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Temporal variation in species composition and abundance of fish and decapods of a tropical seagrass bed in Cockle Bay, North Queensland, Australia

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Abstract

A total of 45 fish species and 55 decapod species were collected by seine net from the seagrass beds in Cockle Bay. The dominant fish species were *Leiognathus bindus, Sillago maculata burrus*, *Favonigobius reichei*, *Lethrinus* sp., and *Pelates sexlineatus* and these accounted for 87.5% of the total numbers. Dominant decapod taxa were *Paratya, Rhynchocinetes* and *Brachycarpus*. These were primarily small species or early juveniles of larger species. Temporal variation in both species composition and abundance was large: the peak number of fishes and decapods occurred in April 1999 and October 1999, whilst biomass was highest in April 1999. Fish and decapod numbers as well as biomass were lowest in August 2000. Temporal changes in the abundance of fishes and decapods corresponded with that of seagrass biomass and abundance of food organisms.

Keywords: *Leiognathus*; *Sillago*; *Paratya*; *Rhynchocinetes*; Seagrass biomass; Nursery function

1. Introduction

The ecological importance of seagrass as food source, nursery habitat and substrate stabilizers in estuaries and coastal areas throughout the world is well established (Klumpp et al., 1989; Haywood et al., 1995; Edgar and Shaw, 1995a,b; Rozas and Minello, 1998; Hemminga and Duarte, 2000). However, most of this information is based on research on temperate seagrass beds. Recent studies on tropical seagrass beds in Australia have shown

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the value of seagrass beds as nursery grounds for juvenile penaeid prawns (Turnbell and Mellors, 1990; Coles et al., 1992, 1993; Lee Long et al., 1993) and as feeding area for dugongs (Marsh et al., 1982).

Queensland has an estimated 23,200 km^2 of seagrass beds of substantial value (Hamdorf and Kikman, 1995), but the fish community of these seagrass beds has not been extensively studied. For example, species composition and biomass of fishes have been reported in tropical seagrass beds of Groote Eylandt and around Cairns, Queensland (Blaber et al., 1992; Coles et al., 1992, 1993) as part of a seagrass monitoring survey of seagrass communities and fauna in dry or wet periods. To date the study of the rich seagrass beds in Cockle Bay, North Queensland has been confined to the distribution, succession and spatial pattern of seagrasses (Birch and Birch, 1984; Coles et al., 1992). However, there are several studies describing the fish and crustacean communities in neighboring habitats such as estuarine, inshore bay and mangrove forests of the adjacent Bowling Green and Cleveland Bays (Jenkins et al., 1984, 1985; Williams and Cappo, 1990; Robertson and Duke, 1990; Simpfendorfer and Milward, 1993; Sheaves, 1995).

The objective of this study was to examine the temporal variation in species composition and abundance of fishes and decapods inhabiting seagrass beds of Cockle Bay, North Queensland, Australia and to determine the relationships between environmental factors and fish and decapod abundance. It is part of a wider study aimed at understanding the trophic relationships of fishes and benthic macrofauna in this tropical Australian seagrass bed. The present study provides information on ecology of a tropical seagrass community in the Pacific Ocean where, compared with the Caribbean (Weinstein and Heck, 1979; Robblee and Zieman, 1984; Heck and Weinstein, 1989; Baelde, 1990), few studies have been carried out.

2. Methods

The study area, Cockle Bay off Magnetic Island, is about 7 km off the North Queensland coast (Fig. 1). Cockle Bay has a water depth of less than 3 m and is protected from prevailing winds by the island, and from the ocean swell by the Great Barrier Reef. The low-energy bay consequently supports a mangrove fringe (McNae, 1966), and a living fringing reef on the outer margins, dominated by Brain Corals (*Goniastrea aspera* (Verrill)) and Soft Corals (*Sarcophyto* spp.).

Cockle Bay contains extensive seagrass beds (200∼400 m wide) extending from the mangrove zone to the fringing reef (Birch and Birch, 1984). The beds in front of the mangrove zone are sparse compared with other parts of the bay. A channel running parallel to the shore and 90 m from the datum point divides the beds into landward and seaward sections. Two areas dominated by seagrass were chosen as sampling stations based on a pilot study in February 1999. The first site (station 1) was located inshore bordering a dense mangrove stand. The second site (station 2) was located in the offshore part of the bay, in front of the fringing reefs. Seagrass vegetation at this site formed a band adjacent to the shoreline approximately 100 m wide.

