Effects of Habitat Disturbance on Coastal Fisheries Resources of Tin Can Bay/Great Sandy Strait

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PROJECT INFORMATION [FRDC No 91/41]

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Duration of Project:	1991-1994
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Cooperating Agencies:	Queensland Commercial Fishermen's Organisation University of Queensland

OBJECTIVES

The objectives of the research project were to:

a) Characterise the estuarine and marine fauna associated of undisturbed and disturbed fisheries habitats at selected sites within the Tin Can Bay/Great Sandy Strait region, southern Queensland;

b) Identify sources of variation and describe levels of variation in abundance of important finfish, crustacean and cephalopod populations and in community structure;

c) Assess whether changes considered undesirable from a fisheries viewpoint may have resulted from disturbances;

d) Provide a basis for the preparation of guidelines for permissible levels of disturbance that result in minimal impacts on fisheries and habitats in northern Australia.

EXECUTIVE SUMMARY

Inter-tidal and sub-tidal wetlands habitats were sampled in Tin Can Bay (25°54'S, 153°02'E), at the southern end of the Great Sandy Strait, Queensland from November 1991 until November 1993. Samples were collected every second lunar month from the night preceding the full moon until three nights after the full moon representing 13 sampling periods. Four sampling methods were used:

1) beam and otter trawls
2) ring nets
3) block nets
4) commercial tunnel nets.

A comprehensive list of fish species found in Tin Can Bay was compiled and characterised in terms of importance to commercial and/or recreational fishing.

The species composition of Tin Can Bay is similar to other subtropical mangrove estuaries with over 100 species of fish being caught. Of these, 39 are of commercial or recreational importance. Four species of commercial prawns (kings (*Penaeus plebejus*), greasies (*Metapenaeus bennettae*), endeavours (*Metapenaeus endeavouri*), and brown tigers (*Penaeus esculentus*), two species of crab (mud (*Scylla serrata*) and sand (*Portunus pelagicus*), and two species of squid (arrow (*Loligo* sp.) and calamari (*Sepioteuthis* sp.) were also taken.

Mid-way through the study, the seagrass at the sparsely vegetated site (Ida Island) suffered a complete die-back of the above-ground vegetation. The seagrass did not recover to its' original vegetation levels for the remainder of the study, effectively leaving a bare substrate.

Two seagrass beds of different above-ground vegetative densities (sparse and dense) were sampled using a beam trawl and ring nets. Beam trawls caught small fish the majority being < 50 mm long standard length. Fish density (No. m^{-2}) was higher in the sparsely vegetated site than the densely vegetated site, with the standing crop (g m^{-2}) being similar at both sites. The species composition of the fish communities was similar with 55% of the fish species occurring in both sites. Fish numbers were dominated by a goby, *Favonigobius exquisitus,* while silverbiddies, *Gerres oyeana*, were the most common by weight. Ring nets caught larger fish mostly > 50 mm standard length. The density (No. m^{-2}) of fish taken in ring nets was similar at both sites with standing crop (g m^{-2}) being higher at the densely vegetated site. The species composition of the fish communities was similar with 57% of the fish species occurring in both sites. Hardyheads, *Atherinomorus ogilbyi,* and silverbiddies, *Gerres oyeana*, were the dominant species at both sites representing > 50 % of the total catch by number. By weight, the sparse site was not dominated by any particular species with no species constituting > 15% of the total catch (Table 2). Two species, silverbiddies *Gerres oyeana* (23%) and blue spotted-stingrays *Amphotistius kuhlii* (24%) dominated the catch by weight at the dense site.

Catches of juvenile prawns in beam trawls revealed four commercial species use Tin Can Bay as a nursery site. Of these, king (*Penaeus plebejus*) were the most abundant comprising 84.9% of the catch. Less abundant were greasy prawns (*Metapenaeus bennettae*) comprising 11.1% of the catch. Both these species were caught in almost equal numbers on both sparsely

and densely vegetated sites. This trend changed dramatically after the above-ground seagrass at the sparsely vegetated site died back. After this event, juvenile king prawns showed a significant preference for the unvegetated site suggesting that it provided a better habitat for their survival. This suggests that shallow water habitats do not have to be continually covered with seagrass to be of value to fisheries.

Fish from within a subtropical *Rhizophora stylosa* mangrove forest were collected to determine its' fisheries value compared to those of other Australian mangrove forests. This was done by comparing the species composition, fish density (No. m^{-2}) and standing crop (g m^{-2}). It was found that subtropical *Rhizophora stylosa* mangrove forests were directly less productive in terms of fish density and standing crop than other Australian mangrove systems studied to date. Fish production in open waters adjacent to mangroves is nevertheless dependent on export of leaf letter from such forests. The species composition of temperate and subtropical mangrove forests comprise between 38% and 75% by number and 32% to 94% by weight of fish of economic value, while fish from tropical mangrove forests are reported to be of little direct economic value but contribute to the production of commercial fisheries in open waters adjacent to mangrove forests.

Stomach analysis on 6 species of economically important fish showed that there are a number of feeding strategies used in the inter-tidal zone. These include feeding on the inter-tidal seagrass and sand/mud flats on the incoming tide before moving into the mangroves as occurs in luderick (*Girella tricuspidata*); feeding mainly in the mangroves with little evidence of feeding on the inter-tidal flats by species such as bream (*Acanthopagrus australis*); and feeding on the inter-tidal flats and mangrove fringes while not taking any prey items directly from within the mangroves as shown by flathead (*Platycephalus fuscus*).

The two types of research netting (fence nets in mangroves and ring nets on seagrass areas) used took the same range of species (55% in common) as caught in a much larger commercial tunnel net. Differences in net mesh sizes meant that the tunnel net did not catch all of the small fish species taken with the research nets. When these are excluded, 66% of the fish species caught were taken in research and commercial nets. Fish densities and standing crop from both types of netting were similar for both the sparsely and densely vegetated sites. This indicated that a small number of nettings over an extended area by a commercial operator may provide the same level of gross information, at lesser cost, as that obtained from many trips using much smaller (research) gear.

Guidelines to identify the value of different fisheries habitat areas are in preparation and when complete, will be distributed to all Local Authorities with a jurisdiction for strategic planning of coastal areas. This will ensure that potential impacts of coastal development are recognised and appropriate mitigation measures are implemented.

RECOMMENDATIONS

1. That the roles of different mangrove, seagrass and bare substrate habitats be recognised in terms of direct or indirect use by fish and crustacean species of economic importance.

2. That a large scale comparison of the positive and negative impacts of natural losses of habitat (e.g. seagrass losses in Hervey Bay, Queensland) in terms of changes in the composition of subsequent fisheries be quantified.

3. That development and success of the Fence Block-Off Method (FBOM) be recognised and that this method be adopted a standard for sampling of mangrove and other littoral wetlands.

4. That the information collected as a result of this study form part of the important base-line data for the Tin Can Inlet and be used as a reference point for comparison with post-construction fish communities if coastal development proposals such as the current Club-Med marina/harbour/residential proceed.

5. That further research projects be undertaken in assessing and documenting the specific roles of inter-tidal wetlands and adjacent terrestrial lands which act as biological contributor to and/or buffer for these wetlands.

I Introduction

Background

Of the total commercial fisheries catch for Queensland, valued at about $210 million annually, over 75% of products (by weight) are from estuary-dependent species (Quinn 1992). Similar findings in New South Wales have shown that estuary-dependent species comprise 66% by weight and 70% by value of the commercial catch (Pollard 1976). Dredge *et al.* (1977) estimated that between 75% and 90% of the landings from the Tin Can Bay/Great Sandy Strait were estuarine-dependent species. This region supported about 70 fishing operations and a fishery worth about $5m annually (Williams 1989). More than 150 major tourist developments have been proposed for the coast of Queensland (Kay 1989) applying considerable pressure to estuarine systems that are already subjected to the impacts of urban development. Any guidelines for the sustainable development in the coastal zone, from a fisheries viewpoint, must be based on an adequate knowledge of the interactions between estuarine habitats and the fisheries resources they support.

Studies of the effects of habitat disturbance on inshore fish faunas have been undertaken elsewhere in temperate environments (eg.; in California (Carlisle 1969) and in South Africa (Emersion *et al.* 1983)). However, it is unlikely the results of these studies can be transferred with any confidence to the significantly different subtropical inshore habitats and faunas of southern Queensland (Johannes and Betzer 1975). Mangrove and seagrass are more extensive, have a larger number of epiphytic algal associates and show higher growth rates in subtropical regions than in temperate areas. Hence the effects of development on these habitats and their faunas may differ. The need for further research on the impact of development on mangrove and seagrass communities has recently been recognised (Hatcher *et al.* 1989). If the fishing industry is to be sustained in terms of productivity, definition of habitat/fishery interactions will ensure further recognition of the specific requirements to protect the habitat. Maintenance of these requirements will provide for long term fisheries production.

Along the east coast of Australia seagrass and mangrove communities have been mapped using traditional field surveys providing a broad definition of fisheries habitats (Coles *et al.* 1985; West *et al.* 1985; Hyland and Butler 1988; Hyland *et al.* 1989). Remote sensing techniques are also being employed by QDPI Fisheries Services to monitor changes in inter-tidal and sub-tidal seagrass and mangrove communities (Lennon and Luck 1990; Danaher and Luck 1991; Danaher and Luck 1992). These techniques are being developed and refined as part of an ongoing project, enabling also the mangroves within large areas to be identified and mapped relatively quickly and at proportionally lower costs (Danaher 1994).

Although some literature exists on inter-tidal and sub-tidal habitat/fish/crustacean interactions (Bell *et al.* 1984; Staples 1984; Staples *et al.* 1985; Robertson and Duke 1987; Morton 1990; Robertson and Duke 1990) much of it has been centred on tropical systems. In Queensland, Fisheries Services biologists have also been involved in a number of studies investigating and documenting the effects of habitat disturbance on fish communities in canals (Morton *et al.* 1988), modified saltmarsh (Morton *et al.* 1987) and seagrass communities used by the bait-worm fishery (Luck 1989). Studies of the recovery of mangroves after and extended inundation of freshwater (Quinn and Beumer 1984) and of seagrass areas following major flooding of adjacent catchments (Preen *et al.* 1993, Hervey Bay seagrass loss - unpublished) have also been undertaken as part of Departmental research into fisheries and habitat relationships. Little is known about many of the different types of subtropical habitats and their interactions with estuarine-dependent fauna.

Extensive habitat studies addressing the interactions of crustacean faunas with seagrass along the Queensland coast and of fishes of subtropical *Avicennia marina* mangrove forests in southern Queensland respectively have recently been undertaken by QDPI Fisheries Service biologists (Coles *et al.* 1985; Morton 1990). Additional related projects commenced in 1990 in Moreton Bay to further our knowledge of the importance of various habitat types to commercially important crustaceans and finfish (Quinn, R. H. pers. comm. 1994, Masel J. pers. comm. 1994).

However, many habitat/fisheries relationships remain poorly understood and ill-defined. Management issues requiring resolution include the specific fisheries values of certain habitat, of certain species of mangroves, of "appropriate" littoral zones and of adjacent land-ward buffer strip width. Existing and projected coastal development has and will continue to impact on current fisheries. Minimising the loss of habitat and subsequent loss of fisheries production is the main outcome of research such as that reported here.

Technical information

The Great Sandy Region currently has large areas of pristine fisheries habitat (including undisturbed seagrass and mangrove areas) as well as areas currently subjected to relatively low human impacts (e.g. sewage discharge at Carlo Point and vessel mooring activity at Tin Can Bay and Pelican Bay). Several large water-front tourist developments are proposed for the Rainbow Beach/ Inskip Point region. Such developments will impact upon fisheries habitat by direct modification through marina development (eg. dredging, reclamation) and indirectly through changes in water quality (increased sewage discharges, higher nutrient levels in stormwater run-off; increased turbidity associated with construction and maintenance of marina facilities). Base line data on the seagrass and mangrove communities and associated fish and crustaceans in the Great Sandy Strait were obtained in 1973 (Dredge *et al.* 1977) and resurveys of the seagrass communities using ground-truthed remote sensing have recently been completed with a high level (83%) of accuracy (Lennon and Luck 1990).

A major impediment to the scientific management of inshore habitats and their dependent fisheries remains the inadequate levels of knowledge of the habitat interactions of inshore species of importance to fisheries, especially finfish and cephalopods in seagrass and mangrove areas. This project sought to identify and document inshore habitat types of prime importance to fisheries and will lead to the further development and refinement of guidelines for permissible levels and types of disturbance. With this knowledge, the critical habitat areas can be identified and afforded greater protection, for example as Reserves for Fisheries Purposes, under fisheries legislation. Amended guidelines would have applicability to other states, particularly Western Australia and the Northern Territory.

Study Outline and Site Description

This study was carried out in Tin Can Bay (25°54'S.,153°02'E.), at the southern end of the Great Sandy Strait, Queensland (Fig.1). It was divided into five broad sections:

1) juvenile and adult fish use of inter-tidal seagrass areas;
2) juvenile prawn use of inter-tidal seagrass areas;
3) fish use of subtropical *Rhizophora stylosa* mangrove forests;
4) mangroves and seagrass: their importance to the feeding patterns of estuary-dependent fish; and
5) research and commercial netting: their relative efficiency in determining fish use of estuarine areas.

Four methods of sampling fish and crustaceans were used:

a) beam and otter trawls
b) block nets
c) ring nets
d) commercial tunnel nets.

Samples from all methods were used to compile a comprehensive species list of fish found within Tin Can Bay (Appendix 1). Species identification was confirmed by staff at the Queensland Museum. Habitat and water quality were also recorded for the study area. Three sites (two in seagrass and one in mangroves) were sampled.

