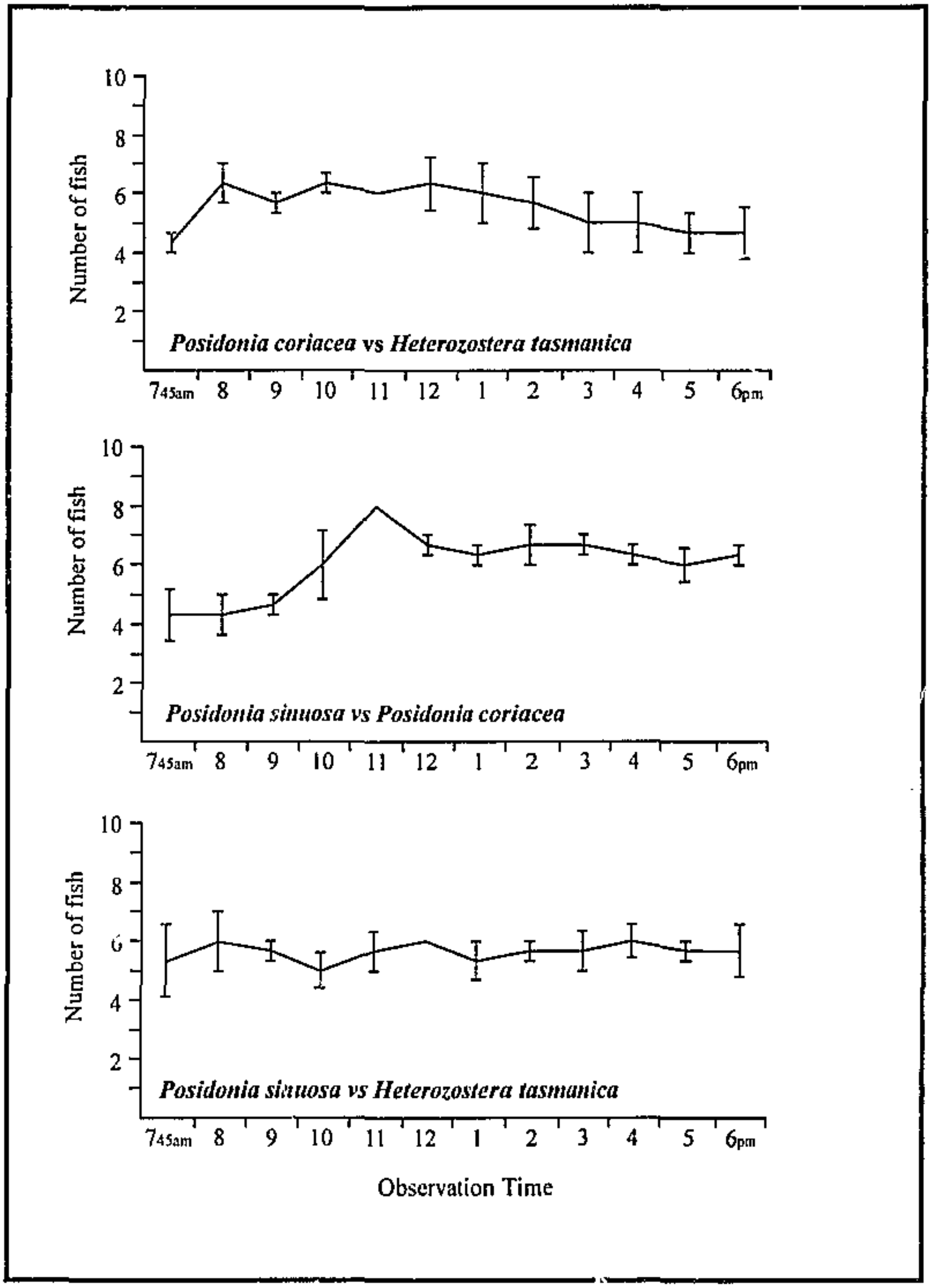


Figure 3.23 Mean numbers (±1S.E) of adult *Stigmatopora argus* observed over a 10-hour period in the thinner of the two seagrass species in each pair-wise comparison of the laboratory experiment.