Fishes and decapods were collected by a 15 m seine net with 3 m drop and 1 mm × 1 mm mesh according to the techniques described in Edgar and Shaw (1995a). The net was set

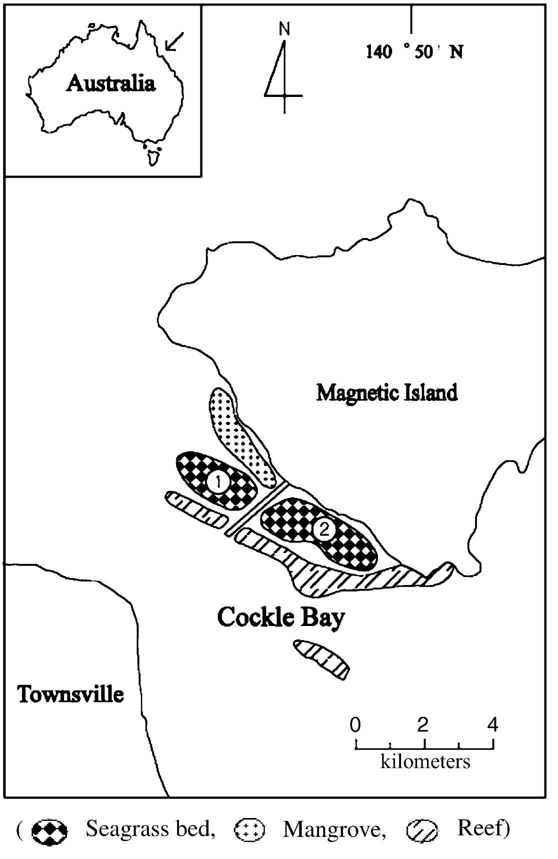

Fig. 1. Map of study sites in Cockle Bay, North Queensland.

from a dingy by first anchoring the boat along the circumference of a circle of 40 m radius. The boat was then pulled by hand up the anchor line without dragging the net while at the same time 12 m ropes attached to the two ends of the net were let out. The boat was then retied to the anchor lines so that the anchor would counterbalance the drag force caused by pulling the net. A period of at least 2 min was allowed to elapse before hauling the net in order to minimize any disturbance to the fish and decapods community caused by the deployment of the net. To prevent the base of the net lifting above the seagrass beds, the net ropes were attached to a 25 kg weight laid on the bottom. Seine netting was carried out during daylight high tides of each sampling period in April and October 1999 and March and August 2000. Four replicate hauls at station 1 and six replicate hauls at station 2 were made at these times. Samples were not taken at station 1 in August 2000 because of adverse tidal conditions. All of the fishes and decapods collected in each seine haul were preserved in 10% formalin in seawater and later transferred to 70% isopropanol. In the laboratory, these samples were identified to at least genus level according to Grey et al. (1983); Gloerfelt-Tarp and Kailola (1985); Holthuis (1993), counted and weighed to the nearest gram wet weight.

Specimens were measured to the nearest mm (fish, standard length SL; shrimp, carapace length CL; crabs, carapace width CW). Crabs were separated on the basis of sex.

Water temperature and salinity was measured at each sampling location. Seagrass biomass was estimated by removal of all plant matter in a 0.01 m^2 plot within each station. In the laboratory, each sample was separated to species and the shoots measured to the nearest cm to determine mean shoot length. Samples were dried at 80 °C for 24 h and weighed to the nearest 1 g for estimation of aboveground seagrass biomass. The identification of seagrass species was adapted from Lanyon (1984).

Two-way analyses of variance (ANOVA) were used to determine if number of individuals, biomass, and number of species differed between stations and months after verification of the normality of the data and homogeneity of variances (Sokal and Rohlf, 1981). The relationships between fish and decapod abundance and seagrass biomass were analyzed using regression.

3. Results

3.1. Seagrass composition and abundance

Of the six seagrass species occurring in Cockle Bay (Fig. 2a), *Cymodocea serrulata* and *Halodule uninervis* were dominant throughout the year (75–90% in biomass). Other relatively abundant species were *Cymodocea rotundata*, *Halophila ovalis* and *Halodule pinifola*. *C. serrulata* was most dominant in October 1999, but there was only minimal change in abundance of this species with season.