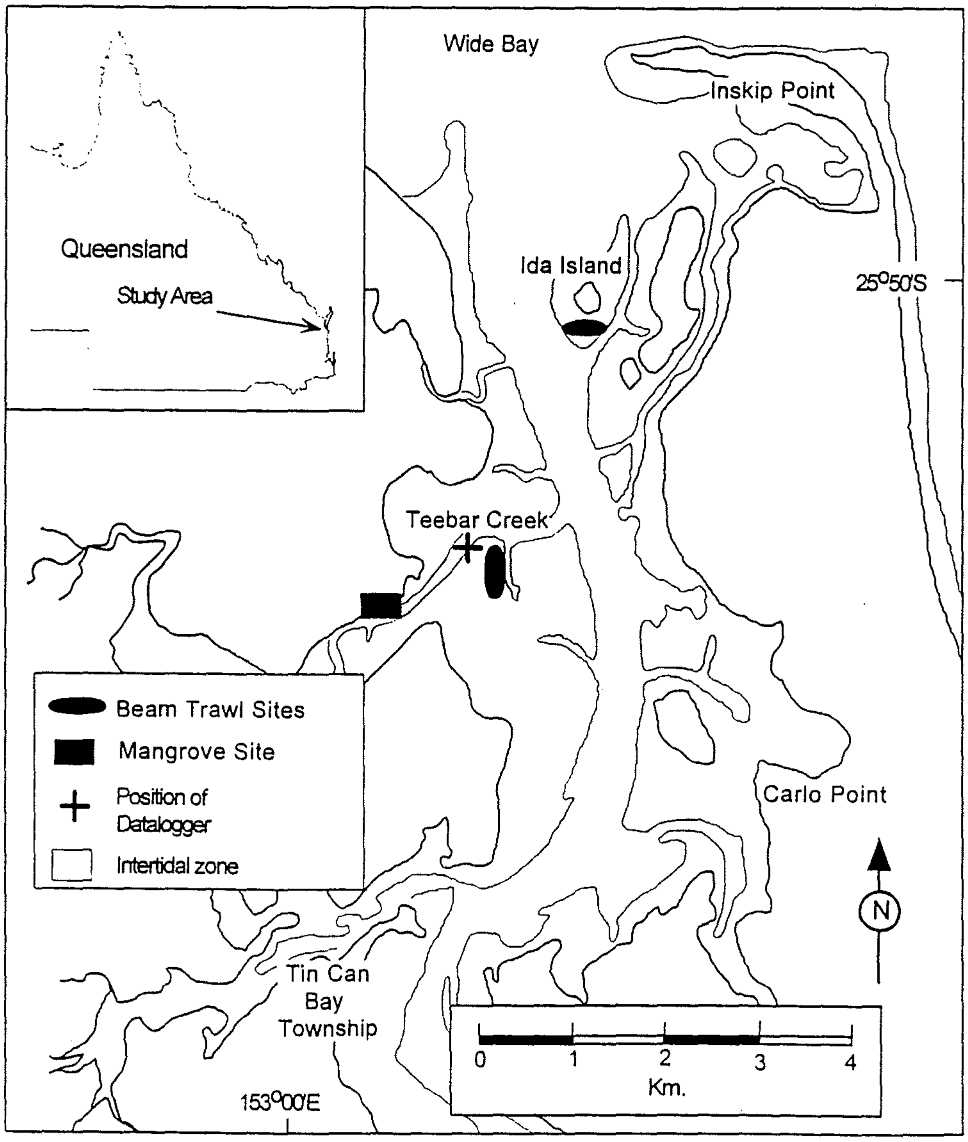
Within the Report, the terms recreational (amateur angling) and commercial fishing are used to represent the two sectors of the fishing industry. The term "economic" is used to described species of importance to either or both recreational and commercial fishers.

Seagrass Sites

Areas within the southern end of the Great Sandy Strait were identified as possible sampling sites from maps of seagrass distribution generated from satellite imagery (Lennon and Luck 1990). Potential sites were then inspected and the relative levels of seagrass abundance assessed. Two sites, Ida Island and Teebar Creek (Fig. 1), were selected to represent two different levels of vegetation cover (sparse and dense respectively). The sites were < 3 km apart, subject to similar weather conditions, > 150 m from the nearest mangrove stands and exposed during the last 2 hr of the run-out (ebb) tide. The sparsely vegetated Ida Island site is located on the eastern side of the main Tin Can Bay channel and the densely vegetated Teebar Creek site on the western side. Each site was about 800 m long and 500 m wide. Within each site beam trawling and ring netting was carried out at different locations.

Six seagrass samples were collected from each of the seagrass beds (sparse and densely vegetated) on the day after fish sampling using a 25 x 25 cm quadrat thrown randomly within the site. A trowel was pushed down around the edges of the sample to cut any rhizomes and roots that may have been connected under the surface. The sample was then lifted out into a 10 mm sieve and washed thoroughly. The collected seagrass was frozen and later identified. The above-ground and below-ground portions of each species were separated. The dry weight was determined after drying each sample in an oven for 48 h at 60°C.

Fig. 1: Site map of Tin Can Bay, Queensland indicating the inter-tidal seagrass and mangrove areas used in the study.



The seagrass composition of both sites was predominantly *Zostera capricorni*. *Halophila* spp. comprised < 1% of the total above-ground dry weight. The mean above-ground seagrass density at the sparse Ida Island site was 5.5 ± 0.3 g m^{-2} (mean ± s.e.) until August 1992. Seagrass at the sparse Ida Island site began dying-back during September 1992. During November 1992, there were still remnants of above-ground vegetation, but by January 1993, the majority of above-ground vegetation had died-back (Fig. 2a). The mean above-ground dry weight for the period after November 1992 to November 1993 was 0.6 ± 0.2 g m^{-2}, a reduction of approximately 89% in vegetation cover. Seagrass cover of the dense Teebar Creek site followed a seasonal pattern with an above-ground dry weight mean of 42.5 ± 2.7 g m^{-2} (Fig 2b).

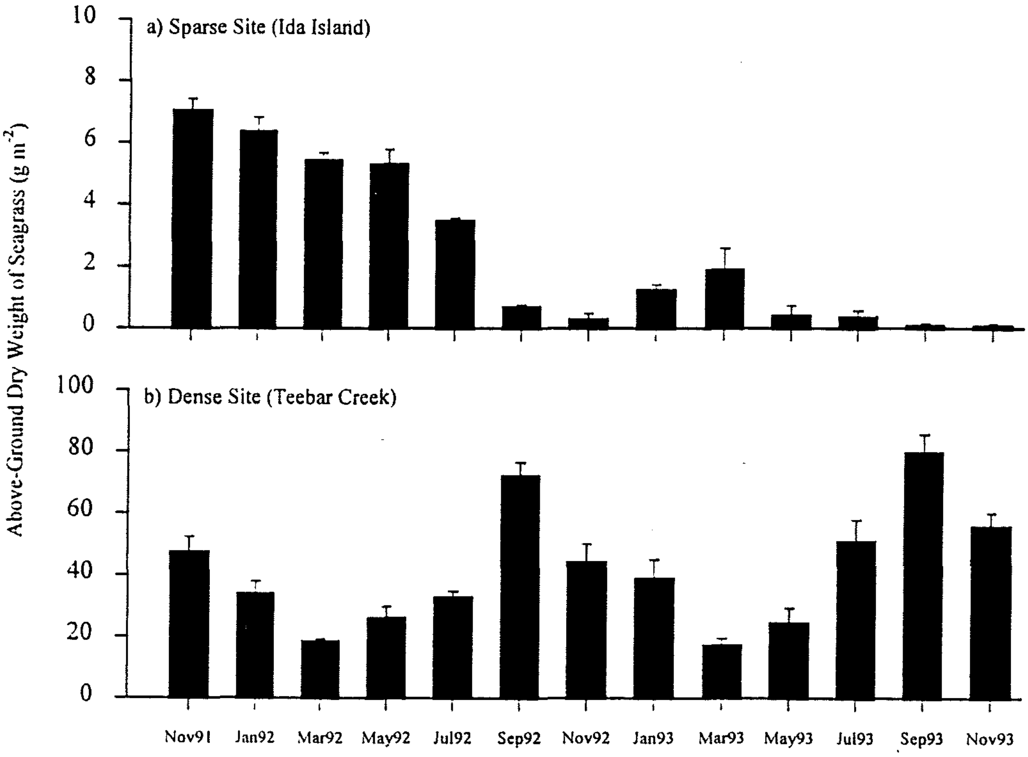


Fig 2: Above-ground dry weight of seagrass from the a) sparse site (Ida Island) and b) dense site (Teebar Creek). Note the different scales for each site. Vertical bars represent the standard error.

Mangrove Sites

A mangrove stand dominated by *Rhizophora stylosa* (< 5 m tall) was selected in Teebar Creek, Tin Can Bay (Fig. 1). *R. stylosa* comprised > 95% of the forest and *Avicennia marina* and *Bruguiera gymnorhiza* accounted for the remaining trees. The site was a small part of an extensive mangrove forest that lines the foreshore of most of the Great Sandy Strait. Saltmarsh extended landward of the site (about 20 m) and natural eucalypt forest existed beyond this. The inter-tidal zone from the saltmarsh to the mean low water mark was about 100 m in width, with *R. stylosa* mangrove forest covering the upper 40 m of the inter-tidal zone. The remaining 60 m of the inter-tidal zone consisted of sandy mud flats from the mangrove fringe to within 30 m of low water. The remaining 30 m of the inter-tidal zone was covered by *Zostera capricorni* seagrass.

Water Quality

Throughout the study, a submersible data-logger (DataSonde 3) was placed on a navigation marker about 300 m from the Teebar Creek beam trawl site (Fig. 1). Each hour, the datalogger recorded water temperature, salinity and tidal height.

Between-site differences in salinity and water temperature were negligible because of their close proximity. Salinity averaged 33.7 ± 0.01 ppt. The high average salinity indicates that the estuary is subjected to a strong oceanic influence and is not greatly affected by freshwater inflows. The water temperature averaged 23.4 ± 0.04°C and followed a seasonal pattern with a minimum daily temperature of 14.6°C in July 1992 and a maximum daily temperature of 32.2°C in January 1993 (Fig. 3). The high maximum temperature was recorded in summer was the result of shallow water being heated while on the inter-tidal zone and receding with the falling tide in mid-afternoon.

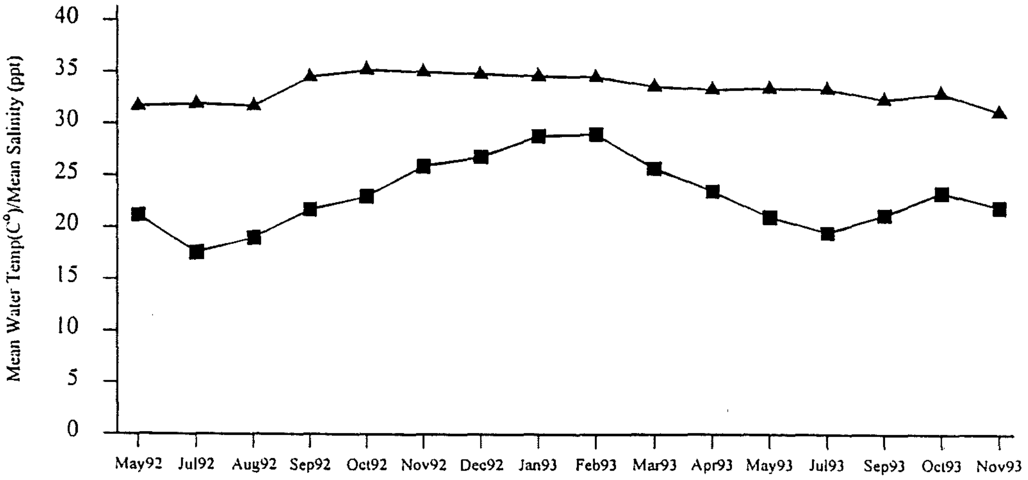


Fig. 3: Mean water temperature and salinity. Each point represents the mean of daily readings taken each month (▲ = salinity; ■ = water temperature).

II Juvenile and Adult Fish Use of Inter-tidal Seagrass Areas.

Methods

(a) Small Fish

Five samples of small fish (< 50 mm S L) were taken at each of the sites with a roller-beam trawl during each of the 13 sampling periods. Each tow lasting 2 min and covered about 50 m. The net and frame used for sampling was a replica of the roller-beam trawl described by Young (1975). Samples were taken every second lunar month at night on the full moon, or on the following two nights, from November 1991 to November 1993 (inclusive). Sampling was carried out at as near a possible to high tide to minimise the effect of tidal currents on catches. Samples were frozen for subsequent identification, measurement and counting.

(b) Large Fish

Three replicates, identical in size (20 x 20 m), were established adjacent to the beam trawl sites. Steel stakes were placed into the substrate during each sampling period allowing identification of the sites at high tide and providing support for the ring nets. Samples were taken by setting a multi-filament ring net (2.4 m high x 100 m long x 18 mm stretch mesh) around the stakes marking each replicate, from aluminium punt, at high tide. The end of each net was overlapped with its' beginning, by about 20 m, to prevent the escape of fish through the join. Fish from each replicate were collected at low tide.

Replicates were sampled on two consecutive nights. At the dense seagrass site (Teebar Creek) this was done one night before and on the full moon and at the sparse seagrass site (Ida Island) on the second and third nights after the full moon. Fish were identified to species, weighed (± 0.5 g) and the standard or total length measured as appropriate.

The counts and weights of fish caught in the beam trawl were positively skewed between sampling periods, so a log transformation (ln[n + 1]), was used to make the variance independent of the mean for subsequent parametric testing. Factorial analysis of variance was used in analysing the data.

Results

a) Small fish (beam trawl catches)

A total of 22 690 individuals representing at least 34 families and 52 species were caught from the two sites. At the sparse seagrass site (Ida Island) two fish species *Favonigobius exquisitus* and *Gerres oyeana* dominated catches comprising over 86% of the catch by number both before and after the above-ground seagrass at this site had died-off. Four fish species

(*Favonigobius exquisitus*, *Gerres oyeana*, *Siganus fuscescens*, and *Pseudorhombus jenynsii*) comprised over 69% of the catch by weight (Table 1). At the dense seagrass site (Teebar Creek) five fish species (*Favonigobius exquisitus*, *Pelates quadralineatus*, *Siganus fuscescens*, *Monacanthus chinensis* and *Centropogon marmoratus*) dominated catches representing over 81% of the catch by number and 73% of the catch by weight (Table 1).

Table 1: Relative abundance and weight for common fish species taken in the beam trawl at the sparsely (Ida Island) and densely vegetated (Teebar Creek) sites. Only fish that comprised > 1% of the total number or > 1% of the total weight have been included. Data for each site is pooled from all tows over 13 sampling periods.

