Examination of the Seagrass and Associated Fauna in Gosford Local Government Area (GLGA) including Correa Bay and Patonga Creek.

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University of Western Sydney
Bringing knowledge to life

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Disclaimer

In undertaking this work the authors have made every effort to ensure the accuracy of the information used. Any conclusions drawn or recommendation made in the report are done in good faith and take no responsibility for how this information and report are used subsequently by others. Note also that the views expressed, and recommendations provided, in this report do not necessarily reflect those of the persons or organizations that have contributed their views or other materials.

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Cover photograph Brisbane Waters National Park, Woy Woy Bay

Summary

The total seagrass cover in Brisbane Water has increased since the aerial photo surveys conducted by West *et al*. 1985 by 8% or 42 hectares. This result, however, requires caution, because the original methodology used for mapping seagrass in 1985 had considerable error because they used 1:25000 aerial photographs. However, there has been a substantial loss, between 43 to 47%, of *Posidonia australis* during the last 20 years. During this time there has been an increase in *Zostera capricorni* of 62-74%. There has been a large reduction in *P. australis* in Woy Woy Bay, Riley's Bay, and Cockle Bay where *Z.capricorni* has replaced it. There has also been a large reduction of *P. australis* at Lobster Beach, but here it was replaced by *Halophila* spp. *Halophila* spp. has also increased in distribution from 0 to 0.44 hectares in the last 20 years.

Smaller reductions in *P.australis* were found at The Broadwater, Caroline Bay, Hubbert's Island, Cockle Channel and Kincumber Broadwater. However, given the inaccuracies of the original mapping methods, it would be best to be cautious with the interpretation of this loss.

The region in Brisbane Water that contained the greatest amount of fish diversity was the central basin. The locations of Woy Woy, Pheagan's Bay, Saratoga, Cockle Channel or Davistown, Koolewong and Blackwell had the greatest species richness. A similar pattern emerged for the abundance of macroinvertebrates. The locations of Woy Woy, Pheagan's Bay, Koolewong and Blackwell had the greatest abundance of macroinvertebrates The central basin of Brisbane Water (especially the western region) has the highest biodiversity for seagrass fauna.

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1 Introduction

1.1 Fragmentation of seagrass habitat

Coastal and estuarine regions are the most rapidly urbanising places on earth (Crooks and Turner 1999; Ehrenfeld 2000) resulting in unprecedented alteration of estuarine habitat worldwide. In Australia alone, there has been an estimated decline of over 45,000 ha (Walker & McComb 1992). Although seagrasses are naturally fragmented by wave action, currents and storm events and bottom feeding animals (Townsend & Fonseca 1998), much of the loss of seagrass has occurred relatively recently (Larkum *et al.* 1989) because of anthropogenic factors. Seagrass habitat is dynamic on a spatial and a temporal scale (den Hartog 1970) with seasonal fluctuations due to variable growth conditions (Ramage & Schiel 1999). The cover and shoot density of seagrass beds can suddenly decline because of storm events (Clarke & Kirkman 1989), epidemic diseases (Olesen & Sand-Jensen 1994a,b), pollution (Cambridge & McComb 1984) erosion (Kirkman 1978), propeller scaring and vessel groundings (Sargent *et al.* 1995), sediment and nutrient loading (Kirkman 1978; Orth & Moore 1983; West 1983; King & Hodgson 1986; Dennison *et al.* 1993), land reclamation and changes in land use (Kemp *et al.* 1983; Larkum & West 1990).

The most widespread and common cause of the decline of seagrass is from the reduction of light availability (Walker & McComb 1992). This occurs by numerous mechanisms including; increased nutrients leading to a proliferation of algae and increased turbidity from suspended sediments (Walker & McComb 1992). These events can be chronic and long-term or one-off pulse events. For example, the have been extensive and steady declines in seagrasses of South Australia, near the major sewage outfalls of Adelaide in a twenty year period 1975 to1995 (Keough and Jenkins 1995).

In Botany Bay (NSW) there has also been a 60% loss of *Posidonia australis* by the mid 1980s (Larkum and West 1990). Furthermore in some areas of the bay *P. australis* has been replaced by *Zostera capricorni.* The same process has occurred in the Pittwater estuary where a substantial decline in the *P.*

australis beds (based on the seagrass cover as reported by West *et al.* 1985) has been in part replaced by *Z. capricorni* (Jelbart 2004). Given the local loss of *P. australis* in Botany Bay and Pittwater it was expected that Brisbane Water would also have experienced similar losses in the last 20-30 years.

The seeding or transplanting of seagrass can be considered an option to restore lost seagrass. However, it is expensive and time consuming to restore seagrass beds by these methods (Fonseca *et al.* 1997; West *et al.* 1990). Projects, which have set out to restore seagrass cover, have met with highly variable success. (Larkum & West 1983; West *et al.* 1990; were unsuccessful, while Thorhaug 1983; McLaughlin *et al.* 1983; Thorhaug 1985 were successful. West *et al.* 1990 was successful until destroyed by storms). In this report, we consider if the option of restoring seagrass would be effective in Brisbane Water.

1.2 Importance of seagrass for estuarine fauna

Seagrass beds are important habitats for the fauna in estuaries, especially for small inconspicuous fish, and the juveniles of larger fish and macroinvertebrates (Heck & Thoman 1984; Middleton *et al.* 1984; Orth *et al.* 1984; Pollard 1984). It is predicted that loss and fragmentation of seagrass has consequences for estuarine fauna. Numerous studies have investigated the effects of reduced patch size and increased edges on species abundance and interactions (e.g. Bell & Hicks 1991; McNeill & Fairweather 1993; Jelbart *et al.* 2006). The diversity of fish has been found to be greater in seagrass beds than in the surrounding unvegetated habitats (multiple seagrass species, Bell & Pollard 1989; *Zostera*, Ferrell & Bell 1991; *Zostera,* Connolly 1994; multiple species, Edgar & Shaw 1995a; *Zostera*, Gray *et al.* 1996; *Posidonia,* Jenkins *et al.* 1996; *Heterozostera*, Jenkins *et al.* 1997a) although this is not necessarily true for fish abundances, sampling times (*Zostera,* Ferrell & Bell 1991; *Posidonia,* Jenkins *et al.* 1996; *Zostera,* Jenkins *et al.* 1997a) or spatial scales (multiple seagrass species, Edgar & Shaw 1995c). Furthermore the faunal assemblages between seagrass and unvegetated habitats also differed (Bell & Pollard 1989; Ferrell & Bell 1991; Jenkins & Wheatley 1998).

Seagrasses alter benthic habitats producing organic matter and assimilating energy (Walker *et al.* 1999). While, direct grazing of the seagrass by macroinvertebrates and fish has been thought to be unimportant for productivity in temperate Australia (Walker *et al.* 1999). Dietary studies have shown only a low proportion of the fish and invertebrates in seagrass consume large quantities of the grass (Klump *et al.* 1989) including the gar fish *Hyporhamphus melanochir,* the leatherjackets *Meuschenia freycineti, Monacanthus chinensis, Meuschenia trachylepsis* (Bell *et al.* 1978; Robertson and Klumpp 1983; Edgar & Shaw 1995a) and the crab *Nectocarcinus integrifrons* (Klumpp & Nichols 1983a; Edgar 1996). Instead it is believed that seagrss beds provide shelter and habitat structure for the numerous fish and invertebrates, concurrent with food availability (Heck & Thoman 1984; Middleton *et al.* 1984; Orth *et al.* 1984; Pollard 1984).

1.3 Importance of seagrass for fisheries

Many commercial species of fish and decapods are associated with seagrass during some stage of their life cycle (reviewed in Connolly *et al.* 1999). In the temperate east coast region of Australia, some of these species include (but are not limited to); juvenile tiger prawns *Penaeus esculentus* and *P. semisulcatus,* eastern king prawns *P. plebejus,* greasyback prawns *Metapenaeus bennettae,* school prawns *M. macleayi,* King George whiting *Sillaginodes punctata,* rock flathead *Platycephalus laevigatus,* bream *Acanthopagrus australis,* black bream *A. butcheri,* blue rock whiting *Haletta semifasciata,* garfish *Hyporhamphus melanochir,* luderick *Girella tricuspidata,* six-spine leatherjacket *Meuschenia freychineti,* sprat *Hyperlophus translucidus* and tarwhine *Rhabdosargus sarba* (Young & Carpenter 1977; Klumpp & Nichols 1983b; Robertson & Klumpp 1983; Ramm 1986; Ferrell & Bell 1991; Coles *et al.* 1993; Edgar & Shaw 1995a, 1995b; Jenkins *et al.* 1997a; MacArthur 1997; Jenkins & Wheatley 1998). Small individuals of non-commercial species also dominate the fish assemblages of seagrass, contributing to the diet of some commercial species (Robertson 1982; Klumpp & Nichols 1983c; Edgar & Shaw 1995b). Even those commercial species that do not physically live in seagrass may benefit from seagrass production through the food chain (Edgar & Shaw 1995a, 1995b).

Declines in seagrass beds have been linked to alterations and declines in fisheries production for that area. For example, in Western Port, Victoria, a 75% decline in seagrass over 15 years led to major changes in the local fisheries catches (MacDonald 1992). The species that declined were those that had strong associations with seagrass (habitat and dietary) while those that did not change or increased were not strongly associated (Jenkins *et al.* 1993; Edgar & Shaw 1995a, Jenkins *et al.* 1997a).

1.4 Aims

The aims of this study were to:

- Estimate the area and extent of seagrass in the Gosford City Local Government area (including Brisbane Water, Correa Bay and Patonga)
- Compare this estimate of seagrass cover with those made by NSW Fisheries over 20 years ago (West et al. 1985)
- Survey the fish and macroinvertebrates in the seagrass *Zostera capricorni* and identify regions of high diversity ("hotspots") within Brisbane Water

The results of this study will provide an estimate of the recent decline or increase in seagrass for Brisbane Water and Patonga.

2 Methods

2.1 Study location

This study was done in the regions of the Gosford City Local Government Area including the Brisbane Water estuary and Patonga Creek (Fig. 2.1; 33.6°S, 151.3°E). There is considerable urban development around the Brisbane Water estuary (Geoscience Australia 2001) although Brisbane Water National Park adjoins western sections of Brisbane Water. Brisbane Water also contains numerous small nature reserves and adjoins Bouddi National Park on the eastern side. Patonga Creek is contained by the Brisbane Water National Park on its north and eastern aspects, with a small residential and holiday population.

The Brisbane Water is a broad but shallow estuary with depths averaging around 5-6 metres in the main body, 2-3 metres in the Kincumber Broadwater and up to 38 metres near the Rip (DEP 1983). The perimeter of the estuary contains extensive shallows, with sediments of sand and silt that support large meadows or beds of seagrass. The estuary is well flushed with saline water, although the upper reaches of some creeks and embayments are brackish (DEP 1983). Creeks such as the Erina, Narrara and Kincumber Creeks provide small freshwater flows in dry conditions (DEP 1983).