Seagrass biomass varied temporally with a peak around October 1999 (Fig. 2b), a decline in March 2000 and a minimum in August 2000. This decline in March 2000, relative to April 1999, occurred soon after Cyclone *Tessi*, which affected the region in February 2000. The cyclone brought heavy rainfall and high winds to this area (AIMS weather reports, 2000).

3.2. Fish and decapod species composition

A total of 702 fish belonging to 45 species and representing 30 families were collected from the Cockle Bay seagrass beds (Table 1). The major families ranked by numbers and biomass were Leiognathidae, Sillagonidae, Lethrinidae, and Tetraponidae. Numerically dominant fish were *L. bindus* (55%), *S. maculata burrus* (12%), *F. reichei* (7%), *Lethrinus* sp.(7%), and *P. sexlineatus* (7%), together accounting for 88% of the catch. The numerically dominant fish species made up only 37% of biomass because of the presence of few large *Arothron manillensis* (36% of biomass) which were high in biomass. Carnivores dominate the trophic composition of the seagrass fish community. These were primarily small fish species or early juveniles of large fish species. Only about 7% exceeded 5 cm standard length.

A total of 328 decapods, belonging to 55 species (41 shrimp, 3 hermit crab, and 11 crab species) and representing 17 families, were collected (Table 2). The major families in terms of both numbers and biomass were Rhychocinetidae, Atyidae, Palaemonidae and Penaeidae. Numerically dominant species were *Paratya* sp. B (13%), *Rhynchocinetes* sp. A

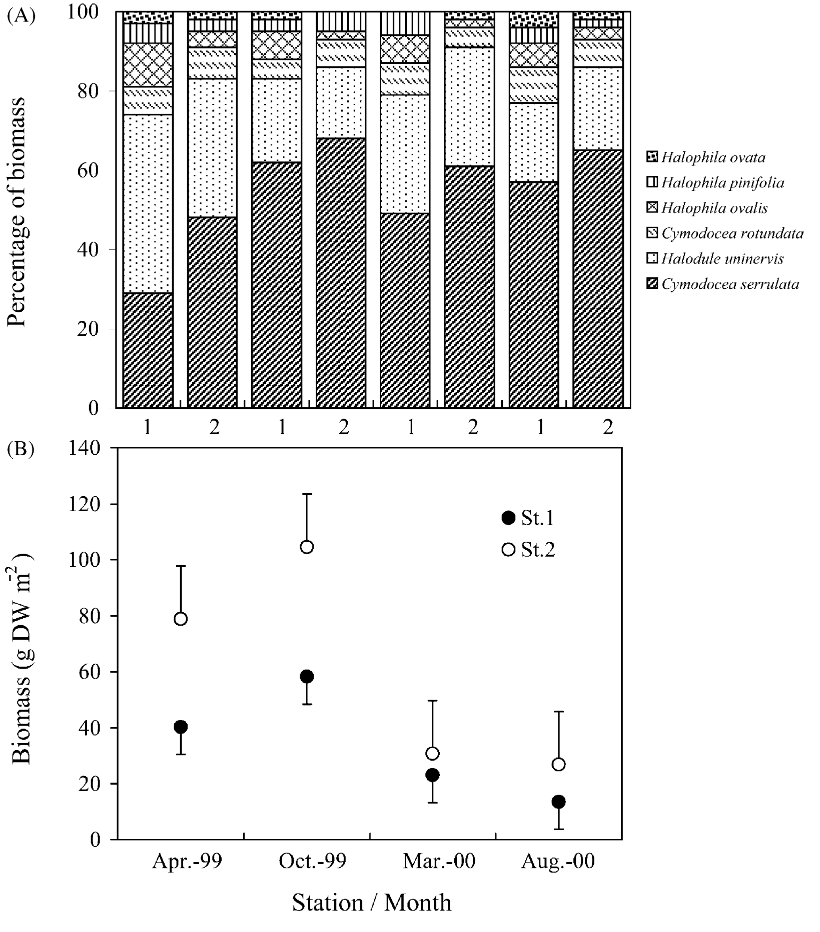

Fig. 2. (A) Proportional abundance of different seagrass species, and (B) total seagrass biomass (±standard error) for two stations off Magnetic Island in Cockle Bay.

