CHAPTER 12. ECOLOGY OF FISH IN SEAGRASS

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Introduction

Beginning with Waite's (1923) *Fishes of South Australia*, the marine fishes of South Australia (SA) have been increasingly well documented. Waite, Scott (1962) and Gomon et al. (1994) have recorded >210 species of cartilaginous and bony fishes for Gulf St Vincent (GSV) and Investigator Strait (IS). While this is potentially a bewildering array of sizes, shapes and colours, observant fishers and divers know that species group according to different habitats.

In the past 20 years some of these species have been described according to their habitat preferences at different stages of their life (see Chapters 28-31). This chapter presents a systematic review of our understanding of fish assemblages occurring in intertidal and subtidal seagrass habitats in GSV/IS. For our purposes, an 'assemblage' is where different species of fish occur together in space and time within a particular habitat, without reference to the strength of their interaction (Jackson & Jones 1999).

Intertidal seagrasses can be further divided into two sub-habitats; those occurring in sheltered, mangrove-lined tidal creeks, and those occurring over more exposed tidal flats. By highlighting the productivity, numbers of species occurring in these habitats, and the relative importance of different habitats to different stages of the life history, we intend to show how conservation of these habitats is important for sustaining populations of individual species, and the species diversity, of the Gulf.

Three research techniques have provided the data for this study. They are: fishery-independent surveys of the fish assemblages; analysis of the diets of fish occurring in or adjacent to the habitat being investigated; and experimental manipulation of one of the sub-habitats.

Seagrass Habitats

The total marine habitat of GSV/IS is estimated at 14 420 km^2, of which 17% (2 438 km^2) is dominated by seagrass (Edyvane 1999; Scott et al. 2000a).

Intertidal seagrass habitat

Intertidal areas are characterised by alternating exposure to air and tidal inundation. Seagrasses, which are found in GSV/IS and are adapted to living in intertidal areas include: *Zostera muelleri, Heterozostera nigricaulis* and *Posidonia* spp. In the Gulf, intertidal seagrasses occur in sheltered areas, on mud and sand flats, and in tidal marine creeks, often adjacent to mangroves and saltmarsh stands (Bryars 2003). Intertidal seagrasses also occur in estuaries, defined here as a discernible channel created from land-based freshwater flows (Bryars 2003). Fish assemblages in estuaries are described in Chapter 14.

Water temperature and salinity are primary determinants of the plants and animals that live in intertidal areas. We give physical data on temperature and salinity fluctuations at three separate intertidal areas in the Gulf: the outer reaches of Barker Inlet; Wills Creek at Price (also known as Price Creek); and Coobowie Bay (Fig. 1). All three sites have annual temperature ranges of 10-25°C, which peak in January-February, and are at a minimum in June-July (Fig. 2). The more northerly sites—Price and Barker Inlet—are subject to higher evaporation rates, so have higher salinities than Coobowie Bay, which is closer to the open sea. At Barker Inlet and Coobowie Bay salinities fluctuate seasonally, while at Price salinity varies sporadically due to local, unseasonal freshwater run-off.

Subtidal seagrass habitats

Subtidal meadows in GSV are found where sands of grain size <0.25 mm occur. These areas are mainly in the central and northern waters, along the western edge of the Gulf, and in the NE bays of Kangaroo I. (Shepherd & Sprigg 1976; Chapters 16, 19). One or more of the genera *Posidonia, Amphibolis, Heterozostera* or *Halophila*, some with several species, comprise the meadows, with cover ranging from <40-100% (see Chapter 11).