Brisbane Water contains extensive seagrass meadows of *Zostera capricorni*, *Posidonia australis* and small stands of *Halophila* spp.. The estuary also contains numerous mangrove forests of *Avicennia marina* and *Aegiceras corniculatum.*

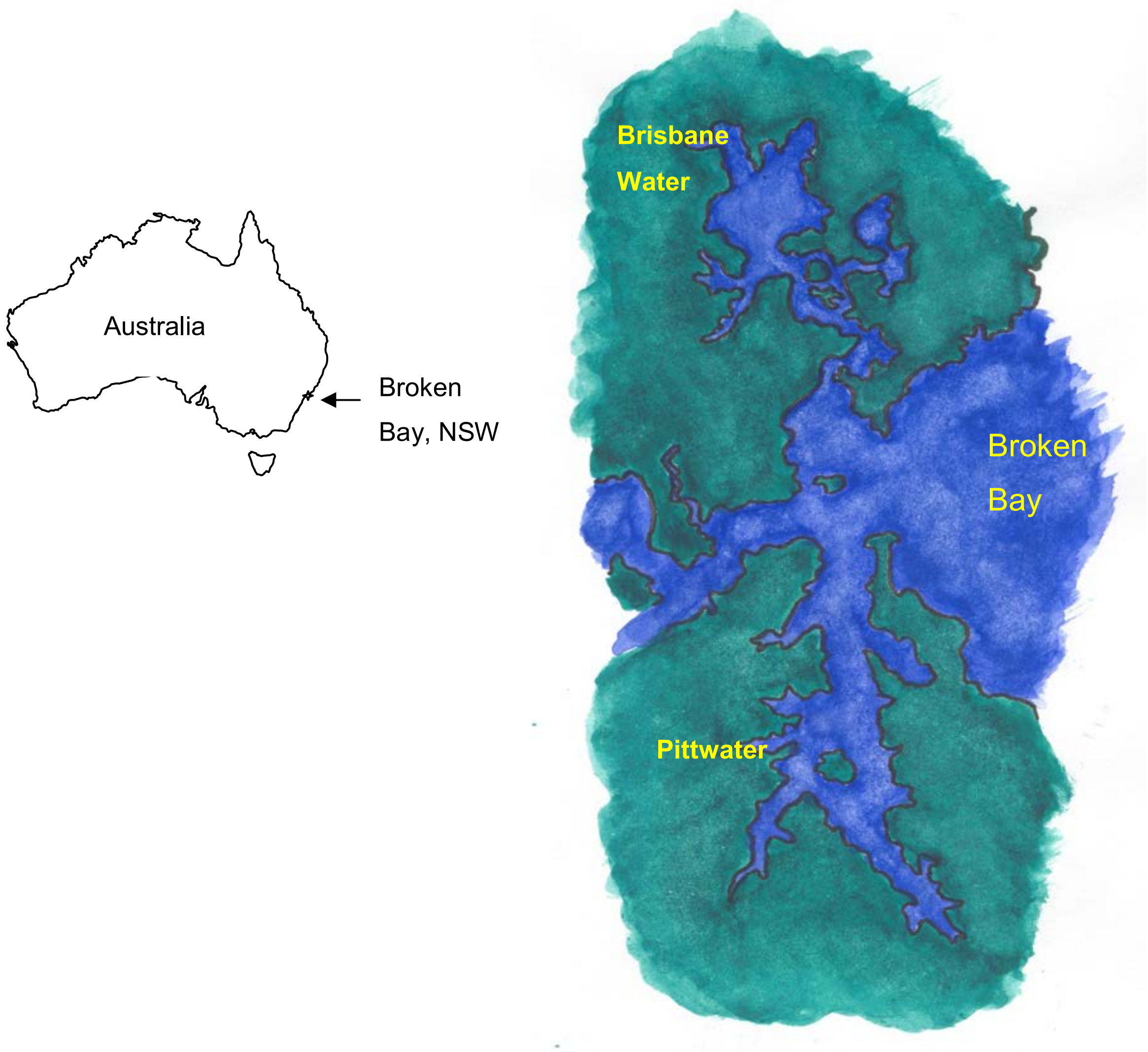

Figure 1: Location of Brisbane Waters on the south-east coast of New South Wales, Australia

2.2 Seagrass habitat in estuaries

Seagrass beds are a prominent feature of the tropical and temperate coastline of Australia. They are specialized marine flowering plants (angiosperms) in soft sediments in estuaries and (Walker *et al.* 1999) are actually not true grasses (Poaceae). Seagrasses are anchored to sediments by a system of rhizomes and roots that stabilize the fine sediment particles (Scoffin 1970; Short & Wyllie-Echeverria 1996) and create clear water conditions in areas that would otherwise be often turbid. They reduce the water movement (Fonseca *et al.* 1982) and provide a stable surface for epiphytes (Harlin 1975). Seagrasses support complex food webs by way of their physical structure and primary production. They are the basis of an important detrital food chain (Harrison & Mann 1975; Short & Wyllie-Echeverria 1996) and provide an important role in the trapping and recycling of nutrients (Hemminga *et al.* 1991). The leaves, roots and rhizomes provide high structural complexity (compared to bare sediments) and provide spatial niches for seagrass fauna (Knowles and Bell 1998). Seagrass beds rank with mangrove forests and coral reefs as some of the most productive coastal habitats (Short & Wyllie-Echeverria 1996) providing unique coastal ecosystems. Seagrass beds also support a dense and diverse epifauna assemblage containing numerous fish and invertebrates (Petersen 1918; Heck & Orth 1980; Heck & Thoman 1984; Middleton *et al.* 1984; Orth *et al.* 1984; Pollard 1984).

2.2.1. Description of Zostera capricorni

Zostera capricorni Aschers is one of the most common seagrass species of the eastern coast of Australia (Conacher *et al.* 1994). It is mostly found in the sheltered bays, estuaries and lagoons of New South Wales, Queensland and also New Zealand (Kuo and McComb 1989). It is a monoecious perennial herb with linear leaf blades (usually 2-6) growing from shoots attached to creeping rhizomes that contain roots. This plant can be wholly submerged or intertidal and extend from brackish water to marine (Kuo and McComb 1989). It possesses flowers borne in spathes that enclose separate female and male flowers (den Hartog 1970).

2.2.2. Description of Posidonia australis

Posidonia australis Hook. *f.* is a perennial herb which is sometimes called tape weed or strap weed because it has straight broad leaves. It grows from just below the low water mark down to 35m in depth (Keough and Jenkins 1995) based largely on water clarity. *Posidonia australis* is generally found in the deeper parts of the Brisbane Water, on the seaward edge of *Zostera* sp. and continues until the water clarity prevents growth. It reproduces mainly by the growth of rhizomes and production of new modules, although being hermaphroditic it does possess bisexual flowers. A spike of flowers is carried on a stalk that can be up to 60cm long.

2.2.3. Description of *Halophila* spp.

Halophila spp. in Brisbane Water is most likely one of two species; *Halophila decipiens* Ostenfeld and *Halophila ovalis* (R. Br.) Hook. *f.* They are often called paddle weed because the leaves are shaped oblong-elliptic (*H.*decipiens) or ovate (*H.ovalis*), like a canoe paddle. These species are found in estuarine or protected marine habitats 2-10 m deep, usually on sand or mud, and in areas not exposed at low tide (Jacobs 1993).

2.3 Identification and mapping of seagrass beds

The seagrasses of the estuary were identified by visual examination and where necessary, by sampling the vegetative structures. The perimeter of each seagrass bed or was walked or boated around and every two metres its geographical position (longitude and latitude) was recorded using a hand held GPS unit. It was necessary to conduct this fieldwork on clear sunny days and when the water clarity was high. Furthermore, for deeper vegetation (such as *Posidonia australis*) a very low tide (spring tide) was required to observe the extent of its growth. These waypoints were then imported into the mapping program *ARC View®* to produce the maps of the seagrass and to calculate the size of the seagrass meadows.

The mapping of the seagrass meadows was conducted over a two-year period and during this time there were some fluctuations in cover. To quantify this change, all seagrass meadows were remapped within the spring and summer of 2004-5 to ensure that the work conducted early in the project was still relevant. Little variation was found over this time period. It appears that during the two-year time period of mapping the seagrass was considerably stable, while experiencing some seasonal change in growth, there were no larger scale changes in distribution.

2.4 Comparison of seagrass maps with historical records

The most detailed historical record of seagrass cover in the Gosford City LGA is the estuarine inventory compiled by Department of Agriculture NSW, Division of Fisheries from 1981 to 1984 (West *et al.* 1985). This survey took aerial photos of the estuary and used a Bausch and Lomb Transfer Scope to trace the vegetation seen from the aerial photos onto topographic maps (1:25000 scale). Some ground-truthing was conducted to ensure the accuracy of the mapping process. This was a large-scale project that mapped the entire estuarine habitats of the NSW Coast and so there was a large margin of error. Fortunately, this method was able to differentiate the different species of seagrass by their colour in the aerial photos so it provides some detail of the historical distribution of the different seagrasses.

2.5 Fish survey

The fish and macroinvertebrate assemblage was sampled using a seine net, 1.5 metres wide (1mm mesh) and dragged 10 metres through the seagrass bed. This sampled 10 m^2 of seagrass. Three drags of the net were used to estimate the density of the small fish captured. A small seine net was used because it effectively captures most of the small fish species found in seagrass beds (Guest *et al.* 2003). Two people were used to haul the net, at a rate of 1m per second. No back net was used on the seine, because few fish were seen to outrun the net as it was hauled. The bottom line of the net was weighed down with lead weights. Visual observation on numerous occasions confirmed that this kept the net down as it pulled through the seagrass. This bottom line momentarily flattened the seagrass, but it was not ripped or shredded by the net. Once the net was hauled it was placed into a large floating container that contained seawater to ensure the fish were submerged during the sorting process. Each fish and macroinvertebrate was then identified and measured (total length mm). Minimal handling of the fish and macroinvertebrates occurred and small hand nets were used to hold the fish. This was done so that fish could be released after identification back into the water with minimal harm.

2.2.4. Identification of fish and macroinvertebrates

Most fish and macroinvertebrates were identified in the field and released at another location within the estuary. There were still some species of fish, however, that could not be identified in the field (especially post-larval fish) so these individuals were taken back to the laboratory alive and placed in marine tanks until identified.

2.2.5. Identification of the macroinvertebrates

Initially, numerous specimens of macroinvertebrates were identified in the laboratory to the species level using a dissecting microscope. This identification was later confirmed by the Australian Museum. This method, however, required considerable amounts of time and included sacrificing the specimens. For these reasons it was decided that the macroinvertebrates would be identified to the order level only (eg. amphipoda, isopoda). The decapods were identified to the family level and the cephalopods were identified to the family or species level. This allowed for quick identification in the field.

3 Results

3.1 Seagrass mapping

The seagrass mapping revealed that there was in total 590.94 hectares of seagrass in Brisbane Water, and 33.48 hectares in Patonga (Tables 1 & 2). Between 1981-1983, NSW Fisheries recorded 5.490 km^2 of seagrass (549.0 hectares), in Brisbane Water and 0.47 km^2 (47 hectares) of seagrass in Patonga Creek. The species of seagrass they reported were the same species as found in this study. This represents an increase in the seagrass of Brisbane Waters of 42 hectares or 8% of the original seagrass from over 20 years ago. There was some decline in the seagrass of Patonga Creek (14 hectares).

Figures 1 – 7 show the results of the seagrass mapping during 2003-2005. In comparison Map 8 shows the area of seagrass recorded between 1981 and 1983 by NSW Fisheries (West *et al.* 1985). A comparison of the maps reveals that the seagrass has not changed greatly in distribution (Figures 1 & 8) although the type of seagrass has significantly changed.

There was 436.8 hectares of *Zostera capricorni,* 91.8 hectares of *Posidonia australis,* 23.9 hectares of mixed *Z. capricorni* and *P. australis,* 3.4 hectares of mixed *Z.capricorni* and *Halophila* spp., 3.4 hectares of mixed *Z. capricorni* and oysters, and 0.44 hectares of *Halophila* spp. (see Tables 1 & 2). The extent of seagrass species reported by NSW DEP (in 1981) and mapped by West *et al.* (1985) found 269 hectares of *Z.capricorni,* 174 hectares of *P.australis,* and 13 hectares of mixed *Z.capricorni* and *P.australis* (Table 1).