SPECIES	Number of fish				Weight of fish			
	Sparse Total No.	% Total No.	Dense Total No.	% Total No.	Sparse Total Weight (g)	% Total Weight	Dense Total Weight (g)	% Total Weight
Favonigobius exquisitus	8620	56.28	2727	36.98	787.0	30.55	305.2	7.54
Gerres oyeana	4670	30.49	284	3.85	521.6	20.25	114.4	2.83
Favonigobius lateralis	378	2.47	204	2.77	156.2	6.07	72.7	1.80
Pelates quadralineatus	239	1.56	1608	21.80	84.4	3.28	1519.2	37.52
Siganus fuscescens	209	1.36	1063	14.41	243.6	9.46	554.2	13.69
Fry type 1	171	1.12	161	2.18	3.2	0.13	3.4	0.08
Arenigobius frenatus	99	0.65	71	0.96	54.4	2.11	56.2	1.39
Monacanthus chinensis	82	0.54	330	4.47	48.4	1.88	144.7	3.57
Centropogon marmoratus	74	0.48	308	4.18	79.9	3.10	469.2	11.59
Lethrinus fletus	57	0.37	90	1.22	33.6	1.30	15.5	0.38
Torquigener whitleyi	33	0.22	16	0.22	42.7	1.66	44.5	1.10
Pseudorhombus jenynsii	27	0.18	56	0.76	233.5	9.06	136.6	3.37
Upeneus tragula	7	0.05	-	-	28.9	1.12	-	-
Arothron hispidus	3	0.02	8	0.11	27.9	1.08	65.8	1.63
Tetractenos hamiltoni	1	0.01	2	0.03	42.4	1.65	83.2	2.05
Arothron manillensis	1	0.01	13	0.18	33.1	1.28	87.3	2.16
Papilloculiceps nematophthalmus	-	-	15	0.20	-	-	87.2	2.15
Chaetoderma penicilligera	-	-	1	0.01	-	-	55.3	1.37
Total for common species (number of species)	14671 (16)	95.81	6957 (17)	94.33	2420.8 (16)	93.98	3814.6 (17)	94.22
TOTAL FOR ALL SPECIES (number of species)	15315 (46)		7375 (51)		2576.3 (46)		4048.8 (51)	

Comparisons of the replicate samples taken from each site indicated that there was no significant difference ($p > 0.05$) between samples in terms of fish density and standing crop. Replicates samples were combined for the estimation of fish density (No. m^{-2}) and standing crop (g m^{-2}). Significant differences occurred in the number of fish ($p < 0.01$) caught between sites. However, there was no significant difference in the weights of the fish caught between sites. This was a result of the large number of *Favonigobius exquisitus* caught at the sparse site (56.3% by number) which weighed on average 0.096 g per fish (only 30.6% of the total weight) and the high number of *Pelates quadrilineatus* caught at the dense site (21.8% by number) weighing an average 0.82 g per fish (37.5% of the total weight). Significant differences occurred between sampling periods ($p < 0.01$) for both numbers and weights of fish caught. This represents the seasonal influx of large numbers of juvenile fish recruiting to the sites. Catches may have been higher at the sparse site because of better catch efficiencies of the beam trawl when sampling less vegetated areas.

b) Large Fish (ring net catches)

The species composition of the fish caught in ring nets was different from those caught in beam trawls with only 23 species occurring in both (28% common). There was little overlap in the size ranges of fish species caught by both methods. This indicates there was minimal overlap in sampling of fish of particular size ranges from within the community. A total of 2 378 fish of 30 families and 48 species were collected. *Gerres oyeana* and *Atherinomorus ogilbyi* numerically dominated the catches from both sites. By weight, the sparse site was not dominated by any particular species with no species constituting > 15% of the total catch (Table 2). Two species, *Gerres oyeana* (23%) and *Amphotistius kuhlii* (24%) dominated the catch by weight at the dense site.

Comparisons of catches taken by the ring nets on consecutive nights (Wilcoxon's paired test) indicated that there was no significant difference at the dense site but there was a significant difference ($p < 0.05$) between nights at the sparse site. Analysis of the catches (in terms of numbers and weights) between replicate sites on the same night indicated that there was no significant difference between replicates for either sites. As a consequence, only data for the first of the consecutive nights was for used in subsequent estimations of fish density and standing crop.

Overall, 1 709 large fish were caught in first night replicates weighing 55 704 g. The number of fish caught at each site was similar (844 at the sparse Ida Island site and 865 at the densely vegetated Teebar Creek site) but the fish caught at the dense site (38 186 g) weighed considerably more than those at the sparse site (22 864 g). Fish density (No. m^{-2}) for both areas was calculated to be 0.06 ± 0.01 fish m^{-2} and the standing crop was 1.64 ± 0.20 g m^{-2} at the sparse site and 2.85 ± 0.92 g m^{-2} at the dense site (Table 3).

Table 2: Relative abundance and weight for common fish species taken in ring nets at the sparsely (Ida Island) and densely vegetated (Teebar Creek) sites. Only fish that comprised > 1% of the total number or > 1% of the total weight have been included. Data for each site is pooled for all replicates over 13 sampling periods.

Species	Number of Fish				Weight of Fish			
	Sparse Total No.	% Total No.	Dense Total No.	% Total No.	Sparse Total Weight (g)	% Total Weight	Dense Total Weight (g)	% Total Weight
Atherinomorus ogilbyi	378	32.61	258	21.15	3205.6	9.40	2265.6	3.86
Gerres oyeana	213	18.38	385	31.56	4470.0	13.10	13538.5	23.04
Hyporhamphus ardelio	114	9.84	56	4.59	4962.1	14.55	2892.7	4.92
Tetractenos hamiltoni	99	8.54	52	4.26	1774.2	5.20	667.5	1.14
Sillago maculata	86	7.42	10	0.82	791.9	2.32	167.4	0.28
Sillago ciliata	74	6.38	51	4.18	2653.0	7.78	4302.9	7.32
Herklotsichthys castelnaui	33	2.85	132	10.82	811.6	2.38	3515.8	5.98
Sillago analis	31	2.67	59	4.84	374.6	1.10	991.0	1.69
Platycephalus fuscus	21	1.81	39	3.20	2359.9	6.92	5518.9	9.39
Sphyraena obtusata	19	1.64	11	0.90	1416.5	4.15	992.8	1.69
Platycephalus indicus	17	1.47	5	0.41	1755.8	5.15	712.4	1.21
Marilyna pleurostictus	13	1.12	-	-	137.7	0.40	-	-
Tylosurus gavialoides	9	0.78	-	-	1569.5	4.60	-	-
Pelates sexlineatus	7	0.60	-	-	542.7	1.59	-	-
Arrhamphus sclerolepis	6	0.52	-	-	587.0	1.72	-	-
Mugil georgii	-	-	15	1.23	-	-	98.1	0.17
Rhinobatus batillum	4	0.35	-	-	3937.1	11.54	-	-
Terapon jarbua	-	-	21	1.72	-	-	121.1	0.21
Papilloculiceps nematophthalmus	-	-	16	1.31	-	-	776.9	1.32
Amphotistius kuhlii	-	-	14	1.15	-	-	14650.2	24.93
Siganus fuscescens	-	-	14	1.15	-	-	33.6	0.06
Arothron manillensis	-	-	10	0.82	-	-	1494.5	2.54
Total for common species (number of species)	1124 (16)	96.88	1148 (17)	94.11	31349.2 (16)	91.90	52739.9 (17)	89.75
TOTAL FOR ALL SPECIES (number of species)	1159 (33)		1219 (43)		34112.2 (33)		58759.8 (43)	

Discussion

There was no significant change in the species composition or number of fish taken from either of the sites from year to year. This would have been expected if the seagrass density had stayed constant throughout the study. The decrease in seagrass at the sparse site (Fig. 2) was expected to cause a corresponding shift in species composition and decrease in fish numbers. The density of seagrass is not as important to the recruitment of larval fish as the need for some type of physical structure (Bell and Westoby 1986; Bell *et al.* 1987).

Although the numbers of fish caught at each site did not change with the seagrass loss, there may have been a species shift in the community. This possibility was examined for the ten most abundant species found at the sparse site with none of the species changing in their relative abundance between years. This is contrary to current knowledge in that bare areas are considered relatively unproductive compared with vegetated areas. In this study, the results indicate that the loss of the seagrass had no effect on the existing community.

Table 3: Comparison of mean density (No. m^{-2}) and standing crop (g m^{-2}) of fish communities using similar estuarine habitats.

Habitat type	Net type	Area sampled (m^2)	Density (No. m^{-2})	Standing Crop (g m^{-2})	Location	Source
seagrass	drop	10	9	15.0	Texas, USA	Gilmore et al. 1978
adjacent to mangroves	seine	1385	0.15	2.9	Queensland Australia	Morton 1990
seagrass	seine	1160	0.53	2.0	Texas, USA	Gilmore *et al.* 1978
seagrass	trawl	260-540	0.22	0.8	Florida, USA	Thayer *et al.* 1987
seagrass	trawl	20,000	0.04	-	New South Wales, Australia	Gibbs and Matthews 1982
sparse seagrass/mud flat	beam trawl ring net	~50 400	4.94 ± 0.45 0.06 ± 0.01	0.83 ± 0.10 1.64 ± 0.20	Tin Can Bay, Australia	Present study
dense seagrass	beam trawl ring net	~50 400	2.27 ± 0.24 0.06 ± 0.01	1.25 ± 0.23 2.85 ± 0.92	Tin Can Bay, Australia	Present study

At the dense site larger but fewer fish were caught. This would indicate that there are less fish in the densely vegetated areas (however this seems unlikely given the increased complexity of the area and the increased habitat for shelter and food production) or that the beam trawl was less efficient in the longer more dense seagrass and allowed a greater number of fish (particularly smaller individuals) to escape. Young and Wadley (1979) using identical gear excluded fish < 6 mm total length and > 10 cm to minimise the effect of net avoidance or escape. The lower limit was set from previous work carried out by Young (1975) and the upper limit from previous experience and underwater observation of the trawl net in operation. As all fish taken in our sampling fell within this range the effect of net avoidance would have been minimal.

Seasonal variations occurred in the density and standing crop of fish caught. This is largely due to the recruitment of juveniles in summer (January - March). For the larger fish, there was a seasonal trend with higher densities and standing crops occurring in autumn (March - July).

Of the studies on density and standing crop of fish using seagrass areas only few have attempted to look at both the small and large fish inhabiting an area (Kjelson *et al.* 1975; Gilmore *et al.* 1978). Our study was designed to use a combination of sampling methods that allow the capture of the entire size range of the fish that inhabit an area. Ring net catches from both the sparse and dense sites are comparable to those of other studies using methods taking similar sized fish (Table 3). The addition of the beam trawl samples to the density increases the number of fish m^{-2} in sparse seagrass by over 80 times and in dense seagrass by 35 times. This indicates that there is a large number of small fish using inter-tidal seagrass beds that often remain unsampled. The importance of this habitat for these fish is therefore not recognised. The standing crop of the small fish taken in the beam trawl is about half that of the ring nets in both sites. This is a substantial contribution that is often not included when the relative production of an area is being assessed as these fish are often not recorded.

In terms of fish production, the inter-tidal areas like those found in Tin Can Bay can be as productive as adjacent mangrove areas. One major difference between the inter-tidal seagrass and mangrove areas is that in the mangrove areas support a large proportion of fish with some economic value but inter-tidal seagrass areas support fish that are not considered to be of direct economic value.

III Juvenile Prawns Use of Inter-tidal Seagrass Areas

Methods

Juvenile and post-larval prawns were collected concurrently with the beam trawl fish, using the same apparatus. Only data for post-larval (2-3 mm carapace length, CL) and juvenile prawns (3-11 mm CL) were used for analysis. Sub-adult prawns (> 11 mm CL) were excluded from the results as these migrate into deeper water and exhibit greater net avoidance (Young 1975; Coles and Greenwood 1983). Juvenile prawn counts were positively skewed between sampling periods so a log transformation (ln[n + 1]) was used to make the variance independent of the mean for subsequent parametric testing. Factorial analysis of variance was used in analysing the data.

Results

A total of 37,023 individuals of four species of juvenile commercial prawns were caught from the two sites. Eastern king prawns, *Penaeus plebejus*, represented 84.9% (31,465) of the total catch; greasy prawns, *Metapenaeus bennettae*, 11.1% (4,090); endeavour prawns, *M. endeavouri*, 2.4% (872); and brown tiger prawns, *P. esculentus*, 1.6% (596).

Penaeus plebejus

Juvenile and post-larval *P. plebejus* dominated the catches at both sites. Of the total juvenile *P. plebejus* catch, 70.9% (22,306) were caught at the sparse site and 29.1% (9,159) at the dense site. Initially (1992), *P. plebejus* numbers between the sparsely or densely vegetated sites were similar (Fig. 4a). Catches at the sparse site were significantly higher ($p < 0.01$) than at the dense site, following the seagrass die-back (November 1992), suggesting that juvenile and post-larval *P. plebejus* prefer bare substrates or their catchability changed. At both sites, during both years, seasonal variations in the abundance of *P. plebejus* were evident ($p < 0.01$) with catches being highest during winter (May - July). This was also the peak recruitment period of post-larval prawns (2-3 mm CL) at both sites (Fig. 5a).

Metapenaeus bennettae

Juvenile and post-larval *M. bennettae* occurred at both sites in almost equal numbers, 45.9% (1,876) at the sparse site and 54.1% (2,214) at the dense site. No significant difference in the abundance was found between the sites. Catches were significantly greater ($p < 0.01$) in winter (May-July) and there was a period of low recruitment following this in spring (September-November) in both years (Fig. 4b). *M. bennettae* were not expected to be abundant in either site as this species is known to prefer less saline habitats (Young 1978) than those of Tin Can Bay.

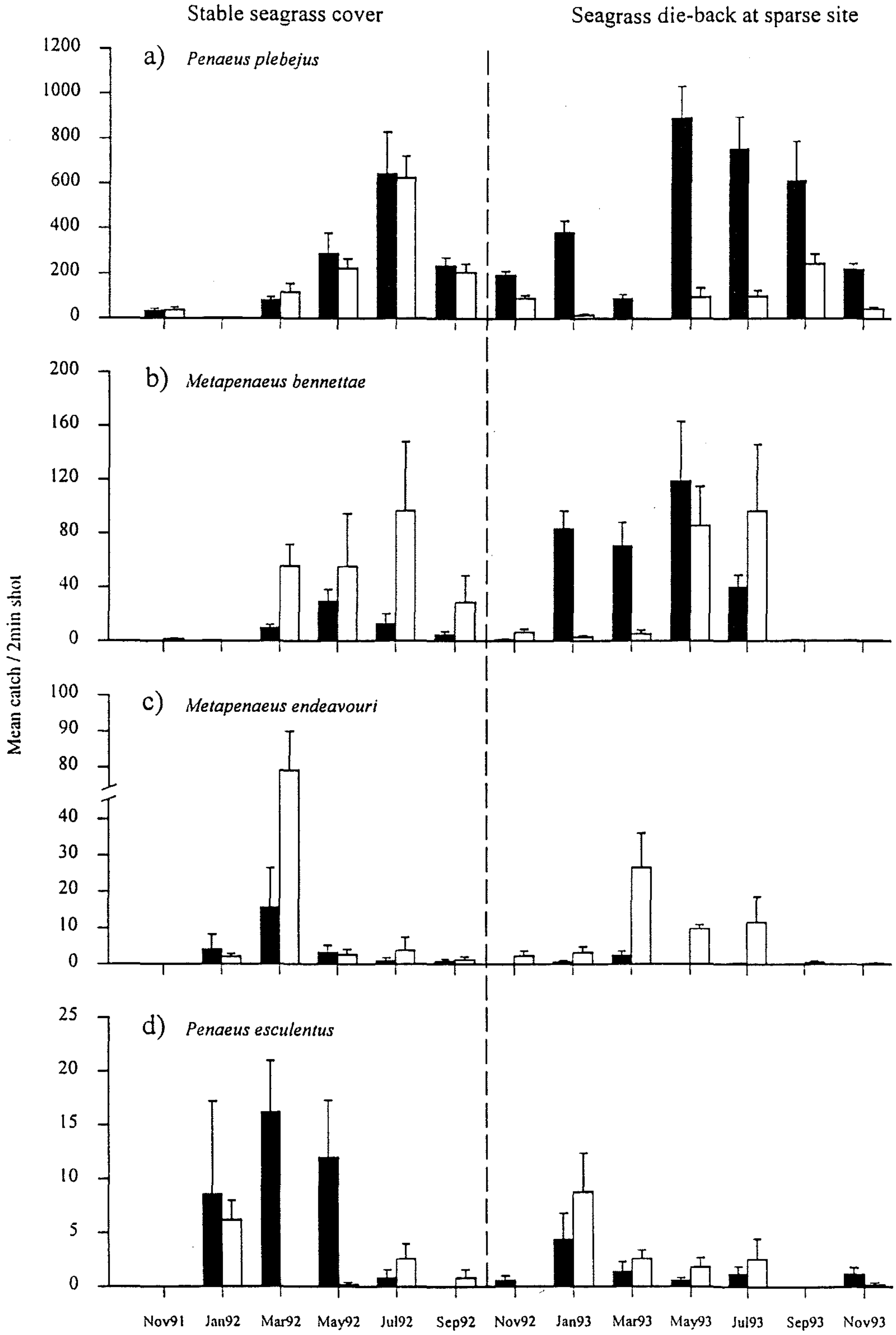


Fig. 4: Bimonthly variations in mean catch per shot of juvenile a) *Penaeus plebejus*, b) *Metapenaeus bennettae*, c) *M. endeavouri* and d) *P. esculentus* at the sparsely vegetated site (solid histograms) and the densely vegetated site (open histograms). Note the different scales for each species. Vertical bars represent standard error. The right hand side of the dashed line indicates seagrass die-back at the sparse site.

