The Temporal and Spatial Variability of *Zostera capricorni* and their Influence on Fish Assemblages in the Brisbane Water Estuary, NSW, Australia.

By

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A thesis submitted in partial fulfilment of the requirements for the degree Bachelor of Science (Honours) in the School of Science & Technology, University of Newcastle.

Declaration

I herby certify that the work embodied in this thesis is the result of original research and has not been submitted to any other University or Institution.

Signed:_____ Date:_____

Teneille Boyland

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Abstract

This study examined the temporal and spatial variability of *Zostera capricorni* bed structure, and the fish assemblages in the Brisbane Water estuary. Investigations into the relationship between seagrass beds and fish assemblages were also carried out. Additionally, two methods of studying fish assemblages, seine netting and visual census were evaluated in order to determine the usefulness of visual census in examining fish assemblages.

The seagrass bed structure displayed significant temporal differences in shoot density, percent cover of seagrass and epiphyte cover, while all seagrass floristics demonstrated spatial variability. The diversity of fish displayed significant temporal variability, while all fish assemblage variables demonstrated significant spatial variability. The length of recreational fish increased in size class during the temporal sampling period, presumably due to the same recruitment of fish being sampled during the study.

The investigation into the relationship between each seagrass variable found that shoot density, leaf length and seagrass percent cover were related to one another, while epiphyte cover was only related to leaf length. It is thought that all of these variables are dependant on the depth of the seagrass bed. There were several significant relationships between seagrass and fish variables, with fish diversity increasing with leaf length, and invertebrate diversity and abundance decreasing with epiphyte cover. The percent cover of seagrass, however, displayed more relationships with fish assemblages than any other seagrass variable. The Ecotrophic guilds of Ecological and

Vertical guilds, displayed similar relationships with seagrass variables, however, vertical guilds were affected by more seagrass variables.

The comparison of different fish assemblage sampling techniques showed that there were no significant differences between seine netting and visual census, however, further research is required into the effectiveness of the techniques in seagrass beds. It was also determined that the visibility greatly affected the estimates of fish diversity and density.

In conclusion, there were temporal and spatial differences in seagrass bed structure, while fish assemblages differed spatially and fish diversity encompassed temporal changes. It was also determined that fish assemblages are affected by the structure of the seagrass beds within the Brisbane Water estuary, and that these seagrass variables are interrelated with one other. Further research into the factors that shape seagrass fish assemblages would be invaluable in the management of these communities.

Chapter 1: Introduction

In the development of a management plan for an estuary it is paramount to have an understanding of the flora and fauna present, as well as the relationships that exist between them. Once this has been established, the best strategy for a management plan can be adopted, thus ensuring the ability to define the best scenario for the management of this estuarine environment. For the present study, the examination of the relationship between seagrass beds and fish assemblages has been identified as an important aspect of the management plan for an estuary. This chapter specifically discusses seagrass beds and the related fish assemblages, and their significance and importance to the Brisbane Water estuarine ecosystem.

Seagrasses are aquatic angiosperms that are highly specialised for life in the marine or estuarine environment. They are found worldwide inhabiting the shallow and sheltered areas of coastal and estuarine waters of generally less than two metres in depth (Kirkman, 1990), taking residence in soft bottom substrates such as sand and mud. However, they have also been found, according to Kirkman (1997) at depths of 47 metres in Esperance, Western Australia. According to McRoy and McMillian (1977) seagrasses have the ability to tolerate fluctuations in salinity, a range of temperatures, and have a broad tolerance for differing light intensity. den Hartog (1977) further asserts that for seagrasses to successfully colonise an area they not only need to be able to tolerate a saline environment, but also be able to function and reproduce when fully submerged in water, need a proficient anchorage system, and need to successfully compete with other organisms under ideal or non-ideal environmental conditions. It is the combination of these qualities that has allowed seagrasses to successfully colonize

coastal and estuarine waters throughout the world, and they are notably prolific in the waters of temperate Australia.

1.1 Threats to Seagrass

Australia contains 30 of the 58 species of seagrass known throughout the world (Watford and Williams, 1998), providing it with a unique and distinctive collection (Larkum *et al*., 1989). An example of Australia's unique seagrass composition is the genus *Amphibolis*, which is endemic to Australian waters (Kuo and McComb, 1989; Watford and Williams, 1998) and is unexpectedly found in intertidal rock pools of exposed coastline in temperate Australia (Keough and Jenkins, 1995), differing from the typical habitat requirements suggested by Kirkman (1990). In New South Wales there are eight species of seagrass present, comprising of the genus's *Posidonia*, *Zostera*, *Halophila* and *Ruppia* (Watford and Williams, 1998), all of which are readily found in estuaries on the Central Coast, New South Wales.

Over the last forty years, two thirds of seagrass beds in New South Wales have been destroyed, as discussed by Lynch *et al*. (2005), with some major estuaries having lost up to 85% of their total seagrass cover (NSW Fisheries, 2002). Being fragile habitats, once the beds have been destroyed, they do not normally recolonize quickly, despite their high productivity (NSW Department of Natural Resources, 2004a). Some species, such as *Posidonia australis*, can take years to recolonize after a disturbance if they recolonise at all, while conversely *Zostera capricorni* is relatively resilient and can recolonize within a period of months (NSW Fisheries, 2002, NSW Department of Natural Resources, 2004a). Larkum (1976) discusses an example of *P. australis* loss in Botany Bay, NSW, suggesting that once degradation occurs, it is self-perpetuating, as more

seagrass is lost due to erosion of the former seagrass beds; in over 44 years there has been no regrowth of *P. australis* in Botany Bay. This destruction of seagrass beds can be the result of natural disturbances, including events of cyclones and storms, or anthropogenic disturbances (Butler and Jernakoff, 1999). However, the majority of seagrass loss can be contributed to human impacts (Shepherd *et al*., 1989), which includes dredging, sedimentation, increased nutrient inputs and boating activities.

Dredging involves the large-scale removal of sediment from a waterway (NSW Department of Natural Resources, 2004a), for the purpose of deepening or widening channels for boating and shipping. The most direct effect dredging has on seagrass beds is the removal of underlying sediments, which results in the destruction of the bed (Lynch *et al*., 2005). Once a waterway has been dredged the subsequent bottom sediments are often too deep, and the resulting light intensities are too low for seagrass recolonization (Lynch *et al*., 2005). Also, increased turbidity is often a consequence of dredging; Kirkman (1997) states that masses of sediment enter the water column during dredging, increasing turbidity and decreasing the amount of light available for the seagrasses. Once these sediments settle out of the water column and onto seagrass beds, the excess of sediment can smother the remaining seagrass (Shepherd *et al*., 1989). Hamdorf and Kirkman (1995) discuss one of the most devastating examples of seagrass sedimentation that occurred in Hervey Bay, Qld in 1992. Here, sediments from floodwaters entered the estuary smothering and subsequently killing 1000km^2 of seagrass, an indirect result of land clearing in the region.

Increased nutrient inputs into estuaries by means of sewage outfalls, agricultural and industrial runoff, often results in the degradation of seagrass beds, as a result of

eutrophication. Shepherd *et al*. (1989) discusses the consequences of the eutrophication process, including algal blooms of phytoplankton in an estuary, resulting in an increase in turbidity and a reduction in light penetration. This diminution of light affects the photosynthetic ability of the seagrass, resulting in seagrass dieback, all of which leads to the degradation of the seagrass bed. Increased nutrients can also increase the growth rates of epiphytic algae located on the leaves of seagrasses (Shepard *et al*., 1989). According to Silbertein *et al*. (1986) the increased epiphyte cover shades the underlying seagrass leaves, this results in an overall decline in seagrass productivity and the consequent loss of seagrass. Floating macroalgae present in estuaries will also increase in growth with increased nutrients; this will result in the shading of seagrass beds by the masses of macroalgae.

Boating activities also have a considerable effect on seagrasses, via moorings and propeller damage. Boat moorings are very common in estuaries, and it is the slack in the mooring chain and its constant movement that effectively scours the seagrass bed. Kirkman (1997) argues that despite the small area of seagrass removed by the scouring action, it interferes with the integrity of the bed, and multiple moorings in the single seagrass bed compound this effect. Careless and ignorance by boat owners results in deep tracks cut into seagrass beds with their propeller (Kirkman, 1997), these tracks can be readily observed in the *Zostera capricorni* beds in Brisbane Water, NSW (pers. obs.). According to Kirkman (1997) these tracks act as small channels for the movement of tidal waters and can result in further erosion (NSW State Pollution Control Commission, 1978).

1.2 Importance of Seagrass Communities

In the past, seagrass communities have been thought to have little or no significance in an estuarine environment, however, more recently they have been internationally recognised as of significant environmental importance by the scientific and local communities (Larkum *et al*., 1989). Major scientific studies concerning seagrass beds have been carried out worldwide, to help in the understanding of the importance and the roles seagrasses play in a coastal environment (Larkum, *et al*., 1989). According to Larkum *et al*. (1989), seagrasses play six important roles in an ecosystem. These roles include 1) influencing the immediate physical environment, 2) stabilising sediments, 3) nutrients and their recycling, 4) producing high levels of primary productivity, 5) provision of food and shelter and 6) acting as nursery ground for numerous estuarine inhabitants for both estuarine and marine species.

Seagrasses are an important component of estuaries, influencing the immediate environment by affecting the movement of water and sediments. Illert and Reverberi (1986) discuss how the leaves of seagrasses affect the movement of water by applying drag and decreasing turbulence, the overall affect is the stabilisation of water currents, which prevents erosion of the bed sediments, also seagrasses affect the movement of sediments in estuaries, as once the water turbulence has decreased, the deposition of sediments increases (NSW Department of Natural Resources, 2004a). Sedimentation in seagrass beds results in a decrease of turbidity in the estuary and an increase in light penetration, ultimately benefiting the seagrass beds themselves.

Organic material is deposited by the seagrasses in the form of decaying leaves (Larkum *et al*., 1989) and by settling organic material out of the water column. This deposition

of organic material allows seagrasses to support an abundant number of detritvores, whose function is to help in the breakdown of organic matter, which in turn assists in the recycling of nutrients. Despite few animals actually consuming the seagrass itself (Kikuchi and Pérès, 1977; Bell and Pollard, 1989), seagrasses are able to support vast foodwebs (Larkum *et al*., 1989). This is because the organisms within the foodweb use the seagrass for shelter, habitat and as a source of food items. Finally, seagrasses provide anchorage for epiphytic species of alga and diatoms residing on the leaves of the seagrass (Kikuchi and Pérès, 1977; Larkum *et al*., 1989), and according to Kikuchi and Pérès (1977), these organisms play an important role in the primary productivity of seagrass ecosystems.

Seagrass ecosystems play an important function of stabilising sediments within an estuary. The sediments removed from the water column will be incorporated into the seagrass root network, hence stabilising the sediments (Hemminga and Duarte, 2000). According to Burrell and Schubel (1977) the efficiency of stabilising sediments depends greatly upon the species of seagrass and its density in an area. Here, the seagrass species will delineate the root structure, rhizome structure and the size of the leaf blades, these factors greatly influence how successfully a seagrass bed can stabilise sediments. For example, the genus *Thalassia* is much more effective at trapping and entangling sediments than the genus *Syringodium* (Hemminga and Duarte, 2000). Some species, such as *Posidonia oceanica*, may even form reef structures, which dissipate wave energy before it impacts on the estuary's shores (Hemminga and Duarte, 2000). In contrast to stabilisation, Christiansen *et al*. (1981) discuss an example of sediment destabilisation in Kyholm, Denmark, attributable to *Zostera marina* dieback. As a result of this seagrass dieback, large amounts of sediment usually held within the

seagrass bed were released into the harbour. This resulted in a major change in Kyholm's coastal morphology, with the shoreline having advanced 35 metres towards the sea. The role of stabilising sediments is obviously extremely important in estuaries because it helps protect the shoreline, and, if the seagrass beds are destroyed, it can result in adverse effects.

According to McRoy and McMillan (1977) the high productivity that is attributed to seagrass beds indicates that there is a high demand for nutrients in the ecosystem, and also a dynamic recycling of nutrients and trace elements. Hemminga and Duarte (2000) state that the most common nutrients used by seagrasses are ammonia, nitrate, phosphate, nitrogen and phosphorus, and are obtained from both the water column and the sediments, through their leaves and roots respectively (McRoy and McMillian, 1977). However, there is a limited supply of these nutrients in the water column and sediments (Hemminga and Duarte, 2000), for example Patriquin (1972) states that the sediments in seagrass beds only contain a five to fifteen day supply of nitrogen. Hence, to meet the high nutrient requirements of seagrasses in these nutrient poor waters and sediments, a complex and dynamic recycling of nutrients must exist. Here. microorganisms are known to be responsible for the recycling of nutrients in the seagrass beds (Larkum *et al*., 1989; Environmental Protection Agency, 1998). According to Larkum *et al*. (1989), nitrogen is the most limiting nutrient in regards to seagrass growth, making it of great importance in the seagrass ecosystem. Hemminga and Duarte (2000) state that the fixation of nitrogen occurs both on the leaves of the seagrass and in the sediments. This is accomplished by a Heterocystous cyanobacterium that is responsible for the nitrogen fixation on seagrass leaves, and a community of microorganisms collectively recycles nitrogen in the sediments. The

latter microorganisms in the sediments, decompose large amounts of organic matter, and release the nutrients back into the ecosystem; the major source of this organic matter is the decaying leaves of the seagrasses themselves and particulate matter filtered out of the water column (Hemminga and Duarte, 2000). The recycling of nutrients in seagrass ecosystems is very complex, comprising of numerous pathways and steps, and it is a very important aspect of seagrass growth and success. For a review of these pathways please see NSW State Pollution Control Commission (1978).

Seagrass beds are the most highly productive ecosystem in the marine environment (McRoy and McMillan, 1977), and according to Day *et al.* (1989), much attention has been focused on the productivity of these ecosystems, with many studies examining this topic. The total productivity of seagrass ecosystems can be contributed to both the seagrass beds themselves and the epiphytic alga residing on their leaves (Larkum *et al*., 1989). It is the combination of these two organisms that result in a productivity comparable to the world's best agricultural crops (McRoy and McMillan, 1977). According to Day *et al*. (1989) the productivity of temperate seagrass beds varies seasonally, with the highest rates of productivity occurring in late spring to early summer however, tropical seagrass beds have a growing season that may occur over the whole year. Productivity of seagrass also varies with the daily or diel cycle, with the peaks in productivity occurring between late morning and early afternoon (Day *et al*., 1989). One of the most common ways to estimate seagrass production is to examine plant biomass (Day *et al*., 1989), which is presented in terms of dry weight. For example, Lynch *et al*. (2005) found that some seagrass beds may produce up to 20 tonnes of dry leaf material per year, resulting in a large amount of organic material being added to the detrital chain.

Seagrass beds provide food and shelter to a diversity of fish guilds from estuarine residents, marine adventitious visitors and marine juveniles (Elliot and Dewailly, 1995). As a food source however, very few species of fish actually ingest seagrass or the epiphytic algae associated with them (Bell and Pollard, 1989), but rather feed on other marine organisms residing within the seagrass bed (Bell and Pollard, 1989; Hindell *et al*., 1999). For example, Bell and Pollard (1989), found the most common feeding strategy to be fish feeding on planktonic and epifaunal crustaceans (Bell and Pollard, 1989). Burchmore *et al*. (1984) further supported this statement as they found that the most common feeding strategy of fish inhabiting seagrass, were those feeding on the crustaceans within in the seagrass bed, while the second most common strategy was fish feeding on the epiphytic algae. A less important feeding strategy are those fish that are piscivorous and feed on smaller fish (Bell and Pollard, 1989; Hindell *et al*., 1999).

According to Kikuchi (1980) the most important function of seagrass beds is to provide shelter to fish and invertebrate communities. The general types of fish that utilise seagrass for shelter include, small cryptic fish, marine juveniles and larger mobile fish (Bell and Pollard, 1989). This utilisation is made possible by the number of microhabitats created by the structural complexity of the seagrass bed (Kikuchi, 1980; Hindell *et al*., 1999). These microhabitats allow fish with different habitat requirements to take shelter within the seagrass bed. Kicuchi and Peres (1977) categorised four guilds of fish based on their microhabitat preference, they include, fish residing on leaves, fish living under the leaf canopy, fish living in the sediment and fish living in the water column above the canopy. Some species of fish may even utilise more than one of these microhabitats during the progression of the day (Bell and Pollard, 1989),

for example members of the Family Labridae reside on the leaves during the day and take refuge in the sediments at night (Bell and Pollard, 1989).

It is widely accepted that seagrass beds act as nursery grounds for many species of juvenile and post-larval fish worldwide (Miller and Dunn 1980; Burchmore *et al.*, 1984; Bell and Pollard, 1989; Bell *et al*., 1988; Jenkins *et al*., 1993). Both commercially and recreationally juvenile fish utilise seagrass beds for food and shelter (Bell *et al*., 1989; Kirkman, 1997), and in New South Wales some of these species include, yellow-fin bream, luderick and leatherjackets (NSW Fisheries, 2002). The high abundance of these juveniles in seagrasses can be attributed to a number of reasons, one being the protection seagrass beds provide against predation (Kirkman, 1997; Nagelkerken *et al*., 2000a; 2001). Hindell *et al.* (1999) state that the complexity of the seagrass environment interferes with the foraging of predators, lowering the rate of prey and predator encounters therefore, survival of the juvenile fishes is greater. Hindell *et al*. (1999; 2000) further asserts that predatory fish forage very little in seagrass beds, this can be the result of behavioural adaptations avoiding seagrass areas during foraging, as the catch per unit effort can be lower compared to that of other habitats. The high abundance of food present is thought to be a second reason for the large numbers of juvenile fish in seagrass beds (Nagelkerken *et al*., 2000b; 2001). As stated earlier, very few fish eat the seagrass itself, instead these fish juveniles feed on the abundant array of planktonic and epifaunal crustaceans present in the seagrass bed (Bell and Pollard, 1989). A third assumption explaining the high occurrence of juvenile fish in seagrass is that seagrass beds intercept fish larvae more successfully than other biotopes (Nagelkerken *et al*., 2001). This success in fish settlement is due to the extensive size of seagrass beds (Nagelkerken *et al*., 2001), and the structure of the beds themselves

may help to settle fish larvae out of the water column comparable to the removal of sediments.

Of late, seagrass beds have been considered as having an economical value (Bell and Pollard, 1989), due to their provision of food and shelter to commercially important fish species. However, not all seagrass beds act as important nursery grounds, as commercial fish larvae may not settle upon them (Bell and Pollard, 1989). A study by Bell *et al*. (1988) found that the settlement of fish larvae depended on the distance of the bed from the mouth of the estuary, as spawning generally takes place outside of the estuaries and bays where the seagrass beds are located (Bell and Pollard, 1989). Fish larvae settle into the first seagrass bed they encounter, once settled they do not migrate between seagrass beds of higher structural complexity (Bell and Westoby, 1986a). So it is the distance of the seagrass bed in relation to the spawning grounds and the movement of currents that affects the abundance of commercially important juveniles. In general, seagrass beds have been evaluated as being the most important marine biotope to juvenile fish (Nagelkerken *et al*., 2000b).

The purpose of this study is to collect and provide information on the relationships between seagrass and fish populations for the Brisbane Water Estuary Process Study, which will assist in the development of a future management plan. There are two aims in this study, they are to determine if there is any temporal and spatial variability in seagrass bed structure and fish assemblages in the Brisbane Water Estuary, and the second is to determine if any significant relationships exist between the structure of the seagrass beds and the fish assemblages.

Chapter 2: Methodology

2.1 Study Site

The study site for this work was Brisbane Water, an extensively modified, wave-dominated estuary (Heap *et al*., 2001, NSW Department of Natural Resources, 2004b), located at 151.334 E and 33.523 S in NSW, Australia; a map of this study site is shown in Figure 1. The estuary covers an area of 27.2km^2 and the catchment comprises of 190km^2 (SMEC, 2002). According to SMEC (2002) the most common land uses in the Brisbane Water catchment are retail, commercial and residential, with the majority of the estuary's shore lined by housing. Brisbane Water also has a significant recreational importance, with boating and fishing being the most popular activities (NSW Department of Natural Resources, 2004b). Along with this, Brisbane Water is home to vast areas of seagrass beds that occupy an area of 5.49km^2 (NSW Department of Natural Resources, 2004b), comprising of the three species *Posidonia australis*, *Zostera capricorni* and *Halophila australis*.