This comparison demonstrates that there has been a 43-47% loss of *Posidonia australis* in Brisbane Water and a 62% increase in *Zostera capricorni.* Including areas where it is found in combination with other seagrasses or oysters, it appears that *Z.capricorni* has increased by as much as 74% on its distribution in 1981-3. *Halophila* spp. has also increased in distribution since this time.

A comparison of Figures 1 & 8 (1981 and 2005) show the following results:

- There has been a large increase in *Z.capricorni* in areas that had no seagrass in 1981. These are Fagan's Bay (67 hectares) and near the mouth of Erina Creek (56 hectares).
- There has been a large reduction in *P. australis* in Woy Woy Bay, Riley's Bay, Cockle Bay and Lobster Beach. At the first three locations it was replaced by *Z. capricorni* and at Lobster Beach it was replaced by *Halophila* spp.
- There have been small reductions in *P. australis* at The Broadwater, Caroline Bay, Hubbert's Island, Cockle Channel and Kincumber Broadwater.
- In some areas that were originally identified as *Z.capricorni* there is now mixed stands of *Z.capricorni* and *P. australis.* These areas include Cockle Channel, Woy Woy Bay, Blackwell Point and near Hubbert's Island.

Table 1: A comparison of the seagrass cover (ha) reported in 1981 (DEP 1983) with the results from our survey in 2003-2005.

	Zostera	*Posidonia*	*Zostera & Posidonia*	*Zostera & Halophila*	*Zostera &* oysters	*Halophila*	Total
Brisbane Water 2005	436.78	91.75	23.88	3.42	34.67	0.44	590.94
Brisbane Water 1981	269.00	174.00	13.00				

Table 2: The area and perimeter of seagrass beds in Brisbane Water and Patonga mapped from 2003-5. Some meadows are a mix of two species.

	Zostera		*Posidonia*		*Zostera & Posidonia*		*Zostera & Halophila*		*Zostera &* oysters		*Halophila*	
	Area (ha)	Perim (m)	Area (ha)	Perim (m)	Area (ha)	Perim (m)	Area (ha)	Perim (m)	Area (ha)	Perim (m)	Area (ha)	Perim (m)
Blackwell Pt	28.34	9668	3.08	3451	5.45	1579.86						
Caroline & Erina creek	50.47	15897	5.29	5220								
Empire & Cockle Bay	86.54	19836	6.59	6110	0.03	10.61						
Fagans Bay	60.04	17020	7.13	5224								
Hardys & Wagstaffe	20.07	13235	19.52	14661			3.42	2873	4.7	1270		
Hubbert's	43.71	21842			8.9	3691.66						
Kincumber	33.16	13533	10.14	7346	3.02	1085.06						
Koolewong	12.91	8470	15.86	8465								
Pelican	19.78	8765							29.97	3289		
Rileys	28.71	9768	2.1	2901								
Saratoga to green Point	23.95	11714	12.99	8415								
Woy Woy	29.1	18311	9.05	7593	6.48	984.62					0.44	367
Total for Brisbane Water	**436.78**	**168066**	**91.75**	**69390**	**23.88**	**7351**	**3.42**	**2873**	**34.67**	**4560**	**0.44**	**367**
Patonga	33.48	12150										

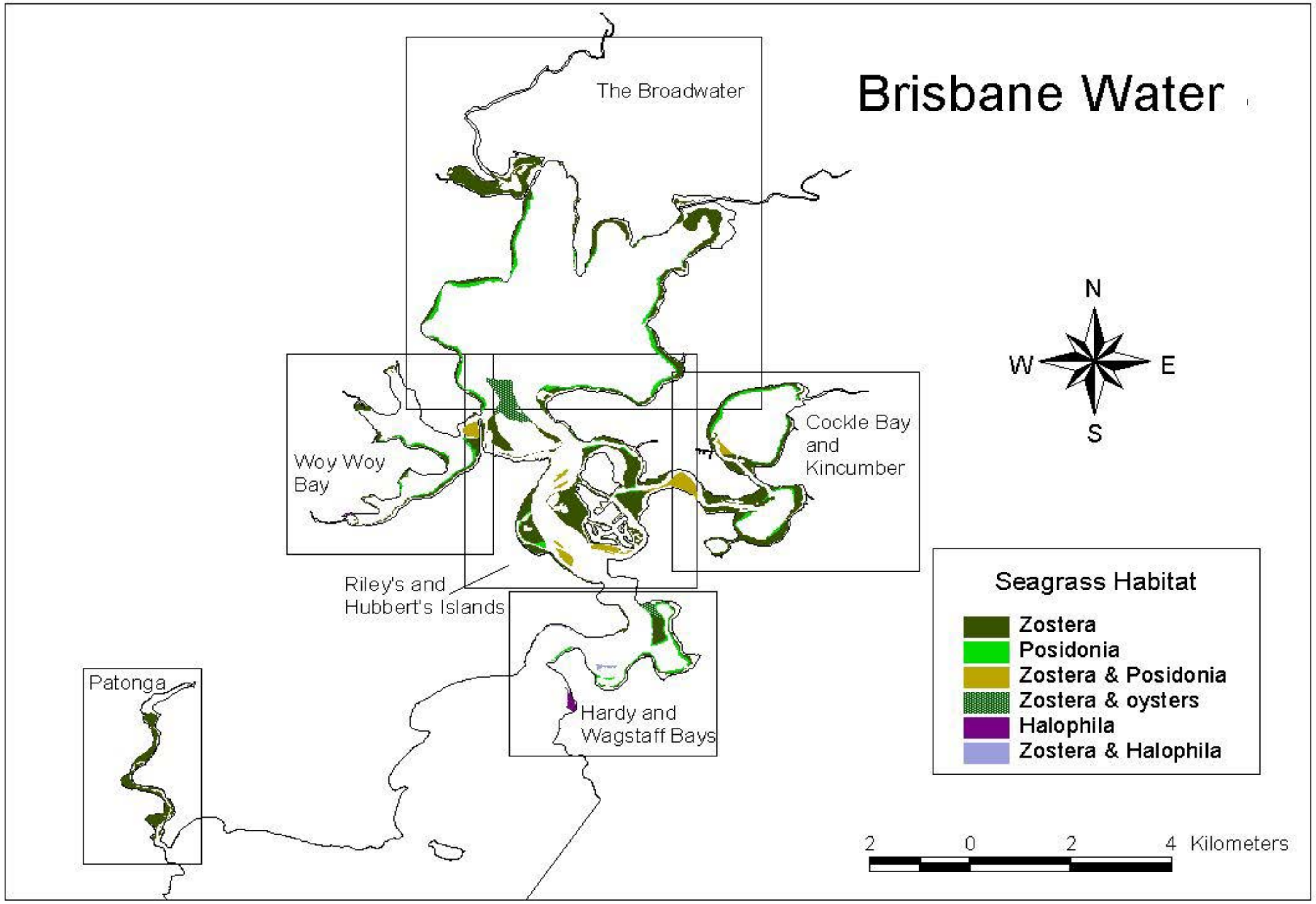

Figure 2: The distribution of seagrass in Brisbane Water and Patonga during 2003-5, including the key to Figures 3-8.

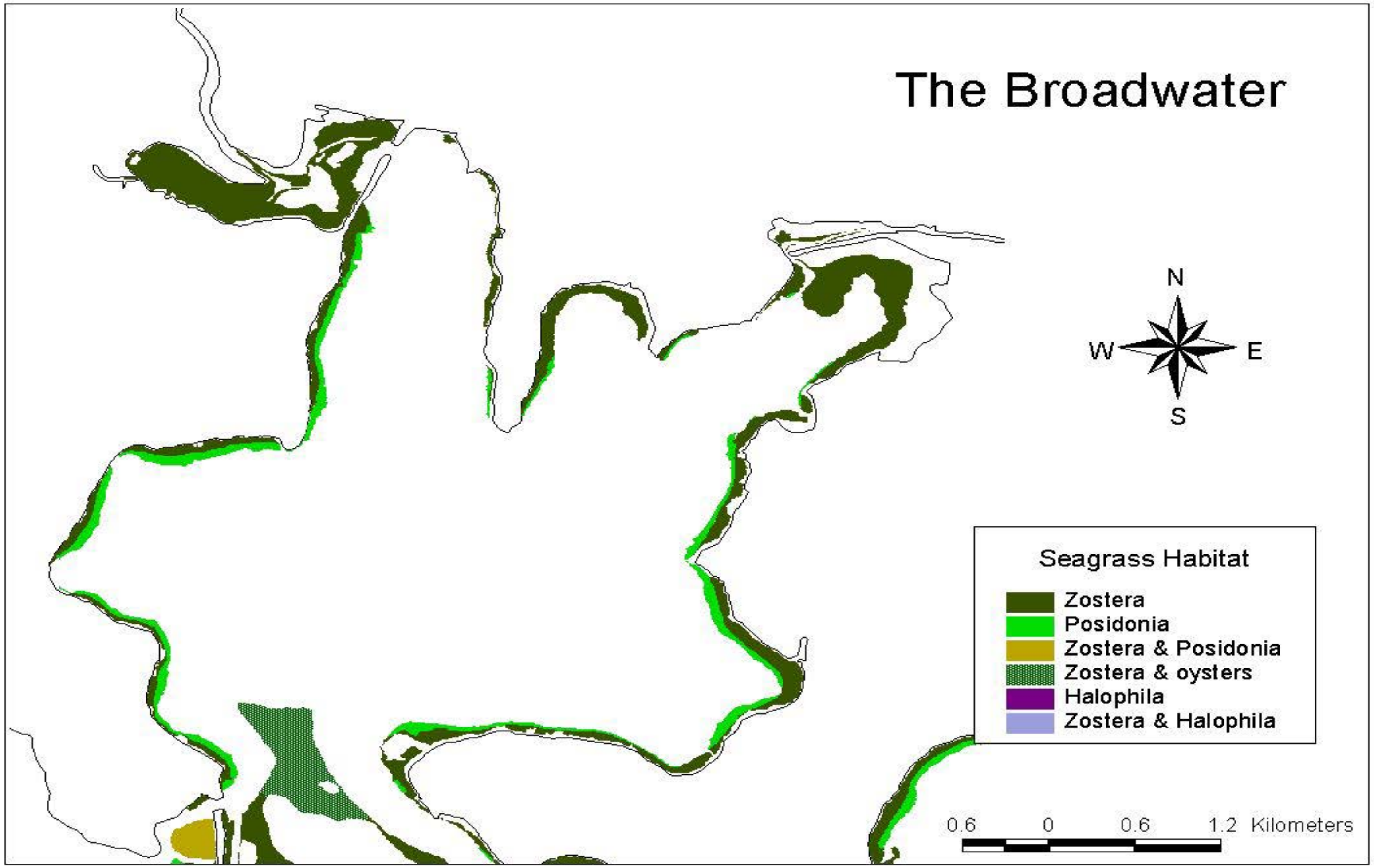

Figure 3: The seagrass of The Broadwater, including Fagan's Bay, Yattalunga, Saratoga and Caroline Bay.