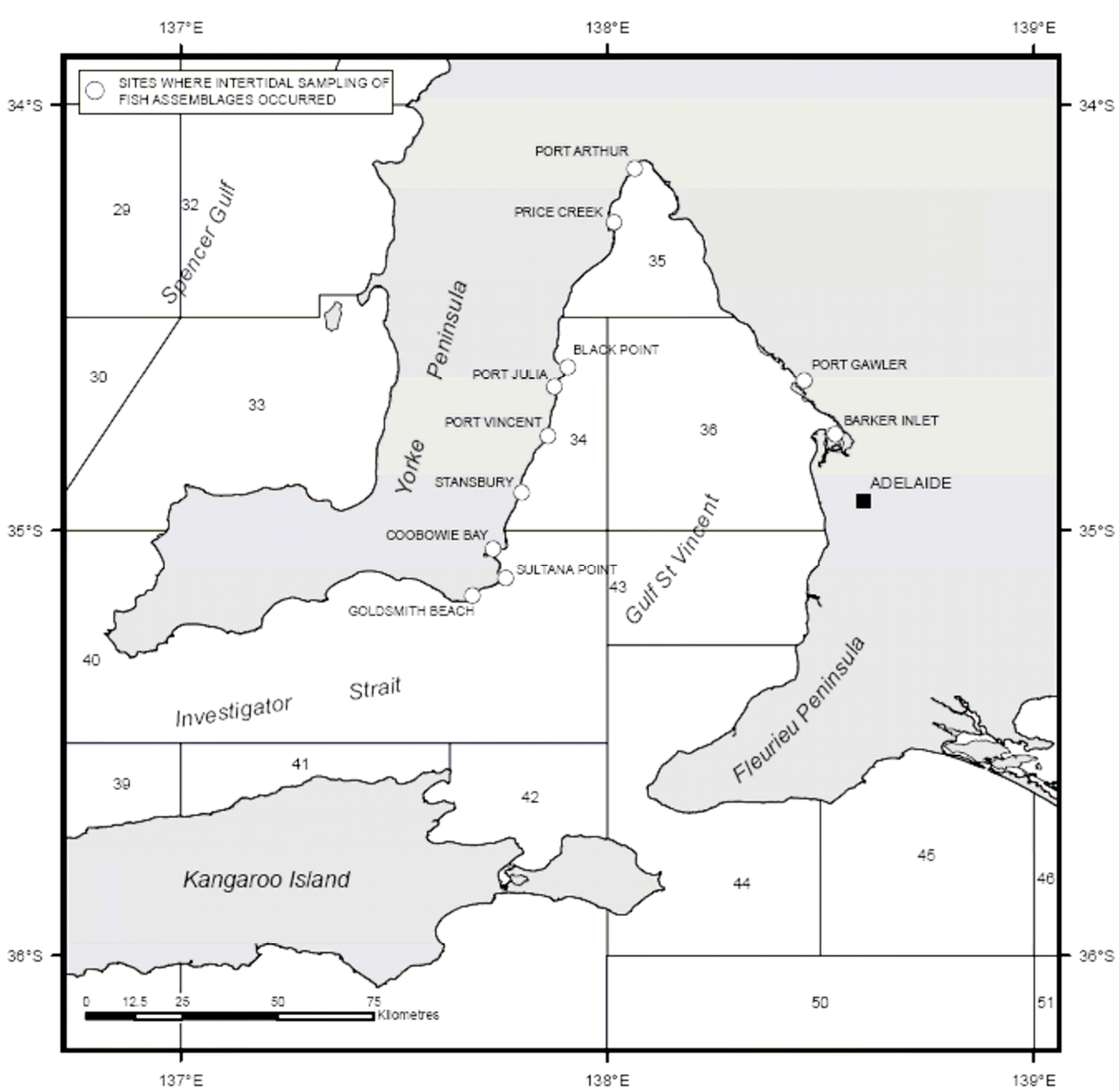

Figure 1. Map of Gulf St Vincent and Investigator Strait, showing locations of sites where sampling of fish assemblages took place between 1981 and 2004, and locations of fishing blocks referred to in the text.

Life Stages of Fish in Seagrass

To understand why fish use seagrass habitats in GSV we need to know the biology of each species. For the most common, or economically important species, we have this information (Chapters 29-31; Bryars 2003). Fish can be divided into seven groups according to which part of their life history uses seagrass habitat, as set out below.

Nursery species

These species recruit into the habitat as recently hatched post-larvae, after their larvae have travelled often large distances before settling over the intertidal seagrass. The high productivity of seagrasses allows the young fish to grow rapidly through the juvenile phase, then either remain in this habitat, or move away to deeper waters. Typical species, which use these areas only as nurseries are King George whiting, Australian salmon and Australian herring.

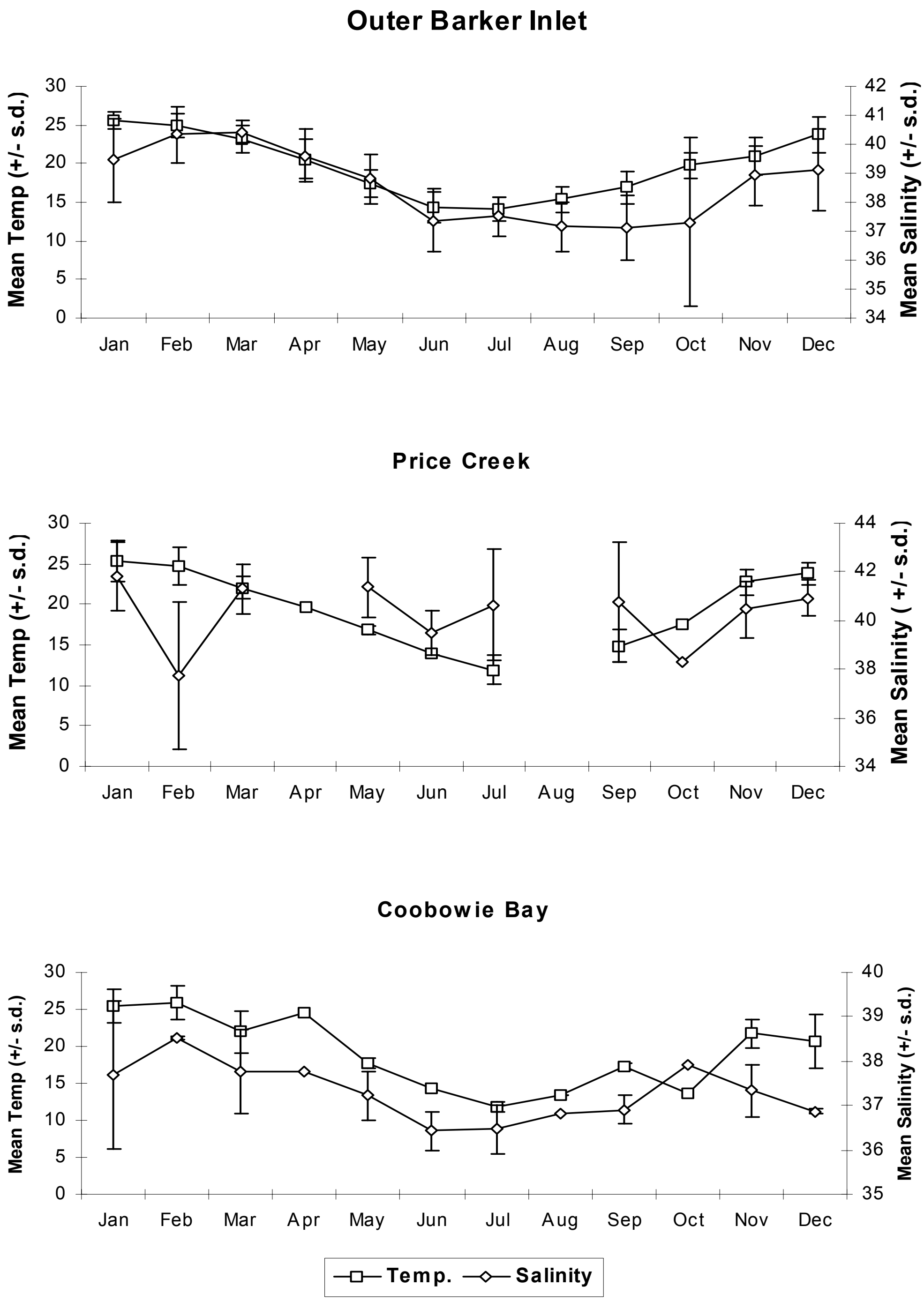

Figure 2. Seasonal variations in mean temperature (°C +/- s.d.) and salinity (p.s.u. +/- s.d.) at three sites in Gulf St. Vincent where fish assemblages over inter-tidal seagrasses were sampled (1981-90).

Adult feeding species

Some species remain associated with seagrass meadows for the remainder of their lives, or they move regularly into the habitat as adults, actively feeding in preparation for reproduction. Some remain in the area to spawn, while others move elsewhere to spawn. Most species found as adults in these areas are active first- or second-order carnivores, such as flathead and snook (Bertoni 1997), detritus feeders, such as yellow-eye mullet, or grazers on seagrass and/or their epiphytes—the algae that grow on seagrass leaves and stems. Such grazers include sea garfish (Chapter 31) and striped perch (Guenther 2002).