Metapenaeus endeavouri

Juvenile and post-larval *M. endeavouri* were not common at either site. Of the total catch, 16.2% (141) were caught at the sparse site and 83.8% (731) at the dense site. Before the seagrass die-back at the sparse site only a few juvenile *M. endeavouri* were caught at either site. After the seagrass was lost from the sparse, a significant ($p < 0.01$) increase in abundance at the vegetated site occurred. Catches were highest around March in both years (Fig. 4c).

Penaeus esculentus

Juvenile *P. esculentus* were not numerous. They occurred in almost equal numbers at both sites, 249 at the sparse site and 347 at the dense site. No significant differences in abundance were recorded between sites. Highest catches occurred in summer (January - March) before and after the seagrass died (Fig. 4d). Juvenile *P. esculentus* are known to prefer seagrass habitat and were not expected to inhabit the sparse site after the seagrass died as expected (Young 1978).

Discussion

The natural loss of the above-ground inter-tidal vegetation may not be as damaging to fisheries production as it is often considered to be, given that there is a shift in species composition of prawns associated with the loss of habitat. The increases in the number of juvenile and post-larval *Penaeus plebejus*, with the loss of vegetation at the sparse site, suggests that the seagrass loss increased the potential prawn production of this species of that site. The substantial increase in the abundance of juvenile *P. plebejus* on the bare substrate conflicts with the commonly held belief that areas covered by seagrass are more productive than unvegetated inter-tidal areas. Juvenile and post-larval *Metapenaeus endeavouri* prefer seagrass habitats (Staples *et al.* 1985) and were not as abundant at the sparse site after the seagrass die-back. Juvenile *M. bennettae* and *P. esculentus* are also known to prefer seagrass as juveniles but their abundances did not decrease after the seagrass die-back.

Fecundity of commercial species of prawns ranges from 100,000 to 1,500,000 ova (Dall *et al.* 1990) indicating that the survival rates of juvenile prawns are very low. Thus it is difficult to estimate the absolute value of a nursery area to a specific fishery. There is no doubt that increased abundance of juvenile prawns will, in the long term, be beneficial by increasing the number of recruits to the adult population, providing a greater food source for higher predators and a potentially higher commercial harvest. A high abundance of juveniles in nursery areas is always desirable but predation, unfavourable environmental conditions, food availability and disease are all factors that may influence survival to maturity.

Post-larval prawns enter estuaries in flood tide currents and settle onto the substrate before being carried back out of the estuary on the ebb tide (Hughes 1969; Hughes 1972; Young and Carpenter 1977). This mechanism places post-larval and juvenile prawns within the estuary but not necessarily in their preferred nursery habitat. Two subsequent events may occur:

1) the juvenile prawns remain in the place of initial settlement and their survival is determined by the prevailing environmental conditions; or
2) the juvenile prawns actively select preferred nursery areas by moving with the tidal currents until a suitable area is found.

There is little information on the ability of juvenile prawns to actively select preferred nursery areas after their initial settlement into an estuary. This is probably due to difficulty in tracking the movements of juvenile prawns over relatively large areas. Data collected in 1992 suggests that the numbers of juvenile *P. plebejus* recruits that settled and remained in the two study sites were about equal until the seagrass at the sparse site died. During 1993, if the seagrass at the sparse site had remained, it would have been expected that the number of juvenile *P. plebejus* recruiting to both sites would have been about equal regardless of the number of post-larval recruits entering the estuary (ie. about the number caught at the dense site). That this clearly was not the case suggests that the juvenile prawns have actively selected the sparse (now bare) site as a nursery ground. The increased numbers of 4-5mm CL *P. plebejus* (Fig. 5b) at this same time suggests that juvenile *P. plebejus* will actively move to preferred nursery areas after having settled in the estuary as post-larvae.

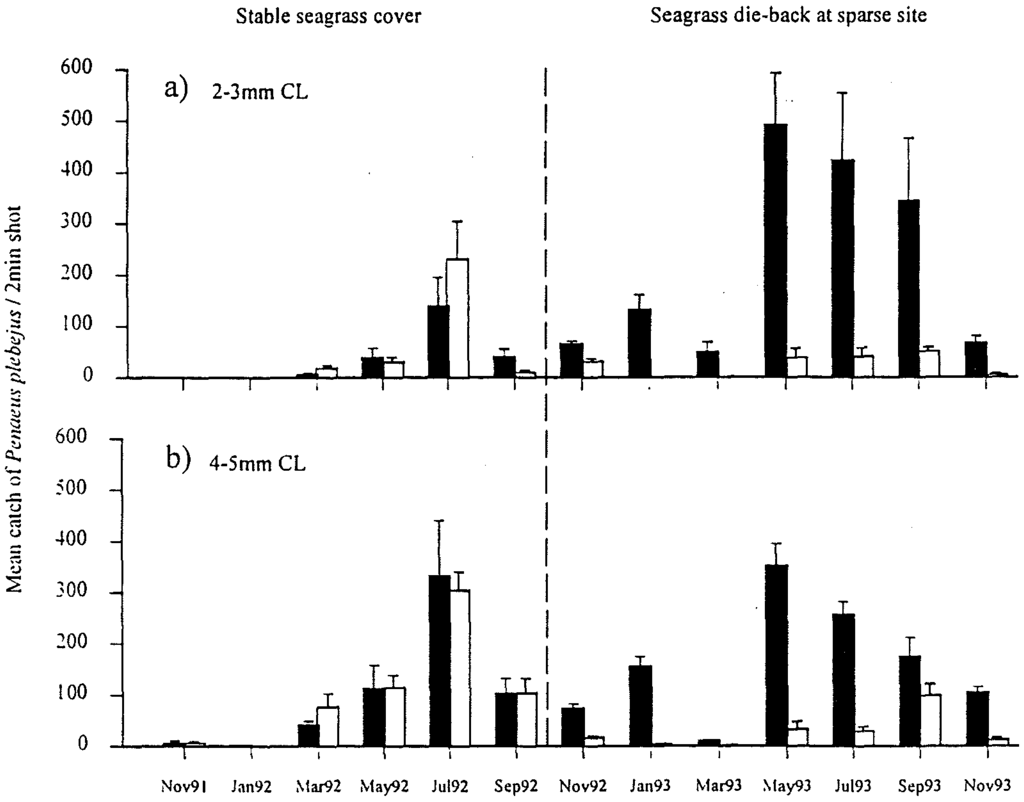


Fig. 5: Bimonthly variations in the mean catch of post-larval (2-3mm CL) and juvenile (4-5mm CL) *Penaeus plebejus* at the sparsely vegetated site (solid histograms) and the densely vegetated site (open histograms). Vertical bars represent standard error. The right hand side of the dashed line indicates seagrass die-back at the sparse site.

In tropical mangrove forests juvenile banana prawns, (*P. merguiensis*) feed and move into and out of the inter-tidal zone with the tide (Robertson 1988a). There is no corresponding information about the movement of juvenile *P. plebejus* and *M. bennettae* within inter-tidal zones but these species may do one of two things: 1) bury in the substrate and emerge only when the tide returns or 2) move in and out of the inter-tidal zone as *P. merguiensis* do. If *P. plebejus* do bury in the substrate then their preference for a bare areas suggests that ease of digging maybe a critically important factor in preferred site selection.

The catchability of juvenile prawns has been shown to change with size, current and substrate (Young 1975; Coles and Greenwood 1983). In the current study the loss of seagrass has not been considered as a major influence on the number of juvenile prawns caught as the extent of above-ground seagrass present at the sparse site before the die-back was very low. This would have provided little protection from being caught in the roller beam trawl. Catch rates were similar in the sparse and densely vegetated sites for the initial stages of the sampling regime. It is therefore considered that the die-back of seagrass at the sparse site did not increase sampling efficiency, leading to the increased catches of juvenile prawns.

Salinity is a major influence on determining the suitability of a nursery area (Ruello 1973; Young 1978; Coles 1979) as penaeid prawns can detect changes in salinity of 1 ppt (Hughes 1969). Juvenile *P. plebejus* prefer saline areas (Young 1978) and were similarly abundant at the two study sites when both were vegetated. As these sites were in relatively close proximity and the salinity averaged > 30 ppt, it is unlikely that salinity influenced settlement into one or the other of the sites. *M. bennettae* prefer low salinities (< 20 ppt) (Coles and Greenwood 1983) and this is probably why this species was not abundant at either site. This preference for lower salinities suggests that the juvenile *M. bennettae* caught at both sites had not settled into a preferred nursery habitat and may explain why there was no significant change in the abundance of *M. bennettae* on the sparse site after the seagrass loss. Other environmental factors such as water temperature, turbidity, plant cover and sediment composition have been previously investigated but no single parameter being a consistent nursery habitat requirement for *Penaeus* spp. or *Metapenaeus* spp. (Penn 1981).

Prawns are opportunistic omnivores feeding on small fish and crustaceans, polychaete worms, bivalve molluscs and protozoans (Racek 1959). The nutrient added by the dying seagrass may have provided a localised habitat favourable to these prey animals allowing greater numbers of juvenile prawns to inhabit the bare substrate. If food availability was limiting, it would be expected that all types of post-larval prawns would have settled into the site.

The loss of seagrass from extensive areas may potentially increase the *P. plebejus* yield in adjacent fisheries. It may also have an adverse effect on other fisheries. Seagrass is a source of food for many estuary-dependent fish and its' loss may create a decrease in the catch of these species, especially sea mullet (*Mugil cephalus*)(Thompson 1963). Short term natural fluctuations in environmental conditions (e.g. vegetation cover, salinity, temperature and turbidity), provide estuary-dependant fauna with a range of conditions that ensure for long-term survival of these species. Permanent destruction and modification of inter-tidal habitat, as a result of coastal development, has the potential to affect all economic fisheries. The greatest threat to fisheries is not from over-fishing or competition for the resource but permanent habitat loss and alteration and pollution (Moberly 1993) as this removes all potential production of the area.

The Great Sandy Straits region currently has extensive areas of sand, mud and seagrass flats that are in a state of flux with seagrass beds continually extending and dying back. These natural fluctuations have provided conditions favourable to the survival of juvenile *P. plebejus* on the sparsely vegetated inter-tidal areas of Ida Island through a combination of high salinity and bare substrate. As environmental conditions change, the suitability of such habitat for *P. plebejus* survival will also change, providing in part, an explanation for year to year variations in commercial prawn catches.

IV Fish Use of a Subtropical *Rhizophora stylosa* Mangrove Forest

Methods

Four replicate sites, identical in width and depth (25 x 40 m), were established in the mangrove sample site at Teebar Creek. Sampling of fish was undertaken by the Fence Block-Off Method (FBOM), described below (Appendix 2). Five parallel corridors (about 20 cm wide) were cut through the mangrove prop roots and low hanging branches along the tidal profile to the mean high tide mark (40 m) (Fig. 6). Nylon hail net (18 mm stretch mesh) was placed in each of the parallel corridors creating four separate replicate sites with an area of 1000 m^2 each. The top of each hail net was sewn to ropes hung between wooden stakes (30 x 30 mm) that were driven into the substrate along the corridors. The bottom of each hail net was buried in the substrate creating a permanent fence. The nets proved to be relatively low in maintenance with minimal leaf letter and algal build-up.

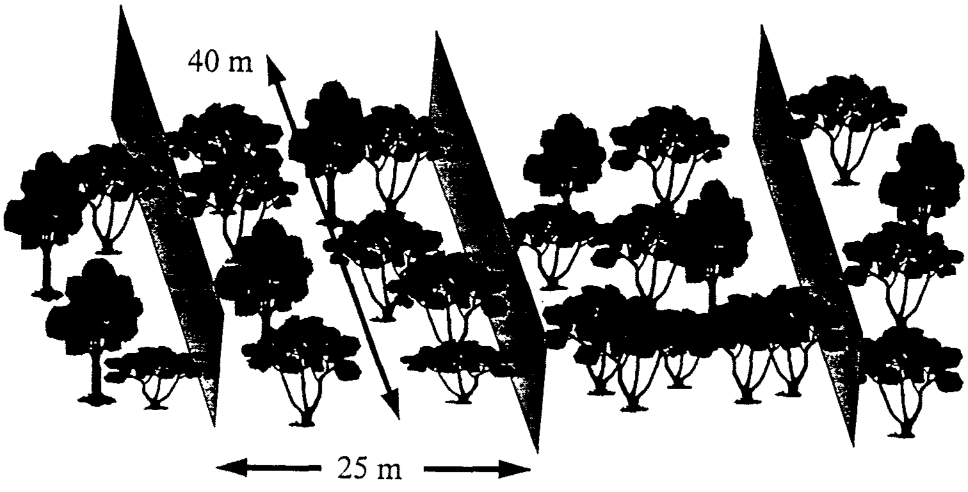


Fig 6: Schematic diagram of the Fence Block-Off Method (FBOM). Permanent nets were positioned through the mangroves with the bottom edge buried in the substrate. Fish sampling was done at high tide by setting a net along the seaward edge of the fence nets, attaching it to each fence and collecting the fish after the tide has fallen.

Samples were obtained by setting a multi-filament block net (120 m long x 1.2 m deep x 18 mm stretch mesh) along the seaward edge of the replicate sites at high tide. At each end of the replicate sites the block net was attached to the permanent fence net to prevent fish moving to adjacent replicate sites as the tide fell. The lead line of the block net was not buried in the substrate. Escape of fish may have occurred as the tide fell. Paired samples were taken from each replicate on consecutive nights, the night before and the night of the full moon, every second lunar month from November 1991 to November 1993 inclusive. Fish from each replicate site were collected from along the block net at low tide. Fish were identified to species, weighed (±0.5 g) and the standard or total length measured as appropriate.