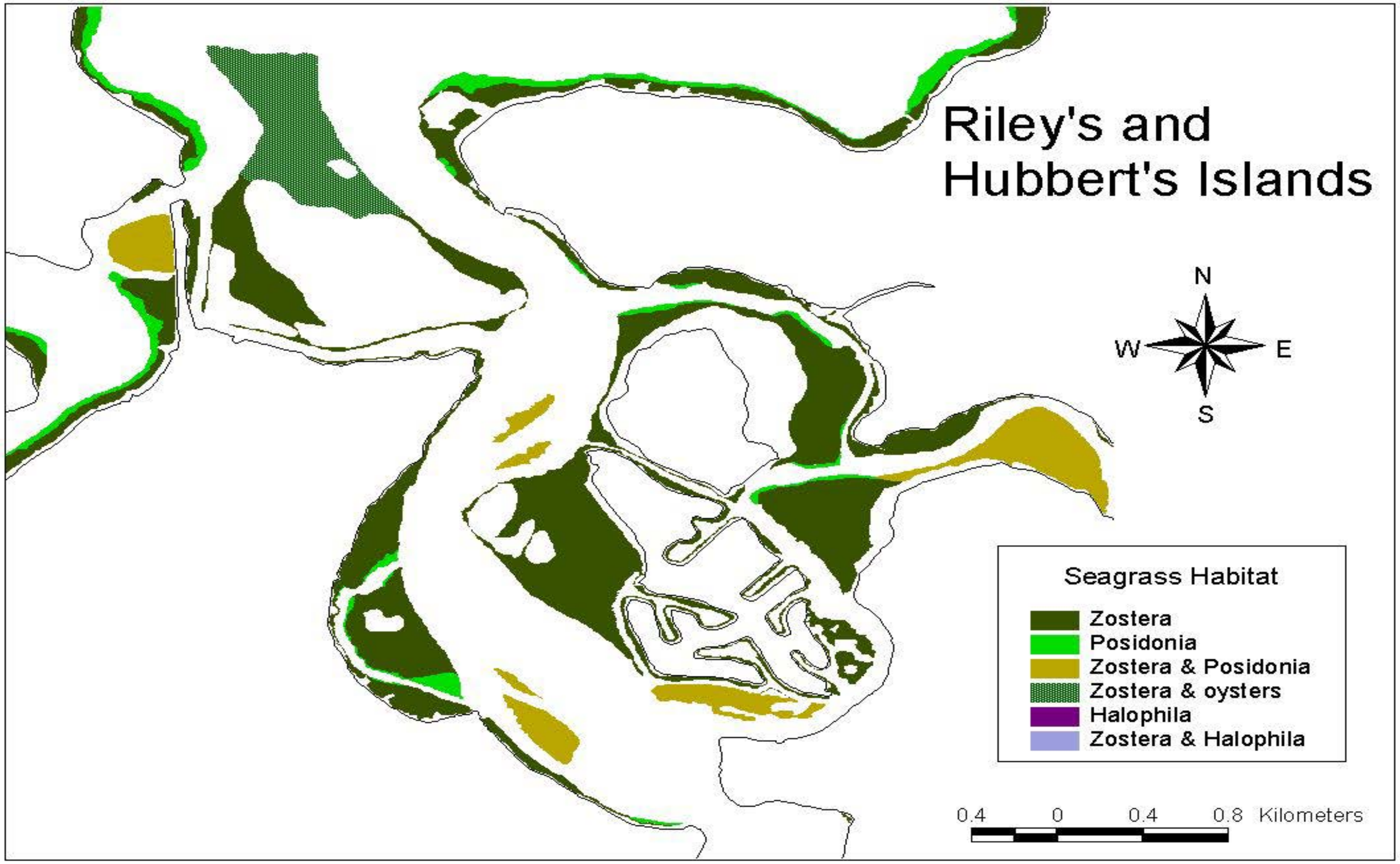

Figure 4: The seagrass of Riley's, Hubbert's, and Pelican Islands, including sections of Woy Woy, Blackwell and Cockle Channel.

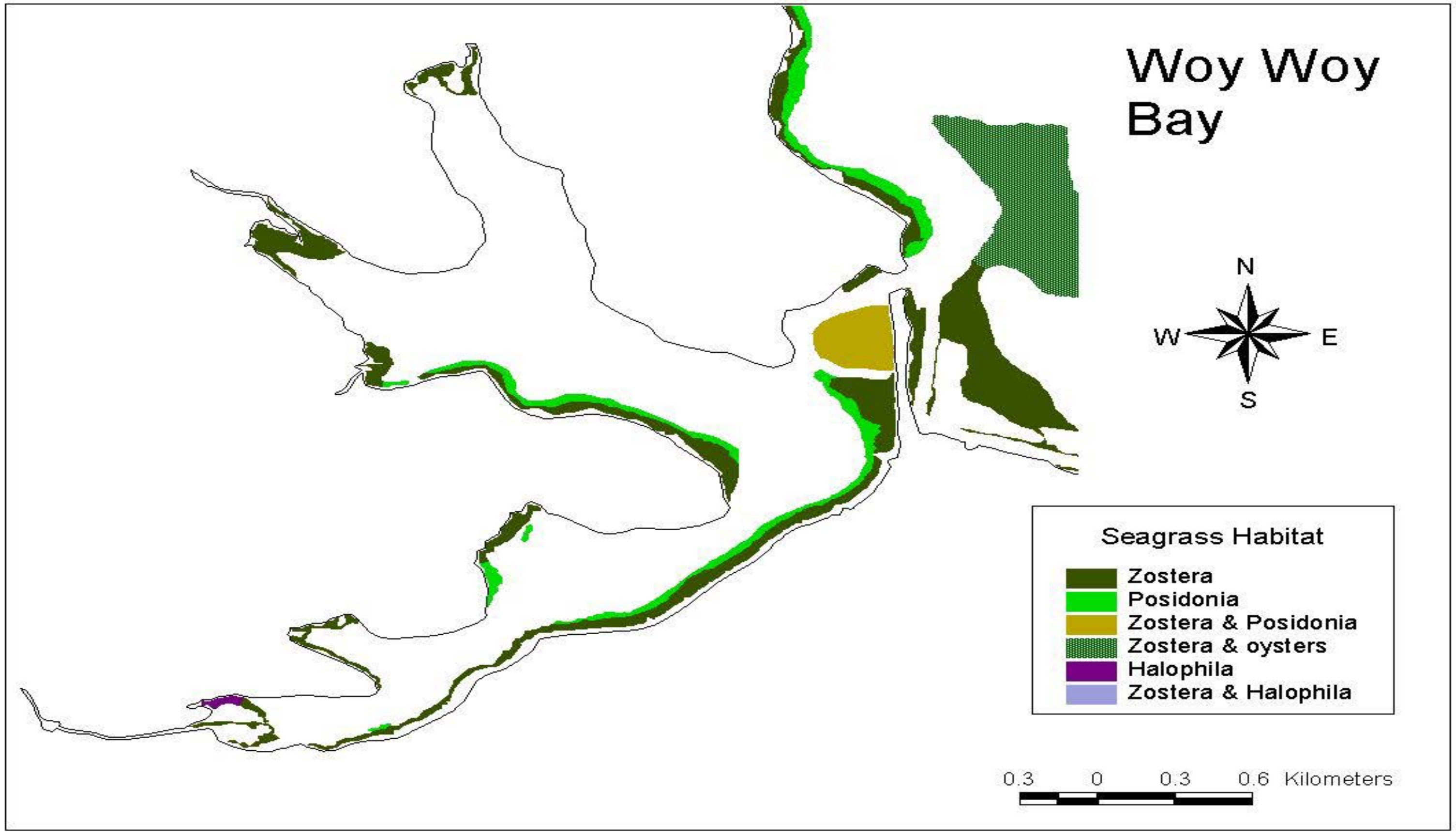

Figure 5: The seagrass of Woy Woy Bay, including Phegan's, Horsfield, Correa and Murphy's Bays and part of Pelican Island.

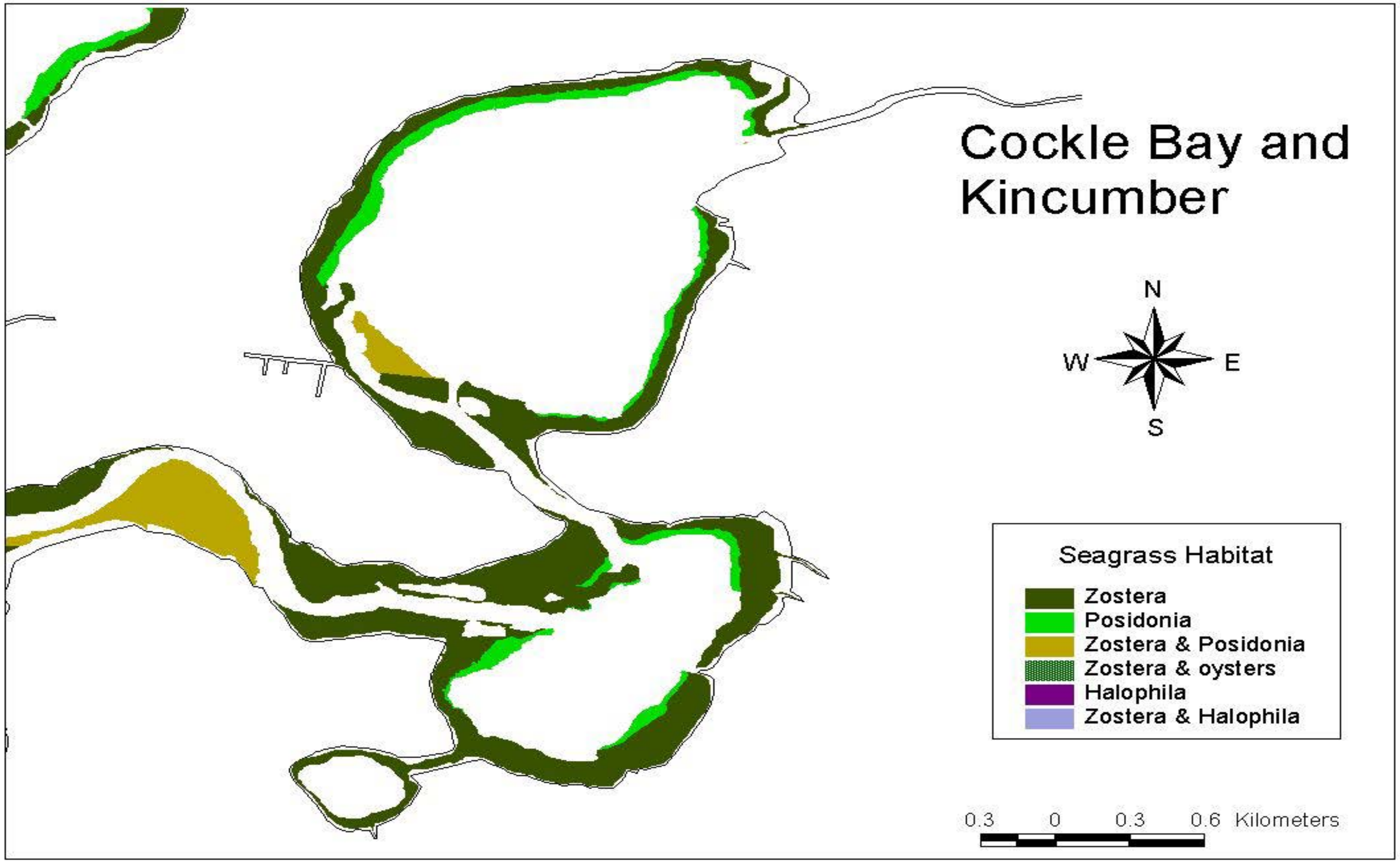

Figure 6: The seagrass of Kincumber Broadwater, Cockle Bay (Bensville) and Cockle Channel.