(13%), *Brachycarpus* sp. B (8%), *Rhychocinetes* sp. E (7%), *Brachycarpus* sp. A (6%), *Rhynchocinetes* sp. C (6%), *Rhynchocinetes* sp. B (5%), *Rhynchocinetes rugulosus* (5%), *Paratya* sp. C (3%), *Paratya australiensis* (3%) and *Penaeus esculentus* (3%). These are made up 73% of numbers of individuals and 59% of total biomass. Most individuals were relatively small: 0.23–1.45 cm CL for shrimps and 0.21–2.43 cm CW for crabs.

3.3. Temporal variation in abundance of fish and decapods

Using two-way ANOVAs, the number of fish species was found to differ significantly between months with a lower value in August 2000 compared with other periods. However, no significant variation in species was found among stations (Table 3, Fig. 3). The number of fish individuals differed substantially between different months and stations (ANOVA, Table 3). Higher number of fish individuals occurred at station 2 than station 1 with the

Table 1
Fishes occurring in seagrass beds in Cockle Bay in order of decreasing number of individuals

Family/species	N	Percentage	B	Percentage	Trophic category[a]
Leiognathidae					
Leiognathus bindus	387	55.13	56.59	18.03	C
Secutor insidiator	4	0.57	1.54	0.49	C
Sillagonidae					
Sillago maculata burrus	86	12.25	26.00	8.28	C
Gobiidae					
Favonigobius reichei	47	6.70	5.67	1.81	C
Acentrogobius multifasciatus	3	0.43	0.92	0.29	D
Glossgobius biocellatus	2	0.28	0.51	0.16	D
Yongeichthys cringer	1	0.14	0.60	0.19	C
Drombus sp.	<1	<0.01	0.05	0.02	C
Cryptocentrus caeruleomaculatus	<1	<0.01	0.13	0.04	C
Lethrinidae					
Lethrinus sp.	47	6.70	22.95	7.31	C
Tetraponidae					
Pelates sexlineatus	23	3.28	4.02	1.28	C
Atherinidae					
Pranesus endrachtensis	16	2.28	7.56	2.41	C
Engraulidae					
Stolephorus sp.	15	2.14	7.92	2.52	C
Mullidae					
Upeneus tragula	12	1.71	5.34	1.70	C
Labridae					
Coris caudimacula	10	1.42	6.06	1.93	C
Halichoeres tenuispinnis	2	0.28	3.57	1.14	C
Stethojulis strigiventer	1	0.14	0.16	0.05	C
Siganidae					
Siganus canaliculatus	9	1.28	4.74	1.51	C
Gerreidae					
Gerres abbreviatus	4	0.57	0.42	0.13	C
Gerres kapas	2	0.28	6.67	2.13	C
Clupeidae					
Escualosa thoracata	4	0.57	0.51	0.16	C
Scorpaenidae					
Paracentropogon vespa	4	0.57	3.58	1.14	C
Tetradontidae					
Arothron manillensis	4	0.57	113.69	36.22	O
Blennidae					
Petroscirtes brevicep	3	0.43	1.22	0.39	C
Haemulidae					
Pomadasys maculatus	2	0.28	0.02	0.01	O

Table 1 (*Continued*)

Family/species	N	Percentage	B	Percentage	Trophic category[a]
Syngnathidae					
Trachyrhampus longirostris	2	0.28	0.43	0.14	C
Syngnathoides biaculeatus	<1	<0.01	1.35	0.43	D
Hippocampus kuda	<1	<0.01	0.05	0.02	C
Tetraponidae					
Mesopristes argenteus	2	0.28	0.78	0.25	C
Sphyraenidae					
Sphyraena pinguis	2	0.28	1.75	0.56	C
Sphyraena sp.	1	0.14	0.07	0.02	C
Platycephalidae					
Onigocia spinosa	2	0.28	1.84	0.59	C
Inegocia japonicus	<1	<0.01	10.68	3.40	C
Monocanthidae					
Acreichthys tomentosus	2	0.28	2.13	0.68	O
Bothidae					
Pseudorhambus elevatus	1	0.14	2.10	0.67	C
Lutjanidae					
Lutjanus sp.	1	0.14	0.21	0.07	C
Lutjanus fulviflamma	1	0.14	10.50	3.35	C
Callionymidae					
Synchiropus sp.	<1	<0.01	0.26	0.08	C
Callionymus meridionalis	<1	<0.01	0.13	0.04	C
Cynoglossidae					
Cynoglossus macropthalmus	<1	<0.01	0.08	0.03	C
Serranidae					
Epinephelus melanostigma	<1	<0.01	0.53	0.17	C
Hemiramphidae					
Hyporhampus affinis	<1	<0.01	0.35	0.11	H
Dactylopteridae					
Dactylopus dactylopus	<1	<0.01	0.13	0.04	C
Soleidae					
Heteromycteris japonica	<1	<0.01	0.05	0.02	C
Apogonidae					
Apogon semilineatus	<1	<0.01	<0.01	<0.01	C
Total	702	100.00	313.86	100.00	