Shannon-Wiener diversity indices, H' (Pielou 1969; Cox 1980), were calculated for each sample [$H' = -\sum_{i=n}^{n} P(i) \ln P(i)$, where $P(i)$ is the ratio of the number of individuals of species i, to the total number, n, of individuals in the sample]. The Wilcoxon test for paired observations (Sokal and Rohlf 1981) was used to compare differences in fish density (No. m^{-2}), standing crop (g m^{-2}) and diversity indices (H') between sample pairs from consecutive nights. Samples in which one or both nights catches were not taken because of inclement weather or fouling of the block net during its setting, were regarded as missing values and not included in the analysis.

A factorial analysis of variance (ANOVA) was used in analysing the between replicate site catches and catches over time for both total numbers and total weights. Fish numbers and total weights were log transformed ($\ln[n + 1]$) to make the variance independent of the mean.

Fish were classified (Thompson 1954; Thompson 1959; Blaber and Blaber 1980; Bell *et al.* 1984; Morton *et al.* 1987; Morton 1990) as belonging to one of five trophic levels for comparisons with other studies:

a) detritivores (feed mostly on detritus);
b) herbivores (feed mostly on plant material);
c) planktivores/microbenthic carnivores (feed mostly on plankton, small epibenthic animals and small amounts of detritus);
d) intermediate carnivores (feed mostly on macrobenthos with limited plant material and small fish); and,
e) predators (feed mostly on fish with limited macrobenthos).

Results

A total of 3,320 fish weighing 141 498 g of 42 species from 24 families were caught in all replicates from both nights over the study period (November 1991 to November 1993). Six species of fish, *Acanthopagrus australis*, *Gerres oyeana*, *Mugil georgii*, *Sillago analis*, *S. ciliata* and *Tetractenos hamiltoni* comprised > 87% by number and > 58% by weight of the catch. No other individual species represented > 3% of the total number caught. Fish of commercial importance in the region (Table 4) comprised > 63% by number and > 87% by weight of the total catch. Of the 42 species taken 11 were represented only once in the replicate samples and 6 occurred only twice (% total number = 0.03 and 0.06 respectively in Table 4).

Table 4: Percentage abundance and biomass for total fishes taken from within a subtropical *Rhizophora stylosa* mangrove forest in Tin Can Bay. J: juvenile, A: adult, C: commercial, R: recreational, -: no direct value

Trophic level and species	% of total number	% of total weight	Life history stage	Fishery
Detritivores				
Liza subviridis	0.06	0.31	J/A	C/R
Mugil cephalus	2.62	19.73	A	C/R
Mugil georgii	13.86	2.52	J	C/R
Myxus elongatus	0.06	0.02	A	C/R
Planktivores/microcarnivores				
Ambassis marianus	0.69	0.05	J/A	R
Atherinomorus ogilbyi	2.83	0.44	J/A	R
Gerres oyeana	13.13	2.39	J/A	R
Herklotsichthys castelnaui	0.66	0.05	A	-
Herklotsichthys koningsbergeri	0.03	<0.01	A	-
Thryssa hamiltoni	0.03	0.01	A	R
Herbivores				
Arrhamphus sclerolepis	0.06	0.15	A	C/R
Girella tricuspidata	0.60	8.79	A	C/R
Hyporhamphus ardelio	1.17	0.64	J/A	C/R
Kyphosus gibsoni	0.03	0.25	A	-
Scatophagus argus	0.12	1.18	A	C
Selenotoca multifasciata	0.09	0.57	A	C
Siganus fuscescens	0.39	0.84	J/A	R
Intermediate Carnivores				
Acanthopagrus australis	13.04	40.44	J/A	C/R
Achlyopa nigra	0.03	0.04	J	R
Arothron manillensis	0.09	0.13	J/A	-
Caranx sp.	0.03	0.07	A	C/R
Dicotylichthys myersi	0.03	0.92	A	-
Gnathanodon speciosis	0.12	0.06	J	C/R
Glossogobius sp.	0.09	<0.01	A	-
Lagocephalus lunaris	0.03	0.15	J	-
Marilyna pleurostrictus	0.09	0.28	A	-
Monodactylus argenteus	0.06	0.04	A	-
Plotosus lineatus	0.03	0.21	A	-
Rhabdosargus sarba	0.09	0.11	J/A	R
Sillago analis	22.77	6.20	J	C/R
Sillago ciliata	8.43	2.39	J	C/R
Scomberoides commersonianus	0.03	<0.01	J	C/R
Tetractenos hamiltoni	15.51	4.38	J/A	-
Terapon jarbua	1.57	0.20	A	-
Predators				
Lutjanus argentimaculatus	0.06	0.92	A	C/R
Lutjanus russelli	0.30	0.55	J/A	C/R
Platycephalus fuscus	0.42	2.48	J/A	C/R
Platycephalus indicus	0.03	0.03	J	C/R
Psammoperca waigiensis	0.03	0.15	A	R
Sphyraena barracuda	0.06	0.33	A	R
Sphyraena obtusata	0.33	0.62	A	R
Tylosurus gavialoides	0.24	1.34	A	R

The total catch from all first night sampling periods was 2 442 individuals weighing 92 909 g. This represents 73.6% by number and 65.7% by weight of the total catch. The Wilcoxon paired-observation test showed a significant difference in the number ($p < 0.01$) and weight ($p < 0.05$) of fish caught in replicate sites on consecutive nights with the first night consistently higher. Changes in Shannon-Wiener diversity indices (H') ($p > 0.05$) and the number of species ($p > 0.05$) present in samples from consecutive nights were not significantly different.

As there was significant differences in the number of fish caught on consecutive nights only samples taken on the first night were included in subsequent analyses. The number of fish caught between replicates ($p < 0.05$) were significantly different. However this pattern was not reflected in the weights ($p > 0.05$). Minor variations in the microhabitat of the replicates may have caused differences in the numbers of fish caught. Replicate 4 had a small natural soak that ran through the mangroves, causing a slight depression with a very small continuous fresh water output even at low tide. This was the only observable difference in the sites and may have attracted certain species of fish. The number ($p < 0.01$) and weight ($p < 0.05$) of fish caught varied significantly across the year indicating a seasonality in abundance of many of the fish species.

Mean fish density for samples taken on the first night from the four replicate sites was 0.05 ± 0.01 fish m^{-2} (± s.e.) (Table 5) and ranged from 0.01 ± 0.00 fish m^{-2} (September 1992) to 0.11 ± 0.02 fish m^{-2} (May 1993). The mean standing crop for the four replicate sites was 2.01 ± 0.53 g m^{-2} and ranged from 0.76 ± 0.26 g m^{-2} (September 1993) to 6.45 ± 1.75 g m^{-2} (July 1992). Shannon-Wiener diversity indices (H') had a mean value of 1.43 ± 0.06 and ranged from 0.83 ± 0.16 (September 1992) to 1.83 ± 0.08 (March 1993) (Fig. 7).

Table 5: Mean density (No. m^{-2}), standing crop (g m^{-2}) and species diversity (H') for fish caught from November 1991 to November 1993 in four replicate sites (1000 m^2 each) of a *Rhizophora stylosa* mangrove forest, Tin Can Bay, Australia.

	Replicate 1	Replicate 2	Replicate 3	Replicate 4
Density (No. m^{-2})	0.03 ± 0.01	0.03 ± 0.01	0.07 ± 0.02	0.08 ± 0.02
Standing Crop (g m^{-2})	1.57 ± 0.53	2.18 ± 0.68	1.78 ± 0.34	2.49 ± 0.77
Species Diversity (H')	1.31 ± 0.16	1.49 ± 0.11	1.29 ± 0.10	1.64 ± 0.09

The water quality at the mangrove site was as described in the Water Quality section of the Study Outline and Site Description.

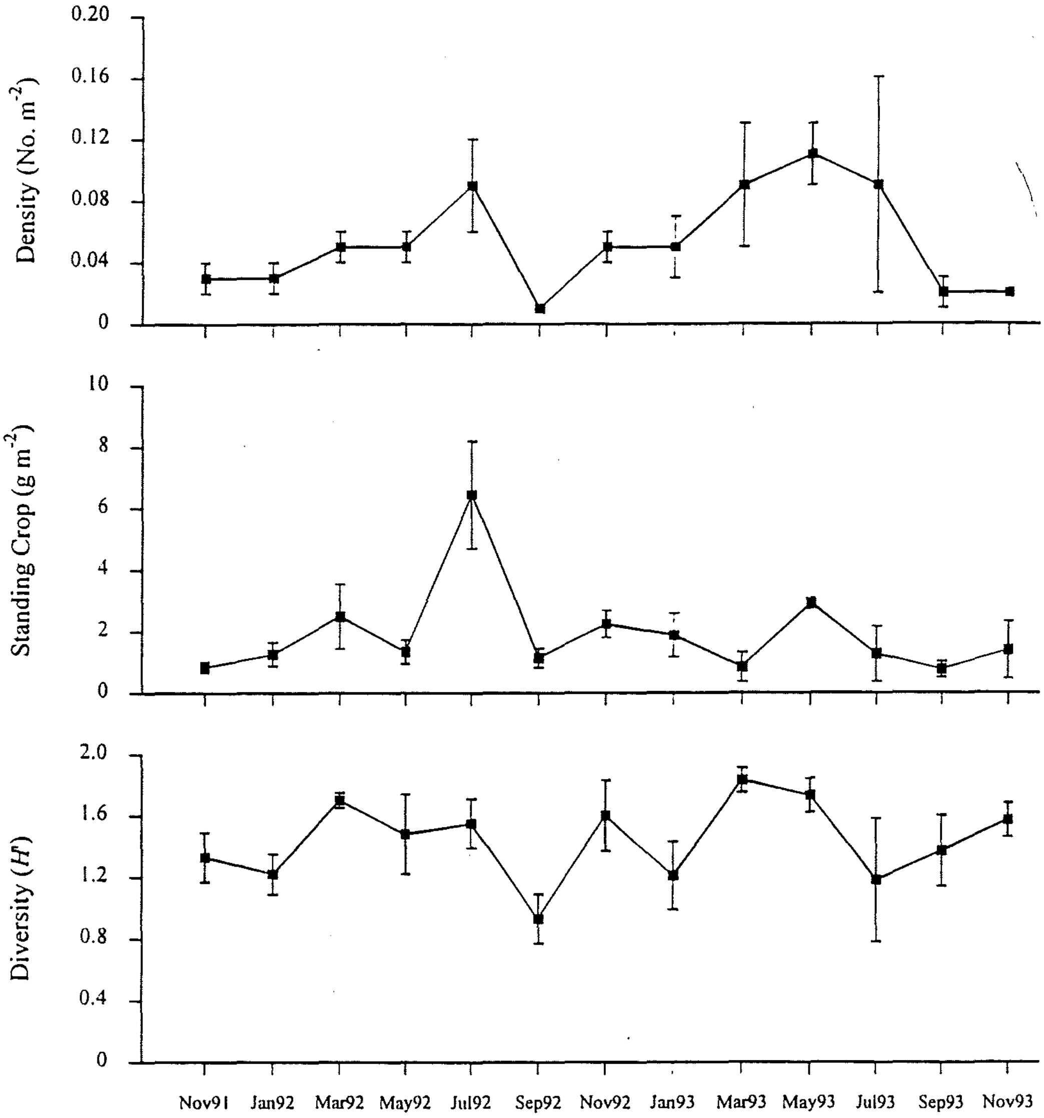


Fig. 7: Fish density (No. m^{-2}), standing crop (g m^{-2}) and Shannon-Wiener diversity (H') taken from four replicate sites within a subtropical *Rhizophora stylosa* mangrove forest from November 1991 to November 1993. All samples were taken at night on the night before the full moon. ■ = Mean (±s.e.) for all replicate sites combined. Note different scales for all figures.

Discussion

Direct use of subtropical *Rhizophora stylosa* mangrove forest by fish is less than that recorded for other types of mangrove forest in Australia (Table 6). The FBOM netting technique resulted in the capture of both pelagic and demersal fish species that enter the mangrove forests rather than just those inhabiting its seaward fringes. From mark and recapture studies of eight species of fish, Morton (1990) estimated the efficiency of the block net to be between 66-100% with an average of 88%. This implies that the recorded number of demersal fish (such as *Sillago analis*, *S. ciliata* and *Platycephalus fuscus*) could be under-estimated by about 12% due to an ability to escape under the lead line of the block net. With our sampling technique only fish present in the forest at the time that the block net was put in place were sampled (ie. at high tide on the night before the full moon). It is possible that some fish had entered and left the forest prior to high tide; if this were the case then our results would be under-estimates. Differences in the catch rates of different replicate sites may also have occurred if fish moved onto the inter-tidal zone following natural depressions as these fill with water. This would have meant that more fish were swimming directly into the replicate site 4 than into other replicate sites because of the natural soak that existed there. Once in replicate site 4 the lateral movement of these fish may have been restricted because of the fence nets. The fence nets would have also restricted access to the fenced areas by fish that initially moved into areas outside the replicate sites.

The fish communities using subtropical *Rhizophora stylosa* mangroves in Tin Can Bay, were dominated by intermediate carnivores. Three of the four most abundant species (*Acanthopagrus australis*, *Sillago analis* and *S. ciliata*) comprised > 40% by number and > 49% by weight of the total catch. The families Atherinidae, Gerreidae, Mugilidae, Sillaginidae, Tetraodontidae and Sparidae represent > 92% of the total number of fish caught. Economically important fish of the families Mugilidae, Kyphosidae, Sparidae and Sillaginidae represented > 61% by number and > 80% of the total weight of the total fish caught. Juveniles and adults of all economically important species were present, except for *Mugil cephalus* which occurred only as adults. The fish density (0.05 ± 0.01 m^{-2}) and standing crop (2.01 ± 0.30 g m^{-2}) of fish in subtropical *R. stylosa* forests are the lowest values reported for Australian mangrove forests (Table 6).

Botany Bay, (34°1'S.,151°11'E.), supports temperate *Avicennia marina* mangrove forests. Bell *et al.* (1984) reported the families Ambassidae, Kyphosidae, Mugilidae, Tetraodontidae and Gerreidae as the most abundant, while Gobiidae and Sparidae were common. In their study, species of economic importance constituted 38% of the individuals and 32% of the total weight but occurred only as juveniles. The proportion of economically important species from forest are lower than those found in the subtropical *Rhizophora stylosa* forest. However the fish density (~0.94 m^{-2}) and standing crop (~6.4 g m^{-2}) are higher.