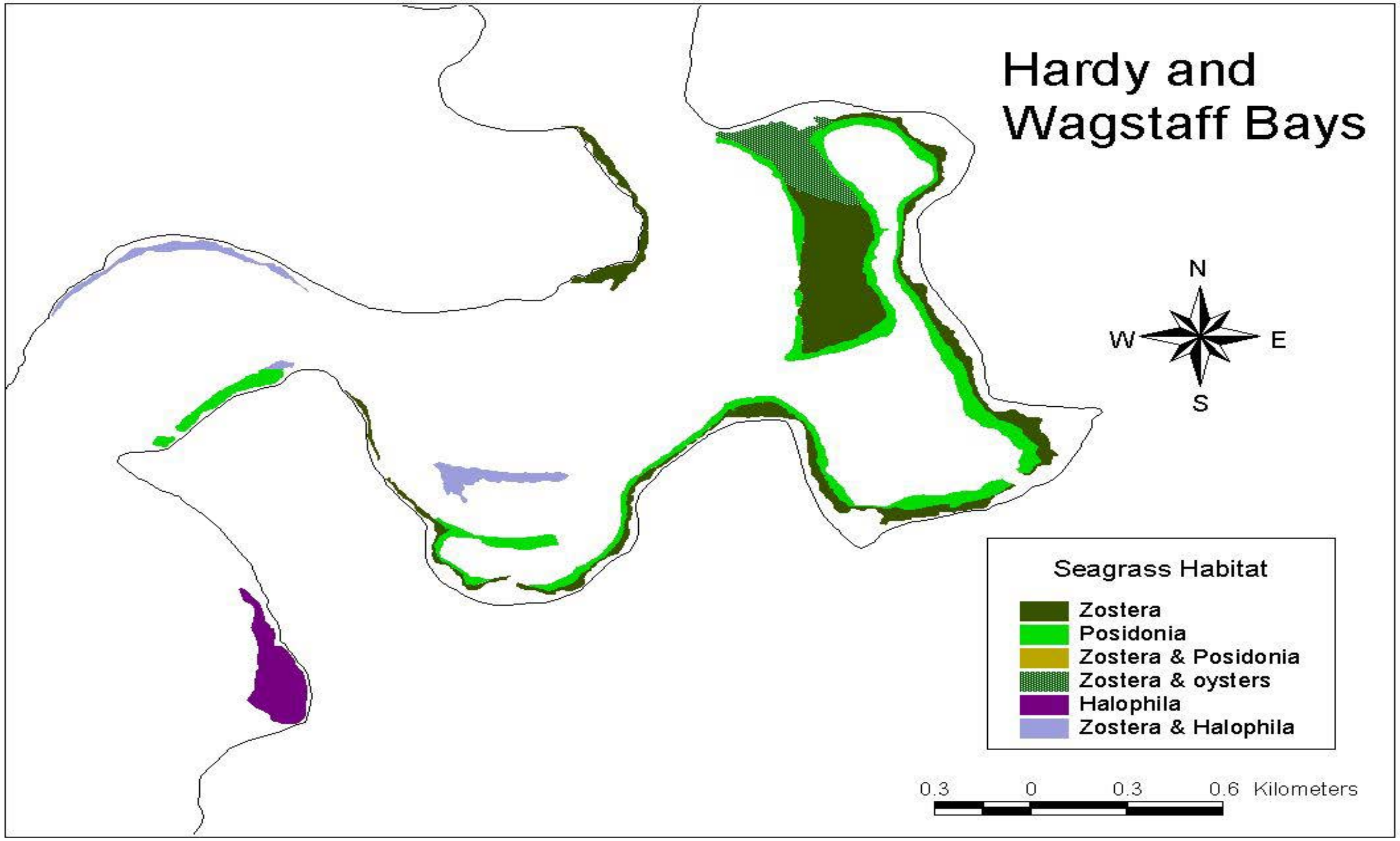

Figure 7: The seagrass of Hardy's, Wagstaffe and Riley's Bays and Lobster, Ettalong and Pretty Beaches.

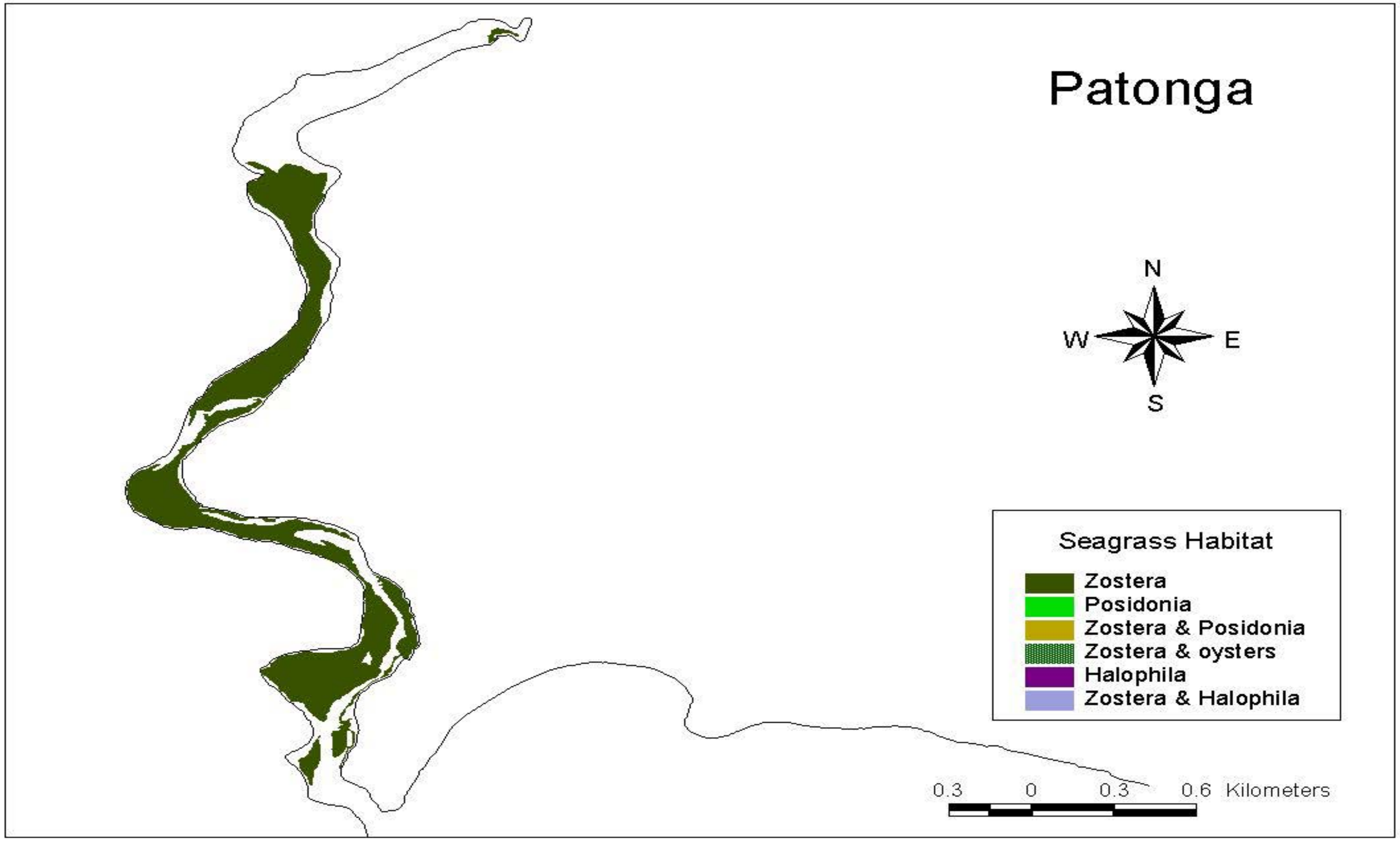

Figure 8: The Seagrass of Patonga Creek.

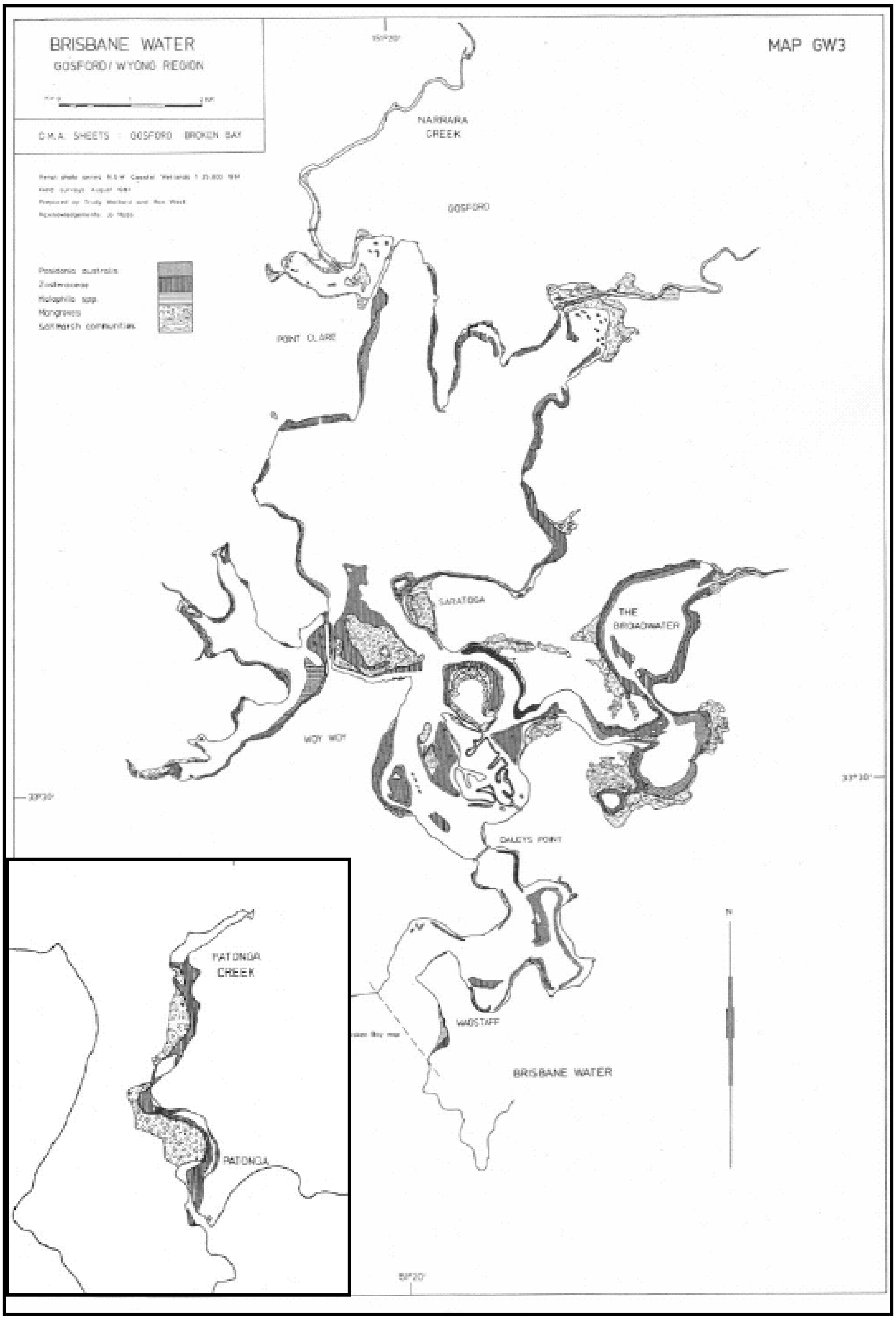

Figure 9: The seagrass of Brisbane Water mapped by NSW Fisheries from 1981-3, including Patonga Creek (taken from West *et al.* 1985).