Spawning species

The species that spawn in and around seagrass meadows are either marine species, which complete their life cycle in seagrass, such as the bridled goby, or those species which enter the habitat as adults, spawn, and then move away. Striped perch, for example, spawn over seagrass meadows during summer, and appear to move to more open waters of the Gulf during winter (Jones, unpublished data).

Estuarine species

Species, which can tolerate a wide range of salinities, are defined as estuarine species (Chapter 14). If intertidal seagrass habitats are sporadically influenced by freshwater run-off, estuarine fish species may migrate into those areas. Depending on the extent of the run-off in space and time, estuarine species may be able to perform all the functions listed above while in the seagrasses. Such species include black bream and river garfish.

Marine stragglers

Occasionally fish species normally found in oceanic waters may appear in intertidal seagrass areas. These 'invasions' may take place because of sporadic high pulses of recruitment, forcing some of the new recruits into less favoured habitats. In September 1988, the normally oceanic spotted warehou, *Seriolella punctata*, 'invaded' the SA gulfs, including Barker Inlet and Price Creek, before suffering significant mortality in those areas (Jones, unpublished data).

Freshwater stragglers

For short periods after intense freshwater run-off, some freshwater-dependent species may be found inhabiting seagrasses. These species include congolli (*Pseudaphritis urvillii*), which was abundant in Barker Inlet immediately after an intense freshwater run-off from the Little Para River in October 1992 (Jones, unpublished data).

Species with unknown function

Little biological information is known about some of the fish species inhabiting intertidal seagrasses. Examples include small schooling species, such as sandy sprats and several species of hardyheads (family Atherinidae).

From our current knowledge of the biology of fish species occurring in seagrass habitats in GSV, we can now estimate the number of species in each of the above life history groups caught at Barker Inlet, Price and Coobowie Bay (Fig. 3).

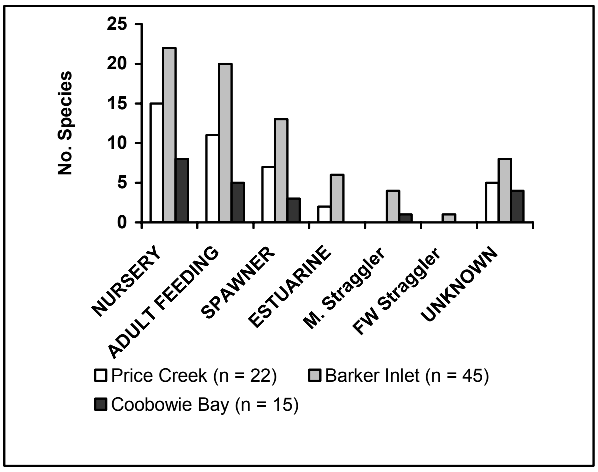

Figure 3. Numbers of species at different life history stages utilizing intertidal seagrass sites in Gulf St Vincent (Barker Inlet, 1984-95; Price Creek, 1989; Coobowie Bay, 1989)

Although the total number of species differs among sites, there is a consistent pattern in the distribution of species within the above life history groups at these sites. The highest number of species use intertidal seagrasses as nurseries, followed by the adult feeding group, and the fewest number of species use the seagrasses for spawning. Even with more information on the biology of the poorly known species, it is unlikely that this pattern will alter much.

Patterns Through Time

Fish assemblages vary over seasons, and over years. For two sites, Price Creek and Barker Inlet, fish densities were higher in warmer months. At Coobowie, although highest densities were observed in March, they remained high until July, and decreased steadily thereafter (Table 1). These variations may reflect differences in the timing of recruitment of some of the more abundant species, such as King George whiting (Chapter 29). In the studies by Connolly (1994a) and Bloomfield & Gillanders (2005) in Barker Inlet, highest densities were found in the warmest month, February, in vegetated and in unvegetated areas. The authors related this to higher productivities in summer.

Table 1. Fish densities, standing biomass and daily production rate of fish assemblages at three intertidal seagrass habitats in GSV in 1989.

Parameter	March'89	May'89	July'89	Sep'89	Nov'89	Mean (+/- s.d.)
Barker Inlet (Site 2)						
Temp (^{0}C)	23.1	17.4	14.1	16.9	21.0	
Fish Density (no m^{-2})	0.33	0.75	0.08	0.50	0.29	0.39 (+/- 0.25)
Standing Biomass (g wet wt m^{-2})	3.21	13.85	0.28	70.64	4.06	18.41 (+/- 29.6)
Daily Production rate (mg AFDW $m^{-2}d^{-1}$)	10.50	21.45	1.16	64.08	11.18	21.67 (+/- 24.77)
Price Creek						
Temp (^{0}C)	22.0	16.8	11.9	14.9	22.8	
Fish Density (no m^{-2})	0.52	0.27	0.18	0.44	0.69	0.42 (+/- 0.20)
Standing Biomass (g wet wt m^{-2})	7.10	3.80	8.32	32.85	19.82	14.38 (+/- 11.96)
Daily Production rate (mg AFDW $m^{-2}d^{-1}$)	17.27	8.48	10.17	33.14	36.41	21.09 (+/- 12.97)
Coobowie Bay						
Temp (^{0}C)	22.0	17.7	11.8	17.3	21.8	
Fish Density (no m^{-2})	1.09	0.65	0.54	0.37	0.26	0.58 (+/- 0.32)
Standing Biomass (g wet wt m^{-2})	8.45	5.97	7.52	5.78	3.58	6.26 (+/- 1.86)
Daily Production rate (mg AFDW $m^{-2}d^{-1}$)	19.48	12.22	9.40	11.67	10.67	12.67 (+/- 3.95)

The decadal study, from 1984-1995, showed a relatively stable structure for assemblages in Barker Inlet (Jackson & Jones 1999). For all sites (three with seagrass, two unvegetated) the number of species was <100, which is characteristic of this kind of habitat in other temperate parts of the world (Jackson & Jones 1999). The assemblage structure was relatively stable in the same season from year to year, compared with the seasonal fluctuations in the same year. It appeared that this 'predictable' stability was driven by timing of immigration and emigration of the dominant fish species.