Avicennia marina mangroves dominate most of the coastal fringe of Moreton Bay, (27°20'S.,153°15'E.) (Hyland and Butler 1988). Studies of undisturbed habitats within this large subtropical estuary found that fish numbers are dominated by the families Chandidae, Atherinidae, Mugilidae, Sillaginidae, Kyphosidae, Hemiramphidae, Tetraodontidae and Sparidae (Stephenson and Dredge 1976; Quinn 1980; Morton *et al.* 1987; Morton 1990). These taxa are similar to those dominating in subtropical *Rhizophora stylosa* and temperate *A. marina* mangrove forests. As in the present study, the families Mugilidae, Kyphosidae, Sparidae, Sillaginidae as well as Hemiramphidae were identified as economically important. These families constitute 75% by number and 94% of the weight of the total catch from within subtropical *A. marina* mangrove forests (Morton 1990). The fish density (0.27 ± 0.14 m^{-2}) is about 5-7 times greater than in subtropical *R. stylosa* and the standing crop (25.3 ± 20.4 g m^{-2}) is about 10 times greater. The standing crop for subtropical *A. marina* mangrove

20.4 g m^{-2}) is about 10 times greater. The standing crop for subtropical *A. marina* mangrove forests is among the highest recorded for any type of estuarine habitat (Morton 1990). Studies currently being carried out on fish communities of *A. marina* in Moreton Bay, using FBOM as in this study, indicate that density and standing crop varies greatly in different temporal regions and with specific moon phases. The results indicate that the density and standing crop of fish using *A. marina* forests within the same Bay may be similar to that found in the *R. stylosa* forests of Tin Can Bay to about one quarter of half of the value reported by Morton (1990) (Quinn R. H., pers. comm. 1994).

Table 6: Comparison of fish density (No. m^{-2}) and standing crop (g m^{-2}) for studies of fish within mangrove forests along the east coast of Australia.

Mangrove forest type or complex	Net type	Area sampled (m^2)	Density (No. m^{-2}) (% economic)	Standing Crop (g m^{-2}) (% economic)	Location	Source
Rhizophora stylosa (subtropical)	block	1000	0.05 ± 0.01 (61)	2.01 ± 0.30 (80)	Tin Can Bay	present study (1991-93)
Avicennia marina (temperate)	block	~1000	~0.94 (38)	~6.4 (32)	Botany Bay	Bell et al. (1984)
Avicennia marina (subtropical)	block	3340	0.27 ± 0.14 (75)	25.3 ± 20.4 (94)	Moreton Bay	Morton (1990)
Rhizophora stylosa, *Ceriops tagal*, *Avicennia marina* (tropical)	trap		3.5 ± 2.4[a] (<6)	10.9 ± 4.5[b] (<36)	Townsville	Robertson and Duke (1990)

a = N m^{-3} as water depth varied greatly in this study.
b = m^{-3} as water depth varied greatly in this study

In tropical Australia, *Rhizophora stylosa*, *Ceriops tagal* and *Avicennia marina* dominate a mixed mangrove forest which has a greater fish diversity than that of subtropical mangrove forests. A study in Alligator Creek (19°21'S.,146°57'E.) identified 128 species of fish inhabiting this type of forest (Robertson and Duke 1987; Robertson and Duke 1990). Planktivorous/microcarnivorous fish of the families Chandidae, Leiognathidae, Engraulidae, Atherinidae, Gobiidae, Clupeidae and Pseudomugilidae constituted > 94% by number and > 64% by weight of the total catch. At present, these fish have little direct economic importance in Australia. The density (3.5 ± 2.4 m^{-3}) and standing crop (10.9 ± 4.5 g m^{-3}) are higher than those found in subtropical *R. stylosa* forests (Table 6) (as it is assumed that each sample was taken on a tide of > 1 m). However the direct economic importance of these fish is much lower than that of fish occurring in temperate or subtropical areas but may contribute to the fish production of economic fish species in open waters adjacent to mangrove forests.

In tropical regions of Australia the primary production of mangroves as leaf litter of *Rhizophora stylosa* is 556 g m^{-2} yr^{-1} (Robertson 1986), *Avicennia marina* 519 g m^{-2} yr^{-1} and *Ceriops tagal* 822 g m^{-2} yr^{-1} (Robertson and Daniel 1989). In temperate regions *A. marina* produces 580 g m^{-2} yr^{-1} of leaf litter (Goulter and Allaway 1979). In *Ceriops* forests much of the leaf litter is removed by crabs (71%) with microbial turnover being very low < 1% yr^{-1} (Robertson and Daniel 1989). Less *Avicennia* leaf litter is consumed by crabs (33%) with microbial turnover being much higher (32%) and tides exporting about 21% of the annual production. The leaves of *Rhizophora* and *Ceriops* have low initial nitrogen concentrations, high C:N ratios and very high tannin concentrations resulting in decay rates slower than that of *Avicennia* leaves which have high initial nitrogen concentrations, low C:N ratio and low tannin content (Robertson 1988b). Although leaf litter production of *Rhizophora* mangroves is similar to that of *Avicennia* the greater export of its leaves and their relatively slower release of carbon and nitrogen suggests that *Rhizophora* may be of less importance for primary production within forests, in estuarine habitats, than are *Avicennia* mangroves. However these mangroves contribute, through the greater export of leaves, to fisheries production in waters adjacent to mangrove stands.

The lower direct use by fish of subtropical *Rhizophora stylosa* forest than in any other reported Australian mangrove forest indicates that this type of forest has a lower direct value to fisheries within the forest. The low catch rates in these forests may have been a result of a reluctancy or inability of fish to enter and use the entire available forest due to the root structure of *R. stylosa* which is not as open and unrestricted as *Avicennia marina* forests. If so, fish may use only the seaward fringe of the forest causing an under-estimation in the density and standing crop of fish using the fringing mangroves and an over-estimation for the rest of the forest. The direct loss to fisheries by the removal of such *R. stylosa* forests and the associated primary productivity may be decreased by retaining and maintaining a fringe of *R. stylosa* along the foreshore of developed areas. If areas of mangrove are to be removed this may provide enough habitat to maintain the fisheries value of the area at least in terms of direct fish production. However, the role of *Rhizophora* forests in exporting leaf litter, for secondary production, in adjacent open waters needs to be determined before any removal of such forests is considered.

V Mangroves and Seagrass: Their Importance to the Feeding Patterns of Estuary Dependent Fish

Methods

A preliminary study on the stomach contents of commercially and recreationally important fish collected by the ring netting and fence netting sampling was undertaken. Individual fish were measured (S.L. ± 0.5 cm) and the stomach removed (from above the cardiac sphincter to just below the pyloric sphincter). The weight and volume of the intact stomach were then measured using graduated measuring cylinders filled with water. On opening the stomach, any prey items were identified into broad taxonomic groups. The intestine below the stomach was also inspected for prey items that may have already passed through the stomach. The prey items were used to determine in which part of the inter-tidal zone a fish had been feeding, if browsing on the seagrass had occurred before entering the mangrove areas or if prey items were all taken from within the mangroves.

Results

As this was only a preliminary study on feeding habits of fish, only 6 species of economically important fish *Acanthopagrus australis*, *Girella tricuspidata*, *Mugil cephalus*, *Platycephalus fuscus*, *Sillago analis* and *Sillago ciliata* were selected and examined.

Of the 339 fish stomachs analysed 203 (60%) contained at least one prey item. The food items found in the stomach of *Acanthopagrus australis* indicates feeding mainly in the mangrove habitat, taking a variety of food items (Table 7). *Girella tricuspidata* was found to have both filamentous algae and seagrass in their stomachs and intestine. The seagrass was always present further along the alimentary tract than the filamentous algae suggesting that this species spends some time during the rising tide feeding on the inter-tidal seagrass areas. *Mugil cephalus*, a detritivore, was found to have only filamentous algae from the stilt mangrove roots in each stomach examined. *Platycephalus fuscus* were shown to eat crustaceans and teleosts (fish) however these prey were not from within the mangroves but occur along the seaward fringe. Both of the *Sillago* species consumed brachyurans (crabs) with *S. analis* taking small amounts of filamentous algae and *S. ciliata* taking carideans (clicking shrimp).

Discussion

From the preliminary data collected it suggests that different feeding strategies are used by the different species of fish examined. *Acanthopagrus australis* the most common of the fish sought after by both recreational and commercial fishers appear to feed very little on the movement across the inter-tidal zone to the mangrove habitat, preferring to feed on the prey items that occur within the mangroves themselves. The omnivorous nature of bream feeding allows utilisation of a wide variety of food items found in the mangroves. The large proportion of brachyurans (27% of *Acanthopagrus australis* with prey items in their stomachs had taken crabs) found in the diet of bream may influence the distance into the mangroves that a fish will penetrate. The diversity and abundance of benthic fauna found in mangrove forests decreases with distance away from the seaward fringe of the mangroves. This would mean that the further into a mangrove forest a fish moves, the less chance it has of finding prey items. Again, within a *Rhizophora* forest the structural root complexity may limit the extent to which a fish can penetrate.

Table 7: Dietary analysis of six recreational and commercial fish species in Tin Can Bay, Queensland.

Species	No. Examined	No. with prey items	Taxa of prey
Acanthopagrus australis	200	42 3 33 1 4 4 2 37 2	Filamentous algae Seagrass Both algae and seagrass Gastropoda Bivalvia Penaeidea Caridea Brachyura Teleostei
Girella tricuspidata	16	11 1 4	Filamentous algae Seagrass Both algae and seagrass
Mugil cephalus	71	19	Filamentous algae
Platycephalus fuscus	18	7 1 1 1	Penaeidea Caridea Brachyura Teleostei
Sillago analis	12	4 4	Filamentous algae Brachyura
Sillago ciliata	22	5 7	Caridea Brachyura

Mugil cephalus, a detritivore, was found to have feed while moving across the inter-tidal zone as indicated by the presence of seagrass in the stomachs. The seagrass was also found in the intestine of mullet indicating that feeding had occurred in the inter-tidal zone before moving into the mangrove to browse on the filamentous algae found on the mangrove root systems. A similar pattern of feeding was observed in the small number of *Girella tricuspidata* that were analysed.

Sillago analis were found to feed mainly on filamentous algae and brachyurans (crabs). This indicates that this species is feeding in the seaward fringe areas of the mangroves and across the front of the inter-tidal zone immediately adjacent to the mangroves. *Sillago ciliata* fed on filamentous algae as well as carideans (clicking shrimp). Although clicking shrimp do not regularly in the mangroves but are common on the inter-tidal zone seaward of the mangrove habitat.

The above feeding patterns indicate strongly that the disturbance of the inter-tidal and mangrove habitat in Tin Can Bay region would severely impact on the ability of the common economically important fish to feed, especially the bream stock. There is currently no information concerning the rates of movement of fish across the inter-tidal zone or their dependance on this habitat or the mangroves as their feeding grounds. The relative periods of time spent in the mangrove or on inter-tidal areas, the timing of the movements, the effects of tidal and moon phase on the feeding patterns of these inter-tidal fish are unknown. In this study, we have been able to demonstrate that different feeding patterns are exhibited by the different species of fish however how the extent to which these patterns reflect the dependance of each species on the different zones is unclear.

VI Research and Professional Netting: Their Efficiency in Determining Fish Use of Estuarine Areas.

Methods

A commercial tunnel netter was employed to fish the same seagrass and mangrove sites that had been selected for the study. This comparatively large-scaled "sampling method" (Quinn 1992) was undertaken three times (February, June and December 1993) with the number, total weight and maximum and minimum length for each species recorded. Sampling times were mid-way between the regular research netting operations. The dense Teebar Creek site was fished on the night of the full moon and the sparse Ida Island site on the night after the full moon. A comparison was made between the results for the tunnel netting and the research netting to determine if the use of a commercial fish netting could provide a replicate of our results in a more cost effective manner. From the estimations made for fish use of the habitats from the fence and ring net sampling, predicted catches for the total area fished by the tunnel net could be made and then compared with the actual catch rates.

The tunnel net was made of 53 mm multifilament stretch mesh while the research nets were made of 18 mm multifilament stretch mesh. The larger mesh of the tunnel net led to a decrease in the total number of fish caught as many of the smaller fish were able to escape. The major differences in the species composition are in the absence of the small fish species (such as *Ambassis marianus* and *Atherinomorus ogilbyi*) and the reduced size range of other species such as *Gerres oyeana* (only fish > 80 mm standard length were caught in commercial nets) and *Sillago* spp. (only fish > 170 mm standard length were caught in commercial nets). Small fish and those fish that would not have been taken by the tunnel net were excluded from the calculations allowing a comparison of fish of equal sizes to be made between the research and commercial tunnel net

Table 8: Fish density (No. m^{-2}) and standing crop (g m^{-2}) for mangrove and seagrass sites after fish species and small individuals have been excluded from the total numbers and weights. Only fish caught on the first night of each sampling period have been included in the calculations.

Sites	Area fished	No. of Shots	No. of Fish	Weight of Fish	Density (No. m^{-2})	Standing Crop (g m^{-2})
Mangrove	1000	46	641	78520	0.014	1.71
Sparse seagrass (Ida Island)	400	32	301	17825	0.024	1.39
Dense seagrass (Teebar Creek)	400	29	394	37879	0.034	3.27

For the sparse Ida Island site the predicted density was estimated by:
{(area of mangroves fished x 0.014*) + (area of seagrass/ sandy-mud x 0.024*)} ÷ total area fished and predicted standing crop:
{(area of mangroves fished x 1.71*) + (area of seagrass/ sandy-mud x 1.39*)} ÷ total area fished
and for dense Teebar Creek site predicted density was estimated by:
{(area of mangroves fished x 0.014*) + (area of seagrass/ sandy-mud x 0.034*)} ÷ total area fished and predicted standing crop:
{(area of mangroves fished x 1.71*) + (area of seagrass/ sandy-mud x 3.27*)} ÷ total area fished
values marked with * are taken from Table 8.

Results

An approximate area of 45,000 m^2 (12,000 m^2 of mangroves and 33,000 m^2 of seagrass/sandy-mud) at the sparse Ida Island site and 44,000 m^2 (14,000 m^2 of mangroves and 30,000 m^2 of seagrass/sandy-mud) at the dense Teebar Creek site were fished with the tunnel net. There was little difference (Appendix 1) in the species composition for the catches from the commercial tunnel net and from the research netting methods (fence and ring). This was the case at both of the sites with the sparse Ida Island site having 0.008 m^{-2} and the dense Teebar Creek site having 0.009 fish m^{-2} or 9 fish per 1000 m^2. This is lower than the predicted catch of 0.021 and 0.028 fish m^{-2} at the sparse and densely vegetated sites respectively (Table 9).

Table 9: Predicted and average actual catches of a commercial tunnel net used to fish areas of seagrass, sand/mud flat and mangroves in Tin Can Bay.

Site	Total Area Fished (m^2)	Area of Mangrove Forest (m^2)	Area of Seagrass/ sandy-mud (m^2)	Predicted Number (No. m^{-2})	Predicted Standing Crop (g m^{-2})	Av. Actual Number Caught (No. m^{-2})	Av. Actual Standing Crop (g m^{-2})
Ida Island	45 000	12 000	33 000	0.021	1.48	0.008	2.2
Teebar Creek	44 000	14 000	30 000	0.028	2.77	0.009	2.07

The tunnel netting at the sparse Ida Island site produced a standing crop of 2.2 g m^{-2} with an predicted value of 1.48 g m^{-2}. For the dense Teebar Creek site the actual standing crop from the tunnel net was 2.07 g m^{-2} with a predicted value of 2.77 g m^{-2}. Although both the predicted values differ from the actual values they are not substantially different.