3.2 Fish and macroinvertebrate survey

There were 35 species of fish (a total of 7837 fish) collected in Brisbane Water during autumn 2003 (Table 3). There were also 6533 macroinvertebrates collected, comprising mostly of crustacean, gastropods, and cephalopods (Table 4). The most numerous fish were the Port Jackson Glassfish (n=2112), Ogilby's Hardyhead (n=2025), and the Large-mouth Goby (n=1329), all of which as adults are small fish and are generally ubiquitous in estuaries of the region. The most numerous macroinvertebrate was the Glass Shrimp (n=3643), which is also a common to seagrass beds in estuaries of southeast Australia.

The region in Brisbane Water that contained the greatest amount of fish diversity was the central basin (Figure 1). The locations of Woy Woy, Pheagan's Bay, Saratoga, Cockle Channel or Davistown, Koolewong and Blackwell had the greatest amount of species richness. There was no such pattern detected for the abundance of fish individuals (Figure 1) and the number of macroinvertebrates groups (Figure 2). A similar pattern emerged, however, for the abundance of all macroinvertebrates. The locations of Woy Woy, Pheagan's Bay, Koolewong and Blackwell had the greatest abundance of macroinvertebrates (Figure 2). The central basin of Brisbane Water (especially the western region) has the highest biodiversity for fauna in seagrass. To see the fauna collected at individual locations within Brisbane Water refer to Appendices 1 and 2 (Figures 12-14: Tables 3 & 4).

Table 3: The fish collected from seagrass during Autumn 2003 in Brisbane Water and Patonga

Family	Species	Common name	Number
Atherinidae	*Atherinomorus ogilbyi*	Ogilby's Hardyhead	2025
Blennidae	*Petroscirstes lupus*	Sabre-toothed Blenny	1
Belonidae	*Tylosurus gavialoides*	Stout Longtom	7
Chandidae	*Ambassidae jacksoniensis*	Port Jackson Glassfish	2112
Clinidae	*Cristiceps aurantiacus*	Golden Weedfish	1
	Cristiceps argyropleura	Silversided Weedfish	3
Diodontidae	*Dicotylichthys punctulatus*	Porcupinefish	29
Eleotrididae	*Philypnodon grandiceps*	Flathead Gudgeon	17
Gerreidae	*Gerres subfasciatus*	Silverbiddy	679
Girellidae	*Girella tricuspidata*	Luderick	26
Gobiidae	*Arenigobius frenatus*	Half-bridled Goby	366
	Bathygobius kreffti	Frayed-finned Goby	9
	Cristatogobius gobioides	Oyster Goby	7
	Redigobius macroston	Large-mouth Goby	1329
Hemiramphidae	*Hyporhamphus australis*	Eastern Garfish	188
Monacanthidae	*Acanthalutere spilomelanurus*	Bridled Leatherjacket	17
	Cantherhinus pardalis	Honeycomb Leatherjacket	102
	Monacanthus chinensis	Fan-bellied Leatherjacket	41
	Meuschenia trachylepis	Yellow Leatherjacket	2
Monodactylidae	*Monodactylus argenteus*	Silver Batfish	1
Mugilidae	*Mugil cephalus*	Sea Mullet	217
Paralichthyidae	*Pseudorhombus jenynsii*	Flounder	1
Poeciliidae	*Gambusia holbrooki*	Mosquitofish	4
Scorpaenidae	*Centropogon australis*	Fortesque	80
Sparidae	*Acanthopagrus australis*	Bream	14
	Rhabdosargus sarba	Tarwine	80
Syngnathidae	*Hippocampus whitei*	White’s Seahorse	2
	Stigmatophora argus	Spotted Pipefish	2
	Stigmatophora nigra	Wide-body Pipefish	3
	Urocampus carinirostris	Hairy Pipefish	159
	Vanacampus margaritifer	Mother of Pearl Pipefish	5
Tetraodontidae	*Tetractenos hamiltoni*	Common Toad fish	57
Tetrapontidae	*Pelatus sexlineatus*	Eastern Striped Trumpeter	249
Platycephalidae	*Platycephalus* sp.	Flathead	1
Sillaginidae	*Sillago ciliata*	Sand Whiting	1

Table 4: The invertebrates collected from seagrass within Brisbane Waters during Autumn 2003

Group / Class	Suborder/ Family / Species	Common name	Number
Amphipoda	Gammaridea	Amphipod	56
Cephalopoda	Sepiolidae / *Sepioloidea lineolata*	Dumpling squid	102
	Idiosepiidae / *Idiosepius notoides*	Pygmy squid	40
	Loliginidae / *Sepioteuthis australis*	Calamary	2
	Sepiidae / *Sepia plangon*	Cuttlefish	1
Decapoda (crabs)	Hymenosomatidae	False spider crabs	50
	Portunidae	Swimmer crabs	24
Decapoda (prawns/shrimp)	Alpheidae	Snapping shrimp	47
	Hippolytidae	Hump-backed shrimps	14
	Palaemondiae / *Palaemon* spp.	Glass shrimp	3643
	Palaemonidae / *Macrobranchium* spp.	Prawns	52
	Penaeidae / *Penaeus* spp. or *Metapenaeus* spp.	Prawns	796
Gastropoda	*Aschoris victoriae*		194
	Austrocochlea constricta		1
	Austrocochlea porcata		63
	Batillaria australis		552
	Bedeva hanleyi		5
	Bembicium auratum		24
	Bittium granarium		50
	Calthalotia corntessei		60
	Nassarius burchardi		513
	Pseudoliotia micans		227
Opisthobranchia	Aplysiidae	Sea-hare	3
Isopoda	Flabellifera	Isopod	5
Polychaeta	Capitellidae	Polycheate	1
Hirudinea		Leech	2
Holothuroidea	Pleurobranchidae	Sea-slug	5

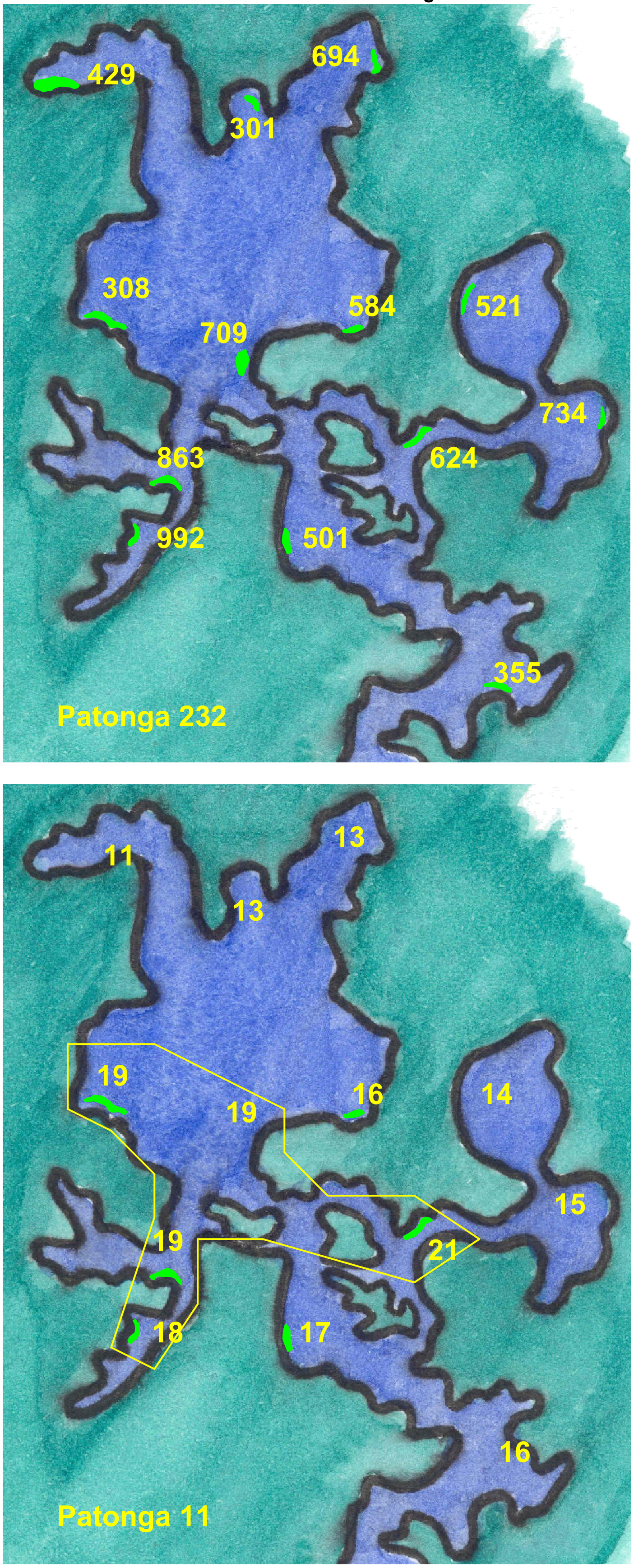

Figure 10: The number of fish (top) and the number of fish species (bottom) collected from each location in seagrass of Brisbane Waters. The yellow line shows the area of high species richness for fish.

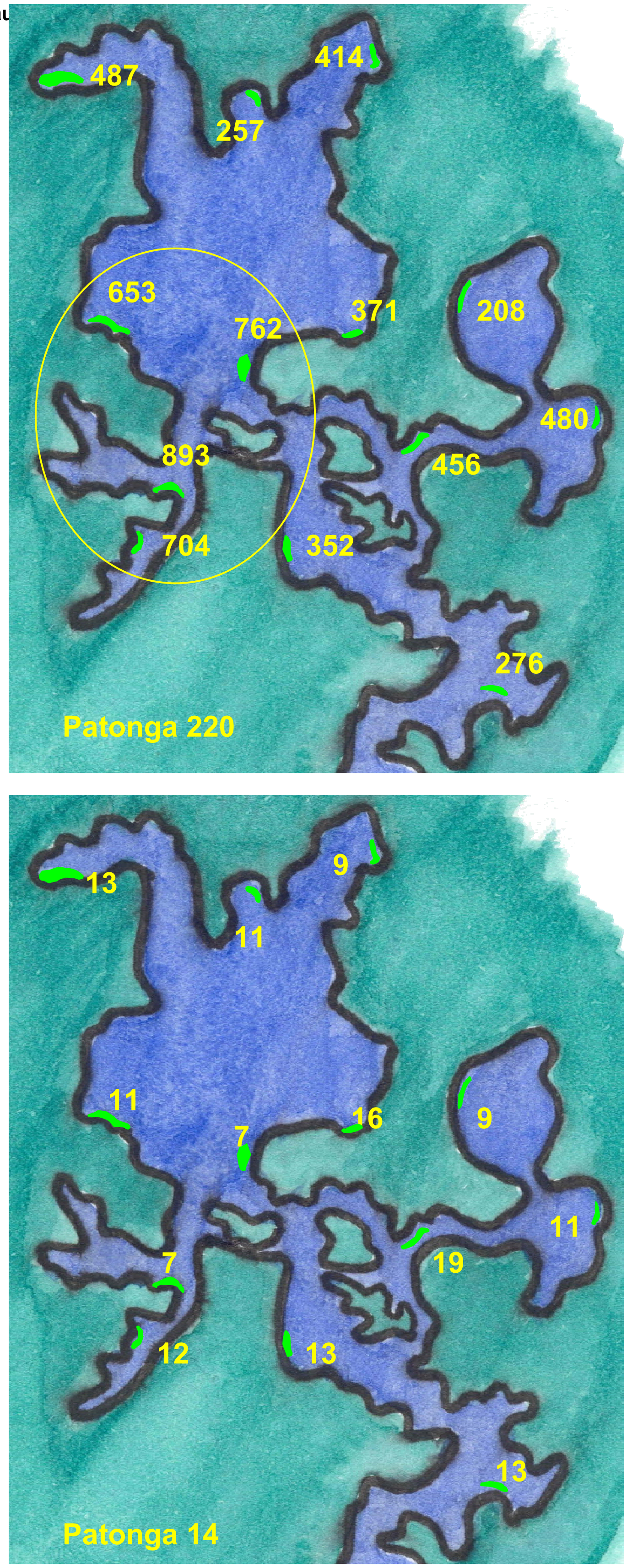

Figure 11: The number of macro-invertebrates (top) and the number of invertebrate groups (bottom) collected from each location in seagrass of Brisbane Waters. The circle shows the area of high macro-invertebrate abundance.