This study was conducted in conjunction with Gosford City Council, as a part of the Brisbane Water Estuary Process Study. The information gathered during this work will be used to help in the development of a management plan, and to contribute to the sustainable use of the Brisbane Water Estuary.

2.2 Study Design

A substantial spatial replication design was chosen for this study, as seen in Figure 2, in order to incorporate all regions of the Brisbane Water estuary. Gosford City Council (1995) identified five waterways including; the Entrance Reach, Woy Woy Reach,

Kincumber Broadwater, Woy Woy Bay and Inlet, and the Brisbane Water Broadwater, these are shown in Figure 1. This study has used these divisions, they have been named respectively Area A, Area B, Area C, Area D, and The Brisbane Broadwater has been divided into two regions of E and F, in order to obtain a representative sample of this large water body. Within each area there are 2 locations, and within each of these 2 sites were sampled, totalling 24 sites in the estuary. The sampling design for this study is illustrated in Figure 3. This study was also temporally replicated twice for both aspects of fish populations and seagrass bed structure, since according to Underwood (1997), temporal sampling is more informative due to the varied nature of ecological process.

2.3. Seagrass Bed Structure

2.3.1 Collection of *Zostera capricorni* samples

All *Z. capricorni* data were collected *in situ*, and no seagrass plants were removed at any stage during the data collection. All seagrass data collection was permitted under Fisheries permit number P03/0032(B). All data were obtained by means of SCUBA and/or snorkelling techniques, with the method chosen depending on the depth of water at each site (Appendix 1.1). All SCUBA operations were carried out under Australian Standard AS2299; which addresses the necessary qualifications and equipment, dive team members, and the requirement of an operations manual and risk assessment. Haphazard replicates were used to collect data in the *Z. capricorni* beds; in this study haphazard replication is more appropriate than random replication as it provides a representative sample of the environment while eliminating bias (Underwood, 1997). The *Z. capricorni* data was collected twice in this study, May/June 2004 (T1) and

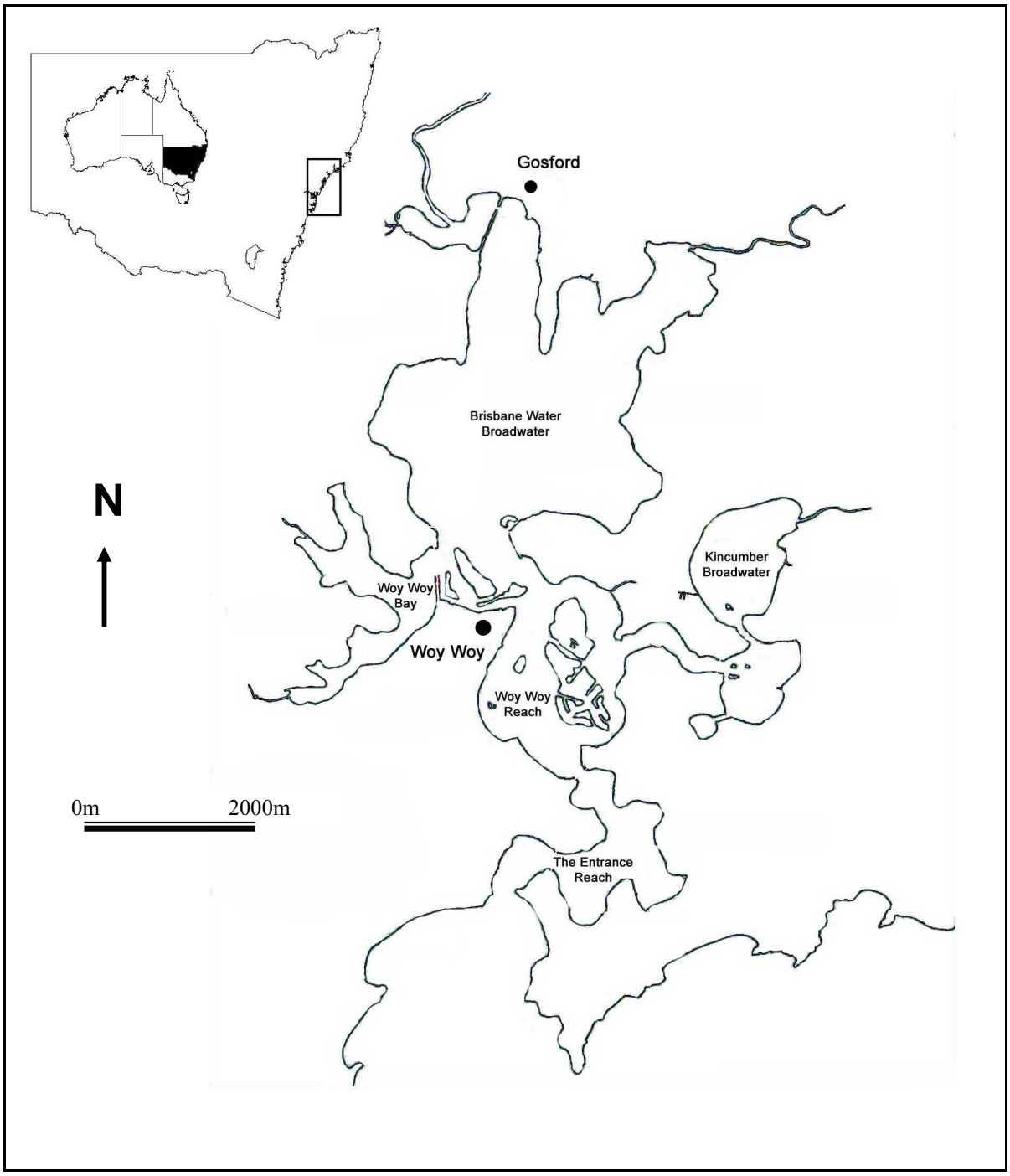

Figure 1: The Brisbane Water Estuary, illustrating the location of the five main water bodies where the study sites for this work were located (from NSW Fisheries, 2004).

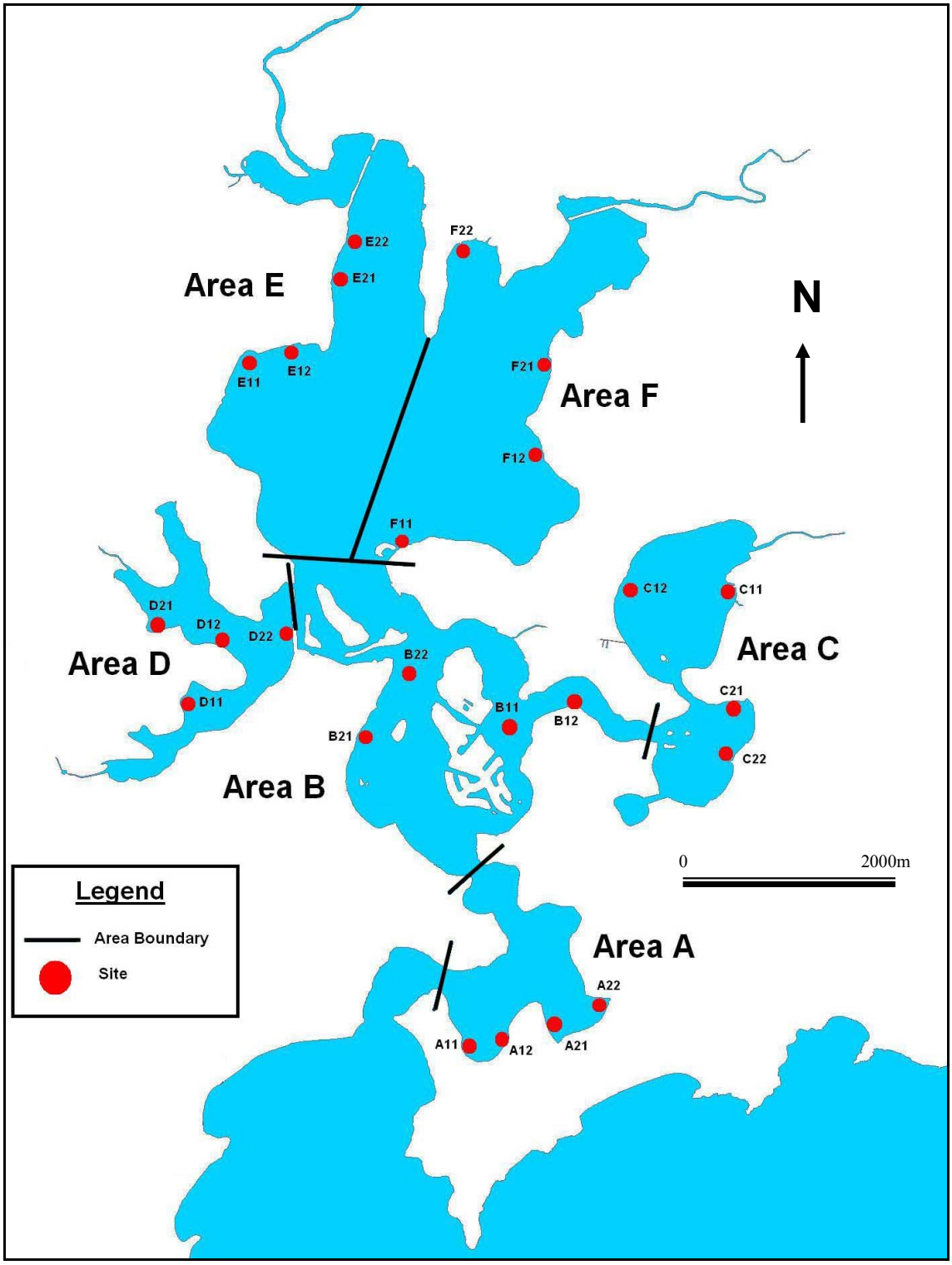

Figure 2: The Brisbane Water estuary illustrating the sampling locations of areas A to F and the 2 locations and 2 sites within each area, totalling 24 sites (from NSW Fisheries, 2004).

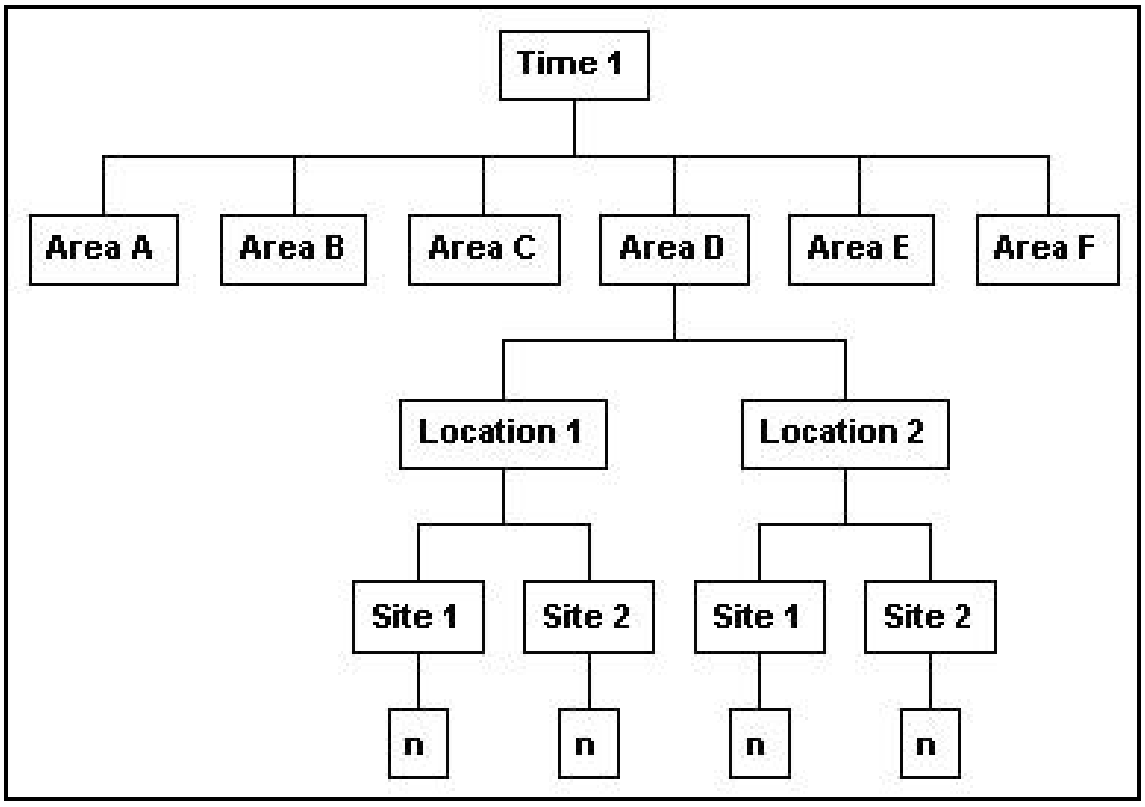

Figure 3: Experimental design for fish and seagrass survey in *Zostera capricorni* beds in Brisbane Water. The design shown is for Time 1, which is also replicated for Time 2, and Area D, which is replicated within each of the other areas. At each site, n = 3 for fish samples, n = 5 seagrass percent cover and shoot density, n = 50 for seagrass epiphyte cover and leaf length.

February - April 2006 (T2). Data was not collected in areas of the seagrass bed that appeared to be damaged from human disturbance, for example damage from boat traffic.

2.3.2 Seagrass Shoot Density

The shoot density of the *Z. capricorni* bed was calculated by using a 0.0625m^2 quadrat (Appendix 1.2), which was placed within a 0.25m^2 quadrat. The number of shoots were counted within this area, and then multiplied by four to achieve a standardised count for

an area of 0.25m^2 (Roberts, D. 2004, pers. comm., 26th April). This standardisation allowed this data to be interrelated with the percent cover of seagrass.

2.3.3 Seagrass Leaf Length

The leaf lengths of ten *Z. capricorni* leaves were measured within each of the five 0.25m^2 quadrats to the nearest 0.5cm (Appendix 1.3). The length of each leaf was measured from the tip of the leaf to the sediment, which included the fibre sheath of the seagrass shoot; the basic structure of a seagrass plant including the fibre sheath and leaves is shown in Figure 4. The reason for measuring to the sediments was to ensure accuracy, especially in poor visibility in *in situ* sampling, as opposed to measuring to the sheath *in vitro,* as carried out by Casey (2003) who measured leaf length to the sheath.

2.3.4 Estimation of Percent Cover of Seagrass

A 0.25m^2 quadrat (Appendix 1.2) was placed within the *Z. capricorni* bed at each site to determine an estimate of the percent cover of seagrass, which was replicated five times. The percent cover of seagrass was determined by a single diver with experience in estimating percent cover, this was done in order to reduce variation which may be encountered with different divers (Kingsford and Battershill, 1998).

2.3.5 Estimation of Percent Cover of Epiphytes

The percent cover of epiphytes for ten *Z. capricorni* leaves was estimated within each of the five 0.25m^2 quadrats. The leaves were chosen haphazardly, and the same diver that conducted percent cover undertook the estimates of percent cover of epiphytes. Since

the percent cover of epiphytes could change over the length of a leaf, the whole leaf was examined and then an average percent cover was estimated.

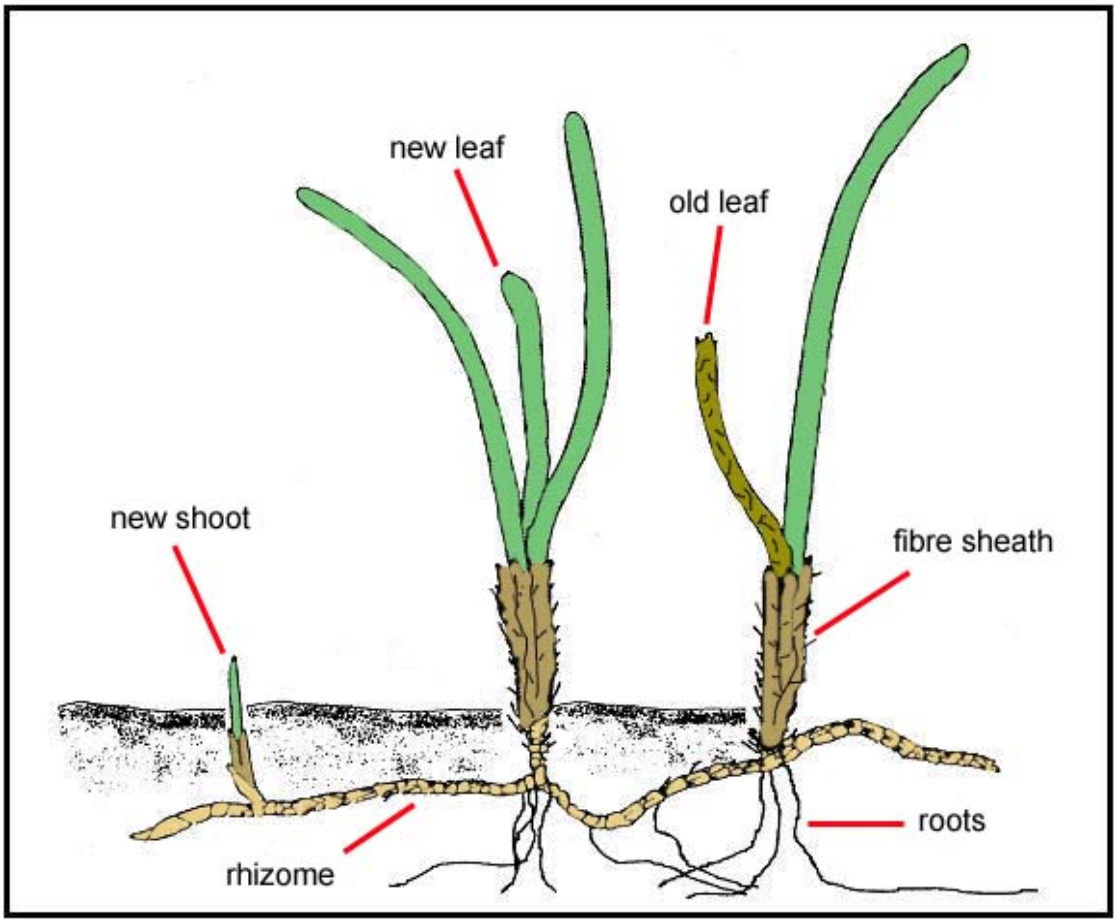

Figure 4: The basic structure of a seagrass plant, showing the fibre sheath and the leaves that were included in the measurement of the leaf length in this study, (from Keough and Jenkins, 1995).

2.4 Fish Assemblage Study

2.4.1 Collection of Fish samples

Seine netting was used to collect fish and macro-invertebrates in the *Z. capricorni* beds. Seine netting is the most widely used technique for conducting fish surveys in seagrass

beds, as it is a simple and fast technique (Nagelkerken and van der Velde, 2004). This technique also provides statistically comparable data for a range of seagrass habitats and environmental conditions (Edgar *et al*., 2001).

In this study a 20-metre seine net was used, with a 2-metre depth, and a mesh size of $8mm^2$, encompassing an area of approximately $157m^2$. The codend of the seine net was 2 metres long and consisted of an $8mm^2$ mesh size. Each replicate haul was conducted during the day, 3 hours either side of the high tide to provide an appropriate water depth between 70cm to 120cm. These depths were chosen so that the lead line could be successfully held on the bottom of the seagrass bed, as areas deeper than 150cm cannot be effectively sampled (Gilmore, 1990). Each replicate haul was haphazardly placed within the *Z. capricorni* bed and each replicate was separated by at least 5m, this is consistent with studies by Gray *et al*. (1996; 1998). Three replicate hauls were conducted at each site as other studies have done, for example Gray *et al*. (1996; 1998) and Jenkins *et al*. (1997).

Two people were required to operate the seine net. The first person deployed the net from a floating device into the water column, while the second person hauled the net out into a straight line. Once the net was completely submerged the net was moved into a semi-circle shape with both ends of the seine net meeting in the middle (Appendix 1.5). During each haul, care was taken to ensure that the float line remained buoyant and that the lead line stayed on the bottom. The net was then hauled in while holding the lead lines together and keeping it close to the bottom, then it was placed back into the floating device. The codend remained in the water until the boat or shoreline was

reached to increase the survival rates of the fish, as this is where the majority of captured fish were located in the net.