CHAPTER 4: DISCUSSION

4.1 FISH COMMUNITY COMPOSITION BETWEEN SEAGRASS HABITATS

Sampling of the fish fauna in seagrass meadows on Success Bank using a small beam trawl indicated that a large number of fish species occupy seagrass meadows in this region. Consequently, like other regions of the world where seagrass meadows form a dominant habitat in coastal regions (Heck & Orth, 1980; Kikuchi, 1980; Bell & Pollard, 1989; Howard *et al.*, 1989), the largest areas of seagrass meadows on Success Bank provide extensive vegetated habitats for many fish species. Although the suite of species collected in this study corresponds to that collected by Hyndes *et al.* (1998) using the same sampling method, comparisons between these two studies indicate that this project only represents a small subset of the species that occur within the seagrass habitats. However, Hyndes *et al.* (1998) showed that the difference in the species composition of fish among seagrass habitats exhibited by small-trawl catches reflected those differences of the broader fish community.

While seagrass meadows provide important habitats for many fish species, the present study clearly indicates that different species of seagrass provide habitats for different assemblages of fish. On Success Bank, seagrass meadows consisting of *P. sinuosa* contain a significantly different composition of fish species to meadows comprising *P. coriacea* (with or without *H. tasmanica*). Whereas *P. coriacea* on its own or mixed with *H. tasmanica* contain similar species compositions. This may be explained by the fact that, although *H. tasmanica* was found in the mixed habitat, *P. coriacea* was the dominant species. While fish densities were greater in *P. sinuosa*, little difference occurred in species richness between the three habitats. These findings coincide with similar studies conducted within meadows consisting of different seagrass species (Middleton *et al.*, 1984; Hyndes *et al.*, 1998; Rotherham & West, 2002).

SIMPER analysis showed that the species *Stigmatopora argus*, *Siphonognathus radiatus* and *Scobinichthys granulatus* were diagnostic of *P. sinuosa* meadows, which reflected their greater abundance, rather than uniqueness in this habitat. This is supported by Hyndes *et al.* (1998) and Hyndes (2000), who found similar results between *P. sinuosa* and *P. coriacea / H. tasmanica* habitats. The greater abundance of *S. argus* and *S. radiatus* in *P. sinuosa* appears to indicate a habitat preference over the other two habitats. In contrast, *Stigmatopora nigra* was found to be diagnostic of *P. coriacea* and the mixed habitat, which reflected its absence from *P. sinuosa* meadows. This was paralleled in the results of Hyndes *et al.* (1998), Hyndes (2000) and Kendrick & Hyndes (2003).

Kendrick and Hyndes (2003) hypothesised that *S. argus* undergoes a size-related migration from one seagrass habitat to another during its life cycle. The authors state that, once reaching maturity (>120mm TL), adults move from the narrow-leaved *P. coriacea* associated habitats to the wider-leaved *P. sinuosa* habitats. This hypothesis has been supported by the present study, as fewer juvenile-sized fish were found in *P. sinuosa* and fewer adult-sized fish were found in either *P. coriacea* or mixed species habitats. The difference in size-classes between *P. sinuosa* and *P. coriacea* (with or without *H. tasmanica*) indicates that the distribution is the result of migration and not just differential mortality, as there was a lack of adult-sized *S. argus* in the *P. coriacea* associated habitats throughout the present study. Similar observations, where large *S. argus* exhibit a preference for the wide-leaved seagrass, has been recorded by few authors examining habitat selection in the *Stigmatopora* species (Steffe *et al.*, 1989).

Similar to Kendrick & Hyndes (2003), findings of this study have shown that *S. nigra* was absent from *P.* sinuosa. Furthermore, this species did not appear to exhibit a preference for *P. coriacea* over the mixed habitat (*P. coriacea / H. tasmanica*).