4 Discussion

4.1 Seagrass cover

The seagrass cover in Brisbane Water has increased since the aerial photo surveys conducted by West *et al*. 1985 by 8% or 42 hectares. This result, however, requires caution, because the original methodology used for mapping seagrass in 1985 had considerable error because they used 1:25000 aerial photographs. Apart from outright loss of seagrass habitat, the composition of seagrass species can be altered, or one species can be replaced with another (Larkum *et al.* 1989, Walker & McComb 1992). It appears that this has occurred in Brisbane Water.

There has been a substantial loss, between 43 to 47%, of *Posidonia australis* during the last 20 years. During this time there has been an increase in *Zostera capricorni* of 62-74%. There has been a large reduction in *P. australis* in Woy Woy Bay, Riley's Bay, and Cockle Bay where it appears to be replaced by *Z.capricorni.* There has also been a large reduction of *P. australis* at Lobster Beach, but here it was replaced by *Halophila* spp. Comparisons between the maps from 1981 and 2005 show clearly this change in species composition. *Halophila* spp. has also increased in distribution from 0 to 0.44 hectares in the last 20 years.

Smaller reductions in *P. australis* were found at The Broadwater, Caroline Bay, Hubbert's Island, Cockle Channel and Kincumber Broadwater. However, given the inaccuracies of the original mapping methods, it would be best once again to be cautious with interpretation of this loss.

In Botany Bay there has been a decline of *P. australis* that has been estimated to be a loss of 60% by the mid 1980s (Larkum and West 1990). Furthermore in some areas of the bay, *P. australis* has been replaced by *Z. capricorni.* This has also been observed in the Pittwater estuary, where a substantial decline in the *P. australis* beds (based on the seagrass cover as reported by West *et al.* 1985) has been in part replaced by *Z. capricorni* (Jelbart 2004). The losses of *P. australis* in Botany Bay have been attributed to storm damage and associated erosion, exacerbated since 1970 by dredging of the entrance. In Brisbane Water, however, there have not been similar dredging activities or exposure of seagrass to storm damage so other explanations must be considered.

The most common reason for seagrass decline in Australia is a decrease in the light reaching the seagrass (Walker & McComb 1992). Increased turbidity from particles in the water or from deposition of silt on leaf surfaces can decrease the light penetration (Walker & Mc Comb 1992). Decreased light penetration would favour *Z. capricorni* over *P.australis* because *Z. capricorni* is generally found in shallower waters of an estuary. It may be no coincidence that *P. australis* is more reliant on clear water conditions than *Z. capricorni.* A decline in *P. australis* and replacement by *Z. capricorni* could indicate that the estuary has decreased in light penetration from increased turbidity or excessive epiphytic algae.

Associated with increased turbidity is the process of infilling, whereby estuaries will accumulate sediments and eventually become shallower. This is a natural process that occurs over geological time scales but has been hastened by anthropogenic activities. A shallower estuary will also favour *Z. capricorni* over *P.australis* because the former is more resistant to desiccation during tidal water recession.

A change in bottom sediments can also favour *Z. capricorni* over *P.australis*, because the former favours a high proportion of silt and clay (11-100%) when compared to *P.australis,* which is found predominantly in sandy sediments (Larkum & West 1990). Increased sedimentation in the estuary can change the sediment regime to a greater portion of silt and clay that favours *Z. capricorni*.

There has been a large increase in *Z.capricorni* in areas of the Gosford City Local Government Area that had no seagrass in 1981. These are Fagan's Bay (67 hectares) and at the mouth of Erina Creek (56 hectares). Historically

(1954) Fagan's Bay had extensive meadows of seagrass so it is possible that the seagrass has recovered to its original distribution.

In some areas that were originally covered with *Z.capricorni* in 1981, there is now mixed stands of *Z.capricorni* and *P. australis.* These areas include parts of Cockle Channel, Woy Woy Bay, Blackwell Point and near Hubbert's Island. This could demonstrate a flux between the two species, and suggests that there may be an ongoing process of succession and decline. The dynamics of the seagrass community should not be simplified. It is difficult to gauge if the changes between *Z. capricorni* and *P.australis* are due to natural fluctuations or human disturbance, but long-term seagrass studies can contribute some understanding to this quandary.

Efforts have been made to restore seagrass beds by seeding or transplanting (Fonseca *et al.* 1997; West *et al.* 1990), however, this has proven to be an expensive and time consuming operation with variable success rates (Larkum & West 1983; West *et al.* 1990; Thorhaug 1983; McLaughlin *et al.* 1983; Thorhaug 1985 West *et al.* 1990). We recommend not to undertake seagrass transplanting techniques, but to consider managing the catchment to reduce sedimentation, turbidity and nutrient enrichment.

There has been the outbreak of *Calerpa taxifolia* in areas of Brisbane Water since the completion of this survey (pers. comm. Teneille Boyland). However, recent experimentation has suggested that this weed experiences episodic growth rates that will ameliorate over time (pers. comm. Tim Glasby). Furthermore, they do not grow as proliferate on dense seagrass as they do on sparse seagrass, and most of the seagrass in Brisbane Water, excluding the seagrass near Erina Creek, is considerably dense.

4.2 Fauna diversity

The cental basin of Brisbane Water (especially the western region) has the highest biodiversity for fauna in seagrass. This includes the most undeveloped region of Brisbane Water, closest to the Brisbane Water

National Park on the western side of the estuary. In a drowned river estuary such as Brisbane Water, it has been suggested that the marine tidal delta and fluvial delta would contain the greatest species richness of estuarine fauna (Roy *et al.* 2001). Our results suggest that the shore regions of the central mud basin had greater species richness for seagrass fauna.

No correlation can be made between the areas of Brisbane Water that have experienced a loss of seagrass (especially *P.australis*) and the biodiversity of seagrass fauna. The limitations of the fauna survey were such that they could not effectively test if areas of seagrass loss had reduced biodiversity. It appears that the diversity of seagrass fauna is more related to the region or zone of the estuary.

The change of seagrass in the estuary to a system dominated by *Zostera capricorni* with a reduction in *Posidonia australis,* could have consequences for the fauna of the estuary. The fish and macroinvertebrate assemblages in *Z. capricorni and P. australis* are significantly different from one another (Middleton *et al.* 1984; Bell and Pollard 1989). In meadows of *Z. capricorni* there is a dominance and abundance of smaller fish from the families Gobiidae and Syngnathidae while in *P. australis* larger individuals are typical (Middleton *et al.* 1984). Seagrass species are thought to use the different seagrasses sequentially, dependant on their body size. The consequence of *Z.capricorni* replacing *P.australis* for seagrass fishes is unknown.

4.3 Recommendations for management

We recommend the ongoing monitoring of seagrass using aerial photos and GIS software analysis. Now that the GCC has a 20 year comparison, long-term seagrass studies can contribute some understanding the fluctuations in seagrass distribution, especially between *Z. capricorni* and *P. australis*.

We recommend not to undertake seagrass transplanting techniques, but to consider managing the catchment to reduce sedimentation, turbidity and nutrient enrichment.

We recommend that the council conduct monitoring of the *Caulerpa taxifolia* outbreak. There has been the outbreak of *Caulerpa taxifolia* in areas of Brisbane Water since the completion of this survey (pers. comm. Teneille Boyland). However, recent experimentation has suggested that this weed experiences episodic growth rates that will ameliorate over time (pers. comm. Tim Glasby).

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5 Appendices

Appendix 1

Figure 12: The number of fish species collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of species abundance. The columns in red represent those beds located in the central mud basin.

Figure 13: The number of fish individuals collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of species abundance. The columns in red represent those beds located in the central mud basin.

Figure 14: The number of macroinvertebrate groups collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of group abundance. The columns in red represent those beds located in the central mud basin.

Figure 15: The number of macroinvertebrates collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of group abundance. The columns in red represent those beds located in the central mud basin.

Appendix 2

Table 5: The fish collected from each location within seagrass beds of Brisbane Water during Autumn 2003

Table 6: The macroinvertebrates collected from each location within seagrass beds of Brisbane Water during Autumn 2003.

Appendix 1

Figure 12: The number of fish species collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of species abundance. The columns in red represent those beds located in the central mud basin.

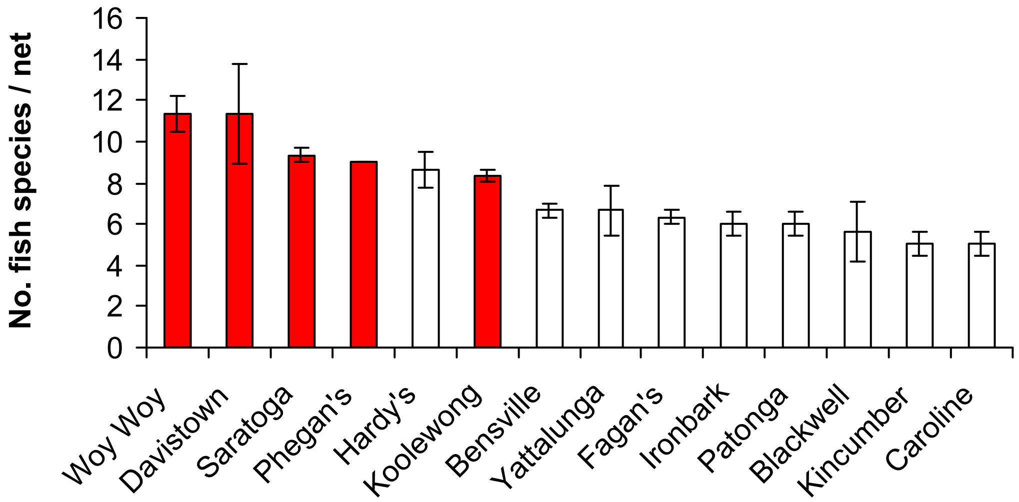


Figure 13: The number of fish individuals collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of species abundance. The columns in red represent those beds located in the central mud basin.