All fish were gently removed from the net and placed into aerated holding containers. Fish were identified to species in the field by referencing books (Hutchins and Swainston, 1999; Kuiter, 2000), a dichotomous key (Kuiter, 1994) and specimen collections. The fish were counted and then the total length, from tip of snout to the end of tail was recorded for post-settlement, recreationally targeted species; the recreationally targeted species are shown in Table 1. Macro-invertebrates were categorised into groups, and, where appropriate, they were identified to species by referencing books (Edgar, 2000) and specimen collections. Once all 3 replicate hauls were completed the fish were then released back into the *Z. capricorni* bed that they were captured in. This sampling regime was temporally replicated twice, once in July – October 2005 (T1) and the second took place in January – April 2006 (T2). All fish collecting and handling were permitted under Fisheries permit number P03/0032(B). Appendix 2.1 provides a species list of all the fish and invertebrates caught during this study.

Table 1: Recreationally targeted fish species from which total lengths were measured. Family names, species name and common names are shown.

RECREATIONALLY TARGETTED SPECIES	
FAMILY	**TARGETED SPECIES**
Hemiramphidae	*Hyporhampus australis* (Eastern Garfish)
Sparidae	*Acanthopagrus australis* (Yellow-finned Bream)
	Rhabdosagrus sarba (Tarwhine)
Girellidae	*Girella tricuspidata* (Luderick)

2.4.2 Ecotrophic Guilds

The fish assemblages were divided into groups in order to obtain an understanding of how different ecological and vertical guilds of fish differed with the structure of the seagrass beds. Each species was assigned an ecological and vertical guild as defined by Elliot and Dewailly (1995) (Table 2) and the definitions of the ecotrophic guilds are shown in Table 2. Appendix 3.1 shows the Ecological and Vertical guild designation for each fish species caught during this study.

Table 2: Definition of different ecotrophic guilds described by Elliot and Dewailly (1995).

Guild Category	Abbreviation	Guild Components
Ecological Guilds	ER	Truly estuarine resident fish
	MA	Marine adventitious visitors
	CA	Diadromous migrant fish
	MS	Marine seasonal migrant fish
	MJ	Marine juvenile migrant fish
	FW	Freshwater adventitious fish
Vertical Guilds	P	Pelagic fish, living in the main water column
	B	Benthic fish, living on or in the substrate
	D	Demersal fish, living in the water layer just above the bed

2.6 Spatial and Temporal Differences Analysis

2.6.1 Seagrass Structure Analysis

A nested Analysis of Variance (ANOVA) was conducted on each of the seagrass floristics of percent cover of seagrass, percent cover of epiphytes, shoot density and leaf

length. Before the analyses were conducted a Cochran's test was carried out to test for homogeneity of variances, an assumption of ANOVA. If the test result was significant this meant that variances were heterogeneous, and an appropriate transformation was undertaken. If the transformation did not result in homogeneity the untransformed data was used, as in large experiments the validity of the test is not affected a great deal by the violation of this assumption (Underwood, 1997). However, no transformed data was required to be used during this study.

2.6.2 Fish Assemblage Analysis

A nested ANOVA was used to determine whether there were any significant differences between Time, Area, Location and Sites, see section 2.6.1 for a detailed description of the analysis. The variables tested with ANOVA included fish diversity, fish abundance without glassfish, glassfish abundance, invertebrate diversity, invertebrate abundance, total diversity and total abundance without glassfish. Glassfish were excluded from the fish abundance and total abundance analyses, and were analysed separately as the abundance of glassfish is very patchy due to the schooling nature of the species and the large numbers obtained from some parts of the Brisbane Water Estuary. It would be difficult to determine whether the significant differences in fish abundance and total abundance were due to differences in the fish and invertebrate assemblages or due to the difference in the glassfish schools. An ANOVA was also conducted on the Ecological and the Vertical guilds to determine if there were any temporal and spatial differences.

Histograms were produced for length of recreationally targeted fish species for each of the four species (Table 1) at each time period, and the mean and median for each species were also calculated. This data could not be analysed in an Analysis of

Variance as the data collected was qualitative. This was because these species were not specifically targeted during the study resulting in a low number of lengths recorded.

2.7 Relationship Analysis

2.7.1 Relationship between Seagrass Floristics

A correlation analysis between each of the seagrass floristics, to determine whether variables were independent of other variables of seagrass bed structure. There is no distinction between dependent and independent variables in this analysis, as it will be determined whether two variables covary (Sokal and Rohlf, 1995). During this analysis a Product-Moment Correlation Coefficient (r_{12}) was calculated and a scatter plot was also obtained with the equation $y = mx + b$. Next a t-test was conducted with the Product-Moment Correlation Coefficient to determine whether the correlation between the two variables was significant.

2.7.2 Relationship between Seagrass Bed Structure and Fish Assemblages

A correlation analysis was used to determine whether there was a relationship between fish and invertebrate assemblage and the seagrass bed structure; see Section 2.7.1 for a detailed description. The fish assemblage variables tested were fish diversity, fish abundance without glassfish, glassfish abundance, invertebrate diversity, invertebrate abundance, total diversity and total abundance without glassfish, and these were tested against each of the seagrass floristics. A correlation analysis was also conducted on both the Ecological guilds and the Vertical guilds with the seagrass beds structure to determine whether there was any relationship between the different guilds and the seagrass floristics.

2.8 Comparison of Fish Assemblage Sampling Techniques

2.8.1 Collection of Data

In the past, underwater visual census techniques have not been commonly used in seagrass beds, according to Nagelkerken and van der Velde (2004) this is due to the turbid nature of the environment. More recently however, Nagelkerken *et al*. (2000c; 2001) and Horinouchi *et al*. (2005) have actually used underwater visual census successfully in seagrass beds. Underwater visual census techniques were used in the current study to assess the fish assemblages in *Zostera capricorni* beds in Area E in Brisbane Water (see Figure 2). All visual census transects were conducted by SCUBA and were carried out under AS2299 (see section 2.3.1 for more detail).

In accordance to a study by Horinouchi *et al*. (2005), the optimum width for a strip transect is one metre wide, as this most cost-benefit width in regards to fish density and species diversity. In the current study a one metre wide, strip transect was used in the *Z. capricorni* beds, consisting of 0.5m on both sides of the centre line, as performed by Horinouchi *et al*. (2005). The length of the transect chosen for this study was 30 metres, and the total area covered by the transect was $30m^2$. This transect length was chosen because at some of the sites sampled the length depended on the size of the seagrass beds and obstructions such as jetties, which prevented any longer transects.

The one metre wide transect was set during the visual census rather than before, as presetting the transect would have required an acclimation period before conducting the visual census to ensure the fish assemblages were no longer affected by the prior disturbance. During each transect the diver pulled the measuring tape (Appendix 1.6) along, while using a compass to ensure the transect line was straight and that the

measuring tape was in the centre of the diver's body. A swimming speed of approximately 1.0m/min was employed in this study as done by Horinouchi *et al*. (2005). During each strip transect a diver identified and tallied the numbers of different species of fish and invertebrate groups that were encountered. The diver recorded, fish swimming above the seagrass bed as well as those hiding among the seagrass, within the one metre wide transect. The data collected with the visual census was compared to that of the seine net by calculating the density and diversity of fish per $10m^2$.

2.8.2 Analysis of Fish Assemblage Sampling Techniques

The data obtained from the Underwater Visual Census was compared to that of Seine Netting by ways of a nested ANOVA. Two locations were nested within each technique and two sites nested within location. The ANOVA was conducted as described in Section 2.6.1. The fish assemblage parameters that were tested were fish diversity, fish density, invertebrate diversity, invertebrate density, total diversity and total density. The glassfish were included in the fish and total density as they were not found in large numbers at these sites and therefore the glassfish alone would not affect the outcome of the Analysis of Variance.

Chapter 3: Pilot Study

3.1 Introduction

A pilot study is an important step when establishing a research directive, as it allows logistical and methodological problems to be minimised when they are encountered during a study (Kingsford and Battershill, 1998). The pilot study involves examining the area of interest (Kingsford and Battershill, 1998) and collecting preliminary data. According to Underwood (1997), this data provides valuable information that is then used to plan the next phase of the study (Underwood, 1997).

During preliminary sampling logistical problems such as time and cost are identified. Once these problems are recognised they then can be controlled and accommodated for in the sampling design of the major study (Kingsford and Battershill, 1998). During the pilot study the optimum size of the sampling unit is determined during the pilot study (Kingsford and Battershill, 1998), as well as the spatial and temporal replication to be used.

According to Kingsford and Battershill (1998), pilot studies also provide important information regarding the variation in abundance or size of the organism being examined. This allows researchers to gain an understanding of the study being conducted, as well as what they can expect to encounter during the work. Preliminary sampling is also the ideal time to train research assistants that will be helping during the research, so that they have an adequate knowledge of the procedures and the target organisms (Kingsford and Battershill, 1998).

This pilot study examined several types of fishing gear that have previously been used in *Zostera capricorni* and *Posidonia australis* beds, as to identify the best technique to employ, in order to gain a better understanding of fish assemblages that exist in these seagrass habitats. The second part of this pilot study examined two different seining techniques previously used in seagrass beds of, a full circle (Jenkins and Wheatley, 1998) and a semi-circle (Nagelkerken *et al*., 2001; Casey, 2003; Nagelkerken and van der Velde, 2004), so that the most advantageous techniques, in regards to time efficiency and ease may be implemented in the main study. The next step of this pilot study was to determine the optimum number of replicates to be performed in the seagrass beds, and the fish assemblages. The final section of this pilot study examined sampling at different time of the day and sampling over different bottom types in order to ascertain which of these factors play a role in the diversity and abundance of fish.

Hence, the aim of this pilot study was to determine the most effective and logistically appropriate methods to be used in the major study.

3.2 Methodology

The first part of this study compared four different sizes of beam trawls to each other to determine the most appropriate size trawl for sampling in *Zostera capricorni* beds. The second part examined two different techniques of seining of forming a full circle and a semi-circle. These two techniques were evaluated based on the area covered by the haul, and the abundance and diversity of fish. The third section determines the optimum number of replicates to be used in the study for both the seagrass bed structure and the number of seine net hauls. The last section involved comparing fish

assemblages during day and night sampling, as well as over seagrass and bare sand substratum.

3.2.1 Beam Trawl

The beam trawl fishing gear requires a boat to pull the net through the study site. Ideally a beam trawl would move through the *P. australis* bed creating minimal disturbance to minimise damage to the seagrass bed, while collecting a representative sample of fish. Each beam trawl was tied off at the stern of the boat, and then lowered into the water column. Once the trawl reached the bottom, the boat then began to move in a straight line at a speed of approximately 4 to 8 knots. Observations were carried out at all times to ensure that it remained on the bottom, and if not the speed of the boat was slowed until it returned to the bottom. The beam trawls were towed for two different time periods of 3 minutes and 5 minutes, and then were quickly removed form the water to prevent fish from escaping. The end of the net was opened and the fish were placed into a container of aerated water to be identified and counted. *Zostera capricorni* beds were also sampled with the beam trawl to compare catch rates of the trawl to that of the seine net.

The first beam trawl that was used in the *P. australis* bed had a total length of 1.4 metres, a width of 0.6 metres, a codend 1 metre in length, a mesh size of 4.5mm. The mouth of the beam trawl was oval shape and opened to a height of 0.4 metres, and this beam trawl was very light in weight. The second beam trawl used was similar in design to the first beam trawl trialled, only larger with a total length of 1.8 metres, a width of 1.3 metres and a mesh size of 4.5mm. The mouth of the beam trawl opened to a maximum of 0.9 metres and the length of the codend was 1.4 metres. The design of the

0.6m and 1.3m beam trawls is shown in Appendix 2.7. The third beam trawl used was made out of a thick steel frame and was 2 meters wide with a height of 1.5 metres. The frame of the beam trawl was rigid and did not have any skis attached to the bottom. This beam trawl had a very heavy weight. The fourth beam trawl consisted of a thin, light steel frame with the dimensions of one metre wide and half a metre high, and the net consisted of a net was two metre long with a mesh size of 5mm. The beam trawl was lowered into the *P. australis* bed at site E21. A diagram of this beam trawl can be seen in Appendix 2.8.

3.2.2 Seining Techniques

There are two different techniques commonly used when using a seine net in seagrass beds, these include circling the net, and forming a semi-circle or D-shape with the seine net. Both of these techniques were tested and evaluated in this pilot study. The dimensions of the seine net used in the pilot study are the same as that given in section 2.4.1.

The first technique of circling the seine net required two people to operate the net. One person was at the starting point and fed the net into the water. The second person walked the seine net into a circle and then returned it to the starting point; the net was then retrieved as discussed in section 2.4.1. The circling technique has been used by previous studies in seagrass habitat, for example Jenkins and Wheatley (1998), used a 20-metre seine net that they circled in *Heterozozstera tasmanica* bed. The second technique of forming a semi-circle was tested in this pilot study. This technique required one person to feed the net into the water while a second walked the seine net into a straight line, once the net was completely submerged both operators walked the

seine net into a semi-circle, meeting in the middle. A more detailed description of this technique may be found in section 2.4.1. This technique has been successfully used in past by Nagelkerken *et al.* (2001), Casey (2003), and Nagelkerken and van der Velde (2004).

3.2.3 Number of Replicates

3.2.3.1 Number of Seagrass Replicates

Replicates of five and replicates of ten were carried out in the *Z. capricorni* beds. This was conducted to determine the most logistically appropriate number of replicates. The seagrass percent cover, percent cover of epiphytes and the leaf length were all done in the 0.25m^2 quadrat and the density of *Z. capricorni* data was collected with the 0.0625m^2 quadrat. All data was collected with scuba and snorkelling techniques as described in section 2.3.1.

3.2.3.2 Number of Fish Replicates

A preliminary survey of fish assemblages was carried out in the *Z. capricorni* to determine the optimum number of seine net replicates. The seine net was hauled through the *Z. capricorni* beds as described in section 2.4.1. Five replicates were conducted in Area C, shown in Figure 2, and the numbers of fish species, invertebrate groups and individuals were recorded. From this data the cumulative species richness of fish was calculated by determining the number of new species recorded in each haul. This cumulation was repeated for the number of new invertebrate groups recorded. These results were then pooled to show the optimum number of replicates, as both the number of species of fish and invertebrates groups will be analysed in this study.

3.2.4 Different Times of Day and Bottom Types

Seine netting was to be conducted in two different times of the day, day and night, and over two different substratum's, seagrass and bare sand. The sampling was to be conducted on different dates, as the fish assemblages at a site would be disturbed during the seine net hauls, and conducting the sampling on different dates ensures that previous hauls do not contaminate the new samples collected. The two different times of day were to be compared to each other, to determine the differences in the fish assemblages between day and night.

Sampling over two substratum types was to be conducted in this study at each of the 24 sites. During this pilot study three hauls were conducted in both the seagrass beds and the bare sand at one site F11 (Figure 2). These seagrass and bare sand samples were compared to each other to determine the differences between the two substrata.

3.3 Results

3.3.1 Beam Trawl

The 0.6m x 0.4m beam trawl was not very successful at collecting fish, as only an average of three shrimp were collected with each haul, and no fish were collected in any of the hauls. The amount of time the beam trawl was hauled for did not make any difference in the number of fish. While watching this beam trawl in the water, it appeared that the mouth of the beam trawl was open very little; this was due to the small opening and design of this trawl. It was also noted that this net did not stay on the bottom, even when the speed of the boat was slowed.

The catches of fish from the 1.3m x 0.9m beam trawl were very low, consisting of ten shrimp and four fish from the Family Gobiidae. The two time periods were trialled, as well as trawling in the *Z. capricorni* beds however, neither of these differences resulted in increase of fish in the haul. This beam trawl had the same problem of staying on the bottom as for the 0.6m x 0.4m beam trawl, and when it was on the bottom it appeared to pass directly over the top of the *Z. capricorni* beds instead of moving through it as desired. The mouth of the beam trawl also appeared to only be open minimally resulting in a decrease in the volume of water passing through the net.

The 2m x 1.5m beam trawl was not physically trialled in the water, due to limitations placed by the size of the boat and the number of personnel available. The advantage of this beam trawl compared to the other trawls was the wide opening, however, this large beam trawl was not practical for the six-meter boat used in this pilot study, as it would not safely fit in the boat. The weight of the frame was not manageable, as it was very heavy and would have been incredibly difficult to be lifted in and out of the water between hauls, by the number of people available. The design and weight of this beam trawl would have resulted in enormous amounts of damage to the *Z. capricorni* beds, as it was very heavy and did not have skis to help glide the beam trawl over the bottom.

The 1m x 0.5m beam trawl was the most successful of the all the beam trawls trialled in this pilot study. The light steel frame allowed the beam trawl to be lifted in and out of the water safely with little effort. This beam trawl did result in some damage to the *P. australis* beds as some shoots were collected in the beam trawl, despite the incorporation of the ski's at the bottom of the frame. The catches of each haul were low in numbers and consisted mainly of shrimp and fish from the Family Sygnathidae,

which are slow swimming fish. No medium or fast swimming fish were caught in this beam trawl in either of the time period's trialled. Table 3 provides a summary of the features of the entire range of beam trawls trialled during the pilot study.

Table 3: A comparison of the features of all the beam trawls trialled. They are ranked 1 to 4 for each feature, where 1 is the most favourable and 4 is the least favourable.

Trawl Size	Mouth Opening	Weight and Handling	Potential Damage to Seagrass	Catch Rates
0.6m	4	2	2	4
1.3m	3	3	3	3
2m x 1.5m	1	4	4	2
1m x 0.5m	2	1	1	1

As the fourth beam trawl was considered the most successful, this beam trawl was then compared to the seine net to determine which of the fishing gears produced a better representation of fish assemblages in *Z. capricorni* beds. The results of the beam trawl and seine net hauls are shown in Table 4. The diversity of fish caught in the beam trawl was two, which is much lower than the seine net fish diversity of fifteen. The beam trawl had a fish abundance of five in the *Z. capricorni* beds, while the seine net caught a fish abundance of 492; this result is much larger than the beam trawl. The diversity and abundance of invertebrates was once again higher in the seine net compared to that of this beam trawl.

Table 4: Comparing Beam Trawl (1m x 0.5m) and Seine Net fishing gears, the diversity and abundance of fish and invertebrates are shown.

		Beam Trawl Area ~ 150m^2	Seine Net Area ~ 150m^2
Diversity	Fish	2	15
	Invertebrates	1	3
Abundance	Fish	5	492
	Invertebrates	11	52

3.3.2 Seining Techniques

The first technique of circling the seine net covered an area of approximately 32m^2 with the 20 metre seine net used in this study. With this technique the one person walking the net was required to pull all of the weight of the net through the *Z. capricorni* bed. The second technique of walking the seine net into a semi-circle covered an area of approximately 157m^2. In this technique the second person walking the net only had to pull the weight of the net into a straight line, and then both of the operators walked the net into a semi circle. Circling the net required more time to conduct each replicate than forming a semi-circle, and it was more difficult for the person walking the seine net into a circle.

3.3.3 Number of Replicates

3.3.3.1 Number of Seagrass Replicates

Originally the number of seagrass replicates used was ten of each of the appropriate quadrat for percent cover of *Z. capricorni*, percent cover of epiphytes, *Z. capricorni* shoot density and leaf length. After trailing ten replicates it was decided that logistically it was too time consuming. The time it took to conduct each site was an

issue when using SCUBA as a certain period of time is allowed at certain depths, and this is reduced when repeated dives are required. Five replicates were then trialled, reducing the amount of time taken to conduct each site.

3.3.3.2 Number of Fish Replicates

The cumulative species richness of the five replicate seine net hauls in Area C is shown in Figure 5a. This graph shows that there is an increase in the number of new fish species caught in the first three replicates. In the next replicates of four and five there are no new fish species caught and cumulative fish species graph does not change. From this cumulative species richness graph it can be seen that the optimum number of replicate seine net hauls is three, as there is no substantial increase in fish species after this replicate.