Virnstein & Curren (1986) (cited in Sogard, 1989) suggest several possible reasons for fish species to leave one habitat and migrate to another, including: the temporary or permanent escape from predators; the movement to new foraging areas after localised depletion of food resources; and minimising competition for limited resources (space, food or mates). Predation levels on *S. argus* are likely to be high as Kendrick & Hyndes (2003) found the tails of more than 90% of live *S. argus* (and *S. nigra*, a smaller pipefish species) in seagrass meadows on Success Bank were damaged as the result of predator attacks. The movement of *S. argus* to the wider-leaved and denser meadows of *P. sinuosa* is likely to reduce the predation risk of larger individuals. This species appears to strongly mimic the seagrass leaves with a long and narrow body shape and olive green pigmentation (Howard & Koehn, 1985; Gommon *et al.*, 1994). Movement in the current, while attached to seagrass leaves, using a prehensile tail, also tends to mimic the movement of seagrass leaves (Howard & Koehn, 1985; Gommon *et al.*, 1994; Jenkins & Sutherland, 1997). As juvenile *S. argus* increase in size, they are likely to lose the ability to remain camouflaged within the narrower seagrass leaves, which increases the risk of predation by larger piscivorous fish (Kendrick & Hyndes, 2003). This is supported by the laboratory experiments which showed that, in the absence of predators, *S. argus* display a preference for the narrower leaves, which will be discussed in more detail in Section 4.2. Similar to *S. argus*, the length distributions of *Scobinichthys granulatus* indicated a similar size-related migration, with the majority of individuals collected from *P. sinuosa* being juveniles (under 140mm) (Gommon *et al.*, 1994). This indicates that *S. granulatus* occupies seagrass meadows (primarily *P. sinuosa*) as a nursery habitat before moving into other regions once reaching maturity. This is supported by Hyndes *et al.*, (1998) who found similar high abundance levels of juveniles in *P. sinuosa*.

In contrast to *S. argus* and *S. granulatus*, *Stigmatopora nigra* did not show any sign of migration between different seagrass habitats, even though the dense seagrass of *P. sinuosa* would be expected to provide greater protection from predators (Kendrick & Hyndes, 2003). Adult-sized *S. nigra*, which are a similar size to juvenile *S. argus*, may be subjected to size-related predation by predators that inhabit *P. sinuosa*, or their short tails cannot grasp the wide leaves of the seagrass (see Section 4.2)

(Kendrick & Hyndes, 2003). However, it is possible that sufficient predator protection is provided in *P. coriacea / H. tasmanica* habitats and *S. nigra* show a preference for the narrower-leaved seagrasses.

Apart from the differences in predation pressure, habitat selection of the above species may be influenced by food availability (Orth *et al.*, 1984; Worthington *et al.*, 1991). Since invertebrate diversity and abundance can be influenced by seagrass leaf morphology,(Edgar & Robertson, 1992) this is also likely to influence fish habitat preference (Orth *et al.*, 1984; Worthington *et al.*, 1991). The results showed that epiphytic biomass was significantly greater in the wider-leaved *P. sinuosa* than the two narrow-leaved seagrasses habitats. Similarly, Trautman & Borowitizka (1997) found that more epiphytic algae were present on a wider-leaved species (*Posidonia australis*) than a narrower-leaved seagrass species (*P. sinuosa*). As a consequence of this, invertebrate abundance levels are generally greater in wide-leaved seagrasses (Harlin, 1975; Borowitzka *et al.*, 1990). This may indicate why fish abundances were greater in the wider-leaved *P. sinuosa* versus the narrower-leaved *P. coriacea* and *H. tasmanica*. Two species of pipefish, *S. argus* and *S. nigra*, were found to predate on the planktonic calanoid copepods suspended in the water column, while attached to both narrow and wide leaf seagrasses (Kendrick, 2002). This indicates that while the ability to forage for food is important, the ability to find a suitable habitat to provide protection from predators may be more important in habitat selection for fish species.

4.2 THE INFLUENCE OF SEAGRASS HABITAT AND STRUCTURE ON FISH ASSEMBLAGES

The present study indicates that the seagrass structure differs between the *P. sinuosa* habitat and habitats containing *P. coriacea* (with or without *H. tasmanica*). However, differences between *P. coriacea* and the mixed (*P. coriacea* and *H. tasmanica*) habitats were less clear. It was found that leaf width differed significantly between all three habitats, while leaf area index (LAI) and leaf density were greater in *P. sinuosa* than the other two habitats. Dry seagrass biomass was found to be greater in *P. sinuosa* compared to the mixed habitat, while dry epiphytic biomass was greater in the two *Posidonia* habitats compared to the mixed habitat. Seagrass leaf length was the only morphological feature that did not differ significantly between the three seagrass habitat. Of these plant variables, regression and BIOENV analyses indicated that, only seagrass leaf width, LAI and leaf density influenced fish densities, biomass and the species composition of fish.