There were no clear trends in species' composition between 1985 and 1994. The majority of dominant species were considered to be relatively stable in this area in the longer term, possibly because they spent only part of their life history in that habitat. Most were widely distributed, using the estuary as a nursery, and so could be less influenced by intrinsic features of these habitats. A few of the species that spent the major part of their lives in this area showed greater variability in abundance from year to year. These species included river garfish and bridled gobies, and their 'closed' populations may have been more prone to local environmental variability, or to the adverse effects of human activities (Jackson & Jones 1999).

Why Fish are in Seagrass

Local and international research has led to four conclusions on the relation between fish and seagrass:

- there are more fish, and different fish assemblages, in seagrass than over adjacent mudflats;

- fish mostly do not eat seagrass itself;
- small fish are better able to escape larger, piscivorous (predatory) fish, if they can hide in seagrass (Orth et al. 1984); and
- loss of seagrass habitat is accompanied by the decline of fish species associated with seagrass. In GSV seagrasses have declined due to pollution and other causes (Anon. 2007; Chapter 11).

Much research has been devoted to explaining why fish associate with seagrass, particularly juveniles of economically important species such as King George whiting. Experiments in NSW showed that experimentally thinning seagrass reduced the abundance of several fish species. This happened even where cages excluded larger predators. Lower abundances of small fish were not, therefore, a consequence of predators eating more small fish (Bell & Westoby 1986). The concept of 'habitat selection' was proposed to explain the lower densities of small fish in thin seagrass. This implied that small fish simply moved about until they found dense seagrass, and remained there for as long as possible.

The theory of habitat selection was tested in the shallow seagrass of Barker Inlet and the Port River. The entire above-ground seagrass canopy was experimentally removed from 30 m^2 patches of seagrass, and 14 days later, fish densities over these patches were compared with densities over three other kinds of patches. The other treatments were; untouched seagrass (the control site); canopy retained, but disturbed as though the canopy had been removed (the procedural control); and unvegetated patches of mud amongst the seagrass (Connolly 1994a).

For the theory of habitat selection to be correct, fish densities in patches with the canopy removed should have been the same as in the unvegetated patches. In fact, fish densities were considerably higher in the 'canopy-removed' patches, than in the unvegetated patches (Fig. 4). For some species, densities were a little lower over the canopy-removed patch, than in the control and procedural control seagrass patches. Clearly, something more than habitat selection was required to explain these fish densities.

Seagrasses have higher densities of epifaunal (living on stems and leaves) crustacean and polychaete prey for small fish than unvegetated areas (Connolly 1997). A simple feeding theory, put forward to explain the fish densities, was that fish would spend more time where there is more food. Re-examination of the experimental patches (above) showed that prey availability was very high in the untouched control site, a little lower in patches from which the canopy had been removed, and very low in the unvegetated patches (Connolly 1995b). The pattern matched precisely the densities of small fish in the patches (Fig. 4), which supported the simple feeding theory.

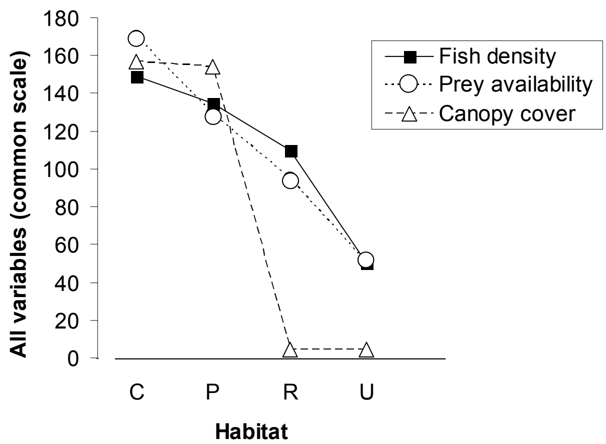

Figure 4. Relationship between total density of small fish (number of fish 30 m^{-2} patch), seagrass canopy cover (m^2 leaf area m^{-2} sediment area) and prey availability (μg DW invertebrate production day^{-1}), for treatments C (control seagrass), P (procedural control seagrass), R (removed canopy seagrass), U (unvegetated mud). Redrawn from Connolly (1994a).

Subsequent experiments with juvenile King George whiting in tanks (mesocosms) confirmed that fish densities are highest where prey are most numerous. When no prey was available, fish tended to select seagrass in preference to unvegetated habitat (Connolly 1994d).

Diet of Fish in Seagrass

Seagrasses in GSV provide a substantial, conspicuous standing biomass of plant material, with high rates of productivity. Algae on seagrass leaves and stems are even more productive (Keough & Jenkins 1995).

One might expect that all this primary productivity would support an abundance of herbivorous fish, but that is not the case. There has been a long-standing scientific debate about levels of herbivory in seagrass beds, and in other submerged aquatic plants in freshwaters. Overall, there are few grazers of seagrass, and direct herbivory is not a major component of seagrass foodwebs in GSV. Many of the invertebrates that consume live seagrass and algae are gastropods (snails), which generally are not important in fish diets (Klumpp et al. 1989). There are exceptions, however, and recreational fishers report that, at times, the stomachs of King George whiting caught over or adjacent to seagrasses in the gulfs contain numerous green, shell-less molluscs, probably elysiid nudibranchs, which graze on seagrasses and/or their epiphytes (K. Jones pers. obs.). The importance of these molluscs to the energetic requirements of whiting is not known.

Garfish is the only fish family in GSV known to derive nutrition by directly consuming fresh seagrass leaves. The presence of eelgrass (*Zostera muelleri*) in the alimentary tract of sea garfish (*Hyporhamphus melanochir*) in GSV is so well known that fishers call this grass 'garweed'. The diet of sea garfish over its life history stages is described in Chapter 31, and shows increasing dietary dependence on *Zostera* as the fish grows. Studies in other parts of Australia, using chemical tracers, have shown that garfish gain energy by assimilating seagrass (Klumpp & Nichols 1983; Connolly 2003). This is done *via* a special digestive mechanism that overcomes the fibrous nature of seagrass leaves (Tibbetts 1997). During the day/night cycle, garfish switch to animal prey at night to obtain protein (Waltham & Connolly 2006).

Several leatherjacket species of GSV ingest live seagrass. Studies in NSW have shown that the seagrass is excreted largely intact, so it is likely that the fish are assimilating sessile animals such as bryozoans and polychaete worms off the leaves, rather than the seagrass itself (Bell et al. 1978).