Discussion

The value for fisheries biologist to interact and communicate with commercial and recreational fishers can not be understated as the fishing industry ultimately benefits from, and funds much of the research that is undertaken. By incorporating and assessing anecdotal information provided by both industry sectors, the state of the fishery in a certain area may be gauged prior to the implementation of extensive and expensive sampling programmes. The use of a commercial tunnel netter during the course of this study provided a valuable interaction with the commercial fishing industry and allowed a cost effective method of sampling to be trialled. The similarity between the two fishing methods (commercial tunnel netting versus research fence and ring nets) provided useful information in itself.

The species composition of catches from both methods was similar (55% in common) when all fish caught were included in the analyses, indicating that the research method did not misrepresent the fish that were in the area because of the smaller area of habitat sampled. When the small fish and small individuals of species that were represented were removed this increased to 66%. If all species from this list that occurred only once or twice were also removed as they could be considered as rare and relatively unimportant in this habitat the number in common increases to 87%. This indicates that in both types of netting the fish that occur in any quantity are represented an that fish important to the area are caught.

The ability of the tunnel net to cover much larger areas than the research gear did not cause an increase in the calculated standing crop of fish caught, with the catches for both sites being within the expected variations. This indicates that the tunnel net could be used as an alternative sampling method to rapidly provide a gross estimate of the direct fish use of a particular habitat.

One way of decreasing the time and cost of evaluating these habitats would be to use the commercial tunnel net fishers who regularly fish areas adjacent to the study sites. Problems encountered with the use of commercial net fishers were the acceptance of the need to fish a certain area at a nominated time. Once overcome, we found invaluable information could be obtained from those working in this industry.

Implications for the Australian Fishing Industry.

Increasing pressure is being placed on estuarine and adjacent habitats for coastal development. Assessment of the location of such development should be based on minimal impact to these fisheries habitats. Subtropical *Rhizophora stylosa* mangrove forests with the lowest fish density and standing crop of any reported mangrove forest in Australia have been identified as an area of relatively lower direct value to fisheries. This does not imply that subtropical *R. stylosa* mangrove forests do not contribute substantially to local fisheries, particularly where oceanic influences predominate. Rather the capacity and role of *R. stylosa* forests to provide primary production in the form of nutrients from leaf litter and algal growing space, nursery sites for juvenile fish of direct and indirect economic importance, feeding and shelter areas for adult fish and stability of the foreshores are nevertheless considerable. Differences in catch between replicate sites indicates the high variability in productivity that can occur over small distances with minor differences in the microhabitat. These differences along with changes in temporal distribution need to be examined before a true indication of the impacts of mangrove habitat loss to local and regional fisheries can be fully quantified.

Extensive seagrass beds subject to short term natural fluctuations (eg. seasonal) may provide different specific benefits to economically important species of fish and crustaceans. The implications for industry are changes in catch composition with subsequent price variation but these changes are usually seasonal and differ from year to year. However, permanent losses of such habitat would lead to declines in overall catches.

The study area, Tin Can Bay, provided an example of a large estuarine system, with relatively little freshwater input, in which both commercial and recreational fishing is successfully undertaken. The system also supports an adjacent deep-water king prawn (*Penaeus plebejus*) fishery. However in overall terms, fisheries production is relatively lower than in an area such as Moreton Bay. The local impacts of permanent habitat losses around Tin Can Bay would be proportionally greater than in other more productive areas.

Intellectual Property

Intellectual Property resulting from this study relates to raw data and analysed results. A copy of these has been lodged with the Fisheries Research and Development Corporation for its records. Published papers will allow general access to the results of this study. Use of any material is subject to the accepted form of appropriate acknowledgment.

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APPENDIX I.

Complete list of species caught using all sampling methods and their occurrence or absence in each sampling method. ✓ = caught by this method. Beam = beam trawling; Ring = ring netting; Fence = fence netting; Com = commercial tunnel netting; Other = otter trawling and line fishing.

Species	Beam	Ring	Fence	Com	Other
Acanthuridae					
Acanthurus sp.	✓				
Ambassidae					
Ambassis marianus	✓	✓	✓		
Anguillidae					
Anguilla sp.	✓				
Antennariidae					
Tathicarpus butleri					✓
Aploactinidae					
Coccotropus sp.	✓				
Apogonidae					
Apogon nigripinnis	✓				
Siphamia roseigaster	✓				✓
Ariidae					
Neoarius australis				✓	
Atherinidae					
Atherinomorus ogilbyi	✓	✓	✓		✓
Belonidae					
Tylosurus gavialoides		✓	✓	✓	
Blennidae					
Petroscirtes sp.	✓				
Bothidae					
Pseudorhombus arsius		✓		✓	✓
Pseudorhombus jenynsii	✓	✓			✓
Callionymidae					
Callionymus limiceps	✓				✓
Carangidae					
Caranx sp.			✓		
Gnathanodon speciosus			✓	✓	
Scomberoides commersonianus		✓	✓		
Centropomidae					
Psammoperca waigiensis	✓	✓	✓		✓
Chaetodontidae					
Paracheatodon ocellatus	✓				✓
Clupeidae					
Herklotsichthys castelnaui		✓	✓	✓	✓
Herklotsichthys koningsbergei		✓	✓	✓	✓
Congridae					
Unidentified sp.	✓				
Cynoglossidae					
Paraplagusia sp.	✓				

Species	Beam	Ring	Fence	Com	Other
Dasyatididae					
Amphotistius kuhlii		✓		✓	✓
Dasyatis fluviorum				✓	
Himantura uarnak				✓	
Diodontidae					
Chiloscyllium punctatum				✓	
Engraulidae					
Thryssa hamiltonii			✓		
Fistularidae					
Fistularia commersonii	✓				✓
Gerridae					
Gerres oyeana	✓	✓	✓	✓	✓
Gobiidae					
Arenigobius frenatus	✓				
Drombus sp.	✓				
Favonigobius exquisitus	✓				
Favonigobius lateralis	✓				
Glossogobius sp.			✓		✓
Gymnuridae					
Gymnura australis		✓			
Harpadontidae					
Saurida endosquamis	✓				✓
Hemirhamphidae					
Arrhamphus sclerolepis		✓	✓	✓	
Hyporhamphus abbreviata		✓			✓
Hyporhamphus ardelio		✓	✓	✓	
Hyporhamphus robustus		✓		✓	
Kyphosidae					
Girella tricuspidata			✓	✓	
Kyphosus gibsoni			✓		
Labridae					
Undientified sp.	✓				✓
Leiognathidae					
Leiognathus sp.	✓				✓
Lethrinidae					
Lethrinus fletus	✓				✓
Lutjanidae					
Lutjanus argentimaculatus			✓	✓	
Lutjanus russelli	✓	✓	✓	✓	✓
Monacanthidae					
Chaetoderma penicilligera	✓				
Monacanthus chinensis	✓	✓			✓
Monacanthus oblongus	✓				✓
Monacanthus peroni					✓
Monodactylidae					
Monodactylus argenteus			✓	✓	
Mugilidae					
Liza subviridis		✓	✓	✓	
Mugil cephalus			✓	✓	
Mugil georgii		✓	✓	✓	
Myxus elongatus			✓		
Mugiloididae					
Parapercis nebulosus					✓
Mullidae					
Upeneus tragula	✓				✓

Species	Beam	Ring	Fence	Com	Other
Ophichthidae					
Pisodonophis boro		✓			
Ostraciidae					
Lactoria cornuta	✓				✓
Pegasidae					
Pegasus volitans	✓				✓
Platycephalidae					
Inegocia harisii	✓				✓
Papilloculiceps nematophthalmus	✓	✓			✓
Platycephalus endrachtensis		✓			
Platycephalus fuscus		✓	✓	✓	✓
Platycephalus indicus	✓	✓	✓	✓	✓
Plotosidae					
Plotosus anguillaris		✓	✓	✓	✓
Pomatomidae					
Pomatomus saltatrix		✓			
Priacanthidae					
Priancanthus sp.		✓			
Rhinobatidae					
Rhinobatos batillum		✓		✓	✓
Rhynchobatidae					
Rhynchobatus djiddensis				✓	
Scaridae					
Unidentified sp.	✓				✓
Scatophagidae					
Scatophagus argus			✓	✓	
Selenotoca multifasciata			✓	✓	
Sciaenidae					
Unidentified sp.					✓
Scombridae					
Scomberomorus munroi					✓
Scorpaenidae					
Centropogon marmoratus	✓				✓
Minous versicolor					✓
Synaneja horrida		✓			
Siganidae					
Siganus fuscescens	✓	✓	✓	✓	✓
Silliganidae					
Sillago analis		✓	✓	✓	✓
Sillago ciliata		✓	✓	✓	✓
Sillago maculata	✓	✓		✓	✓
Sillago sp.	✓				
Solidae					
Achlyopa nigra		✓	✓	✓	✓
Sparidae					
Acanthopagrus australis	✓	✓	✓	✓	✓
Pagrus auratus					✓
Rhabdosargus sarba	✓	✓	✓	✓	✓
Sphyraenidae					
Sphyraena barracuda		✓	✓	✓	
Sphyraena obtusata	✓	✓	✓	✓	✓
Syngnathidae					
Urocampus sp.	✓				

Species	Beam	Ring	Fence	Com	Other
Teraponidae					
Pelates quadralineatus	✓	✓			✓
Pelates sexlineatus	✓	✓		✓	✓
Terapon jarbua		✓	✓		
Tetraodontidae					
Arothron hispidus	✓			✓	✓
Arothron manillensis	✓	✓	✓	✓	✓
Dicotylichthys myersi			✓	✓	
Lagocephalus lunaris			✓		
Marilyna pleurogramma	✓	✓		✓	✓
Marilyna pleurostrictus	✓	✓	✓	✓	✓
Tetractenos hamiltoni	✓	✓	✓	✓	✓
Torquigener whitleyi	✓	✓			✓
Tricanthidae					
Tripodichthys angustifrons	✓	✓			✓
Unidentified Larval fish					
Fry type 1	✓				
Fry type 2	✓				
White bait	✓				

APPENDIX II

Fence Block-Off Method.

Four replicate sites, identical in width and depth (25 x 40 m), were established. Sampling of fish was undertaken by the Fence Block-Off Method (FBOM), described below.

Five parallel corridors (about 20 cm wide) were cut through the mangrove prop roots and low hanging branches along the tidal profile to the mean high tide mark (40 m) (Fig. A). Nylon hail net (18 mm stretch mesh) was placed in each of the parallel corridors creating four separate replicate sites with an area of 1000 m^2 each. The top of each hail net was sewn to ropes hung between wooden stakes (30 x 30 mm) that were driven into the substrate along the corridors. The bottom of each hail net was buried in the substrate creating a permanent fence. The nets proved to be relatively low in maintenance with minimal leaf letter and algal build-up.

Samples were obtained by running a multi-filament block net (120 m long x 1.2 m deep x 18 mm stretch mesh) along the seaward edge of the replicate sites at high tide. At each end of the replicate sites the block net was attached to the permanent fence net to prevent fish moving to adjacent replicate sites as the tide fell. The lead line of the block net was not buried in the substrate. Escape of fish may have occurred as the tide fell.

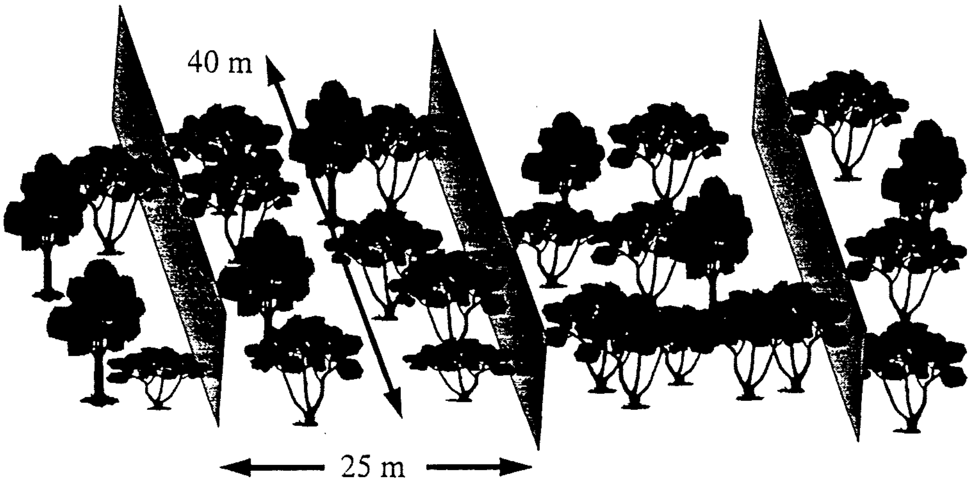


Fig A: Schematic diagram of the Fence Block-Off Method (FBOM). Permanent nets were positioned through the mangroves with the bottom edge buried in the substrate. Fish sampling was done at high tide by setting a net along the seaward edge of the fence nets, attaching it to each fence and collecting the fish after the tide has fallen.

Sample pairs were taken from each replicate on consecutive nights to allow the effects of fishing on an area to be observed. If random movement is the expected habit of estuarine fish then it would be reasonable to assume that because the samples are only a very small part of the entire system catches should remain constant or at least not show any significant differences over extended periods of time. Fish from each replicate site were collected from along the block net at low tide.

This method of netting has a number of advantages over those that have previously been used.

1. After the initial set up of the net there is no disturbance to the surrounding substrate as the fences are left in place permanently.
2. A considerable amount of time is saved by having only a small amount of net to set, the block net, along the front of the fences.
3. The lower impact on habitat and speed of setting the block net minimises the disturbance to fish present in the sample area.
4. In areas that are not exposed to prevailing winds there is very little maintenance on the hail net itself as it is not effected by the sun and it is difficult for natural events to tear it.
5. This type of netting provides a system of replication that can be extended depending on the need. The fences can be extended as far into the littoral zone as is necessary.
6. There is a decrease in the available area that fish may escape. In other methods of blocking off areas, the whole net sits on the bottom allowing a large area under which fish can escape. With this method fish may only escape under the block net at the front of the fences.
7. In areas where this type of net can be employed the water is often highly turbid and this may be an advantage in that the fish frequenting the area are conditioned to use senses other than sight to navigate their way through the mangrove forest. The fence nets would not disturb the fish but present a barrier to be navigated around.
8. Areas within inter-tidal wetlands can be sampled by constructing the fences to the required distance and then setting a front and back block net when sampling. This allows only those fish inside the are to be sampled and stop fish entering the site from the back as the tide falls.
9. Paired sampling on consecutive nights, using this method and others, has shown that fish inhabiting mangrove areas are resident to an area. It is unlikely that fish using the area in which a set of fence nets has been constructed would not have encountered the fences prior to the sampling night/day and would therefore not be disturbed by them.