Previous studies have generally focused on the influence of seagrass density on fish assemblages and have shown this variable plays a significant role in the habitat preference of fish species (Bell & Westoby, 1986c, 1986b; Edgar *et al.*, 1994; Edgar & Shaw, 1995a; Jenkins *et al.*, 1997; Jenkins & Wheatley, 1998; Hindell *et al.*, 2000a). Bell & Westoby (1986b, 1986c) demonstrated that as seagrass density decreased, fish (and decapod) species richness and abundance also decreased. Furthermore, the authors hypothesised that other variables may have an influence on the organisation and distribution of species. The present study supports Bell & Westoby's (1986b, 1986c) hypothesis that other seagrass variables, as well as seagrass density, appear to influence habitat selection. Leaf area index had a considerable influence on the species richness, total fish abundance and total fish biomass within the three seagrass habitats in at least one of the two months where this relationship was examined. LAI, as well as leaf width, also influenced the species composition. Heck & Orth (1980) suggested that seagrass species with greater surface area should provide more protection from predators than plants with lower surface area. This hypothesis was supported by the present study and Hyndes *et al.* (1998) in which, species richness, total fish abundances and biomass were greater in *P. sinuosa* (wide-dense canopy cover) than the other *P. coriacea* associated habitats (narrow-sparse canopy cover).

In their study looking at habitat use of odacid fishes, MacArthur & Hyndes (2001) hypothesised that the lower abundances of *Siphonognathus radiatus* in *P. coriacea* compared to *P. sinuosa* meadows were based on the lower seagrass densities of the former habitat. By examining the relationship between these variables, the present study indicates that seagrass density does not appear to influence the distribution of this species. In comparison, regression analyses showed that abundances of *S.*

radiatus were influenced by leaf width, which reflected more individuals being collected from the wider-leaved *P. sinuosa* than the narrower-leaved *P. coriacea*. However, there is no clear biological reason for this to be the case, since, unlike the *Stigmatopora* species, body morphology of *S. radiatus* does not strongly mimic the seagrass leaves. This result indicates that other factors may influence the distribution of *S. radiatus*. Dry epiphytic biomass was also shown to influence abundance levels of *S. radiatus*, indicating that its greater abundance in *P. sinuosa* could be related to food availability. The dietary composition of the fish species was beyond the scope of this project and further research is suggested in this area.

Leaf width was also found to influence the habitat preference of *Stigmatopora argus*, the most abundant species present in the study. Even though *S. argus* was abundant in seagrass with both wide and narrow leaves, the adult-sized fish were most abundant in the wide-leaved seagrass (*P. sinuosa*), while the juveniles occurred predominantly in the narrow leaved seagrass (*P. coriacea / H. tasmanica*). As described in Section 4.1, these findings concur with results of other studies (Steffe *et al.*, 1989; Jenkins & Sutherland, 1997; Hyndes *et al.*, 1998; Kendrick & Hyndes, 2003) and was suggested that the size-related movement of *S. argus* to the wider-leaved seagrass is related to predation pressure and the ability of this species to grasp seagrass leaves with their prehensile tail.

By using *in situ* artificial seagrass, leaf width has also been shown by Jenkins & Sutherland (1997) to influence species richness and total abundances of fish. The previous authors found that the higher abundance levels in the narrow-leaf beds were due to higher numbers of *Stigmatopora* fishes. Unlike the present study, species richness and total abundance were shown to be greater in narrower-leaved beds over the wider-leaved beds. However, the conclusions from this study need to be considered with some caution. The authors' choice of leaf width (5mm versus 58mm) was "extreme" and the wider leaf does not simulate the natural seagrass of the area. The authors also had different seagrass densities, which may have had considerable influence of the species composition, as more fish were present in the denser (narrower) seagrass.