As it turns out, seagrass meadows are fundamentally important to fish nutrition, but only after the leaves, roots and epiphytic algae have died and begun to decay. This detritus is consumed by microbes and small invertebrates, which are then eaten by larger invertebrates that become, in turn, prey of fish. This detrital pathway is by far the most important in food webs for fish associated with seagrass meadows (Chapter 38).

The diet of seagrass fish in GSV fits the pattern found the world over, with crustaceans being the most common prey. Many fish species also take polychaete worms, and some consume bivalve molluscs, such as small clams (Klumpp et al. 1989). A study in GSV showed that King George whiting, for example, prey largely on small crustaceans such as copepods and amphipods when the fish are juvenile. As the fish grow towards 100 mm long they consume more polychaete worms (Connolly 1995a).

Another study in GSV established an important role for seagrass in the nutrition of yellowfin whiting (*Sillago schomburgkii*). In the northern Gulf, yellowfin whiting occur mainly over the wide, intertidal mudflats between coastal mangrove forests and subtidal seagrass meadows at high tide, moving to the mouths of mangrove-lined creeks at low tide. The study identified ratios of stable isotopes of the component carbon atoms of the seagrass. Similar ratios were found in polychaete worms in the seagrass, and again in the yellowfin whiting that ate those worms. This was strong evidence that organic material from the seagrass is ultimately a major source of energy for the yellowfin whiting (Connolly et al. 2005a,b).

Fish also prey on other fish in the seagrass. The extent of this piscivory has been quantified for many species in Victoria (Hindell et al. 2000), but not yet in GSV. The Victorian studies ranged from large species, such as WA salmon (*Arripis truttaceus*), to smaller species, such as pike-headed hardyheads (*Kestratherina esox*) and weedfish (family Clinidae).

Local Research on Fish in Seagrass

Intertidal seagrass

Our knowledge of fish in GSV relies on studies carried out by different researchers over many years, using sampling methods specifically designed for each study. The variety of sampling methods used gives us a more comprehensive picture of the entire suite of fish in seagrass, but comparisons among the studies become difficult, since fish catches are highly dependent on the method used. As background, therefore, we first summarise methods previously used to study fish in seagrass.

Fishes associated with seagrass in Barker Inlet have been sampled with two types of gear—small-mesh seines (drag nets) and buoyant pop-nets. Edgar & Shaw (1995a) used small-mesh beach seines to sample over *Zostera* and adjacent unvegetated sites at Barker Inlet and Port Gawler during summer. A seine 15 m long, with 1 mm mesh, was dragged over 12 m and hauled into a boat. The area sampled was ~77 m^2, and calculated densities adjusted for the catch efficiency of the net. Connolly (1994a) used small mesh seines of 5 m and 22 m length to sample fish assemblages over *Zostera* and adjacent unvegetated sites. Catch efficiency averaged 68% (Connolly 1994a). In later studies, Connolly (1994b,c) used beach seines and buoyant pop-nets (25 m^2, 1 mm mesh) over vegetated and unvegetated areas. Bloomfield & Gillanders (2005) similarly used seines (4 m × 1.5 m, 1 mm mesh, dragged over ~9 m^2) and 9 m^2 pop-nets, similar to Connolly's (1994c), to study fish assemblages of salt marsh, mangroves, seagrass beds, and unvegetated areas in Barker Inlet

Jackson & Jones' long-term beach seine sampling study from 1984-1995 sought indices of relative abundance of several economically important species, and they used a seine net 120 m long, with 30 mm mesh in the wings and 9 mm in a central pocket, covering ~2 292m^2 (see also Chapters 29, 30). The net was hauled to the edge of the shore, and catch efficiency averaged 80% (Jones, unpublished data), but varied between species (Jackson & Jones 1999). The same sampling methods were used at Price Creek and Coobowie Bay bimonthly during 1981-2 and 1986-1990, and in spot surveys at seven other intertidal seagrass sites on eastern Yorke Peninsula during the 1980s (Fig. 1).

Table 2. Number of demersal and pelagic finfish species sampled in beach seine surveys of eastern and western GSV, 1986-90 over intertidal seagrass habitats. Pelagic/tightly schooling species include: hardyheads, salmon, herring, blue and sandy sprats. Other schooling species, which are known to graze on seagrasses in GSV, e.g. southern sea garfish and striped perch, are included among demersal species.

Site	Demersal species	Pelagic species	Total
Barker Inlet	18	5	23
Port Arthur	6	1	7
Price Creek	18	3	21
Black Point	7	-	7
Port Julia	12	2	14
Port Vincent	14	3	17
Stansbury (sth of spit)	8	2	10
Coobowie Bay	10	3	13
Sultana Point	14	2	16
Goldsmiths Beach	10	2	12

Here, we provide information (Table 1) on the standing biomass and fish production rates from the three comparative sites, Barker Inlet. Price Creek and Coobowie Bay. To calculate biomass, fish densities were converted to standing biomass (g m^{-2}) from length/weight relationships (see Edgar & Shaw 1995a; McGlennon & Kinloch 1997), and daily fish production was calculated as ash-free dry weight (AFDW) in mg AFDW m^{-2} day^{-1}, (using the AFDW/wet weight ratio of 0.22) adjusted for water temperature (for methods see Edgar & Shaw 1995a,b). For all other sites we simply provide information on the total numbers of demersal and pelagic species recorded during the intertidal seagrass surveys (Table 2).

Subtidal seagrasses

In contrast to the plethora of studies for intertidal seagrasses, fishery-independent sampling of fish over subtidal seagrasses in GSV is in its infancy, and the few studies using demersal beam trawls remain unpublished. However, data from commercial and recreational fisheries occurring over seagrasses, demonstrate the importance of seagrass habitats to these fisheries. Harvest data (kg live weight) were obtained from catch and effort records from commercial net fishers operating in the Gulf and the north coast of Kangaroo I. from 1998 and 2002 (Knight et al. 2005).

The commercial haul-net fishery is a traditional component of the multi-species marine scale fishery (Jones 1982; Fowler 2005; Noell et al. 2006), and fishers use nets to 600 m long in waters <5 m deep mainly over seagrasses, but also over unvegetated habitats (McArthur 2003). During 1998-2002, this fishery in GSV and Kangaroo I. reported >31 species harvested, either directly targeted or taken as saleable by-catch. To compare species' composition between the independent surveys and the fishers' catch data, we have summed the annual harvest of each species for the period 1998-2002, and ranked them in descending order of harvest weight (Table 3).

