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Density, Biomass and Species Composition of Fish in a Subtropical *Rhizophora stylosa* Mangrove Forest

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Abstract. Juvenile and adult fish were sampled from within a subtropical *Rhizophora stylosa* mangrove forest in Tin Can Bay, Australia, every second lunar month from November 1991 to November 1993. On all sampling occasions replicate samples were taken on two consecutive nights. In all, 3320 fish were collected, representing 42 species and weighing 141 498 g. Significantly fewer fish were caught on the second night than on the first night. Economically important fish of the Families Atherinidae, Mugilidae, Gerreidae, Sparidae and Sillaginidae represented >76% by number and >74% of the total weight caught. The mean density of fish in the forest was 0·04 ± 0·01 m^{-2}, with a biomass of 1·3 ± 0·2 g m^{-2}. This is lower than that found in similar studies on other mangrove communities. The fish community was dominated by detritivores and intermediate carnivores, many of which are of economic value. Although the fish use of this subtropical *R. stylosa* forest was low, this habitat is important as a feeding and nursery area for fish species that contribute to the fisheries value of the region.

Extra keywords: block-net, community structure.

Introduction

Although mangrove forests are found along the entire coastline of Queensland, few studies have investigated the fish communities that enter these habitats at high tide (Stephenson and Dredge 1976; Morton 1990; Robertson and Duke 1990). This has meant that the loss of such habitats has not been quantifiable in terms of fisheries productivity. The pressures to develop or disturb coastal fisheries habitats, especially estuaries, are of major concern to commercial and recreational fishers because of the associated decreases in the extent of potential feeding and nursery sites for estuary-dependent species (Poiner *et al.* 1992; Burchmore 1993). Between 1974 and 1987, 8.4% of mangrove forests and 10.5% of saltmarsh–claypan areas between Coolangatta and Caloundra in south-eastern Queensland were lost as a result of development of marinas, canal estates, resorts, shipping wharves and an extension of the Brisbane Airport (Hyland and Butler 1988). Pressure on foreshore areas, especially in southern Queensland estuaries, is increasing with over 150 developments recently proposed (Kay 1989). Documentation of habitat usage by fish and the ability to provide accurate assessments of the impact of coastal developments on fisheries are critical if areas of high fisheries value are to be maintained.

The ecological roles that shallow-water habitats play as nursery grounds, shelter areas and as nutrient sources are documented to some extent for Queensland waters (Robertson and Duke 1987, 1990; Morton 1990; Robertson and Blaber 1992; Sheaves 1992). But it is still difficult to quantify losses to local and regional fisheries when intertidal habitats are disturbed because of the lack of baseline data. Retention and conservation of small areas of mangrove or seagrass within an estuary are equally difficult to defend given that the fisheries value of a small area of habitat is seen as inconsequential over the total area of the estuary. However, over time, the sum of these small areas cumulatively constitutes a large part of the habitat that sustains a renewable resource (Burchmore 1993).

The relative value, in terms of primary and secondary production and fish use, of different types of mangrove forests within the same geographic region is unknown as no concurrent studies have been done. Most studies describing fish communities using mangrove forests have used netting methods, such as trawling and seine-net hauling, to catch fish from the seaward fringe (Ruello 1975; Kjelson and Colby 1977; Yanez-Arancibia *et al.* 1980). This still begs the question: to what extent do fish enter the mangrove forest? Several studies have attempted to address and resolve this question by using stake- or block-nets (Stephenson and Dredge 1976; Bell *et al.* 1984; Blaber *et al.* 1985; Thayer *et al.* 1987; Morton 1990; Robertson and Duke 1990). Block-netting allows larger, more mobile fish to be captured, but the different net sizes and techniques used make these studies difficult to compare. The present study aimed to

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catch juvenile and adult fish entering the mangrove forest and using it as a feeding or nursery area. Because any disturbance within the mangrove forest could influence the fish use of an area, a system of sampling mangrove forest fish fauna was developed that *(a)* did not disturb the mangroves after the initial construction, *(b)* was non-disturbing to fish in the forest when the block-net was put in place, *(c)* was passive in the sense that fish inhabiting the area would become used to the presence of the permanent nets between sampling periods, *(d)* can be modified for larger or smaller areas, and *(e)* is easy to set. This allowed replicate sampling within one site, which could be extended to more sites if desired, and identification of small differences in habitat that may affect the homogeneity of sampling cells within the site selected.