4.3 THE EVALUATION OF HABITAT PREFERENCE OF AN ABUNDANT SEAGRASS FISH SPECIES

The use of artificial seagrass in the laboratory experiments, showed that both juvenile and adult *S. argus* had a strong preference towards the narrower leaves of *P. coriacea* and particularly *H. tasmanica*. However, this preference was more pronounced for the juvenile fish. Hence, where seagrass density and leaf height remained constant and the influence of food availability and predation were removed, *S. argus* least preferred the wider artificial seagrass representing *P. sinuosa* and preferred the narrower leaves of *P. coriacea* and *H. tasmanica*. Since all treatments contained similar leaf densities, the wider-leaved treatments would have been characterised by greater LAI, which may provide a confounding influence in the habitat selection of the fish. However, this would suggest that fish prefer lower LAI, whereas regression analyses indicated that the abundance of adult-sized *S. argus* was not influenced by LAI. Thus, LAI is unlikely to influence the habitat preference of *S. argus* in the experiments.

As stated earlier, Kendrick & Hyndes (2003) suggest that the absence of juvenile *S. argus* from *P. sinuosa* was related to their body size and the limited movement in their prehensile tail, preventing them from attaching to the wider leaves of *P. sinuosa*, therefore restricting these fish to the narrower leaves of *P. coriacea* and *H. tasmanica*. The results of the habitat preference experiment appear to support this hypothesis. However, adult *S. argus*, which have the ability to attach to wider leaves, showed a preference for the narrow-leaved seagrass in the laboratory experiments.

The experiment shows that a greater abundance of *S. argus* would be expected to occupy seagrass habitats with narrower leaves. While field sampling showed this was true for juveniles (<120mm TL), which were in great abundance in habitats containing *P. coriacea* (with or without *H. tasmanica*), this was not the case for adult-sized fish, which were most abundant in the wider-leaved *P. sinuosa* habitats (see Section 4.1). As discussed earlier, *S. argus* undergo a size-related migration from *P. coriacea* and mixed habitats to *P. sinuosa*, indicating that factors other than leaf width influence habitat preference of the species.

The habitat preference of both juvenile and adult *S. argus* could be influenced by their ability to avoid predation (Ryer, 1988; Kendrick & Hyndes, 2003). This species appears to strongly mimic the seagrass leaves (see Section 4.1). Kendrick & Hyndes (2003) hypothesised that the ability of this species to remain camouflaged within the narrower seagrass leaves is likely to diminish with increasing fish size. Therefore, movement to the wider-leaved and denser meadows of *P. sinuosa* is likely to reduce predation pressure on larger *S. argus*. This study further suggests that this shift in habitat is likely to, at least partially, be explained by predation, since even the adults of this species exhibited a preference for narrower leaves in the absence of predation.

Since adult *S. nigra* are a similar size to juvenile *S. argus*, the results for juvenile *S. argus* are presumably applicable to *S. nigra*. Thus, *S. nigra* would exhibit a similar preference for the narrower leaves, which supports the findings from the field sampling *i.e.* that this species was absent from *P. sinuosa*. Thus, similar to juvenile *S. argus*, the short tails of *S. nigra* may not allow it to grasp the wide leaves of the seagrass (Kendrick & Hyndes, 2003).

Although the varying habitat preference of both juvenile and adult *S. argus* are possibly related to the avoidance of predation, these differences may also be connected to variations in the availability and preference of food. Several authors have shown that the composition and abundance of invertebrates can differ significantly between seagrass habitats (Borowitzka *et al.*, 1990; Jernakoff & Nielsen, 1998; Lavery *et al.*, 1998). Kendrick (2002) found that the diets of *S. argus* (and *S. nigra*) mainly consisted of planktonic calanoid copepods. The *Stigmatopora* species of pipefish are described as "sit and wait" feeders, as most prey is taken from the water column, while the fish are attached to the seagrass blades. However, individuals can swim a short distance to capture prey (Howard & Koehn, 1985;

Jenkins & Sutherland, 1997; Kendrick & Hyndes, 2003). Jenkins & Sutherland (1997) hypothesised the preference of *Stigmatopora* spp. for denser seagrass beds may be due to the hydrodynamics of water currents concentrating their food source, planktonic copepods. However, *Stigmatopora* species were abundant in both dense and sparse seagrasses (Kendrick & Hyndes, 2003).