N: number of individuals per seine haul, B: Biomass per seine haul

[a] C: carnivore, H: herbivore, O: omnivore, D: detritivore.

highest value in April and October 1999 (Fig. 3). A significant difference was observed between months for fish biomass, but not among stations (Table 3). Fish biomass of station 1 was higher in March 2000 when a few *A. manillensis* of large size were present. However, at station 2, the highest biomass was in April 1999 (Fig. 3).

Table 2
Decapods occurring in seagrass beds in Cockle Bay in order of decreasing number of individuals

Family/species	N	Percentage	B	Percentage	Range of CL[a] and CW[b]
Penaeiodea					
Penaeidae					
Penaeus esculentus	10	3.05	7.65	27.46	0.33–1.43
Metapenaeus endeavouri	7	2.13	0.62	2.23	0.21–0.82
Penaeus semisulcatus	4	1.22	2.27	8.15	0.23–1.42
Atypopenaeus stenodactylus	2	0.61	0.20	0.72	0.44–0.85
Metapenaeus wellsi	<1	<0.00	0.08	0.29	0.42–0.87
Penaeus canaliculatus	<1	<0.00	0.19	0.68	0.83
Penaeus latisculatus	<1	<0.00	0.09	0.32	1.12
Caridea					
Rhynchocinetidae					
Rhynchocinetes sp. A	43	13.11	1.06	3.80	0.22–0.61
Rhynchocinetes sp. E	24	7.32	0.54	1.94	0.21–0.63
Rhynchocinetes sp. C	18	5.49	0.43	1.54	0.22–0.68
Rhynchocinetes sp. B	16	4.88	0.27	0.97	0.21–0.63
Rhynchocinetes rugulosus	16	4.88	0.32	1.15	0.21–0.59
Rhynchocinetes sp. D	4	1.22	0.08	0.29	0.26–0.64
Atyidae					
Paratya sp. B	44	13.41	0.83	2.98	0.24–0.51
Paratya sp. C	11	3.35	0.18	0.65	0.22–0.55
Paratya australiensis	10	3.05	0.20	0.72	0.24–0.62
Caridina sp.	9	2.74	0.38	1.36	0.41–0.55
Paratya sp. A	8	2.44	0.15	0.54	0.23–0.52
Paratya atacta	6	1.83	0.08	0.29	0.22–0.58
Syncaris sp.	4	1.22	0.03	0.11	0.21–0.49
Palaemonidae					
Brachycarpus sp. B	25	7.62	2.76	9.91	0.32–0.55
Brachycarpus sp. A	21	6.40	2.27	8.15	0.31–0.58
Palaemon sp. C	7	2.13	0.07	0.25	0.22–0.55
Palaemon sp. A	3	0.91	0.03	0.11	0.25–0.51
Leptocarpus sp.	2	0.61	0.01	0.04	0.24–0.49
Brachycarpus sp. D	1	0.30	0.04	0.14	0.22–0.25
Brachycarpus sp. C	1	0.30	0.06	0.22	0.24
Palaemon sp. D	<1	<0.00	<0.01	<0.00	0.22
Palaemon sp. B	<1	<0.00	<0.01	<0.00	0.21
Palaemon litoreus	<1	<0.00	<0.01	<0.00	0.26
Hippolytidae					
Latreutes sp. A	7	2.13	0.30	1.08	0.11–0.52
Saron sp.	2	0.61	0.01	0.04	0.24–0.29
Latreutes sp. C	1	0.30	0.37	1.33	0.42
Latreutes mucronatus	1	0.30	0.01	0.04	0.22
Hippolyte sp.	1	0.30	0.19	0.68	0.27
Thor sp.	<1	<0.00	<0.01	<0.00	0.23
Alpheidae					
Alpheus sp.	2	0.61	0.03	0.11	0.22
Alpheus parasocialis	1	0.30	0.05	0.18	0.23–0.55

Table 2 (*Continued*)