We investigated the density, biomass and species composition of fish using a subtropical *Rhizophora stylosa* mangrove forest in Tin Can Bay, at the southern end of the Great Sandy Strait. This estuary has large areas of pristine *R. stylosa* mangroves that are under increasing threat of development and for which no baseline fisheries data have been collected. The innovative sampling method allowed a comprehensive assessment of the fish communities of this type of habitat.

Materials and Methods

Site

A mangrove stand dominated by *Rhizophora stylosa* (<5 m tall) in Teebar Creek, Tin Can Bay (25°54′S,153°02′E), was the sampling site. *R. stylosa* comprised >95% of the forest and *Avicennia marina* and *Bruguiera gymnorhiza* accounted for the remaining trees. The site was part of an extensive mangrove forest wetland that lines the foreshore of Tin Can Bay (Fig. 1). Salt-marsh, dominated by *Sporobolus* sp. salt couch, extended behind the site (about 20 m) and natural eucalypt forest existed beyond this. The intertidal zone from the seaward edge of the salt-marsh to mean low water was about 100 m. *R. stylosa* mangrove forest covered the upper 40 m of the intertidal zone. The remaining 60 m of the intertidal zone consisted of sandy mud-flats from the mangrove fringe to within 30 m of low water. The lower 30 m of the intertidal zone was covered by *Zostera capricorni* seagrass. Tides were semi-diurnal, leaving the mangroves exposed during every low tide.

Sampling Regime

Four sampling cells, identical in width (25 m, parallel to the shoreline) and depth (40 m, perpendicular to the shoreline), were established (Fig. 2). Five parallel corridors (about 20 cm wide and 25 m apart) were cut through the mangrove prop roots and low-hanging branches to the mean high tide mark (40 m). Nylon hail-net (18-mm stretched mesh, 1·2 m high) was placed in the parallel corridors, creating four separate cells of 1000 m^2 each. The top of each hail-net was sewn to ropes hung between wooden stakes (30 × 30 mm) that were driven into the substratum along the corridors. The bottom of each hail-net was buried in the substratum, creating a permanent fence.

Each cell was sampled on consecutive nights, the night before and the night of the full moon, every second lunar month from November 1991 until November 1993. This provided a replicate pair of samples for each cell during each sampling period. Samples were obtained by running a multi-filament block-net (120 m long × 1.2 m deep, 18-mm stretched mesh) along the seaward edge of the cells at high tide. At the end of each cell the block-net was attached to the permanent fence-net to prevent fish moving between cells as the tide fell. The lead line of the block-net was not buried in the substratum and fish may have escaped under it as the tide fell. Fish from each cell were collected from along the block-net at low tide. Fish were identified to species and weighed (±0·5 g) and the standard or total length measured as appropriate.

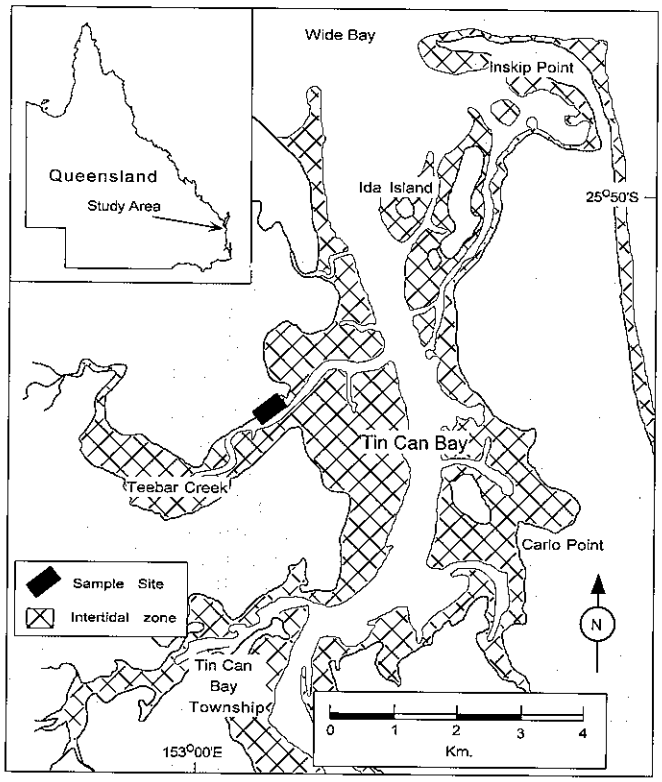

Fig. 1. Position of the sampling site in Tin Can Bay.