The results of this series of experiments have indicated that seagrass leaf width plays a significant role in the habitat selection of *S. argus*. However, fish species that do not show the same body morphology and orientation, as the *Stigmatopora* species are less likely to be influenced by leaf width. While regression analysis indicated that *S. radiatus* (Long-rayed weedwhiting) was influenced by leaf width, there is no clear biological reason for this to be the case. Although, abundance levels were greatest in the wider leaves of *P. sinuosa*, *S. radiatus* was also found in the other two habitats, which may suggest that for this species and other species with similar morphology factors may be influencing its habitat preference (see Section 4.2).

4.4 ENVIRONMENTAL MANAGEMENT IMPLICATIONS

This study has shown that numerous fish species occupy the various seagrass habitats in the Success Bank region of Western Australia. However, unlike other parts of Australia's coast (Pollard, 1984; Bell & Pollard, 1989), few economically important species occupy these seagrass meadows during juvenile or adult-stages of their life cycle. Numerous species in eastern Australia have been shown to use seagrass meadows as nursery habitats, before migrating to other habitats to spawn. The lack of economically important species inhabiting the seagrass meadows within Success Bank in the present study concurs with Hyndes *et al.* (1998).

Although, seagrass meadows do not play a direct role in fisheries production within the region, they may provide an indirect role by providing food for larger fish that migrate through the area. Seagrass beds generally support large number of small fish species and/or juveniles of larger species (Bell & Pollard, 1989) and could potentially be an important food source for larger migrating species. Hyndes *et al.* (1998) found that various syngnathid and clinid species are an important component of the diets of the rock flathead *Leviprora laevigatus*. Seagrass meadows may also contribute significantly to the food source of juvenile King George whiting in sandy habitats (adjacent to the seagrass *Posidonia*) through the production of detritus (cited in Connolly *et al*, 1999).

Recently, the Environmental Protection Authority (EPA) considered a proposal from Cockburn Cement Limited (CCL) to dredge shellsand from locations within the Success Bank region (EPA, 2001). The proposal states that an estimated 77.1ha of *P. sinuosa* meadows and 6.9ha of *P. coriacea / H. tasmanica* meadows will be removed (EPA, 2001). The results of this study have shown that each of these seagrass habitats has distinct fish assemblages and the removal of such extensive areas could have an impact on local secondary production, a concern that was also identified by Hyndes *et al.* (1998) and Lavery *et al.* (1998). This study has shown that, for a given area, the greatest loss of production will be found in the *P. sinuosa* meadows. Extrapolated figures from the present study indicate that, if the proposal is accepted, and if fish cannot migrate to and utilise surrounding seagrass areas, an estimated loss of 237,000 fish (representing 1500kg) is expected from the removal of 77.1ha of *P. sinuosa*. Although these values may not seem excessive for the size of area, it is important to note that the present project sampled only a subset of the full suite of species within the seagrass habitats, as sampled by Hyndes *et al.* (1998). Using the data from this more extensive study, more than 1.2 million fish (representing ~38,000kg) could be lost, indicating that the proposed seagrass loss could have an impact on regional secondary production.

Posidonia sinuosa is the dominant habitat in the southern portion of the region, while *P. coriacea / H. tasmanica* is dominant in the northern portion (Lord, 2000). As mentioned previously, the species composition differs significantly among the different seagrass habitats, although many species migrate between nursery, spawning and feeding habitats at various stages of their life cycle. However, if large areas of the seagrass habitats are removed, fish are unlikely to recolonise other habitats (Hyndes *et al.*, 1998). For example, the suite of species associated with *P. sinuosa* is unlikely to migrate and re-settle into other seagrass habitats such as *P. coriacea*. Furthermore, the loss of one seagrass habitat type could also have an influence on the biodiversity of another seagrass habitat, since some species (*e.g. Stigmatopora argus*) migrate from one habitat (*P. coriacea*) to another (*P. sinuosa*).