The cumulative number of invertebrates groups collected in Area C is shown in Figure 5b. This graph shows that there is little difference in the number of invertebrate groups recorded between any of the hauls. An increase of one group occurs in the third replicate and then plateaus. The optimum number of replicates for the cumulative invertebrate groups is three as this is when the first increase in the number of groups is found. Five replicates are not the optimum number of replicates from this graph, as more time is required to conduct another three replicates to achieve an increase of only one more group.

The cumulative number of fish species and invertebrate groups were pooled and this is shown in Figure 5c. This graph shows that after three replicates there is a plateau in the number of fish species and invertebrate groups. Therefore to achieve a high diversity of

fish species and invertebrate groups together the optimum number of replicate seine net hauls is three.

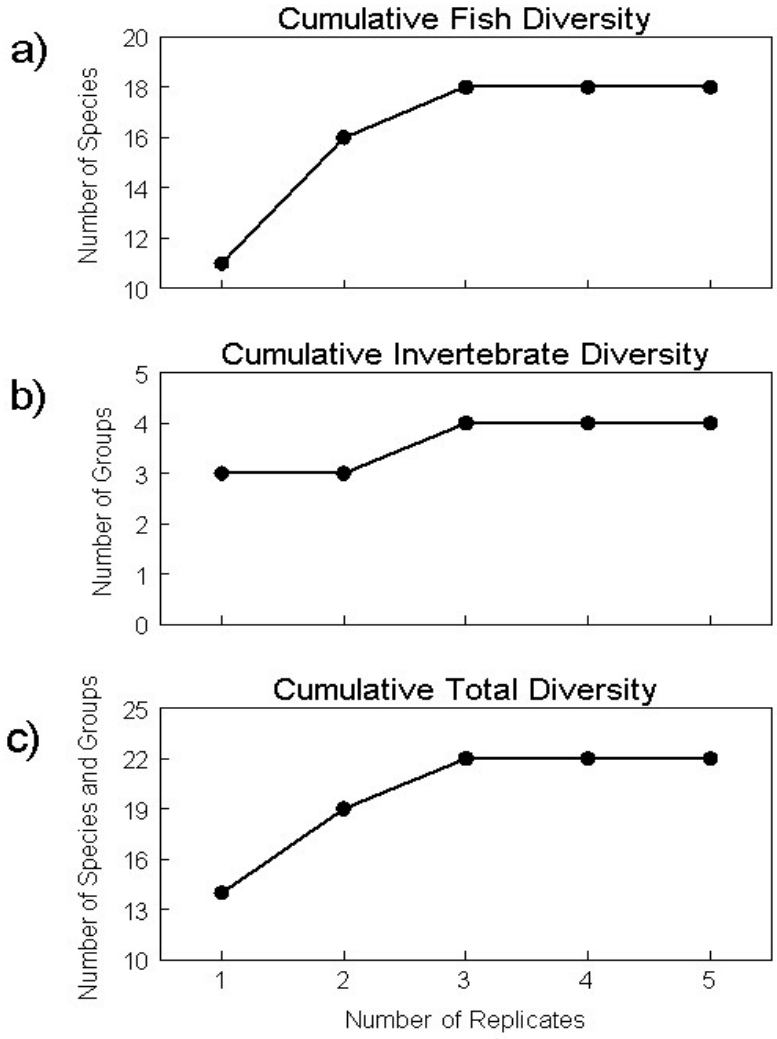

Figure 5: The species diversity of a) fish, b) invertebrates and c) total diversity. The cumulative number of each variable caught in the pilot study, in Area C over five replicate hauls of the seine net.

3.3.4 Different Times of Day and Bottom Types

Originally the day and night sampling was to be conducted during this study, in order to determine how the diversity and abundance of fish changed through day and night.

However, no sampling was ever conducted at night due to resource limitations. There was not enough time during the study to conduct this sampling, as well as limitations of resources, such as people and boats, not to mention safety implications. Sampling of different bottom types was conducted during the pilot study, the means of seagrass and bare sand substrates are shown in Table 5. There was very little difference in the mean diversity of fish however; the abundance of fish was much greater over seagrass than bare sand. There were no invertebrates caught over bare sand at all. When both seagrass and bare sand substrates were sampled, the time taken to conduct sampling at each site increased, resulting in a higher demand on time and resources.

Table 5: The mean diversity and abundance of fish and invertebrates caught in Seagrass and over Bare Sand in the Pilot Study.

Fish Assemblage Variable	Seagrass Mean SE	Bare Sand Mean SE
Fish Diversity	8.50 $\pm$ 2.04	6.50 $\pm$ 1.22
Fish Abundance	1944.50 $\pm$ 65.73	109.00 $\pm$ 38.38
Invertebrate Diversity	2.50 $\pm$ 0.41	0.00 $\pm$ 0.00
Invertebrate Abundance	26.00 $\pm$ 14.70	0.00 $\pm$ 0.00

3.4 Discussion

3.4.1 Beam Trawl

Through the trialling of the four different types of beam trawls it was found that the 1m x 0.5m steel frame beam trawl, caught five fish and eleven shrimp in *Zostera capricorni*, compared to the 0.6m x 0.4m beam trawl that only caught three shrimp, the 1.3m x 0.9m beam that caught ten shrimp and five fish, and the 2m x 1.5m could not possibly be physically trialled. The 1m x 0.5m beam trawl was the most successful at

sampling fish assemblages as it caught the most number of species and abundance of fish. This beam trawl was also the easiest to employ as it stayed on the bottom of the seagrass bed, while the 0.6m x0.4m and 1.3m x 0.9m beam trawls had difficulty staying on the bottom during sampling, even when the speed was lowered. It was the combination of the being the most successful at sampling the fish assemblage and ease of use that made this beam trawl the optimum of all the ones trialled.

Once the most advantageous beam trawl had been chosen it was then tested against the seine net to determine which gear type was the most successful and practical. The seine net resulted in a much higher diversity and abundance of fish species than the beam trawl. The diversity of fish was seven times greater using the seine net compared to the beam trawl, while the abundance of fish increased one hundred fold when seine netting. The diversity and abundance of invertebrates was also greater in the seine net than in the beam trawl. A reason for the great difference in catch rates can be explained by the disturbance from the boat (Guest *et al*., 2003), which alerts fish to the approaching trawl. Another reason for lesser catch rates of beam trawls is the narrow width of the opening (Guest *et al*., 2003), allowing the beam trawl to sample only a small transect of the seagrass bed. A further advantage of the seine net over the beam trawl is that it is not as resource dependent, as a boat and more consumables are required to conduct the fish survey. The seine net fishing gear was considered to be the most advantageous technique as it provided a higher diversity and abundance of fish, and it required fewer resources. Guest *et al*. (2003) conducted a study that compared the use of a beam trawl and a seine net in seagrass habitat. They concluded that seine nets are more effective at sampling fish assemblages in seagrass beds than beam trawls, as they have a greater catch rate and the data obtained is able to be compared to that of other studies. For

these reasons the seine net was employed during the major study to conduct the fish assemblage survey.

3.4.2 Seining Techniques

The two different techniques for conducting seine net hauls were evaluated based on the area covered, time and difficulty to conduct each haul. The semi-circle method covered an area of 157m^2, which is nearly five times greater than the circling techniques that cover an area of 32m^2. The semi-circle technique was also much easier to conduct than the circle, as the person pulling the net was not required to exert as much force pulling the net into a straight line, and then both net operators towed the net into the semi-circle. In the circle technique the person walking the net had to pull the entire way with no help. Since the semi-circle technique was the easiest to conduct it was also the quickest haul to perform as well. The combination the greater area, ease of hauling and lesser time requirement made the semi-circle the most advantageous technique to use when conducting the fish assemblage survey in the *Zostera capricorni* bed therefore, this was the technique employed during the main study.

3.4.3 Number of Replicates

The number of seagrass replicates originally used in this pilot study was ten. The time taken to conduct ten replicates was substantial and was resource consuming, as this data was collected with SCUBA. Due to these reasons the number of replicates was dropped to five, which obviously required less time and resources to conduct. A study by Aioi (1980) used only three replicates when sampling seagrass bed structure, while a study by Orth and Moore (1986) used four seagrass replicates. The number of seagrass

replicates used in the present study was still greater than those by the previous studies stated, so it was believed to be an acceptable number of replications. In summary the combination of the time and resource restraints, as well as methodology from other studies, resulted in the five seagrass replicates being chosen for the main study.

During this pilot study the optimum number of fish replicates was determined by assessing the cumulative number of species. Each fish, invertebrate and total number of species was accumulated and for each variable the optimum number of replicates was determined to be three. Many studies in the past have used three replicate hauls of seine nets, for example Blanc *et al*. (2001), Gray *et al*. (1996), Gray *et al*. (1998) and Jenkins *et al*. (1997). One study by Mattila *et al*. (1999) only used two replicate seine net hauls. Three replicates seine hauls are commonly used in studies of fish assemblages in seagrass beds, and it was determined through this pilot study that three hauls provided the optimum species richness. For these reasons three replicates were used in the main study of fish assemblages in Brisbane Water.

3.4.4 Different Times of Day and Bottom Types

The times of day that were originally to be conducted were day and night. Only day sampling was conducted, as night sampling was evaluated as being too time and resource consuming during this study, as well as difficult. Other studies have conducted fish assemblage sampling in seagrass at night, for example Guest *et al*. (2003) and Mattila *et al*. (1999). These studies found that night sampling yielded a higher numbers of species and individuals than day sampling. Despite the advantages of night sampling it does have disadvantages of being more difficult, expensive (Guest *et al*., 2003), and

the lack of light increases risk of injury from marine animals. Due to these disadvantages night sampling was not to be undertaken in the main study.

Two different types of substratum, seagrass and bare sand, were sampled during this pilot study. Both of these bottom types yielded similar fish diversity and abundance, with different species composition. Sampling both substrata required additional time and resources to be utilised, as it effectively doubled the time to conduct fish assemblage sampling at one site. Many studies have compared fish assemblages of seagrass and bare sand substrata, for example Gray *et al*. (1998) and Jenkins *et al*. (1997) however, it was deemed too resource consuming considering the constraints of this study. Therefore, bare sand was not sampled in the main study; instead the fish assemblages inhabiting *Zostera capricorni* were examined in this study.

In conclusion, this pilot study has examined different methods, replicate numbers, and substrate types, and it is concluded that five seagrass replicates, and three semi-circle, seine net replicates are conducted in the *Zostera capricorni* beds in Brisbane Water, as they provide the most effective and logistically appropriate methods to be employed during the study on the fish assemblages.

Chapter 4: Results

4.1 Temporal and Spatial Differences

4.1.1 Temporal and Spatial Differences in Seagrass Bed Structure

4.1.1.1 Shoot Density

The shoot density of *Zostera capricorni* was higher in Time 2 (Feb-April 2006) than compared to Time 1 (May-June 2004) (Table 6), and there was a significant difference between Time 1 and 2 when analysed in an ANOVA (Table 7) with $p < 0.05$. There were no significant differences among Locations (Area), however, there was a significant differences among Sites (Time x Area x Location). There were also no significant interactions between Time x Area and Time x Location (Area) (Table 7).

4.1.1.2 Leaf Length

Leaf length did not demonstrate any differences among Times or Locations (Area), nevertheless, there were significant differences found among Sites (Time x Area x Location) and Quadrats (Time x Area x Location x Site) (Table 7). There was no significant interaction between Time x Area, however, there was a significant interaction between Time x Location (Area) (Table 7).

4.1.1.3 Percent Cover of Seagrass

There was an increase in percent cover of seagrass between Time 1 and Time 2 (Table 6), and there was no significant difference found among Time (Table 7). There were no differences found between Locations (Area), however, there was a significant difference between Sites (Time x Area x Location) (Table 7). There was a significant interaction

found between Time x Area, however, there was no interaction found between Time x Location (Area).

4.1.1.4 Percent Cover of Epiphytes

The percent cover of epiphytes demonstrated a decrease between Time 1 and Time 2 (Table 6), this difference was supported when analysed in an ANOVA, as there was a significant difference found between the two time periods, $p < 0.001$(Table 7). There was a significant difference found among Locations (Area) and Sites (Time x Area x Location) (Table 7), however, there were no differences found among Quadrats (Time x Area x Location x Site) (Table 7). There were no significant interactions found between Time x Area, and Time x Location (Area).

Table 6: A comparison of Time 1 and Time 2 *Z. capricorni* shoot density, leaf length, percent cover of seagrass and percent cover of epiphytes. The mean ± standard error (SE) was calculated for each time.

Seagrass Floristic	Time 1 Mean ± SE	Time 2 Mean ± SE
Shoot Density	56.83 ± 2.25	74.17 ± 2.56
Leaf Length	23.66 ± 0.32	27.49 ± 0.42
Percent Cover	69.00 ± 1.92	77.04 ± 1.65
Epiphyte Cover	86.99 ± 0.52	57.23 ± 0.86

Table 7: Results of the nested analysis of variance of *Z. capricorni* seagrass floristics in Brisbane Water. Significant results are denoted by: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source of Variation	DF	Shoot Density		Percent Cover	
		MS	F	MS	F
Time	1	18026.67	7.26*	3880.10	8.73*
Area	5	4033.44	No Test	4031.60	No Test
Location (Area)	6	4189.07	1.69	880.52	1.98
Site (Time x Area x Location)	24	1191.47	3.4***	750.73	5.99***
Time x Area	5	1978.03	0.8	4172.10	9.39**
Time x Location (Area)	6	2483.47	2.08	444.27	0.59
Residual	192	350.47		125.36	
Source of Variation	**DF**	**Leaf Length**		**Epiphyte Cover**	
		MS	F	MS	F
Time	1	8801.34	1.15	528660.17	38.45***
Area	5	22167.77	No Test	24848.65	No Test
Location (Area)	6	9130.35	1.2	15150.67	1.1***
Site (Time x Area x Location)	24	2642.97	8.49***	6744.35	7.98***
Quadrat (Time x Area x Location x Site)	192	311.35	12.64***	845.09	2.5
Time x Area	5	4351.51	0.57	20491.62	1.49
Time x Location (Area)	6	7626.82	2.89*	13748.17	2.04
Residual	2160	24.62		337.93	

4.1.2 Spatial and Temporal Differences in Fish Assemblages

4.1.2.1 Diversity and Abundance

Temporally all of the fish assemblage variables increased from Time 1 to Time 2, with the exception of Glassfish Abundance, which, decreased from Time 1 to Time 2 (Table 8). When analysed in an ANOVA there was found to be significant differences at $p < 0.05$ for fish diversity, invertebrate abundance, total diversity and total abundance (Table 9), however, there were no differences found between Time for fish abundance, glassfish abundance, and invertebrate abundance (Table 9). Spatially there were no differences found among Locations (Area), while there were significant differences

found among Sites (Time x Area x Location) for all of the fish assemblages variables (Table 9). There were significant interactions between Time x Area for fish diversity, glassfish abundance and total diversity (Table 9), however, there were no interactions between Time x Location (Area) for any of the fish assemblage variables.

Table 8: A comparison of Time 1 and Time 2 fish assemblage variables. The mean ± standard error (SE) were calculated for each time. Note: w/o gf = without glassfish.

Ecological Guild	Time 1 Mean ± SE	Time 2 Mean ± SE
Fish Diversity	10.86 ± 0.36	11.79 ± 0.40
Fish Abundance w/o gf	133.47 ± 14.08	154.21 ± 9.99
Glassfish Abundance	315.67 ± 89.98	133.61 ± 44.19
Invertebrate Diversity	3.53 ± 0.13	3.99 ± 0.12
Invertebrate Abundance	163.76 ± 16.92	266.57 ± 32.46
Total Diversity	14.39 ± 0.45	15.68 ± 0.44
Total Abundance w/o gf	297.24 ± 30.56	420.78 ± 39.89

4.1.2.2 Ecotrophic Guilds

4.1.2.2.1 Ecological Guilds

The abundance of estuarine residents and marine adventitious visitors increased from Time 1 to Time 2, while marine juveniles decreased (Table 10). When analysed in an ANOVA, there were no differences found among Time for estuarine residents and marine juveniles, while, marine adventitious visitors had a significant difference among Time (Table 11). Marine adventitious visitors were also the only ecological guild to have a significant difference among Location (Area) (Table 11). All of the three ecological guilds resulted in significant differences among Sites (Time x Area x Location) (Table 11). There was a significant interaction between Time x Area for marine juveniles, and there were no interactions for Time x Location (Area).

Table 9: Results of the nested analysis of variance of fish assemblage parameters measure in the *Z. capricorni* beds in Brisbane Water. Significant results are denoted by: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Note: w/o gf = without glassfish; # denotes transformation via Sqrt (x + 1).

Source of Variation	DF	Fish Diversity		Fish Abundance w/o gf		Glassfish Abundance	
		MS	F	MS	F	MS	F
Time	1	31.17	12.65*	15479.51	1.53	1.19×10^6	5.27
Area	5	58.36	No Test	31356.26	No Test	1.41×10^6	No Test
Location (Area)	6	6.33	2.57	25557.33	2.52	3.10×10^5	1.37
Site (Time x Area x Location)	24	21.01	4.27***	18998.19	3.01***	4.55×10^5	1.73*
Time x Area	5	26.76	10.85**	18133.66	1.79	9.97×10^5	4.41*
Time x Location (Area)	6	2.47	0.12	10149.63	0.53	2.26×10^5	0.5
Residual	96	4.92		6308.48		2.62×10^5	

Source of Variation	DF	Invertebrate Diversity		Invertebrate Abundance #	
		MS	F	MS	F
Time	1	7.56	4.48	373.76	10.85*
Area	5	3.36	No Test	169.98	No Test
Location (Area)	6	0.41	0.24	45.65	1.32
Site (Time x Area x Location)	24	2.13	2.92***	74.90	4.71***
Time x Area	5	3.68	2.18	43.75	1.27
Time x Location (Area)	6	1.69	0.79	34.46	0.46
Residual	96	0.73		15.91	

Source of Variation	DF	Total Diversity #		Total Abundance w/o gf #	
		MS	F	MS	F
Time	1	60.06	10.14*	439.4052	9.37*
Area	5	77.61	No Test	220.9143	No Test
Location (Area)	6	7.92	1.34	66.4998	1.42
Site (Time x Area x Location)	24	27.83	4.15***	95.8404	4.13***
Time x Area	5	41.16	6.95*	57.4107	1.22
Time x Location (Area)	6	5.92	0.21	46.904	0.49
Residual	96	6.71		23.1859	

Table 10: A comparison of the abundance of fish Ecological guilds in Time 1 and Time 2. The mean ± standard error (SE) was calculated for each time.

Ecological Guild	Time 1 Mean ± SE	Time 2 Mean ± SE
Estuarine Resident	409.11 ± 91.45	272.94 ± 45.23
Marine Adventitious Visitors	3.89 ± 1.51	10.85 ± 3.19
Marine Juvenile	15.82 ± 4.05	11.81 ± 1.19

Table 11: Results of the nested analysis of variance of ecological guilds of fish in the *Z. capricorni* beds in Brisbane Water. Significant results are denoted by: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source of Variation	DF	Estuary Resident		Marine Adventitious		Marine Juvenile	
		MS	F	MS	F	MS	F
Time	1	6.67×10^5	2.66	1743.06	12.8*	580.01	3.98
Area	5	1.57×10^6	No Test	963.84	No Test	2882.58	No Test
Location (Area)	6	3.32×10^5	1.32	860.98	6.32*	346.38	2.38
Site (Time x Area x Location)	25	4.95×10^5	1.88*	721.44	1.98*	805.59	2.08**
Time x Area	5	9.66×10^5	3.84	156.40	1.15	3485.29	23.92***
Time x Location (Area)	6	2.51×10^5	0.51	136.15	0.19	145.69	0.18
Residual	96	2.62×10^5		363.73		386.63	

4.1.2.2.2 Vertical Guilds

When comparing the temporal variability of vertical fish guilds in *Z. capricorni* pelagic fish decreased between Time 1 and Time 2, while, benthic and pelagic fish increased in abundance (Table 12). When tested in an ANOVA, it was found that benthic and demersal fish had a significant difference among Time (Table 13). Only benthic fish were found to have a significant difference among Locations (Area), while, all of the three guilds had significant differences among Sites (Time x Area x Location) (Table

13). Pelagic fish had a significant interaction between Time x Area, however, there were no interactions found between Time x Location (Area) for any of the vertical guilds (Table 13).