Family/species	N	Percentage	B	Percentage	Range of CL[a] and CW[b]	
Crangonidae						
Lissosabinea sp.	1	0.30	0.02	0.07	0.24–0.58	
Desmocarididae						
Desomocaris sp.	1	0.30	<0.01	<0.00	0.23–0.52	
Nematocarcinidae						
Nematocarcinus sp.	<1	<0.00	<0.01	<0.00	0.21	
Subtotal	313	95.43	21.87	78.50		
Anomura						
Diogenidae						
Clibanarius taeniatus	6	1.83	0.34	1.22		
Clibanarius sp.	<1	<0.00	0.03	0.11		
Diogenes sp.	<1	<0.00	0.01	0.04		
Subtotal	6	1.83	0.38	1.36		
Brachyura					Female	Male
Portunidae						
Thalamita integra	3	0.91	0.49	1.76	0.81–0.83	0.82
Thalamita cooperi	1	0.30	0.07	0.25	1.32	0.82
Portunus pelagicus	<1	<0.00	0.07	0.25		2.42
Portunus emarginatus	<1	<0.00	0.07	0.25		1.71
Majidae						
Naxia aries	4	1.22	1.71	6.14	0.22–0.83	0.81–1.31
Huenia sp.	<1	<0.00	2.08	7.47	1.71	
Xanthidae						
Zosimus aeneus	1	0.30	0.05	0.18	0.72	
Parthenopidae						
Daldorfia sp.	<1	<0.00	1.02	3.66		1.72–2.33
Dromiidae						
Petalomera lateralis	<1	<0.00	0.04	0.14	0.22–1.34	0.25–0.84
Leucosiidae						
Leucosia sp.	<1	<0.00	0.01	0.04	0.82	0.51–1.12
Ocypodidae						
Uca sp.	<1	<0.00	<0.01	<0.00	0.73–1.35	0.83
(Subtotal)	9	2.74	5.61	20.14		
Total	328	100	27.86	100		

N: number of individuals per seine haul, B: Biomass per seine haul
[a] CL: Carapace length in shrimps.
[b] CW: Carapace width in crabs.

The two-way ANOVAs revealed that the number of decapod species, number of decapod individuals, and decapod biomass differed significantly between months and among stations, with the largest numbers occurring at station 2 (Table 3, Fig. 4). There was a slight month × station interaction for decapod biamass (Table 3). At station 2, number of decapod species

Table 3
F-values and levels of significance for the two-way ANOVA's of number of individuals, biomass [log $(N+1)$, log $(B+1)$] and number of species (S) of fish and decapod

Source of variation	d.f.	Fishes			Decapods		
		log $(N+1)$	log $(B+1)$	S	log $(N+1)$	log $(B+1)$	S
Month	3	22.06*	146.8**	134.08**	63.12**	43.19**	23.07*
Station	1	39.67*	20.09	16.78	20.67*	31.23*	31.49*
Month × station	2	1.01	2.45*	1.11	1.51	2.11*	0.89

* $0.01 < P < 0.05$.
** $P < 0.01$.