Since seagrass meadows often contain distinctly different fish assemblages than algal reefs and bare sand (Jenkins & Wheatley, 1998; Guidetti, 2000), many fish will not have the ability to move into other coastal habitats, or back into the same area from which seagrass has been removed. Loss of seagrass areas is therefore likely to result in high predation levels or starvation of those fish that have lost that habitat. Thus, reducing the amount of seagrass through either degradation or removal will influence both biodiversity and secondary production. This study has shown that coastal managers not only need to consider the seagrass in general, but also specific habitats, such as *P. sinuosa* or *P. coriacea*, to ensure that fish species biodiversity is retained. Furthermore, if the purpose of management is the restoration and mitigation of marine biodiversity and ecosystem function through, the transplantation of seagrass into either degraded or unvegetated areas, managers need to consider the types of seagrass habitat that should be restored. This study has provided valuable information to help the management of seagrass-dominated marine ecosystems, including the conservation of seagrass meadows and the biodiversity of the faunal assemblages associated with them.

CHAPTER 5: CONCLUSIONS & FUTURE RESEARCH

The findings described in this study have shown that plant morphology appears to play a significant role in influencing fish faunal assemblages associated with seagrass meadows. Species composition varied significantly between seagrass habitats containing *P. sinuosa* and those containing *P. coriacea* (occurring with or without *H. tasmanica*), however, there were no significant differences between the *P. coriacea* associated meadows. The study showed that leaf width differed significantly between all habitats, while leaf area index and leaf density were greater in *P. sinuosa* than the other two habitats. Dry seagrass biomass was found to be greater in *P. sinuosa* compared to the mixed habitat, while dry epiphytic biomass was greater in the two *Posidonia* habitats compared to the mixed habitat. Seagrass leaf length was the only morphological feature that did not differ significantly between the three seagrass habitats.

The species composition, richness and abundances of fish appear to be influenced by seagrass structure with leaf area index (LAI) and leaf width influencing fish variables. Based on the contrasting results from fieldwork and laboratory experiments conducted for this study, there appears to be an interaction between plant morphology and other factors. The study indicates that fish species select a habitat that will reduce their risk of predation and/or provide suitable amount of food. However, the ability to avoid predation and forage for food is equally dependant on body shape, size or the ability to mimic the natural surroundings as it is on habitat complexity.

The results from this project have clear implications for the environmental management of near-shore marine ecosystems including the conservation of seagrass meadows and the biodiversity of the faunal assemblages associated with them.

Although this project has provided valuable information concerning fish habitat selection, further research needs to be conducted to properly determine and understand the underlying factor/factors that contribute to why fish fauna select one seagrass habitat over another. The laboratory experiments conducted for this study have concentrated on one particular species that has a unique form of body morphology. It is suggested that similar experiments be conducted with other dominant fish species with differing body morphologies. This would enable a more comprehensive examination of the factors influencing habitat selection. These experiments could include seagrass characteristics such as seagrass leaf width, leaf density and leaf area index.

Heck & Orth (1980) hypothesised that the habitat selection of fish species is primarily influenced by the risk of predation. The laboratory experiment in the present study indicated, when the risk of predation was removed, that adult *S. argus* preferred the narrower artificial seagrass representing *P. coriacea* and *H. tasmanica* over the wider leaves representing *P. sinuosa*. It is recommended that further laboratory-controlled experiments be conducted to determine whether *S. argus* show a similar habitat preference when a predator is incorporated into the trials. Tanner & Deakin (2001) conducted similar habitat preference experiments with juvenile western king prawns and found that their habitat preference was strongly influenced by the presence of a predator.

As shown in the present study, seagrass meadows support a large number of fish species. Availability of suitable habitat to protect those species from predators could be a limiting resource. Heck & Orth (1980) suggest that competition, between individuals and/or species, is important among animals in seagrass meadows. They suggest that, in low to medium seagrass densities, competition for space may be important in determining which species is protected from predation by plant biomass. Competition could therefore be a significant influence among most non-schooling small fishes. Heck and Orth (1980) also suggest that, as seagrass density increases, the risk of predation is reduced and therefore competition for space becomes less important. It is suggested that laboratory-based experiments examine the interaction between various species of fish of similar or different body morphology, when resources, such as food or space, are limited.

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