Table 12: A comparison of the abundance of fish Vertical guilds in Time 1 and Time 2. The mean ± standard error (SE) was calculated for each time.

Vertical Guild	Time 1 Mean ± SE	Time 2 Mean ± SE
Pelagic	351.04 ± 91.32	222.13 ± 44.74
Benthic	78.32 ± 10.20	210.50 ± 24.54
Demersal	6.49 ± 0.80	11.46 ± 1.30

Table 13: Results of the nested analysis of variance of vertical guilds of fish in the *Z. capricorni* beds in Brisbane Water. Significant results are denoted by: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source of Variation	DF	Pelagic		Benthic		Demersal	
		MS	F	MS	F	MS	F
Time	1	5.98×10^5	2.5	6.29×10^5	44.84***	890.03	18.97**
Area	5	1.55×10^6	No Test	8.96×10^4	No Test	595.24	No Test
Location (Area)	6	3.12×10^5	1.3	6.84×10^4	4.87*	93.56	1.99
Site (Time x Area x Location)	25	4.69×10^5	1.8*	4.24×10^4	2.62***	127.39	2.97***
Time x Area	5	1.11×10^6	4.62*	1.99×10^4	1.42	171.89	3.66
Time x Location (Area)	6	2.40×10^5	0.51	1.40×10^4	0.33	46.92	0.37
Residual	96	2.67×10^5		1.62×10^4		42.88	

4.1.3 Fish Length

The mean length of *Hyporhampus australis* increased from Time 1 to Time 2 (Table 14). The median and the mode increased from 151-200mm to 201-250mm (Figure 6 a and b). *Acanthopagrus australis* decreased in mean length from Time 1 to Time 2 (Table 14), and the median size class also decreased, as 101-150mm was the modal size

class in Time 1 (Figure 6c) and in Time 2 fish were only found in the 40-70mm size class (Figure 6d). *Rhabdosagrus sarba* decreased slightly in mean length between Time 1 and Time 2 (Table 14), and there was no difference in the median or mode (Figure 6 e and f). The mean length of *Girella tricuspidata* increased from Time 1 to Time 2 (Table 14), and the mode also increased from 0-50mm to 51-100mm (Figure 6 g and h), however, the median size class increased from 51-100mm to the 101-150mm size class.

Table 14: A comparison of Time 1 and Time 2 of the mean length of recreational fish species. The mean $\pm$ standard error (SE) was calculated for each time.

Recreational Fish Species	Time 1 Mean $\pm$ SE	Time 2 Mean $\pm$ SE
Hyporhampus australis	209.57 $\pm$ 3.93	214.97 $\pm$ 3.26
Acanthopagrus australis	110.52 $\pm$ 9.78	63.80 $\pm$ 2.24
Rhabdosagrus sarba	82.91 $\pm$ 1.18	74.71 $\pm$ 1.08
Girella tricuspidata	116.80 $\pm$ 15.21	129.96 $\pm$ 14.06

4.2 Relationships between Seagrass and Fish

4.2.1 Relationship between Seagrass Floristics

The correlation analysis between shoot density and leaf length had a high Production-Moment Correlation Coefficient (Table 15), suggesting that there is a strong negative relationship between these two seagrass floristics. Figure 7a demonstrates this highly correlated negative relationship between the two variables. Through statistical testing of the coefficient a significant result was obtained at $p < 0.001$ (Table 15) verifying that the relationship between shoot density and leaf length is highly significant. Shoot density and percent cover of seagrass also exhibited a high, positive correlation (Table 15), this relationship between these variables in shown in Figure 7b. Leaf length and epiphyte cover also demonstrated a strong negative relationship as shown in Figure 7c.

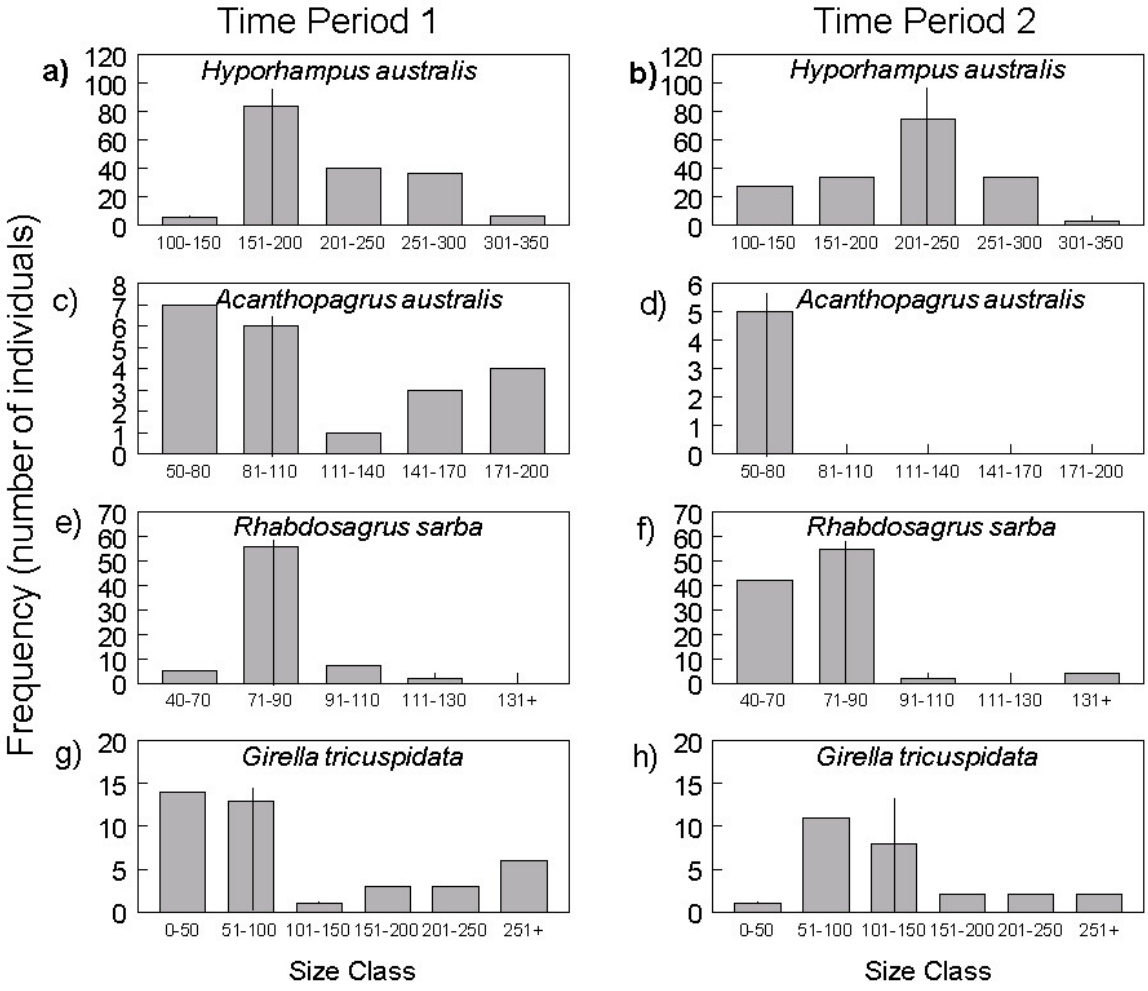

Figure 6: Size class frequency histograms of the two time periods for each species a) *Hyporhampus australis* (Eastern Garfish) Time 1 and b) Time 2, c) *Acanthopagrus australis* (Yellow-finned Bream) Time 1 and d) Time 2, e) *Rhabdosagrus sarba* (Tarwhine) Time 1 and f) Time 2, g) *Girella tricuspidata* (Luderick) Time 1 and h) Time 2. The solid black line shows the median.

When a t-test was carried out on the correlation coefficient a significant result of $p < 0.001$ was obtained confirming the relationship between leaf length and epiphyte cover. No relationships were established between shoot density and epiphyte cover, leaf length and percent cover or percent cover and epiphyte cover through this correlation analysis (Table 15).

Table 15: Results of the correlation analysis between each of the seagrass floristics of *Z. capricorni*. Values shown are the Product-Moment Correlation Coefficient, and significant results are denoted by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Shoot Density	Leaf Length	Percent Cover	Epiphyte Cover
Shoot Density	-	-0.561***	0.23*	0.132
Leaf Length		-	-0.025	-0.376***
Percent Cover			-	-0.086
Epiphyte Cover				-

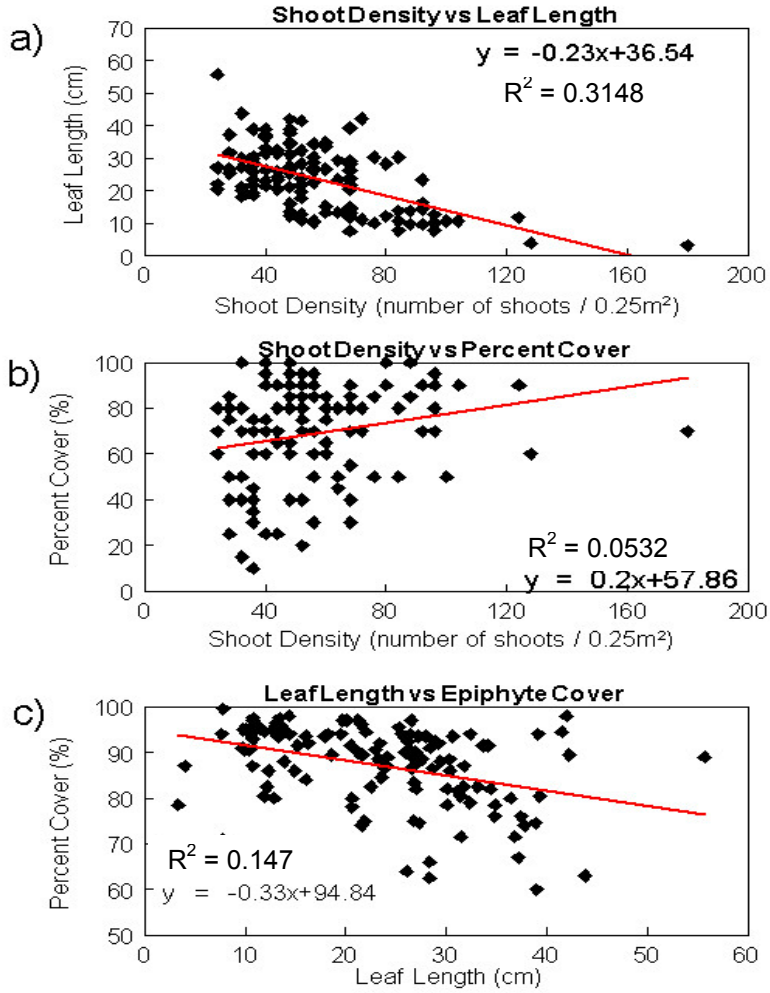

Figure 7: Scatter plots demonstrating relationship between seagrass floristics a) Shoot Density vs Leaf Length; b) Shoot Density vs Percent Cover of seagrass; c) Leaf Length vs Epiphyte Percent Cover. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

4.2.2 Relationship between Seagrass Bed Structure and Fish Assemblages

4.2.2.1 Diversity and Abundance

4.2.2.1.1 Shoot Density

All of the fish assemblage variables, except glassfish abundance, did not have a significant relationship with shoot density. The abundance of glassfish had a negative Product-Moment Correlation Coefficient, shown in Table 16. This relationship between shoot density and glassfish abundance is shown in Figure 8a, which demonstrates the highly correlated, negative relationship between the two variables, as the shoot density increases the abundance of the glassfish decreases.

4.2.2.1.2 Leaf Length

The correlation analysis between leaf length and fish diversity resulted in a positive correlation coefficient. This relationship is shown in Figure 8b, which demonstrates the increasing diversity of fish with increasing leaf length. This correlation coefficient relationship was then subjected to significance testing and the relationship between the two variables was found to be significant at $p < 0.01$. Total diversity of fish and invertebrates also shows a positive relationship with leaf length, and this relationship is illustrated in a scatter plot in Figure 8c. The high correlation coefficient for these variables is shown in Table 16, and through a t-test was determined to be significant at $p < 0.05$.

4.2.2.1.3 Percent Cover of Seagrass

The diversity of fish demonstrated a significant negative correlation coefficient with the percent cover of seagrass, so the diversity of fish decreased with increasing percent

cover (Figure 9a). The abundance of glassfish also displayed a negative relationship with percent cover, as shown in Figure 9b. Invertebrate abundance also displayed a significant negative relationship with percent cover (Figure 9c), as did total diversity (Figure 9d). The correlation coefficient obtained was found to be significant (Table 16) confirming that a relationship does exist between percent cover and glassfish abundance. No significant relationships were found between percent cover and the abundance of fish, invertebrates and total abundance.

4.2.2.1.4 Percent Cover of Epiphytes

The diversity and abundance of invertebrates demonstrated a highly correlated, negative relationship with the percent cover of epiphytes on leaves. The scatter plots for invertebrate diversity and abundance are shown in Figure 10a and 10b respectively, demonstrating a decrease in numbers when the percent cover of epiphytes increases. Both of these fish assemblage variables have been determined to have a significant relationship with percent cover of epiphytes ($p < 0.05$ in Table 16). Total abundance also had a significant relationship with the percent cover of epiphytes at $p < 0.05$ (Table 16). The highly correlated, negative relationship between epiphyte cover and total abundance is shown in Figure 10c, as the total abundance of fish and invertebrates decreased when the percent cover of epiphytes on the leaves of the seagrass increased.

Table 16: Results of the correlation analysis between fish assemblage variables and seagrass floristics of *Z. capricorni*. Values shown are the Product-Moment Correlation Coefficient, and significant results are denoted by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Shoot Density	Leaf Length	Percent Cover	Epiphyte Cover
Fish Diversity	-0.016	0.168*	-0.245**	0.021
Fish Abundance	-0.115	0.035	-0.156	-0.050
Glassfish Abundance	-0.183*	0.156	-0.312**	0.131
Invertebrate Diversity	0.031	0.121	-0.188*	-0.195*
Invertebrate Abundance	0.054	0.162	-0.010	-0.211*
Total Diversity	-0.033	0.197*	-0.283***	-0.021
Total Abundance	0.001	0.133	-0.127	-0.175*

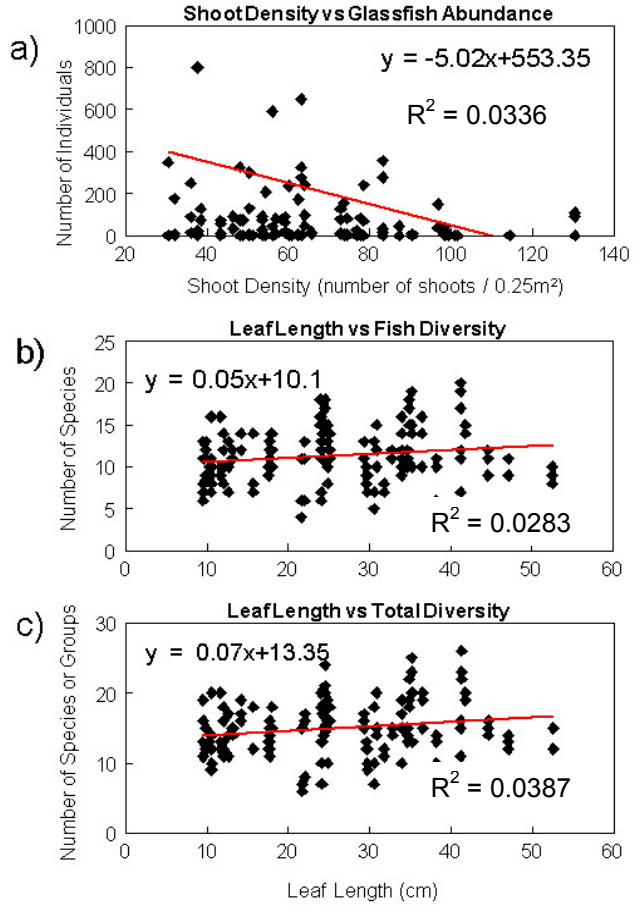

Figure 8: Scatter plots demonstrating relationship between seagrass floristics and fish assemblage variables; a) Shoot Density vs Glassfish Abundance; b) Leaf Length vs Fish Diversity; c) Leaf Length vs Total Diversity. The linear line with the equation of $y = mx + b$, is shown only to demonstrate relationship.

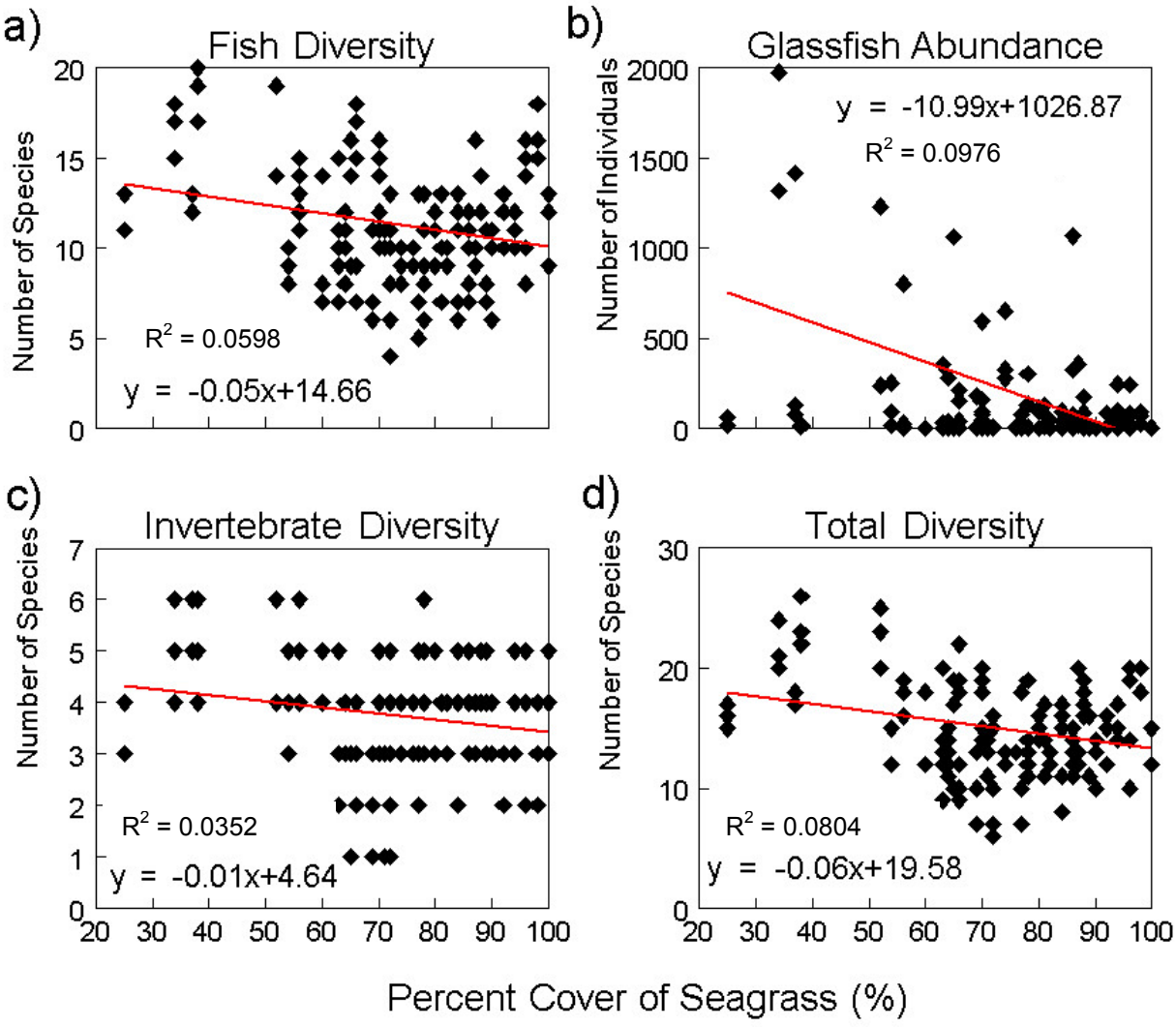

Figure 9: Scatter plots demonstrating relationship between Percent Cover and fish assemblage variables; a) Percent Cover vs Fish Diversity; b) Percent Cover vs Glassfish Abundance; c) Percent Cover vs Invertebrate Diversity; d) Percent Cover vs Total Diversity. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