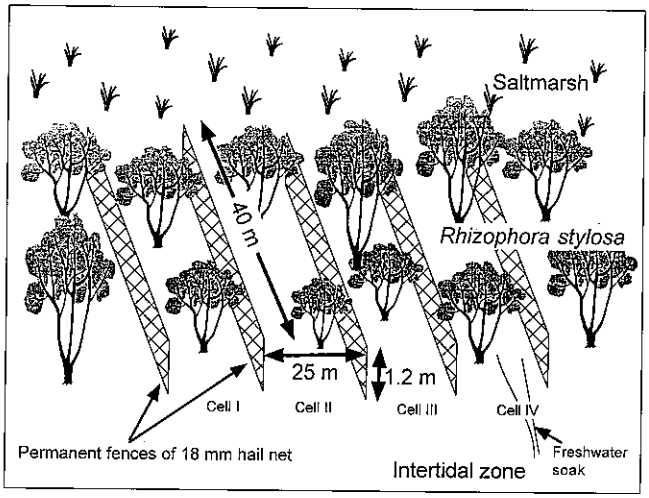

Fig. 2. Diagrammatic representation of the block-net set-up within the mangrove forest.

Analysis

A Shannon–Wiener diversity index, H' (Pielou 1969), was calculated for each sample: $H' = -\Sigma_{i=n}^{n} P(i) \ln P(i)$, where $P(i)$ is the ratio of the number of individuals of species i to the total number of individuals in the sample. The Wilcoxon test for paired observations (Sokal and Rohlf 1981) was used to compare differences in fish density, biomass and diversity index between replicate pairs from consecutive nights. Samples not taken because of bad weather or fouling of the block-net during setting were regarded as missing values and not included in the analysis.

Analysis of variance (ANOVA) was used to compare catches between cells and over time for both total number and total weight of fish caught. Fish numbers and total weights were log-transformed—$\ln(n + 1)$—to make the variance independent of the mean.

Fish were classified as belonging to one of five trophic categories (Thompson 1954, 1959; Blaber and Blaber 1980; Bell *et al.* 1984; Morton *et al.* 1987; Morton 1990) for comparisons with other studies (Table 1): *(a)* detritivores, *(b)* herbivores, *(c)* planktivores/microbenthic carnivores (feeding on plankton, small benthic animals and small amounts of detritus), *(d)* intermediate carnivores (feeding on large benthic animals, with some vegetation and small fish), or *(e)* predators (feeding on fish, with some large benthic animals).

Hydrology

Throughout the study, a submersible data-logger (DataSonde 3) was placed on a navigation marker about 300 m from the sampling site, recording water temperature, salinity and tidal height each hour. These factors were recorded to evaluate their effect on fish numbers and species composition entering the mangrove forest.

Results

Fish Community

In all, 3320 fish weighing 141498 g and comprising 42 species were caught in all cells from both nights. The fish community was dominated by detritivores and intermediate carnivores. Six species of fish—*Acanthopagrus australis*, *Gerres oyeana*, *Mugil georgii*, *Sillago analis*, *S. ciliata* and *Tetractenos hamiltoni*—comprised >86% by number and >58% by weight of the catch. The Families Atherinidae, Gerreidae, Mugilidae, Sillaginidae, Tetraodontidae and Sparidae represented >92% of the total number of fish caught. Economically important fish (i.e. fish sought after by recreational or professional fishers as food or bait and representing >2% of the total number caught) of the Families Atherinidae, Mugilidae, Gerreidae, Sparidae and Sillaginidae represented >76% by number and >74% of the total weight caught (Table 1). Juveniles and adults of these economically important families were present, except that *Mugil cephalus* was caught only as adults and *M. georgii*, *Sillago analis* and *S. ciliata* were caught only as juveniles. Of the 42 species taken, 12 were represented only once in the samples and 6 occurred only twice (0·03% and 0·06% of the total number, respectively, in Table 1).