Problems that have been encountered or are foreseen with this method are:

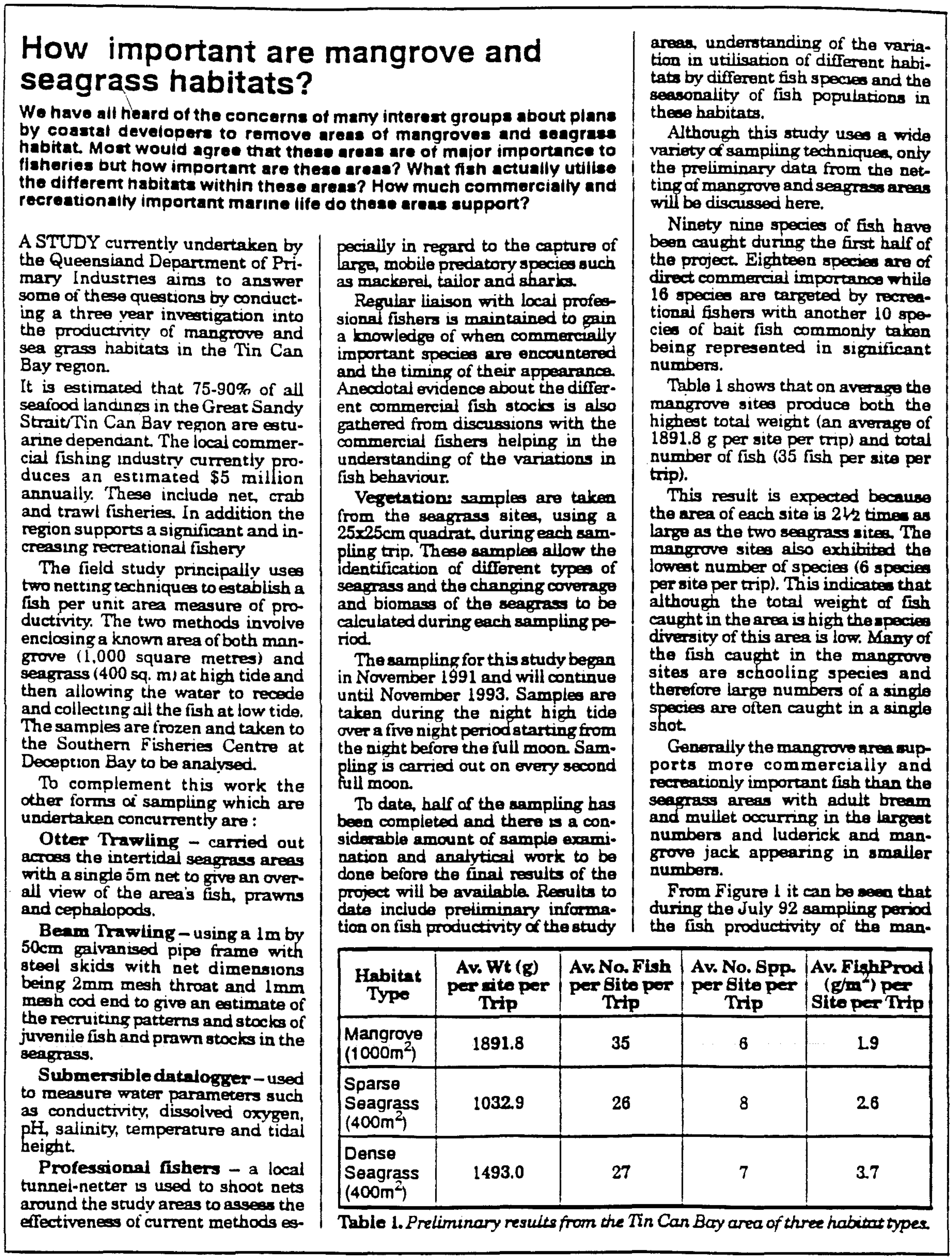
1. Leaf build-up on the net can be a problem especially if the wind conditions at the time are holding the leaf litter in the sites.
2. The fences may also stop fish moving laterally through the mangrove forest and therefore may have some effect on catch rates.
3. Funnelling of fish along natural soaks or creeks may also cause catch rates to be more variable if these run directly into the fence.
4. In areas where there is little substrate for algal growth the presence of the net

may encourage algal growth and therefore modify the habitat and subsequently the fish community.

This FBOM is currently being successfully used in a study of *Avicennia marina* mangrove forests in Moreton Bay looking at the variability of different sites and the effect of lunar phase on the numbers of fish using mangrove forests.

Appendix III

: published paper in Queensland Fisherman



How important are mangrove and seagrass habitats?

We have all heard of the concerns of many interest groups about plans by coastal developers to remove areas of mangroves and seagrass habitat. Most would agree that these areas are of major importance to fisheries but how important are these areas? What fish actually utilise the different habitats within these areas? How much commercially and recreationally important marine life do these areas support?

A STUDY currently undertaken by the Queensland Department of Primary Industries aims to answer some of these questions by conducting a three year investigation into the productivity of mangrove and sea grass habitats in the Tin Can Bay region.

It is estimated that 75-90% of all seafood landings in the Great Sandy Strait/Tin Can Bay region are estuarine dependant. The local commercial fishing industry currently produces an estimated $5 million annually. These include net, crab and trawl fisheries. In addition the region supports a significant and increasing recreational fishery

The field study principally uses two netting techniques to establish a fish per unit area measure of productivity. The two methods involve enclosing a known area of both mangrove (1,000 square metres) and seagrass (400 sq. m) at high tide and then allowing the water to recede and collecting all the fish at low tide. The samples are frozen and taken to the Southern Fisheries Centre at Deception Bay to be analysed.

To complement this work the other forms of sampling which are undertaken concurrently are :

Otter Trawling – carried out across the intertidal seagrass areas with a single 5m net to give an overall view of the area's fish, prawns and cephalopods.

Beam Trawling – using a 1m by 50cm galvanised pipe frame with steel skids with net dimensions being 2mm mesh throat and 1mm mesh cod end to give an estimate of the recruiting patterns and stocks of juvenile fish and prawn stocks in the seagrass.

Submersible datalogger – used to measure water parameters such as conductivity, dissolved oxygen, pH, salinity, temperature and tidal height.

Professional fishers – a local tunnel-netter is used to shoot nets around the study areas to assess the effectiveness of current methods especially in regard to the capture of large, mobile predatory species such as mackerel, tailor and sharks.

Regular liaison with local professional fishers is maintained to gain a knowledge of when commercially important species are encountered and the timing of their appearance. Anecdotal evidence about the different commercial fish stocks is also gathered from discussions with the commercial fishers helping in the understanding of the variations in fish behaviour.

Vegetation: samples are taken from the seagrass sites, using a 25x25cm quadrat, during each sampling trip. These samples allow the identification of different types of seagrass and the changing coverage and biomass of the seagrass to be calculated during each sampling period.

The sampling for this study began in November 1991 and will continue until November 1993. Samples are taken during the night high tide over a five night period starting from the night before the full moon. Sampling is carried out on every second full moon.

To date, half of the sampling has been completed and there is a considerable amount of sample examination and analytical work to be done before the final results of the project will be available. Results to date include preliminary information on fish productivity of the study areas, understanding of the variation in utilisation of different habitats by different fish species and the seasonality of fish populations in these habitats.

Although this study uses a wide variety of sampling techniques, only the preliminary data from the netting of mangrove and seagrass areas will be discussed here.

Ninety nine species of fish have been caught during the first half of the project. Eighteen species are of direct commercial importance while 16 species are targeted by recreational fishers with another 10 species of bait fish commonly taken being represented in significant numbers.

Table 1 shows that on average the mangrove sites produce both the highest total weight (an average of 1891.8 g per site per trip) and total number of fish (35 fish per site per trip).

This result is expected because the area of each site is 2½ times as large as the two seagrass sites. The mangrove sites also exhibited the lowest number of species (6 species per site per trip). This indicates that although the total weight of fish caught in the area is high the species diversity of this area is low. Many of the fish caught in the mangrove sites are schooling species and therefore large numbers of a single species are often caught in a single shot.

Generally the mangrove area supports more commercially and recreationly important fish than the seagrass areas with adult bream and mullet occurring in the largest numbers and luderick and mangrove jack appearing in smaller numbers.

From Figure 1 it can be seen that during the July 92 sampling period the fish productivity of the man-

Habitat Type	Av. Wt (g) per site per Trip	Av. No. Fish per Site per Trip	Av. No. Spp. per Site per Trip	Av. FishProd (g/m^2) per Site per Trip
Mangrove ($1000m^2$)	1891.8	35	6	1.9
Sparse Seagrass ($400m^2$)	1032.9	26	8	2.6
Dense Seagrass ($400m^2$)	1493.0	27	7	3.7

Table 1. *Preliminary results from the Tin Can Bay area of three habitat types.*

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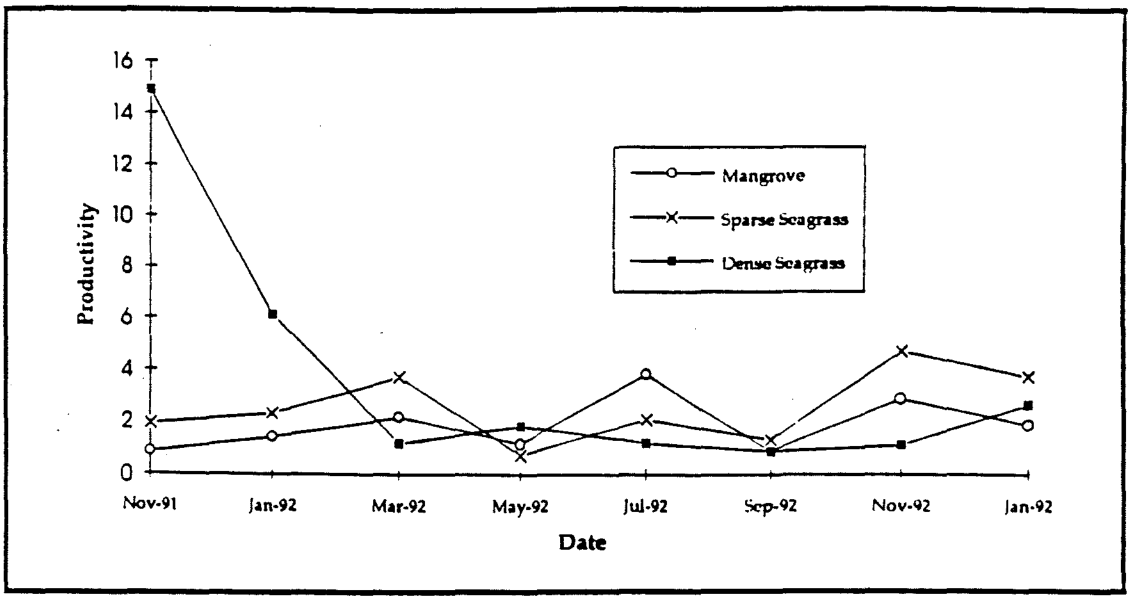

Figure 1. *Average fish biomass (g / sq. m / site / sampling period) for mangrove, sparse seagrass and dense seagrass habitats in the Tin Can Bay region over a 14 month period.*

grove area was approximately double that of the seagrass areas and three times as high as the productivity for the mangrove area in May-92 and Sept-92. This is a result of large catches of bream and mullet during July-92 which is about the time that bream school to spawn and the mullet are at the end of their spawning movements and the large schools move into the estuaries away from the open surf beaches.

The mangrove area also appears to be an important nursery area for juvenile summer and gold-lined whiting presumably for its ability to provide food and shelter from predators. Other species that commonly occur in the mangrove areas but have little of no economic importance are flicker mullet, silver biddies and the common toado.

The fish productivity of the mangrove site may be underestimated as the tidal heights change constantly throughout the sampling period thus causing different levels of water to flood into the mangroves. If this water does not reach the back of the nets then the estimate of the area from which the sample is taken will be to high. This problem is being rectified by measuring the actual distance that the water penetrates into the mangroves at different tidal heights. This will allow a more precise estimation of the productivity to be made.

Table 1 shows both of the seagrass types (sparse and dense) exhibiting similar catch statistics however the dense area has a higher average productivity by weight with slightly lower average number of species.

These results are biased by the capture of seven relatively large blue spotted rays (0.5-4kg) during the Nov-91 sampling period. The rays contributed a large percentage of the biomass of the dense seagrass catch for this period as can be seen in Figure 1.

If this one off capture of rays is disregarded then the average weight per site per trip is very similar for all sampling periods. This indicates that overall fish biomass productivity is similar in the relative values of dense or sparsely vegetated areas.

The seagrass areas tend to produce the species of less direct economic importance. Common species occurring being southern herring, hardy heads and yellowtail pike. Those fish that are of commercial value and occur in moderate to low numbers include adult summer and gold-lined whiting, bar and dusky flathead.

Preliminary study of the diets of several species has indicated that some fish (eg. luderick) feed as they travel across the seagrass areas with the flooding tide. Once the water has reached the mangroves they enter and feed on the algae growing on the mangrove roots. This component of the study is continuing and therefore further detailed information on feeding patterns for the common fish species being sought.

Significant pressures are being placed on the Great Sandy Strait region, other Queensland coastal environments and elsewhere in northern Australia by coastal development and increasing recreational fishing activities.

There is a need to assess the relative values of different habitats to major commercial and recreational fish, crustaceans and molluscs so that preferred and critical habitats can be protected.

The information from this study will allow the preparation of guidelines for acceptable levels of disturbance resulting in minimal impacts on coastal fisheries.

The further definition of environmental and habitat characteristics of highly productive areas will facilitate protection of such highly valuable coastal fisheries habitats by redirecting development into areas less productive for fisheries.

Ian Halliday
QDPI Fisheries Division

Appendix V

Platform Presentations

1994 AMSA Conference

Fish of a subtropical *Rhizophora stylosa* mangrove forest.

1993 & 1994 Deception Bay

Two seminars through the course of the Project to scientist and industry representatives

1994 Tin Can Bay Seafood Fest

Presented study findings at an Industry field day along with providing educational material on wetlands.

Appendix IV

Scientific Papers in preparation

Four papers are currently in preparation or are being refereed at the present time:

Halliday, Ian A. Influence of natural fluctuations in seagrass cover on commercial prawn nursery grounds of Tin Can Bay, Queensland. (submitted to Australian Journal of Marine and Freshwater Research)

Halliday, Ian A. and Young, W. R. Density, standing crop and species composition of fish in a subtropical *Rhizophora stylosa* mangrove forest. (submitted to Marine Biology)

Halliday, Ian A. Fish communities of *Zostera capricorni* seagrass beds in Tin Can Bay, Queensland. (in preparation)

Halliday, Ian A. Effectiveness of using commercial fishers for determining the fish use of estuarine areas. (in preparation)