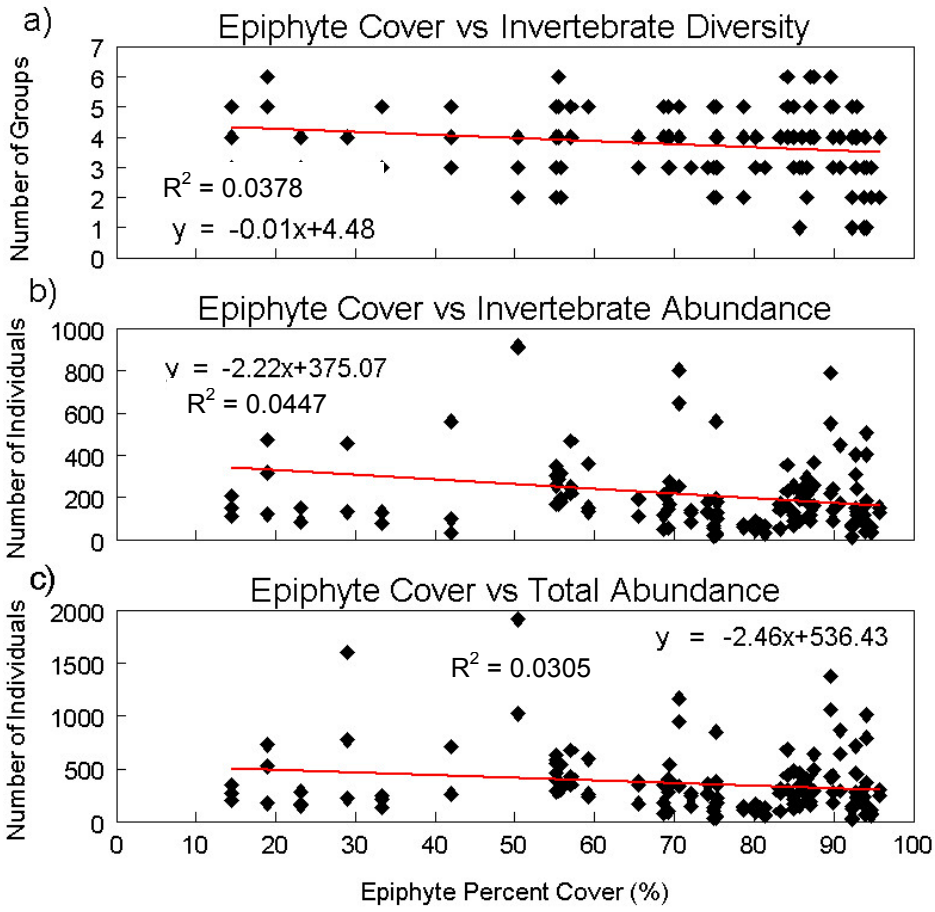

Figure 10: Scatter plots demonstrating relationship between Epiphyte Cover and fish assemblage variables; a) Epiphyte Cover vs Invertebrate Diversity; b) Epiphyte Cover vs Invertebrate Abundance; c) Epiphyte Cover vs Total Diversity. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

4.2.2.2 Ecotrophic Guilds

4.2.2.2.1 Ecological Guilds

4.2.2.2.1.1 Estuarine Residents

In the ecological fish guilds estuarine residents showed a negative correlation with shoot density of *Z. capricorni* (Figure 11a). Significance testing was conducted with a t-test, on the correlation coefficient of estuarine residents and shoot density to determine

whether the relationship was significant. The result from this t-test was significant at $p < 0.05$ (Table 17). When the guild estuarine residents were correlated with leaf length, the scatter graph (Figure 11b) showed a positive relationship between the two variables, demonstrating that with increasing leaf length the abundance of Estuarine Residents increased. The Product-Moment Correlation Coefficient for these variables (Table 17) was determined to be significantly correlated at $p < 0.05$. Estuarine residents once again produced a high correlation coefficient with the percent cover of *Z. capricorni*, shown in Table 17. The scatter plot between estuarine residents and percent cover demonstrates this strong negative correlation (Figure 12a), as the percent cover of *Z. capricorni* increases the abundance of estuarine residents decreases. This correlation was determined to be significantly different at $p < 0.01$ (Table 17). The correlation between estuarine residents and epiphyte cover however, did not produce a significant correlation.

4.2.2.2.1.2 Marine Adventitious Visitors

Marine adventitious visitors did not produce any significant correlations with shoot density, leaf length or epiphyte cover. The percent cover of *Z. capricorni* however, did produce a high correlation with marine adventitious visitors. This correlation between marine adventitious visitors and percent cover is shown in Figure 12b, demonstrating a positive relationship as percent cover increases so does the abundance of fish in this ecological guild.

4.2.2.2.1.3 Marine Juvenile Visitors

The correlation between marine juveniles and shoot density, leaf length and epiphyte cover did not produce any significant correlations. There was however, a relationship

between marine juvenile abundance and percent cover of *Z. capricorni*, this relationship is demonstrated in the scatter plot in Figure 12c. This plot shows a negative relationship between these two variables, as the abundance of marine juveniles decreases with increasing percent cover. This relationship was determined to be significantly correlated at $p < 0.01$ (Table 17).

Table 17: Results of the correlation analysis between ecological fish guilds and seagrass floristics. Values shown are the Product-Moment Correlation Coefficient, and significant results are denoted by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Shoot Density	**Leaf Length**	**Percent Cover**	**Epiphyte Cover**
Estuarine Residents	-0.186*	0.168*	-0.307***	0.104
Marine Adventitious	0.025	0.018	0.207*	-0.089
Marine Juveniles	-0.100	-0.059	-0.291***	0.053

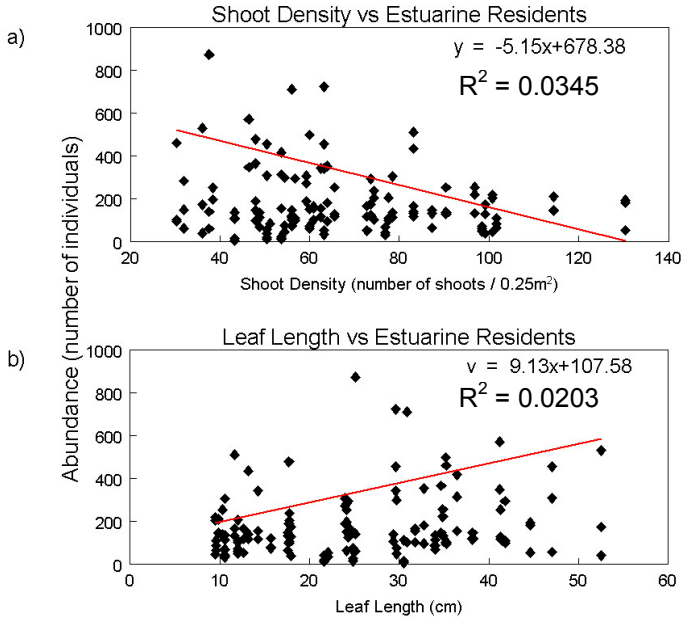

Figure 11: Scatter plots demonstrating relationship between seagrass floristics and Estuarine Residents; a) Shoot Density vs Estuarine Resident abundance b) Epiphyte Cover vs Estuarine Resident abundance. The linear line with the equation of $y = mx + b$, is shown only to demonstrate relationship.

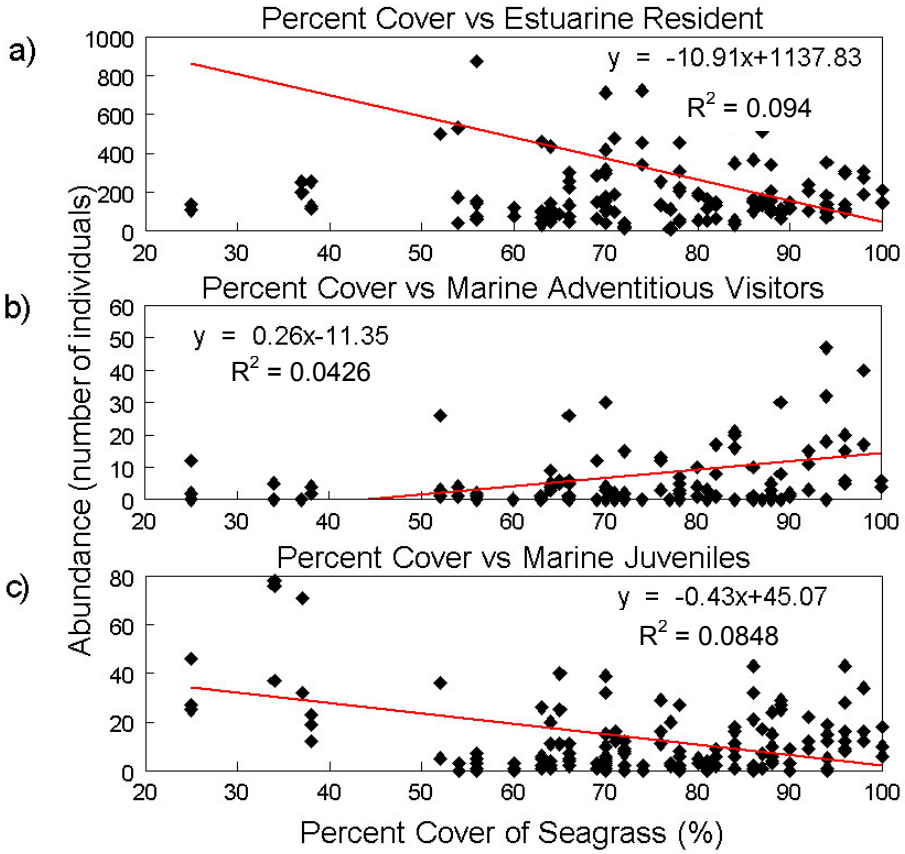

Figure 12: Scatter plots demonstrating relationship between Percent Cover of seagrass and Ecological Guilds; a) Percent Cover vs Estuarine Resident abundance b) Percent Cover vs Marine Adventitious Visitor abundance; c) Percent Cover vs Marine Juvenile abundance. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

4.2.2.2.2 Vertical Guilds

4.2.2.2.2.1 Pelagic

The correlation analysis between pelagic fish and shoot density results in a negative relationship as demonstrated in Figure 13a. The abundance of pelagic fish decreases as the shoot density of *Z. capricorni* increases. The correlation coefficient between these two variables was significant at $p < 0.05$ (Table 18). Leaf length, unlike shoot density, resulted in a positive relationship as shown in Figure 13b. The density of pelagic fish

increased when the leaf length of the seagrass increased. This relationship was found to be significant at $p < 0.05$ (Table 18) when the correlation coefficient was analysed in a t-test. The percent cover of seagrass negatively affected the pelagic fish guild, as the abundance of fish decreased when the percent cover of the seagrass bed increased (Figure 13c). Through significance testing, it was established that this highly, negative relationship was significant at $p < 0.001$ (Table 18). The percent cover of epiphytes however, did not result in any significant relationships.

4.2.2.2.2.2 Benthic

Through a correlation analysis, there was no relationship between the benthic fish guild and shoot density, leaf length and epiphyte cover (Table 18). There was, however, a negative relationship between benthic fish and the percent cover of epiphytes, as the abundance of benthic fish decreased when epiphyte cover increased (Figure 14). It was established through significance testing that this relationship was significant at $p < 0.05$ (Table 18).

4.2.2.2.2.3 Demersal

The Demersal fish guild did not produce a significant relationship with shoot density (Table 18), however, there was a highly correlated, positive relationship between demersal fish and leaf length. Figure 15a demonstrates this positive relationship, as when the leaf length increases so too does the abundance of demersal fish. This relationship was determined to be significant through significance testing at $p < 0.001$ (Table 18). The demersal fish guild produced a negative relationship with both percent cover of seagrass and the percent cover of epiphytes. Both of these negative relationships are shown in Figure 15b and Figure 15c respectively, demonstrating a

decrease in demersal fish abundance when the percent cover of seagrass or epiphytes increases. Through significance testing, both demersal fish and percent cover of seagrass, and demersal fish and percent cover of epiphytes results in a significant negative relationship at $p < 0.05$ (Table 18).

Table 18: Results of the correlation analysis between ecological fish guilds and seagrass floristics. Values shown are the Product-Moment Correlation Coefficient, and significant results are denoted by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

	Shoot Density	**Leaf Length**	**Percent Cover**	**Epiphyte Cover**
Pelagic	-0.180*	0.168*	-0.311***	0.091
Benthic	0.055	0.115	0.032	-0.201*
Demersal	-0.150	0.484***	-0.175*	-0.193*

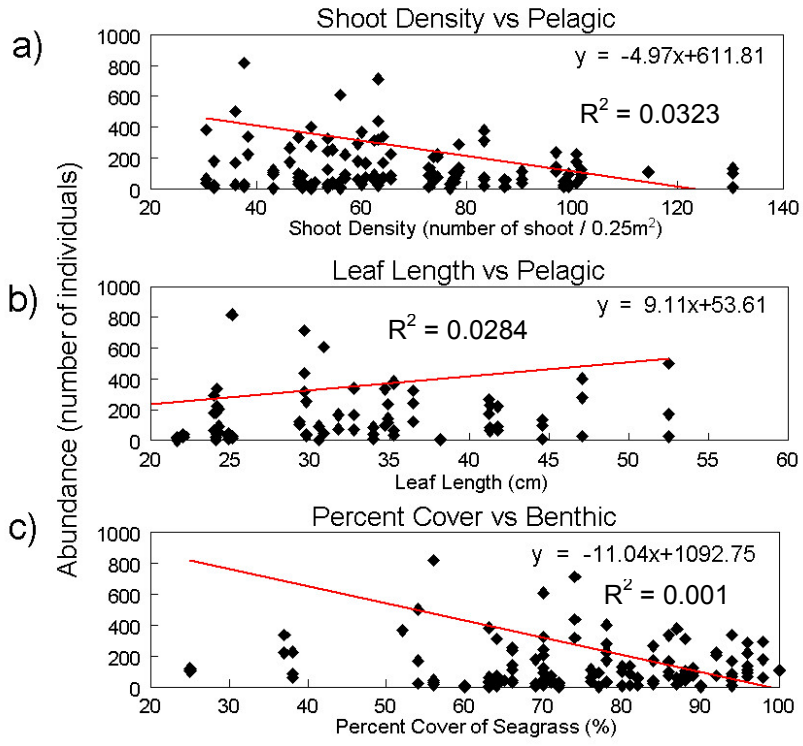

Figure 13: Scatter plots demonstrating relationship between seagrass floristics and Pelagic fish abundance; a) Shoot Density vs Pelagic abundance b) Leaf Length vs Pelagic abundance; c) Percent Cover vs Pelagic abundance. The linear line with the equation of $y = mx + b$, is shown only to demonstrate relationship.

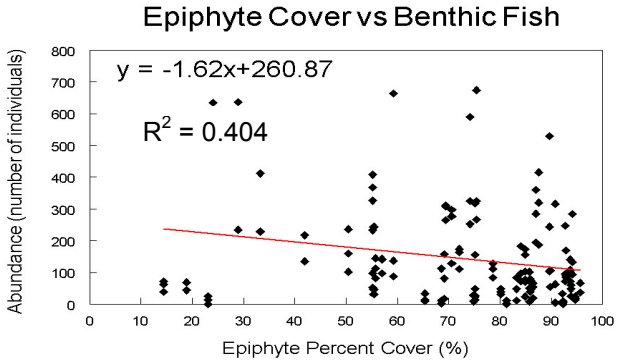

Figure 14: A scatter plot demonstrating the highly correlated negative relationship between Epiphyte Percent Cover and Pelagic fish abundance in *Z. capricorni* in the Brisbane Water estuary. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

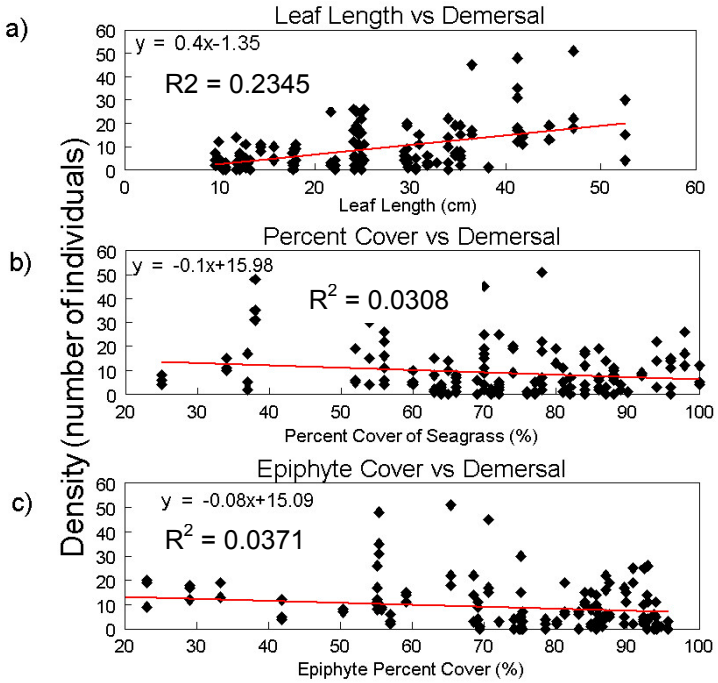

Figure 15: Scatter plots demonstrating relationship between seagrass floristics and Demersal fish abundance; a) Leaf Length vs Demersal abundance b) Percent Cover vs Demersal abundance; c) Epiphyte Percent Cover vs Demersal abundance. The linear line with the equation of y = mx + b, is shown only to demonstrate relationship.

4.3 Comparison of Fish Assemblage Sampling Techniques

Seine netting and underwater visual census shows little difference in the mean diversity of fish between the two techniques (Table 19). During an ANOVA these techniques were found not to be significantly different in fish diversity (Table 20). This was also the case for fish density, as it was there was no significant difference between the techniques. However, the means for fish density in Table 19 show a much higher mean number of fish in the seine netting technique than compared to visual census. The mean diversity and density of invertebrates is greater in seine netting than compared to visual census (Table 19), these differences were found to be significantly different in the ANOVA (Table 20). The total diversity and density of fish and invertebrates combined demonstrate little difference between the means of seine netting and visual census (Table 19). This was confirmed in the ANOVA as no differences were found among techniques. However the total diversity exhibited a significant difference among Locations (Technique). The difference between the two Locations is illustrated in Figure 16. There is little difference between the means for each site within each location. However, Locations 1 and 2 show a huge difference in the mean diversity and density of fish. During the visual census technique, the visibility experienced by the diver in Location 1 was five metres compared to that of Location 2, which had a visibility of approximately 0.5m to 1m.

Table 19: A comparison of the fish assemblage variables between Seine netting (Seine) and Underwater Visual Census. The mean per $10m^2$ for each technique is shown with standard error (SE).