Table 1. 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 category and species	% of total number	% of total weight	Life history stage	Fishery
Detritivores				
Liza dussumieri	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
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
Planktivores/microbenthic carnivores				
Ambassis marianus	0·69	0·05	J/A	R
Gerres oyeana	13·13	2·39	J/A	R
Herklotsichthys castelnaui	0·66	0·05	A	R
Herklotsichthys koningsbergeri	0·03	<0·01	A	R
Pranesus ogilbyi	2·83	0·44	J/A	R
Thryssa hamiltoni	0·03	0·01	A	R
Intermediate carnivores				
Acanthopagrus australis	13·04	40·44	J/A	C/R
Achlyopa nigra	0·03	0·04	J	R
Arothron manilensis	0·09	0·13	J/A	—
Caranx sp.	0·03	0·07	A	C/R
Dicotylichthys myersi	0·03	0·92	A	—
Gnathanodon speciosus	0·12	0·06	J	C/R
Gobiidae	0·09	<0·01	A	—
Lagocephalus lunaris	0·03	0·15	J	—
Lutjanus russelli	0·30	0·55	J/A	C/R
Marilyna pleurostictus	0·09	0·28	A	—
Monodactylus argenteus	0·06	0·04	A	—
Plotosus lineatus	0·03	0·21	A	—
Psammoperca waigiensis	0·03	0·15	A	R
Rhabdosargus sarba	0·09	0·11	J/A	R
Scomberoides commersonianus	0·03	<0·01	J	C/R
Sillago analis	22·77	6·20	J	C/R
Sillago ciliata	8·43	2·39	J	C/R
Terapon jarbua	1·57	0·20	A	—
Tetractenos hamiltoni	15·51	4·38	J/A	—
Predators				
Lutjanus argentimaculatus	0·06	0·92	A	C/R
Platycephalus fuscus	0·42	2·48	J/A	C/R
Platycephalus indicus	0·03	0·03	J	C/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

Sampling on Consecutive Nights

The total catch from all first night-sampling periods comprised 2442 individuals and weighed 92909 g. This represented 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 each cell on consecutive nights, with the first-night catch being consistently higher. Changes

in the Shannon–Wiener diversity index (H') for samples from consecutive nights were not significantly different (Table 2).

As there were significant differences in the number of fish caught on consecutive nights, only samples taken on the first night were included in further analyses. The number of fish caught was significantly different between cells ($P < 0.01$), with Cell IV consistently containing greater numbers of fish, but this result was not reflected in biomass or species diversity (Table 3). Minor variations in the microhabitat of the cells may have caused differences in the numbers of fish caught. Cell IV had a natural freshwater soak that ran through the mangroves, causing a slight depression with a very small continuous water output (unmeasured) at low tide (Fig. 2). This was the only visible difference between cells and may have attracted greater numbers of fish and thus affected the homogeneity of the cells. The number of fish caught varied significantly between sampling periods ($P < 0.01$), indicating that in winter (May and July) a greater number of fish were using the forest (Fig. 3).

Fish Density, Biomass and Diversity

The mean density of fish caught on the first night from the four cells was 0·04 ± 0·01 m^{-2} (± s.e.) and ranged from 0·01 ± 0·01 m^{-2} (September 1992) to 0·10 ± 0·03 m^{-2} (May 1993) (Table 4). The mean biomass for the four cells was 1·33 ± 0·21 g m^{-2} and ranged from 0·48 ± 0·36 g m^{-2} (September 1993) to 5·54 ± 3·41 g m^{-2} (July 1992). The Shannon–Wiener diversity index (H') had a mean of 1·39 ± 0·07 and ranged from 0·73 ± 0·17 (September 1992) to 1·83 ± 0·27 (March 1993).

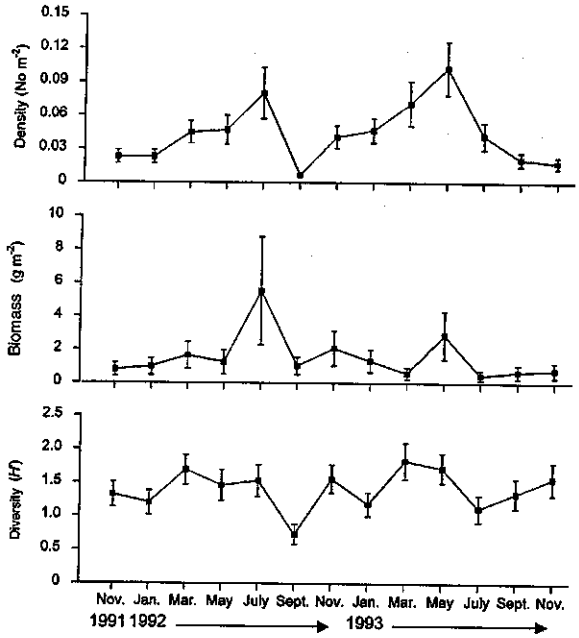

Fig. 3. Fish density (no. m^{-2}), biomass (g m^{-2}) and Shannon–Wiener diversity (H') taken from four sampling cells within a subtropical *Rhizophora stylosa* mangrove forest from November 1991 to November 1993. ■, mean (± s.e.) for all cells combined.