Table 3. Fish species living in seagrass, ranked in descending order of abundance in three fishery-independent studies, and in two studies of the harvest of commercial (Com.) and recreational (Rec.) line fisheries. J & J 1999 = Jackson & Jones (1999); C. 1994a = Connolly (1994a); B & G 2005 = Bloomfield & Gillanders (2005); GSV Com. = GSV/KI Commercial hauling-net fishery; Metro Rec = Recreational line fishery in Adelaide metropolitan waters.

Fish Species	**Rank J & J 1999**	**Rank C (1994a)**	**Rank B&G (2005)**	**Rank GSV/ KI Com.**	**Rank Rec. Adel Metro**
King George whiting *Sillaginodes punctata* (Cuvier, 1829)	1	2	3	3	1
atherinids (several sp.) Family Atherinidae	2	1	1		
yellow-eye mullet *Aldrichetta forsteri* (Valenciennes, 1836)	3	5	4	7	13
striped perch *Pelates octolineatus* Jenyns 1842	4	3	5	9	12
sea garfish *Hyporhamphus melanochir* (Valenciennes, 1847)	5	7	7.5	1	3
weedy whiting *(*Famil*y* Odacidae)	6	9.5		11	8
gobies (2 spp.) Family Gobiidae	7	4	2		
river garfish *Hyporhamphus regularis* (Günther, 1866)	8				
blue sprat *Spratelloides robustus,* Ogilby, 1897	9	25.5			
cobbler G*ymnopistes marmoratus* (Cuvier, 1829)	10		6		
leatherjackets (several spp.) Family Monocanthidae	11		9.5	8	4*
Australian herring *Arripis georgianus* (Valenciennes, 1831)	12	27.5		2	2
other whiting, including yellow-fin & school. Family Sillaginidae	13	15.5		6	6
flounder (2 spp.) Order Pleuronectiformes	14	15.5	7.5	17	22
congolli *Pseudaphrytis urvilli,* (Valenciennes 1831)	15				
Australian salmon *Arripis truttaceus* (Cuvier, 1829)	16			4	5
crested weedfish Family Clinidae	17	9.5			
jumper mullet *Liza argentea* (Quoy & Gaimard, 1825)	18.5			16	
Toadfish (several sp.) Family Tetraodontidae	18.5		9.5		
syngnathids (several sp.) Family Syngnathidae	19	6,8	4		
Anchovy *Engraulis australis* (White 1790)	20				
Southern fiddler *Trygonorrhina guanerius,* Whitley, 1932)	21				
black bream *Acanthopagrus butcheri* (Munro*,* 1949)	22			13	
flathead (2 spp.) Family Platycephalidae	23			15	9
siphon fish *Siphaemia cephalotes* (*C*astelnau, 1875)	24				
snook *Sphyraena novaehollandiae* Günther, 1860	25.5			5	10
estuary catfish *Cnidoglanis macrocephalus* (Valenciennes, 1840)	25.5				37
old wife *Enoplosus armatus* (Shaw, 1790)	26				35
sandy sprat *Hyperlophus vittatus* (Castelnau, 1875)	27				
eagle ray *Myliobatis australis* Macleay, 1881	28			10	20
Dusky morwong *Dactylophora nigricans* (Richardson, 1850)	29				18

*In McGlennon & Branden (1994) leatherjackets were omitted from the species list in the survey; however, they were reported as 3rd – 4th highest CPUE for mixed seagrass/bryozoan/oyster/razorfish habitats. They were arbitrarily assigned a rank of 4 for this fishery.

Part of the recreational line fishery in the Gulf is in waters <10 m deep, over relatively flat substrates, including seagrasses, bryozoans, oyster or razor fish beds, and bare sediments. Table 3 lists fish species recorded from the 1992-3 recreational fishing survey by McGlennon & Branden (1994), off metropolitan Adelaide, between Port Noarlunga and St Kilda, ranked according to estimated harvest weight.

Fish Assemblages in Seagrass

Distribution and patterns in fish assemblages

Fish assemblages vary in space according to habitat, and in time. Seagrass fish assemblages are composed of mostly demersal and schooling fishes. Taking a broad-scale view of the Gulf, the surveys along Yorke

Peninsula and in Barker Inlet in the 1980s showed that there were greater numbers of demersal species than pelagic or schooling species at those sites (Table 2). At Barker Inlet and Price Creek, there were substantially higher numbers again of demersal species, compared with Coobowie Bay. This may be related to the proximity of those seagrasses to mangrove-lined creeks, as has been found on the east coast of Australia (Jelbart et al. 2007).

To compare intertidal and subtidal seagrass fish assemblages, we ranked the top 31 species found in the Barker Inlet seagrasses from the three studies described above. We then ranked those species according to their harvest levels in the two fisheries (Table 3). Caution is needed in interpreting these rankings, as the fish species caught are selected by the mesh size of the nets and by the size of hooks used in the line fishery. Additionally, certain species of fish have different values to commercial fishers than to recreational fishers, and these two groups of fishers will therefore target different species (Jones 1982; Fowler 2005).

The comparison shows some interesting links (Table 3). Firstly, the rankings of the three fishery-independent studies are generally similar. King George whiting stood out as a high ranking species (rank 1-3) for the three studies, as well as for the fisheries, indicating it is one of the dominant species in seagrass fish assemblages. Sea garfish similarly ranked highly in the fisheries, and was ranked among the top species from Barker Inlet. One family of fishes occurred in very different densities in different studies. Syngnathids (seahorses and pipefish) were one of the common families in the studies by Connolly (1994a) and Bloomfield & Gillanders (2005), but were ranked much lower in the long-term study by Jackson & Jones (1999). This is almost certainly due to the different mesh size of nets used in these studies (1 mm for the first two studies and 9 mm in the pocket of the seine used by Jackson & Jones 1999), rather than a difference in abundance. Syngnathids are a diverse and abundant family of fishes in these habitats in southern Australia and especially in GSV (Chapter 13).