Fish Assemblage Variable	Seine Mean ± SE	UVC Mean ± SE
Fish Diversity	0.63 ± 0.06	0.75 ± 0.17
Fish Density	10.22 ± 1.35	3.33 ± 1.08
Invertebrate Diversity	0.23 ± 0.01	0.06 ± 0.04
Invertebrate Density	6.07 ± 1.38	0.06 ± 0.04
Total Diversity	0.86 ± 0.07	0.81 ± 0.17
Total Density	16.29 ± 2.52	13.39 ± 1.09

Table 20: Results of the nested analysis of variance of seine netting vs underwater visual census in the *Z. capricorni* beds in Brisbane Water. Significant results are denoted by: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source of Variation	DF	Fish Diversity		Fish Density	
		MS	F	MS	F
Technique	1	0.09	0.05	285.04	4.41
Location (Technique x Area)	4	1.70	21.76**	64.59	12.13**
Site (Technique x Area x Location)	16	0.08	1.54	5.32	0.35
Residual	23	0.51		15.23	
Source of Variation	**DF**	**Invertebrate Diversity**		**Invertebrate Density**	
		MS	F	MS	F
Technique	1	0.19	44521***	13.68	294.8**
Location (Technique x Area)	4	0.00	0.00	0.05	0.07
Site (Technique x Area x Location)	16	0.01	1.24	0.70	2.35
Residual	23	0.01		0.30	
Source of Variation	**DF**	**Total Diversity**		**Total Density**	
		MS	F	MS	F
Technique	1	0.02	0.01	998.85	13.83
Location (Technique x Area)	4	1.69	17.13*	72.22	1.83
Site (Technique x Area x Location)	16	0.10	2.15	39.45	0.93
Residual	23	0.05		42.79	

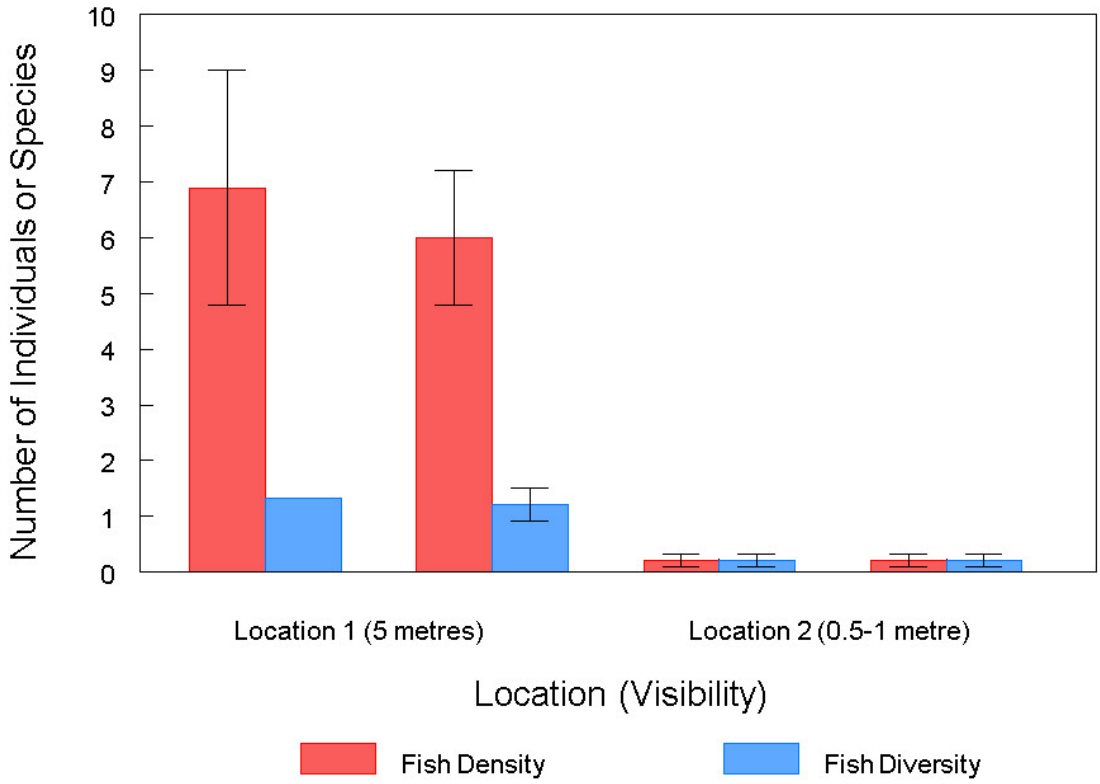

Figure 16: The significant difference among Locations encountered during the visual census technique of sampling fish assemblages. Location 1 experienced 5m visibility, while Location 2 had 0.5m to 1m visibility.

Chapter 5: Discussion

5.1 Temporal and Spatial Differences

During this study there was an increase in shoot density from Time 1 (May/June) to Time 2 (February-April), with Time 1 coinciding with late autumn to early winter while Time 2 occurred in late summer to mid autumn. Turner and Scharwz (2006) also found that shoot density of *Z. capricorni* increased during summer months, as did Larkum *et al*. (1984) who recorded a 2-fold increase in the shoot density of *Z. capricorni* during summer. The higher shoot density during summer can be explained in two ways. The first explanation is the dieback experienced by *Z. capricorni* during winter months (Larkum *et al*., 1984), which can be attributed to the decline in seagrass growth rates with decreasing water temperature (Kirkman *et al*., 1982). The second reason for the increase in shoot density from winter to summer is the germination of new seagrass seedlings during this period of time, as Peterken and Conacher (1997) found a high number of germinating seedlings in April, with a peak occurring in May.

This study did not show any significant temporal differences in leaf length of *Zostera capricorni*, however there was a general trend that leaf length increased during Time 2 (Table 6). Previous studies, for example, Larkum *et al*. (1984) examined temporal changes in leaf length and determined that the leaf length of *Z. capricorni* changed temporally, with a peak occurring in late summer. Larkum *et al*. (1984) concluded that the increase in leaf length was due to the increased abundance of new shoots in the *Z. capricorni* bed. Kirkman *et al*. (1982) also found temporal changes in the leaf length of *Z. capricorni*, with the highest average length being recorded in late autumn.

The percent cover of seagrass showed significant temporal and significant spatial changes, among Sites, during this study. This suggested that the percent cover of the *Zostera capricorni* changed temporally during the study and that spatial differences in the percent cover occurred at Site level. In the past many studies have examined the change in seagrass bed cover in estuaries via the use of aerial photography, however very few past studies have examined temporal changes in the internal percent cover of individual seagrass beds. More recently, Heildelbaugh and Nelson (1996), compared the use of destructive seagrass biomass calculations to the use of non-destructive percent cover estimates. This study found that percent cover estimates were more effective at detecting changes in seagrass bed cover than biomass estimates, and that less time is required to obtain data compared to drying and weighing biomass samples.

The percent cover of epiphytes decreased from Time 1 to Time 2, however the reasons for this decrease is uncertain, as very few studies have examined the temporal changes in seagrass epiphytes. It is generally thought that the density and cover of epiphytes is dependent on changing levels of nutrients in the estuarine environment. However, Hays (2005) found no distinct effect of increased nutrients on epiphytic algal biomass, and epiphyte density is more appropriately explained by the abundance of invertebrate grazers (Heck and Valentine, 2006). A study by Heck *et al*. (2000) determined that small grazers control the cover of epiphytic alga, and concluded that invertebrate grazers and nutrient levels must be examined simultaneously to gain an understanding of the effects of nutrient loading on seagrass beds. In the present study, the epiphyte percent cover corresponds to an increase in invertebrate density in *Zostera capricorni*, this supports the study by Heck *et al*. (2000), indicating that the decrease in epiphytic algae is due to an increase in invertebrate grazers.

This study found that the diversity of fish assemblages inhabiting *Zostera capricorni* varied temporally throughout this study, while there was no difference in fish abundance. This was also found in a study conducted by Middleton *et al*. (1984) who found that the diversity of fish inhabiting *Z. capricorni* varied temporally, while there was no change in fish abundance. The present study did present spatial differences in fish assemblage structure, as fish diversity, invertebrate diversity, total diversity and the abundance of glassfish displayed differences among Areas, while all of the variables displayed differences among sites. The spatial variability of fish assemblages has been documented by numerous studies for example, Middleton *et al*. (1984); Jenkins *et al*. (1997); Blanc *et al*. (2001); Griffiths (2001). Blanc *et al*. (2001) describe fish assemblages as being spatially unstable, due to numerous variables such as seagrass structure and water parameters influencing fish assemblage composition.

Assemblages of fish were divided into the guilds, as defined by Elliot and Dewailly (1995) in order to gain an understanding of how different associations of the fish guilds changed throughout the study. The ecological and vertical guilds showed similar temporal and spatial trends comparable to the fish assemblage variables. Of the ecological guilds only marine adventitious visitors demonstrated any temporal changes in abundance in the *Zostera capricorni* beds. However, all of the three Ecological guilds displayed spatial variability among Sites. The Vertical guilds of Benthic and Demersal demonstrated significant temporal changes in abundance, with the exception of pelagic fishes, as this guild did not display any significant temporal changes. Unfortunately, no previous Australian seagrass bed studies have adapted the use of the Ecotrophic Guilds defined by Elliot and Dewailly (1995).

The length of post-settlement fish increased in size class from Time 1 to Time 2, for three of the four species targeted, *Hyporhampus australis*, *Acanthopagrus australis* and *Girella tricuspidata*. The length increased to the next size class for each of these three species, however, *Rhabdosagrus sarba* did not increase in size during this study. This suggests that there was a recently large recruitment of juvenile *Hyporhampus australis*, *Acanthopagrus australis* and *Girella tricuspidata* into seagrass beds in the Brisbane Water estuary. The increase of fish into the larger size class could possibly be due to the sampling of the same cohort during the study, as juvenile fish do not migrate between beds (Bell and Westoby, 1986a). The numbers of juveniles of the most common size classes, decreased from Time 1 to Time 2. This decrease in abundance could be from pressures of predation or the movement of these larger juveniles into more advantageous habitats. This study did not focus on juvenile recreational fish species in Brisbane Water and therefore not enough data was obtained to appropriately analyse these populations. However, the changes in juvenile recreational fish in Brisbane Water should be examined in order to determine the importance of seagrass beds to recreational fishing in and outside the estuary.

5.2 Relationships Between Seagrass Floristics

There was a significant negative relationship between shoot density and leaf length during this study, as the number of shoots increased the leaf length decreased. Previous studies by Conacher *et al*. (1994) and Turner and Schwarz (2006) also found that the leaf length of *Zostera capricorni* was shorter in seagrass beds with high shoot densities, and that it was longer in beds with low shoot densities. Conacher *et al*. (1994) believed that this relationship between shoot density and leaf length is dependant on depth, as

they found that the lower shoot densities and higher leaf lengths occurred in deeper waters. West (1990) confirmed that shoot density is related to depth, as it was found that the shoot density decreased with increasing water depth.

Seagrass shoot density and percent cover have a significant positive relationship, as percent cover increases with increasing shoot density. This relationship can be explained by the increase in area covered by increasing shoot density of *Zostera capricorni*, therefore resulting in an increase in percent cover. Larkum *et al*. (1984) also examined the relationship between the shoot density of *Z. capricorni* and percent cover, and found that there is a significant positive relationship between the two variables. The present study, also found a significant negative relationship between leaf length and epiphyte cover, as the cover of epiphytes decreased with increasing leaf length. It has previously been stated by Conacher *et al*. (1994) that leaf length increases with increasing depth, and with increasing depth algae become less abundant due to the reduction in availability of light (Piazzi *et al*., 2004). Lepoint *et al*. (1999) further support this statement as they found that the biomass of epiphytes decreased with increasing depth. Therefore, a negative relationship exists between leaf length and epiphyte cover due to the two variables behaving conversely to one another with increasing depth.

5.3 Relationships Between Seagrass and Fish

This study found that there was a negative relationship between shoot density and the abundance of glassfish, as the shoot density increased the abundance of glassfish decreased. This negative relationship may not be directly affected by the percent cover of seagrass, but be affected by other factors related to seagrass percent cover. As stated

previously the leaf length of seagrass decreases when the shoot density increases, and West (1990) also found that shoot density decreased with increasing depth. Therefore the leaf length of the seagrass and the water depth are most likely the factors affecting the distribution of this schooling species. Conversely, there were no relationships detected between shoot density and the diversity and density of fish. A study by Bell *et al*. (1987) found that there was no relationship between seagrass shoot density and the abundance of juvenile fish. Their study determined that juvenile fish settle into the first seagrass bed they encounter, and do not discriminate between beds of differing densities. According to Bell and Westoby (1986a), once settled, the juvenile fish do not migrate between beds; instead they locate the most beneficial microhabitat within the same seagrass bed. Therefore, it is the fact that fish do not discriminate between differing densities that explains the lack of relationship between shoot density and fish diversity and abundance.

Leaf length was found to have a significant positive relationship with the diversity of fish, while the leaf length did not affect the abundance of fish. During the present study the diversity of fish increased with increasing leaf length. A study by Bell and Westoby (1986b) also found the same relationships between the leaf length of seagrass and the diversity and abundance of fish. Their study found that when the leaf length of seagrass decreased the fish diversity also decreased, and that the abundance of fish was not affected by leaf length. The height of the seagrass canopy affects the diversity of fish, as the number of microhabitats changes with differing leaf length (Kikuchi, 1980; Hindell *et al*., 1999). As the leaf length decreases, the number of microhabitats also decreases resulting in a decrease in diversity. The abundance of fish, however, was not affected by leaf length, presumably because the fish inhabiting the available

microhabitats flourish in these conditions, possibly due to the lack of interspecies competition.

In this study the percent cover of seagrass demonstrated a significant negative relationship with fish diversity, glassfish abundance and invertebrate diversity. These negative relationships are probably not solely due to the changes in percent cover, but are complex and related to other seagrass and environmental variables. As discussed earlier when percent cover of seagrass increased, there too was an increase in shoot density. The increasing shoot density affected the abundance of glassfish negatively, but also when shoot density increased the seagrass leaf length decreased, and leaf length affects the diversity of fish assemblages. Finally the leaf length of seagrass beds is greatly affected by the depth of the seagrass bed, which in turn may influence the structure of fish assemblages. Unfortunately, very few studies have examined the percent cover of seagrass beds, with the exception of Larkum *et al*. (1984), however, it is evident that seagrass bed structure is complex, being shaped by numerous variables, and in turn influencing fish assemblage structure.

The epiphyte percent cover had little affect on the fish assemblages, presumably due to very few fish species feeding on seagrass epiphytes. However, the diversity and abundance of the invertebrate assemblage had significant negative relationships with epiphyte cover. A previous study by Bolonga and Heck (1999) determined that the abundance of invertebrates increased with increasing epiphyte biomass as the invertebrates fed on the epiphytes, however the present study actually showed that the diversity and abundance of invertebrates decreased with increasing epiphyte cover; this negative relationship can be explained by the abundance of invertebrate grazers. When

grazers are in low abundance the cover of epiphytes increases, and the inverse occurs when invertebrate grazers are in high abundance. Heck and Valentine (2006) support this theory as they assert that the biomass of seagrass epiphytes is affected by the abundance of grazers rather than increases in nutrient loads. In conclusion, epiphyte cover is very important to invertebrate grazers (Schneider and Mann, 1991) as it is a food source for these organisms, and epiphyte cover is regulated by the abundance of these grazers.

Seagrass floristics were also tested for significant relationships with the Ecotrophic guilds, which included Ecological and Vertical Guilds. The Ecological guild of estuarine residents demonstrated relationships with seagrass floristics similar to that of fish assemblage variables. For instance, estuarine residents had a significant negative relationship with shoot density, as did glassfish abundance. As stated previously, the relationship between fish and shoot density is affected by depth (Conacher *et al*., 1994) and leaf length; estuarine residents also demonstrated a positive relationship with leaf length, increasing in abundance with increasing leaf length. Like other fish assemblage variables, estuarine residents also demonstrated a negative relationship with the percent cover of seagrass. This relationship, however, is complex and is affected by other seagrass variables such as shoot density and leaf length, but the relationship is ultimately limited by depth (Conacher *et al*., 1994).

The marine adventitious visitors only possessed a relationship with the percent cover of seagrass, however, unlike other fish assemblage variables and estuarine residents, this guild demonstrated a positive relationship with seagrass percent cover. This relationship was greatly influenced by *Hyporhampus australis* (Eastern Garfish), as this

species was the most common marine adventitious visitor encountered during this study. The higher seagrass percent cover previously discussed, resulted in a higher shoot density and a lower leaf length, thus representing an ideal habitat for *Hyporhampus australis*. Marine juvenile fish also demonstrated a negative relationship with the percent cover of seagrass. Despite this negative relationship, the majority of data occurred in higher percent cover range. The most common fish species contributing to the abundance of marine juveniles were, *Girella tricuspidata* (Luderick), *Acanthopagrus australis* (Yellow-finned Bream) and *Rhabdosagrus sarba* (Tarwhine). All of these species were mainly observed over seagrass beds with high percent cover, high shoot densities and low leaf lengths. Their relationship with percent cover is possibly related to their diet, with *Girella tricuspidata* feeding primarily on algae (Kuiter, 2000), while *Acanthopagrus* and *Rhabdosagrus australis* feed on bottom dwelling invertebrates and small fish (Kuiter, 2000). The abundance of algae is related to light penetration and depth (Lepoint *et al*., 1999), with higher abundances of algae occurring in shallower waters, where seagrass beds are typically short and dense, thus explaining the abundance of *Girella trcuspidata*. While the abundance of *Acanthopagrus australis* and *Rhabdosagrus sarba* can be explained by the presence of their prey items in short seagrass compared to that longer seagrass. Unfortunately, only one study could be found that examined the percent cover of seagrass (Larkum *et al*., 1984), and no Australian studies have used Ecological guilds to examine fish assemblages in seagrass beds.

When Vertical guilds of fish were examined, the pelagic fish were found to have a significant negative relationship with shoot density, a positive relationship with leaf length and a negative relationship with percent cover of seagrass. These relationships

are the same as estuarine residents and other fish assemblage variables as established in this study. Benthic fish, however, did not exhibit any relationships with the above variables but did have a negative relationship with epiphyte cover. This relationship can be explained by the presence of invertebrate grazers, which may be a significant food resource for benthic fish. As stated previously, epiphyte cover increased when the abundance of invertebrates decreased, as epiphyte cover is limited by the abundance of grazers (Heck and Valentine, 2006). When this occurs the abundance of benthic fish also decreased due to the absence of invertebrate grazers, which are a possible food source. Demersal fish also displayed a significant negative relationship with epiphyte cover, presumably due to the lack of prey items. Demersal fish, however, did not display any relationship with shoot density, but did exhibit a typical positive relationship with leaf length and a negative relationship with percent cover.

5.4 Underwater Visual Census Techniques

Fish assemblages in seagrass beds are most commonly assessed by the use of netting techniques. However, there are other methods of examining fish assemblages that are non-destructive and do not require the capture of the fish themselves. Underwater visual census techniques for example, are non-destructive and have been successfully used by Nagelkerken *et al*. (2000c; 2001) and Horinouchi *et al*. (2005) to examine fish assemblages in seagrass beds. This technique, however, is not commonly used in seagrass due to the poor visibility encountered in estuaries (Nagelkerken and van der Velde, 2004). The present study compared the use of seine nets and visual census when examining fish assemblages in *Zostera capricorni* beds in the Brisbane Water estuary. The density of fish per $10m^2$ was found not to be significantly different between seine

netting and visual census. This finding is different to a study conducted by Horinouchi *et al*. (2005), who compared a visual census strip transect to seine netting. Their study found that the visual census underestimated the number of fish species, compared to seining. However, Horinouchi *et al*. (2005) observed all of the species during the visual census study that were caught during seining. In the present study, the density of fish was greater in the seine net as compared to the visual census, suggesting that the visual census underestimated the number of fish individuals however, there was found to be no significant difference between the two techniques. The observed underestimation of fish abundance could have been due to the structural complexity of the seagrass bed, as it may have interfered with the divers ability to observe all of the fish present within the transect.

During the comparison of fish assemblage sampling techniques, the visibility encountered at Location 1 was approximately five, while Location 2 only had a visibility of half a metre to one metre. This resulted in very different diversity and density estimates of fish assemblages, with Location 1 having a much higher diversity and density estimates than Location 2, which had poor visibility. Therefore, the visibility encountered during visual census greatly affects the estimations of fish assemblages, and this study recommends that visual census should only be undertaken in ideal conditions, in good visibility.

Visual census techniques have both advantages and disadvantages when examining fish assemblages in seagrass beds. An advantage of visual census is that it is a non-destructive technique and fish are not captured during sampling, resulting in minimal stress to the fish. In contrast to this, seine netting results in the capture of fish, which, in

turn, stresses the animals leading to the possible death of fish (pers. obs.). Visual census, however, does have its disadvantages, one, for example, being the requirement of favourable environmental conditions such as good visibility in order to conduct the research. Visual census is also more time consuming than seine netting and requires more resource. Overall, visual census is a useful method of assessing fish assemblages in seagrass beds when compared to seine netting, as it is a non-destructive technique, however, it is time and resource consuming, and again requires ideal environmental conditions.