Table 2. Wilcoxon paired-observation test for fish density (no. m^{-2}), biomass (g m^{-2}) and species diversity (H') from catches taken on consecutive nights

$^{**}P < 0.01$; $^{*}P < 0.05$; n.s., not significant

Data set	Z-value	Significance
Density	–4·10	**
Biomass	–2·03	*
Species diversity	–1·42	n.s.

Table 3. Sources of variation for ANOVA for fish density (no. m^{-2}), biomass (g m^{-2}) and species diversity (H') [ln(n + 1)]

$^{**}P < 0.01$; n.s., not significant

Data set	Source of variation	d.f.	s.s.	F-ratio
Density	Year	1	1·91	9·13**
	Month	5	11·26	10·77**
	Replicate	3	9·55	15·23**
	Residual	10	2·09	
Biomass	Year	1	0·52	0·56 n.s.
	Month	5	4·07	0·88 n.s.
	Replicate	3	7·03	2·53 n.s.
	Residual	10	9·27	
Species diversity	Year	1	0·03	1·09 n.s.
	Month	5	0·44	3·20 n.s.
	Replicate	3	0·23	2·81 n.s.
	Residual	13	0·27	

Hydrology

The water quality of the mangrove site was predominantly oceanic rather than estuarine. Salinity ranged from 22·3 to 36·2, with a mean of 33·7. The high mean reflects the limited freshwater input at the sampling site causing little dilution of the oceanic water entering from the nearby bay (Fig. 1). Water temperature ranged from 14·6°C to 32·2°C, with a mean of 23·4°C. Water depth at the front edge of the permanent fence-nets ranged from 0·67 m to 1·19 m. The variations in tidal height during sampling periods had no effect on the number of fish caught from within each cell.

Table 4. Mean density (no. m^{-2}), biomass (g m^{-2}) and species diversity (H') for fish caught from November 1991 to November 1993 in four cells (1000 m^2 each) of a *Rhizophora stylosa* mangrove forest, Tin Can Bay, Australia

	Cell 1	Cell 2	Cell 3	Cell 4
Density	0·02 ± 0·01	0·03 ± 0·01	0·05 ± 0·01	0·06 ± 0·02
Biomass	0·69 ± 0·24	1·34 ± 0·45	1·49 ± 0·50	2·07 ± 0·70
Species diversity	1·20 ± 0·12	1·46 ± 0·13	1·23 ± 0·12	1·64 ± 0·13

Discussion

Fish Density and Biomass

Economically important fish species contributed substantially to the number (>76%) and biomass (>74%) of fish entering the *Rhizophora stylosa* forest. This pattern of use is found in temperate and subtropical *Avicennia marina* forests; Bell *et al.* (1984) reported 38% of the density and 32% of the biomass and Morton (1990) reported 75% of density and 94% of the biomass being of commercial value. Juveniles of all abundant commercial species were commonly caught in all three studies, with the exception of *Mugil cephalus* in the present study and *Girella tricuspidata* in Morton (1990). In contrast, juveniles of commercial fish species enter tropical mangrove forests less frequently (Blaber *et al.* 1985; Robertson and Duke 1987) but are often found in the subtidal waters along the mangrove fringes (Sheaves 1992). Although only a few commercial species were taken in the small-meshed (3 mm) trap-nets of Robertson and Duke (1990), commercial species such as *Lates calcarifer* (barramundi), *Acanthopagrus berda* (black bream), *Lutjanus argentimaculatus* (mangrove jack), *Scomberoides* sp. (queenfish), *Liza dussumieri* (mullet) and *Sillago sihama* (whiting) contributed significantly to the overall biomass of their catches.

Species Diversity

The fish species diversity found in subtropical mangroves is lower than that found in tropical systems. In the present study, the species diversity of fish entering *R. stylosa* forests (42 species) was similar to that of fish entering subtropical *A. marina* in Australia (65 species, Stephenson and Dredge 1976; 42 species, Morton 1990) and subtropical *R. mangle* in Florida, USA (64 species, Thayer *et al.* 1987). Tropical mangrove systems have greater species diversity, with >100 species being recorded (Blaber *et al.* 1985; Blaber and Milton 1990; Robertson and Duke 1990; Sasekumar *et al.* 1992). Although the proportions of commercial species within subtropical and tropical mangrove habitats differ greatly, both habitats are important in sustaining commercial and recreational fisheries. The nursery and feeding areas provided by subtropical mangroves support intermediate carnivores that constitute the majority of the catch in these areas, whereas the secondary production of planktivores/microbenthic carnivores sustained by tropical mangrove systems provides a food source for species (often percivores) that seldom enter the mangrove forest.