Density and production of fish assemblages vary through space and time. When we compare Coobowie Bay, Barker Inlet and Price Creek, we find highest average densities at Coobowie Bay, and lowest at Barker Inlet (see Table 1), although densities varied seasonally at all sites. Ranking for the measures of productivity are opposite those for density. Mean productivity was highest at Barker Inlet (21.7 mg m^{-2} day^{-1}), and lowest at Coobowie Bay (12.7 mg m^{-2} day^{-1}). The higher rates at Barker Inlet and at Price were due to very high rates estimated for September and November 1989 (see Table 1). Catches at those times had relatively high numbers of larger fish—yellow-eye mullet at Barker Inlet, and jumper mullet and black bream at Price.

Table 4. Estimated fish production (mg AFDW.m^{-2}.d^{-1}) at Barker Inlet and Port Gawler in *Heterozostera* seagrass beds, and at unvegetated sites, sampled in Jan, Feb, 1991 (from Edgar & Shaw 1995a).

Site	**Total Fish Production (mg AFDW.m^{-2}.d^{-1}) (+/- s.e.)**	**Demersal Fish Production (mg AFDW.m^{-2}.d^{-1}) (+/- s.e.)**
Port Gawler, *Heterozostera*	17.2 (6.5)	2.2 (0.7)
Port Gawler, unvegetated	0.73 (0.41)	0.40 (0.24)
Barker Inlet, *Heterozostera*	77.8 (7.8)	77.8 (7.8)
Barker Inlet, unvegetated	4.4 (2.1)	4.4 (2.1)

Edgar & Shaw's (1995a) study, extending across southern Australian coastal waters, focused on variation of biomass and fish production levels, rather than fish densities. At both SA sites (see Table 4), fish production levels were an order of magnitude higher over *Heterozostera*, than over adjacent unvegetated habitat. Lower production rates were observed at Port Gawler than in Barker Inlet. This may reflect the more exposed conditions at Port Gawler, because Edgar & Shaw (1995a) have shown a significant underlying inverse relation between production and wave exposure across southern Australia.

Seagrass Residency Index

There has been little fishery-independent sampling of fish populations over subtidal seagrasses in GSV, so we know little of the life history strategies of species, which are not economically important. Scott et al. (2000) devised a seagrass residency index (SRI) by drawing on the knowledge of 'experts' in the biology of several of the economically important species, which reside in intertidal and subtidal seagrass for some of their lives. This was a 'desktop' rather than a field study, and was subject to several assumptions. It noted that a species might be associated with seagrass, but did not therefore assume that the species was necessarily entirely dependent on seagrass.

The life cycle of each species was divided into a larval/juvenile stage, an adult/spawning stage and an adult/feeding stage. Species and their life history stages were ranked according to their association with all habitats, which included shallow seagrasses, sheltered reefs, unvegetated areas and waters >30 m deep (Scott et al. 2000). The data were combined, averaged and standardized in the range 0-1. The species are listed in Table 5, in descending order of association with seagrass. As all these species are found in GSV, the results are relevant to this Gulf. The life histories of sea garfish, King George whiting, Australian salmon and herring described in Chapters 29-31 confirm these rankings.

Table 5. Major economically important fish species in GSV listed in decreasing order of their association with seagrasses (modified from Table 2 in Scott et al. (2000), omitting ranks assigned to major invertebrate species).

Common Name	Taxonomic Name	Seagrass Residency Index (SRI)
sea garfish	*Hyporhamphus melanochir*	1.00
leatherjacket	Family Monocanthidae *	0.97
King George whiting	*Sillaginodes punctata*	0.74
yellow-fin whiting	*Sillago schomburgkii*	0.55
Australian salmon	*Arripis truttaceus*	0.55
Australian herring	*Arripis georgianus*	0.53
snapper	*Pagrus auratus*	0.42
sand flathead	*Platycephalus bassensis*	0.26
mulloway	*Argyrosomus japonicus*	0.26
Australian sardine	*Sardinops sagax*	0.08

*includes >1 species of leatherjacket, as individual species are rarely identified by fishers.

To reinforce these results, McArthur et al. (2003) then investigated the mathematical relationship between commercial fishing effort, the area of seagrass in each commercial fishing block and annual catches for several of these species throughout SA waters (Fig. 5). They found that the area of seagrass in a fishing block was a significant predictor of annual catch of sea garfish and King George whiting. Both these species have a very high SRI value, although leatherjackets were not investigated. For most species with lower SRIs, the area of seagrass was not a significant predictor of annual catch.

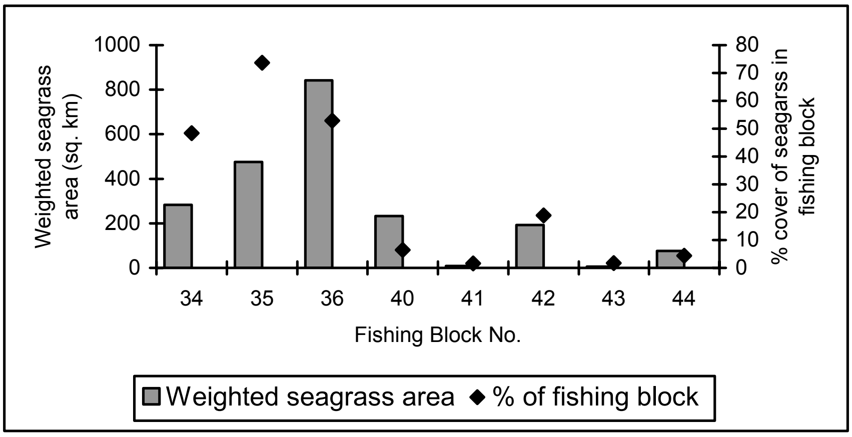

Figure 5. Spatial extent and proportion of cover of seagrasses according to fishing blocks located in GSV /IS (adapted from McArthur (2003). Locations of the fishing blocks are seen in the map of the area in Chapter 30.

Comparison of Seagrass and Unvegetated Habitats

Comparative studies of fish assemblages in Barker Inlet in seagrass and adjacent unvegetated habitats (Connolly 1994a; Jackson & Jones 1999; Bloomfield & Gillanders 2005) enable us to compare rigorously the fish species' composition for these habitats in this inlet. The 10 most abundant demersal fish species in each study were ranked in ascending order of abundance (after excluding pelagic, highly schooling species, such as hardyheads and blue sprats). Ranks were then averaged (Table 6a). King George whiting, striped perch, garfish, pipefish, weedy whiting, and weedfish (family Clinidae) all had higher rankings at seagrass sites, whereas yellow-eye mullet, flounder, and yellowfin whiting ranked more highly at unvegetated sites. Gobies were the only group of species showing similar rankings in both habitats (Table 6a). All three investigations showed higher numbers of species at seagrass sites than at unvegetated sites (Table 6b). Note that it cannot be inferred from Table 6b that the number of species has declined over time, because each study used slightly different methods in different areas. Over the 1985-1994 period, Jackson & Jones (1999) did not observe any significant trend in number of species taken at any of the sampling sites.