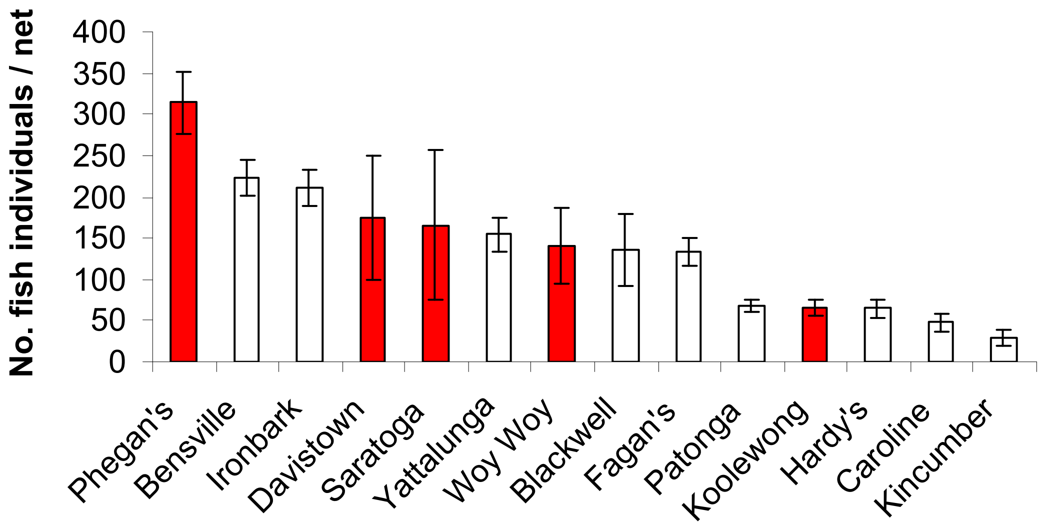


Figure 14: The number of macroinvertebrate groups collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of group abundance. The columns in red represent those beds located in the central mud basin.

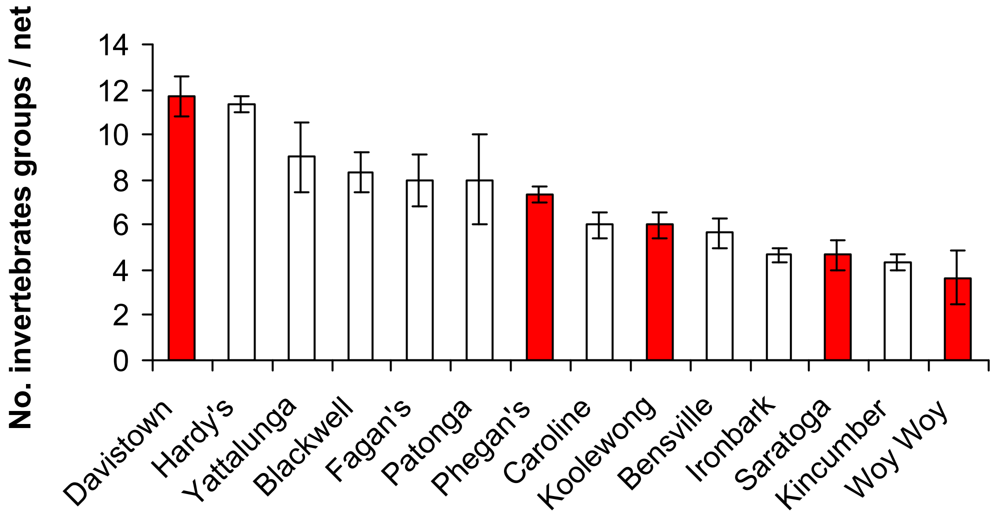
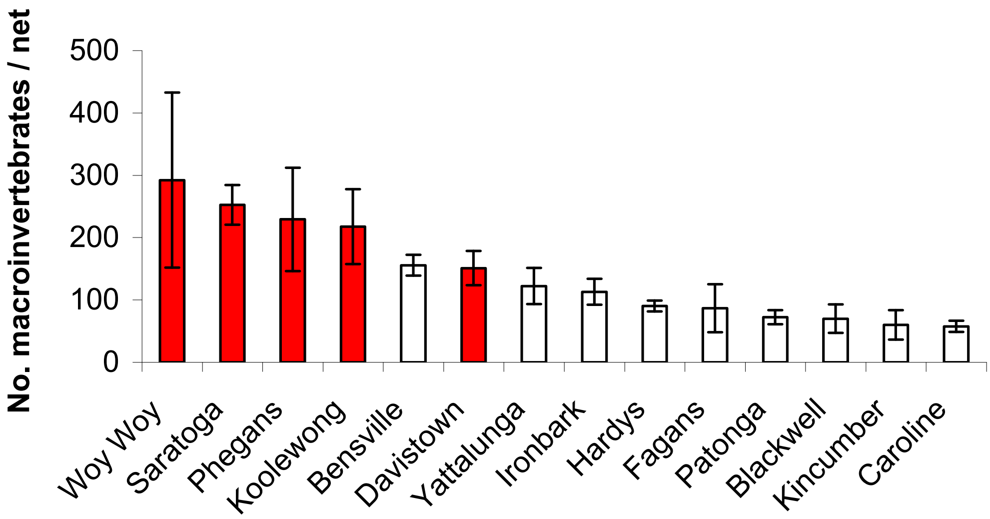


Figure 15: The number of macroinvertebrates collected from seagrass beds in Brisbane Waters. The beds are listed from the highest to the lowest in order of group abundance. The columns in red represent those beds located in the central mud basin.



Appendix 2

Table 7: The fish collected from each location within seagrass beds of Brisbane Waters during Autumn 2003.

Family	Species Name	Common Name	Bens-ville	Black-well	Caroline Bay	Davis-town	Fagan's Bay	Hardy's Bay	Ironbark	Kincum-ber	Koole-wong	Patonga	Phegan's Bay	Sara-toga	Woy Woy Bay	Yatta-lunga
Atherinidae	*Atherinomorus ogilbyi*	Ogilby's Hardyhead	491	23	137	68		105	125	279	3	42	114	192	394	52
Belonidae	*Tylosurus gavialoides*	Stout Longtom		1						3			2			1
Blennidae	*Petroscirstes lupus*	Blenny Sabre-tooth									1					
Chandidae	*Ambassidae jacksoniensis*	Port Jackson Glassfish	2	107	6	342	15	16	337		91	43	363	382	199	209
Clinidae	*Cristiceps argyropleura*	Silversided Weedfish	2			1										
	Cristiceps aurantiacus	Golden Weedfish						1								
Diodontidae	*Dicotylichthys punctulatus*	Porcupinefish	3	1	4		4	1	2	3	3		4	3	1	
Eleotrididae	*Philypnodon grandiceps*	Flathead Gudgeon					6				11					
Gerreidae	*Gerres subfasciatus*	Silverbiddy	65	85	56	31		98	29	48	8	22	2	7	58	170
Girellidae	*Girella tricuspidata*	Luderick	3	5		2	1				1			13		1
Gobiidae	*Arenigobius frenatus*	Half bridled Goby	26	27	46	15	86	17	44	12	7	2	17	4	3	60
	Bathygobius kreffti	Frayed-finned Goby		1		1		4								3
	Cristatogobius gobioides	Oyster Goby								7						
	Redigobius macroston	Large-mouth Goby	89	209	18	61	240	2	109	1	14	54	447	2	52	31
Hemiramphidae	*Hyporhamphus australis*	Eastern Garfish	12	1					1	151	2	1	3	3	4	10
Monacanthidae	*Acanthalutere spilomelanurus*	Bridled Leatherjacket				10					5		1		1	
	Cantherhinus pardalis	Honeycomb Leatherjacket		2		31			2		2		1	27	37	
	Meuschenia trachylepis	Yellow Leatherjacket													2	
	Monacanthus chinensis	Fan-bellied Leatherjacket			4	10			3		1		11	6	6	
Monodactylidae	*Monodactylus argenteus*	Batfish				1										
Mugilidae	*Mugil cephalus*	Sea Mullet		15	10	4	16	59	30	5	13	11	1	23	26	4
Paralichthyidae	*Pseudorhombus jenynsii*	Flounder													1	
Platycephalidae	*Platycephalus* sp.	Flathead								1						

Poeciliidae	*Gambusia holbrooki*	Mosquitofish					4									
Scorpaenidae	*Centropogon australis*	Fortesque	6	7	3	7		23			9	1	4	7	12	1
Sillaginidae	*Sillago ciliata*	Sand Whiting												1		
Sparidae	*Acanthopagrus australis*	Bream	2		2			4		1		1	3			1
	Rhabdosargus sarba	Tarwine	8	6		3	3	7	3	3	18	2	7	1	18	1
Syngnathidae	*Hippocampus whitei*	White's Seahorse				1								1		
	Stigmatophora argus	Spotted Pipefish													2	
	Stigmatophora nigra	Wide-body pipefish				2									1	
	Urocampus carinirostris	Hairy Pipefish	4	2	3	16	51	5		3	30		6	9	10	20
	Vanacampus margaritifer	Mother of Pearl Pipefish				3								2		
Tetraodontidae	*Tetractenos hamiltoni*	Toad fish	4	2	6	1	3	3	2	4	11		1	7		13
Tetrapontidae	*Pelatus sexlineatus*	Trumpeter	17	7	5	13		9	7		78	53	5	19	36	
Total fish number			**734**	**501**	**300**	**623**	**429**	**354**	**694**	**521**	**308**	**232**	**992**	**709**	**863**	**577**
Species richness			**15**	**17**	**13**	**21**	**11**	**15**	**13**	**14**	**19**	**11**	**18**	**19**	**19**	**15**

Table 8: The macroinvertebrates collected from each location within seagrass beds of Brisbane Waters during Autumn 2003.

Group/Class	Suborder / Family / Species	Common Name	Bens-ville	Black-well	Caroline Bay	Davis-town	Fagan's Bay	Hardy's Bay	Iron-bark	Kin-cumber	Kool-ewong	Pat-onga	Phea-gan's Bay	Sara-toga	Woy Woy	Yatta-lunga
Amphipoda	Gammaridea	Amphipod	1	1		7	8	10	6		4	11	3			5
Cephalopoda	Idiosepiidae / *Idiosepius notoides*	Pygmy squid			2	10		9	1		4	1		5	5	3
	Loliginidae / *Sepioteuthis australis*	Calamary								1				1		
	Sepiidae / *Sepia plangon*	Cuttlefish												1		
	Sepiolidae / *Sepioloidea lineolata*	Dumpling squid	4	13	2	4	1	21	3	5	1	2	16	10	18	2
Decapoda	Alpheidae	Snapping shrimp	4	1		5		16	3	4	3	4	1	1	2	3
	Hippolytidae	Hump-backed shrimp						5				4		3	2	
	Palaemonidae / *Macrobranchium* spp.	Prawns			34	3	4								8	3
	Palaemonidiae / *Palaemon* spp.	Glass shrimp	177	178	87	261	3	82	109	93	569	181	213	696	835	159
	Penaeidae / *Penaeus* spp.	Prawns	5	3	95	11	242	12	282	23	59	4	1	36	23	
	Hymenosomatidae	False spider crab	1	3		4		27	2		5	1	6			1
	Portunidae	Swimmer crab	6		2	3		1	1		3	3	1			4

Gastropoda	*Aschoris victoriae*			18		19	57				2	3	78			17
	Austrocochlea constricta									1						
	Austrocochlea porcata						63									
	Battilaria australis		168	16	1	24	3	15		74	1		249			1
	Bedeva hanleyi			1		1	1									2
	Bembicium auratum					24										
	Bittium granarium				19	4	16							11		
	Calthalotia corntessei			3		8		15		2		1				31
	Nassarius burchardi		108	54	13	2	84	20	7	3	2	1	84			135
	Pseudoliotia micans		4	59		64		43		3		3	51			
	Unidentifed	Flat round brown				1										
Hirudinea		Leech														2
Holothuroidea	Pleurobranchidae	Sea slug	2		1											2
Isopoda	Flabellifera	Isopod				1	3						1			
Opisthobranchia	Aplysiidae	Seahare			1		2									
Polychaeta	Capitellidae	Polychaete										1				
No. invertebrate groups			**11**	**13**	**11**	**19**	**13**	**13**	**9**	**9**	**11**	**14**	**12**	**7**	**7**	**16**
No. invertebrate individuals			**480**	**352**	**257**	**456**	**487**	**276**	**414**	**208**	**653**	**220**	**704**	**762**	**893**	**371**