Methodology Considerations

The density and biomass of fish using *R. stylosa* were lower than those recorded for other Australian mangrove systems (Table 5); however, no standard netting technique has been used in all cases. With the exception of Morton (1990), direct comparison between catches cannot be made because of differences in netting techniques and net mesh sizes. Continuing studies on fish communities of *A. marina* forests in Moreton Bay by the Queensland Department of Primary Industries, using the same methods as this study, indicate that density and biomass vary in different spatial regions and with different moon phases. Indications are that the variation in fish density and biomass for *A. marina* forests on the islands of Moreton Bay may be as low as 10–20% of that reported by Morton (1990) for mangroves adjacent to a tidal creek (R. H. Quinn, personal communication).

Block-netting resulted in the capture of both pelagic and demersal fish that entered the mangrove forests rather than just those inhabiting the edges. From mark-and-recapture studies involving eight species of fish, Morton (1990) estimates the efficiency of the block-net to be between 66% and 100%, with an average of 88%. This implies that the number of demersal fish (such as *Sillago analis*, *S. ciliata*

Table 5. Comparison of fish density (no. m^{-2}) and biomass (g m^{-2}) for studies of fish within mangrove forests along the eastern coast of Australia

Mangrove forest type or complex	Net type and mesh size	Area sampled (m^2)	Density (no. m^{-2}) (% economic)	Biomass (g m^{-2}) (% economic)	Location and latitude	Source
Rhizophora stylosa (subtropical)	Block, 18 mm	1000	0·04 ± 0·01 (76)	1·3 ± 0·2 (74)	Tin Can Bay, 25°54′S	Present study (1991–93)
Avicennia marina (temperate)	Block, 13 mm	~1000	~0·94 (38)	~6·4 (32)	Botany Bay, 34°1′S	Bell *et al.* (1984)
Avicennia marina (subtropical)	Block, 18 mm	3340	0·27 ± 0·14 (75)	25·3 ± 20·4 (94)	Moreton Bay, 27°29′S	Morton (1990)
Rhizophora stylosa, *Ceriops tagal*, *Avicennia marina* (tropical)	Trap, 3 mm	Unknown	3·5 ± 2·4[A] (<6)	10·9 ± 4·5[B] (<36)	Townsville, 19°21′S	Robertson and Duke (1990)

[A]Units are no. m^{-3}, as water depth varied greatly in this study.
[B]Units are g m^{-3}, as water depth varied greatly in this study.

and *Platycephalus fuscus*) may be underestimated in the present study by about 12% because these fish are able to escape under the lead line of the block-net. Surface-swimming fish such as mugilids and hemirhamphids may have jumped over the top of the net and small species such as atherinids and gobioids would have been able to swim directly through the mesh of the net, causing an underestimate of their numbers. With our sampling technique, only fish that were present in the forest at the time that the block-net was put in place and that were large enough to be captured in the mesh were sampled. It is also possible that some fish entered and left the forest before high tide and thus were not represented in these samples.

The differences in catch rates for the sampling cells may be explained if fish moved into the intertidal zone by following natural depressions as they filled with water. This would cause more fish to swim directly into Cell IV than into the other cells because of the natural soak that existed. Once these fish were in Cell IV, their lateral movement 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 cells.

The low fish use of subtropical *R. stylosa* forest, compared with all other forest types (Robertson and Blaber 1992), may have been a result of a reluctance 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 as that of *A. marina* forests. If so, fish may use only the seaward fringe of the forest, causing an underestimation in the density and biomass of fish using the fringing mangroves and an overestimation for the rest of the forest.

Although the fish use of this type of mangrove is low, compared with that of other types of mangrove forests, the large undisturbed *R. stylosa* forests along much of the foreshore within Tin Can Bay allow a lucrative commercial and recreational fishery to be maintained. The results indicate that there is a large variance in the fish use of particular microhabitats within small regions of seemingly homogeneous habitat and that temporal (seasonal) variations play a significant role in determining forest use. These variations need to be considered when the results of this study are extrapolated to encompass areas similar to Tin Can Bay or areas not near the study site but with similar mangrove communities.

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