Densities of fishes in Barker Inlet have been found to be generally greater over seagrass than over unvegetated areas (see Figs 4, 6). Fish production has also been found to be orders of magnitude greater over seagrass than over unvegetated areas (Edgar & Shaw 1995a).

Table 6a. Averaged rankings of the ten most abundant fish species at seagrass and unvegetated sites in Barker Inlet, as found by three independent studies (see text for details).

Seagrass Sites		**Unvegetated Sites**	
Species	**Average Rank (+/- s.e.)**	**Species**	**Average Rank (+/- s.e.)**
King George whiting	1.3 (0.6)	yellow-eye mullet	1.5 (0.9)
gobies	3.0 (1.5)	gobies	2.3 (2.1)
striped perch	3.7 (2.0)	King George whiting	3.5 (1.3)
yellow-eye mullet	3.7 (0.6)	striped perch	4.7 (1.5)
sea garfish	4.6 (3.6)	sea garfish	5.3 (1.8)
syngnathids	6.0 (2.3)	flounders	5.3 (1.6)
weedy whiting	7.0 (1.5)	yellow-fin whiting	7.0 (1.7)
flounders	8.0 (0.6)	syngnathids	8.2 (3.5)
weedfish	8.7 (1.0)	weedy whiting	8.8 (0.8)
yellow-fin whiting	8.7 (1.5)	weedfish	8.8 (1.5)

Table 6b. Number of teleost and elasmobranch species in intertidal seagrass and unvegetated sites in Barker Inlet from three independent studies (see text for details).

Study period	**No. species at vegetated sites**	**No. species at unvegetated sites**	**Reference**
1985-94	36 (Kings Beach) 37 (Quarantine Station) 36 (Section Bank)	27 (Angas Inlet) 28 (North Arm)	Jackson & Jones (1999)
1990-91	36 (19 in April 1991)	Max. 9 in April 1991	Connolly (1994a)
2002-03	17	16	Bloomfield & Gillanders (2005)

Conclusions

Seagrasses are a conspicuous component of the seascape of GSV, covering extensive areas in shallow, soft-sediment environments. Seagrass meadows provide habitat for many fishes at various stages of their lives, supporting key commercial and recreational fisheries. Even species that are not normally associated with seagrass meadows derive nutrients and other benefits from seagrass. Seagrass is more productive than unvegetated areas, and supports higher densities of fish, and more diverse assemblages of fish. Few fish eat seagrass leaves directly; it is the detritus from shed leaves and stems that supports the seagrass foodwebs.

Loss of seagrass reduces the production of fish, and the decline of seagrasses in GSV (Chapter 11) must therefore have had serious consequences for fish production in the Gulf. The fragmentation of remaining seagrass meadows has also been shown recently to have a strong negative effect on fish assemblages and densities in several places around Australia (Connolly & Hindell 2006; Jelbart et al. 2006). This is an active, ongoing area of research in GSV (Tanner 2003).

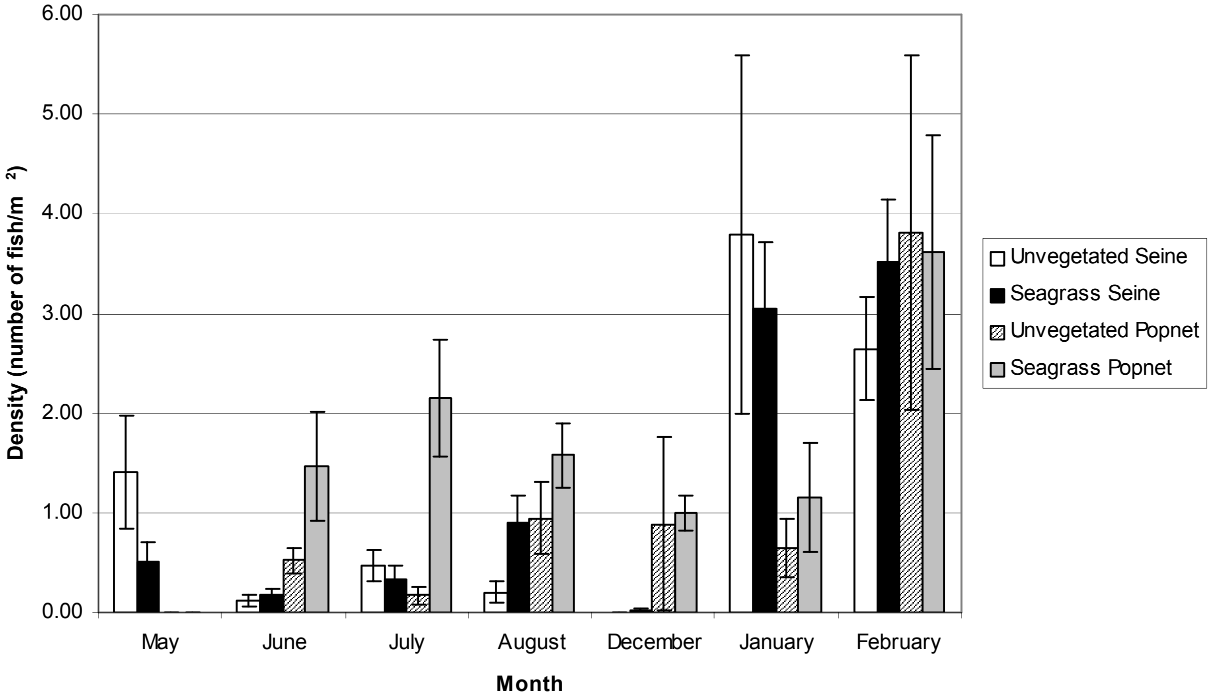

Figure 6. Average density of fishes (no of fish/m^2 ± SE) in seagrass and unvegetated habitats sampled with seine and popnets in Barker Inlet 2002-2003 (Note: no popnets were used in May).

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