5.5 Implications and Further Research

This study was only able to examine the fish assemblages twice temporally due to resource limitations, however, further temporal analysis of the fish assemblages in Brisbane Water is strongly recommended. Regular temporal sampling throughout the year would provide valuable information about how the fish assemblage changes during the year, and give an indication of settlement periods into the seagrass beds of recreational fish species. Further investigations of underwater visual census, as a non-destructive technique for examining fish assemblages, would also prove valuable for researchers, to validate the present study that showed it is a credible technique to sample fish assemblages. The impact that differing visibilities have on diversity and density estimates would provide valuable information for further research to assess whether visual census would be an appropriate technique to utilise within other estuaries. One possibility would be examining the relationship between different visibilities to diversity and density estimates. Here, a standard fish number could be established with known visibility, allowing fish assemblages to be estimated with differing visibilities.

This study has started to uncover the relationships that exist between seagrass bed structure and fish assemblages. Further research into these relationships could provide a more in depth idea of how fish assemblages respond to changing seagrass beds structure. However, seagrass bed structure is not the only variable to affect fish assemblage composition, water parameters also have an effect on fish assemblages and also should be further investigated. As stated previously the Ecotrophic guilds developed by Elliot and Dewailly (2005) have not knowingly been employed in Australian estuaries before this study, but have been commonly used to assess fish assemblages in Europe. Perhaps it is because these guilds were originally defined for use in European estuaries, but the division of fish assemblages into these guilds provide a valuable way of assessing the changes of fish assemblages in seagrass beds. More studies should employ the use of these guilds, as they provide a valuable way of determining the composition of fish assemblages, compared to solely assessing fish assemblage variables of diversity and density.

5.6 Conclusion

In conclusion, the structure of the seagrass bed demonstrated temporal and spatial differences within Brisbane Water estuary. The diversity of fish assemblages demonstrated significant temporal changes, while the entire fish assemblages had significant spatial differences. The results of this study have also shown that relationships exist between seagrass floristics and fish assemblages. Though further research is suggested, this study identifies that seagrass floristics are in fact involved in shaping fish assemblages, which is of significant importance to the Brisbane Water Estuary Process Study.

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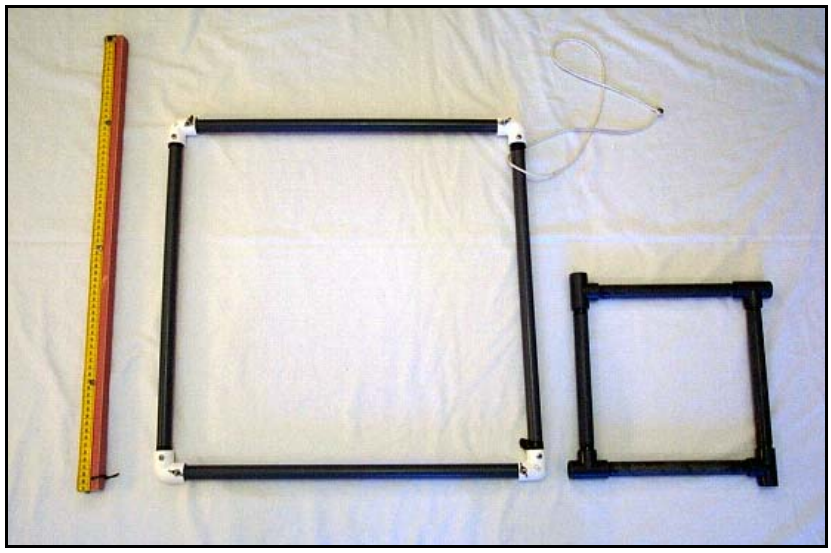
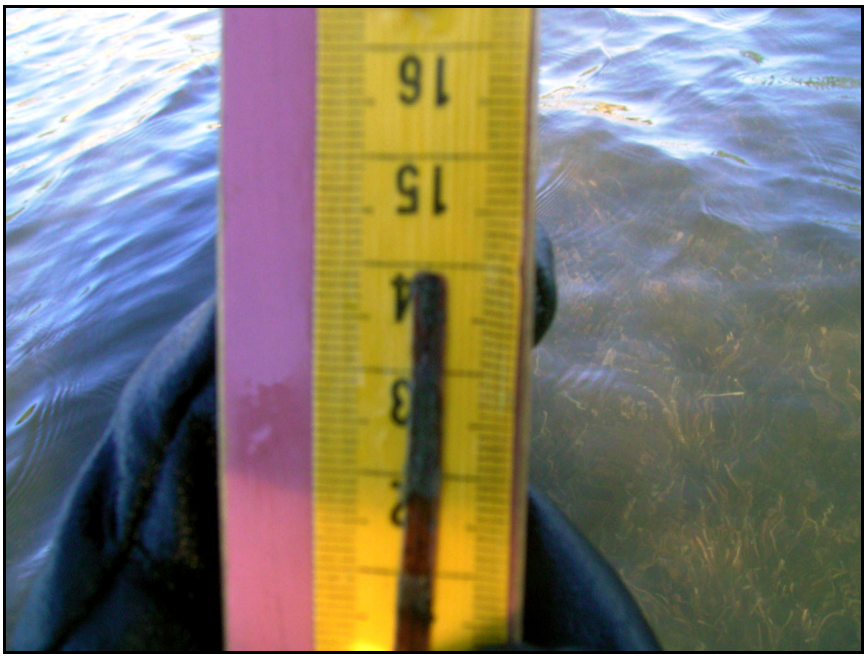
APPENDIX 1

Appendix 1.1: The diving equipment used to conduct seagrass replicates and underwater visual census, all diving was conducted under Australian Standard AS2299 (Photo by D. Roberts).



Appendix 1.2: The equipment used to conduct seagrass replicates, the measuring stick used to measure seagrass leaf length (left), the 0.25m^2 quadrat used for seagrass percent cover (centre), and the 0.625m^2 quadrat used to determine seagrass shoot density (right).

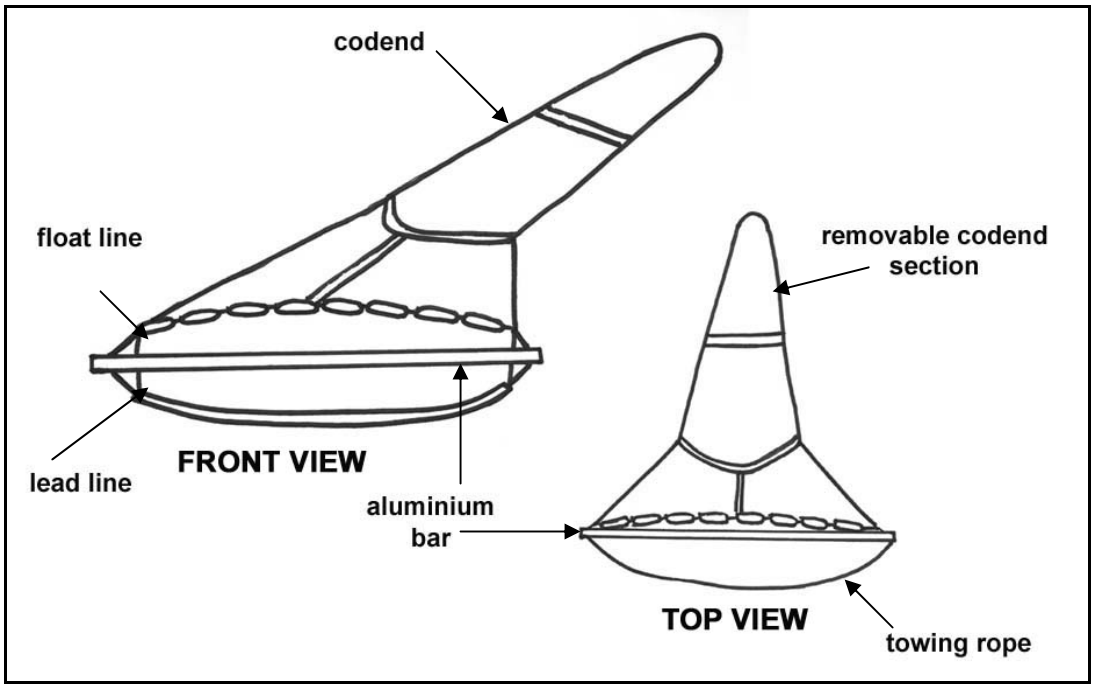


Appendix 1.3: Demonstrating the technique of measuring seagrass leaf length with rounding the length to the nearest 0.5cm.

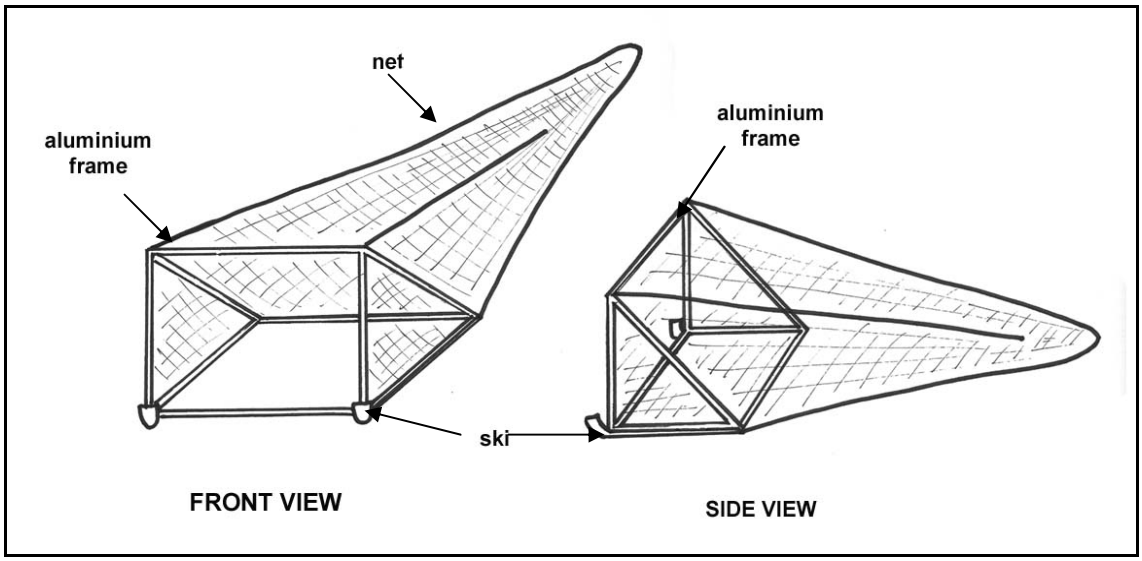
Appendix 1.5: Hydrolab® submersible datalogger used for obtaining water quality replicates of Temperature, DO, pH and Salinity (Source: Zimmerman, 2003).

Appendix 1.4: Demonstrating the seine net semi-circle method, note that the seine net is first walked into a straight line first (top) and then walked into a D-shape (bottom).

Appendix 1.6: Measuring tape setup used for Underwater Visual Census of fish assemblages in seagrass beds. Note the metal peg used to anchor the measuring tape in the seagrass bed.



Appendix 1.7: The design of the 0.6m x 0.4m and 1.3m x 0.9m beam trawls trialled in the pilot study, front and top views are shown.



Appendix 1.8: The design of the 1m x 0.5m beam trawl trialled in the pilot study, front and side views are shown, note the skis attached to the bottom of the frame to aid in movement through the seagrass bed.

APPENDIX 2

Appendix 2.1: A summary of fish and invertebrate species identified in samples taken from Brisbane Water for this study. Family names, species and common names are shown.

PHYLUM CHORDATA **SUBPHYLUM VERTEBRATA** **SUPERCLASS GNATHOSTOMATA** **CLASS CHONDRICHTHYES** **UROLOPHIDAE** *Trygonoptera testacea* (Common Stingaree) **CLASS OSTEICHTHYES** **CLUPEIDAE** *Hyperlophus vittatus* (Sandy Sprat) **SYNODONTIDAE** *Synodus jaculum* (Tail-blotch Lizardfish) **BATRACHOIDIDAE** *Batrachomoeus dubius* (Eastern Frogfish) **HENIRAMPHIDAE** *Hyporhamphus australis* (Eastern Garfish) **BELONIDAE** *Tylosurus gavialoides* (Stout Longtom) **ATHERINIDAE** *Atherinomorus ogilbyi* (Ogilby's Hardyhead) **SYNGNATHIDAE** *Filicampus tigris* (Tiger Pipefish) *Vanacampus margaritifer* (Mother of Pearl Pipefish) *Vanacampus poecilolaemus* (Long-snout Pipefish) *Urocampus carinirostris* (Hairy Pipefish) *Stigmatopora argus* (Spotted Pipefish)	*Stigmatopora nigra* (Wide-body Pipefish) *Hippocampus whitei* (White's Seahorse) **PLATYCEPHALIDAE** *Platycephalus fuscus* (Dusky Flathead) **SCORPAENIDAE** *Centropogon australis* (Fortescue) **TERAPONTIDAE** *Pelates sexlineatus* (Eastern Striped Trumpeter) **CHANDIDAE** *Ambassis jacksoniensis* (Port Jackson Glassfish) **APOGONIDAE** *Siphamia cephalotes* (Little Siphonfish) **SILLAGINIDAE** *Sillago ciliata* (Blue-nose Whiting) *Sillago maculata* (Trumpeter Whiting) **SPARIDAE** *Acanthopagrus australis* (Yellow-finned Bream) *Rhabdosargus sarba* (Tarwhine) **GERREIDAE** *Gerres subfasciatus* (Common Silver Belly) **MULLIDAE** *Parupeneus signatus* (Black-spot Goatfish) **MONODACTYLIDAE** *Monodactylus argenteus* (Silver Batfish)

Appendix 2.1 cont.

GIRELLIDAE
Girella tricuspidata (Luderick)

ENOPLOSIDAE
Enoplosus armatus (Old Wife)
Brachaluteres jacksonianus (Pygmy Leatherjacket)

MUGILIDAE
Aldrichetta fosteri (Yellow-eye Mullet)
Liza argenta (Flat-tail Mullet)
Mugil cephalus (Sea Mullet)
Myxus elongatus (Sand Mullet)

SPHYRAENIDAE
Sphyraena viridis (Eastern Blue Groper)

CLINIDAE
Cristiceps australis (Crested Weedfish)

BLENNIIDAE
Petroscirtes lupus (Brown Sabretooth Blenny)

GOBIIDAE
Bathygobius kreffti (Frayed-fin Goby)
Favonigobius tamarensis (Tamar River Goby)
Nesogobius sp (Twin-bar Sand-goby)
Redigobius macrostoma (Large-mouth Goby)
Cristatogobius gobioides (Oyster Goby)
Arenigobius bifrenatus (Bridled Goby)
Arenigobius frenatus (Half-bridled Goby)
Gobiopterus semivestitus (Glass Goby)

SIGANIDAE
Siganus nebulosus (Happy Moments)

PARALICHTHYIDAE
Pseudorhombus jenynsii (Small-tooth Flounder)

MONACANTHIDAE
Manocanthus chinensis (Fan-belly Leatherjacket)
Meuschenia freyineti (Six-spine Letherjacket)
Meuschenia trachleppis (Yellow-finned Leatherjacket)
Acanthaluteres spilmelanurus (Bridled Leatherjacket)

TETRAODONTIDAE
Tetractenos hamiltoni (Common Toadfish)

DIODONTIDAE
Diodon nichthemerus (Globefish)

PHYLUM MOLLUSCA
CLASS CEPHALPODA

OCTOPODIDAE
Hapalochaena maculosa (Blue-ringed Octopus)

SEPIDAE
Sepia plangon (Mourning Cuttle)

SEPIOLODAE
Dumpling Squid

PHYLUM ARTHROPODA
SUBPHYLUM CRUSTACEA
CLASS MALACOSTRACA
ORDER DECAPODA

PENAEIDAE
Prawn

PALAEMONIDAE
Macrocrachium sp (Glass Shrimp)
Shrimp

PORTUNIDAE
Crab
Portunus pelagius (Blue-swimmwe Crab)

PARASTACIDAE
Yabbie

APPENDIX 3

Appendix 3.1: Fish species encountered in Brisbane Water Estuary with guild characteristics from Elliot and Dewailly (1995). See Table 2 in Section 2.5.3 for an explanation of abbreviations.

Family	Genus Species	Common Name	Ecological Guild	Vertical Guild
Urolophidae	*Trygonoptera testacea*	Common Stingaree	MA	D
Clupeidae	*Hyperlophus vittatus*	Sandy Sprat	MA	P
Synodontidae	*Synodus jaculum*	Tail-blotch Lizardfish	MA	P
Batrachoididae	*Batrachomoeus dubius*	Eastern Frogfish	MA	B
Hemiramphidae	*Hyporhamphus australis*	Eastern sea garfish	MA	P
Belonidae	*Tylosurus gavialoides*	Stout longtom	MA	P
Atherinidae	*Atherinomorus ogilbyi*	Ogilby's hardyhead	ER	P
Syngnathidae	*Filicampus tigris*	Tiger Pipefish	ER	D
	Vanacampus margaritifer	Mother of Pearl Pipefish	ER	D
	Vanacampus poecilolaemus	Long-Snout Pipefish	ER	D
	Urocampus carinirostris	Hairy pipefish	ER	D
	Stigmatopora argus	Spotted Pipefish	ER	D
	Stigmatopora nigra	Wide-body Pipefish	ER	D
	Hippocampus whitei	White's seahorse	ER	D
Platycephalidae	*Platycephalus fuscus*	Dusky flathead	MA	B
Scorpaenidae	*Centropogon australis*	Fortesque	ER	B
Terapontidae	*Pelates sexlineatus*	Eastern striped trumpeter	ER	P
Chandidae	*Ambassis jacksoniensis*	Port Jackson glassfish	ER	P
Apogonidae	*Siphamia cephalotes*	Little siphonfish	ER	P
Sillaginidae	*Sillago ciliata*	Blue-nose Whiting	MJ	P
	Sillago maculata	Trumpeter whiting	MJ	P
Pomatomidae	*Pomatomus saltatrix*	Tailor	MA	P
Sparidae	*Acanthopagrus australis*	Yellow-finned bream	MJ	P
	Rhabdosargus sarba	Tarwhine	MJ	P
Gerreidae	*Gerres subfasciatus*	Silver biddy	ER	P
Mullidae	*Parupeneus signatus*	Black-Spot Goatfish	MJ	P

Appendix 3.1 cont.

Family	Genus Species	Common Name	Ecological Guild	Vertical Guild
Monodactylidae	*Monodactylus argenteus*	Silver Batfish	MJ	P
Girellidae	*Girella tricuspidata*	Luderick	MJ	P
Enoplosidae	*Enoplosus armatus*	Old wife	MJ	P
Mugilidae	*Aldrichetta fosteri*	Yellow-eye Mullet	ER	P
	Liza argentea	Flat-tail mullet	ER	P
	Mugil cephalus	Sea Mullet	MJ	P
	Myxus elongatus	Sand mullet	ER	P
Sphyraenidae	*Sphyraena obtusata*	Striped sea pike	ER	P
Labridae	*Achoerodus viridis*	Eastern blue groper	MJ	P
Clinidae	*Cristiceps australis*	Crested weedfish	MA	B
Blenniidae	*Petroscirtes lupus*	Brown sabretooth blenny	ER	B
Gobiidae	*Bathygobius kreffti*	Frayed-fin goby	ER	B
	Favonigobius tamarensis	Tamar River Goby	ER	B
	Nesogobius sp	Twin-bar Sand Goby	ER	B
	Redigobius macrostoma	Large-mouth goby	ER	B
	Cristatogobius gobioides	Oyster Goby	ER	B
	Arenigobius bifrenatus	Bridled Goby	ER	B
	Arenigobius frenatus	Half-bridled goby	ER	B
	Gobiopterus semivestitus	Glass Goby	ER	B
Siganidae	*Siganus nebulosus*	Happy moments	ER	P
Paralichthyidae	*Pseudorhombus jenynsii*	Small-tooth flounder	ER	B
Monacanthidae	*Monacanthus chinensis*	Fan-belly leatherjacket	ER	D
	Meuschenia freycineti	Six-spine leatherjacket	ER	D
	Meuschenia trachylepis	Yellow-finned leatherjacket	ER	D
	Acanthaluteres spilomelanurus	Bridled leatherjacket	ER	D
Tetraodontidae	*Tetractenos hamiltoni*	Common toadfish	ER	D
Diodontidae	*Diodon nichthemerus*	Globe Fish	ER	P