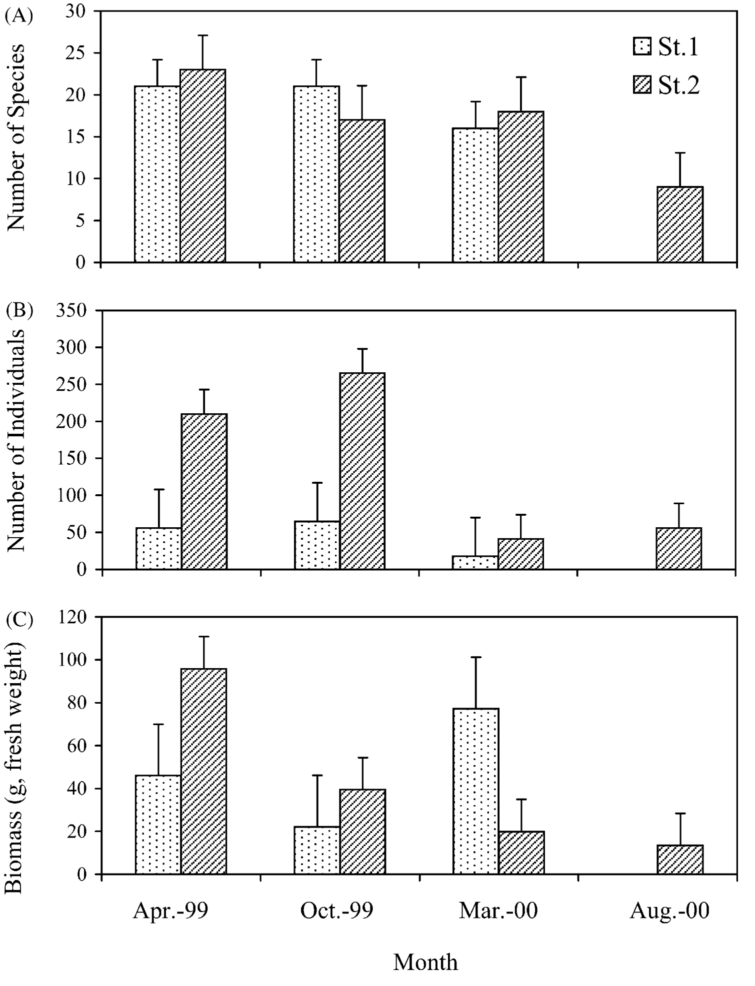

Fig. 3. Temporal variation in number of species (A), number of individuals (B), and biomass (per seine haul) of fishes (C) in seagrass beds at two stations in Cockle Bay, 1999–2000.

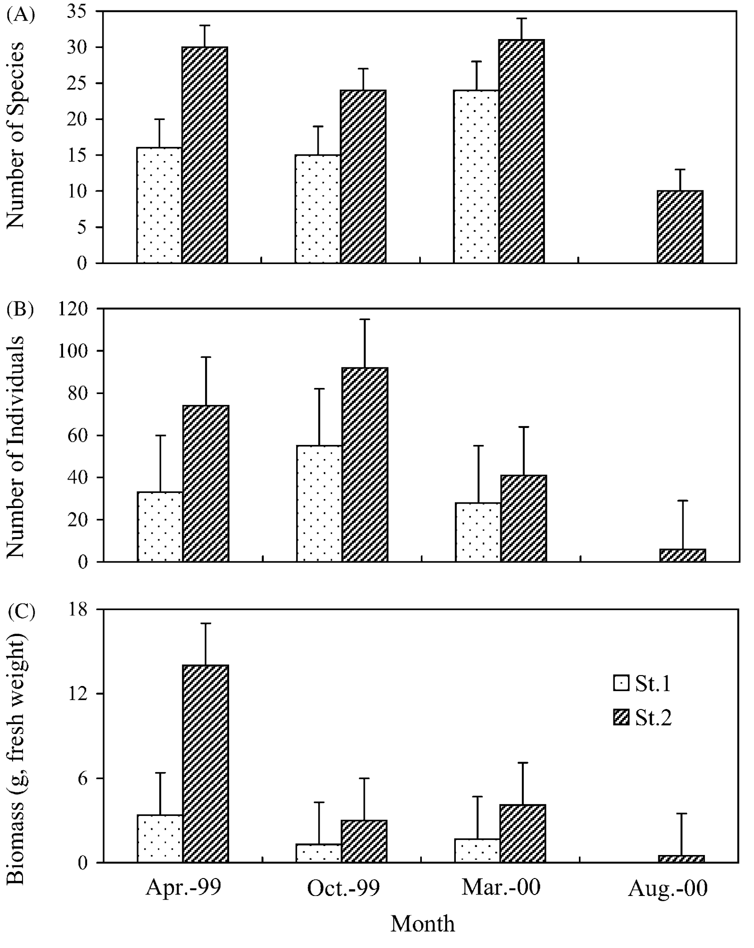

Fig. 4. Temporal variation in number of species (A), number of individuals (B), and biomass (per seine haul) of decapods (C) in seagrass beds at two stations in Cockle Bay, 1999–2000.

was more than 20 species except in August 2000 and number of decapod individuals was highest in October 1999, while biomass of decapods was highest in April 1999 when an abundance of large *P. esculentus* was found (Fig. 4).

Seagrass biomass variation corresponded closely with temporal variation of the abundance of fishes and decapods over the study period (Fig. 5). Numbers of individuals per seine haul of both fishes ($r^2 = 0.94$, $P < 0.01$) and decapods ($r^2 = 0.85$, $P < 0.01$) were strongly correlated with seagrass biomass.

4. Discussion

A total of 45 fish species was recorded from the seagrass beds of Cockle Bay and of these *L. bindus*, *S. maculata burrus*, *F. reichei*, *Lethrinus* sp. and *P. sexlineatus* were numerically

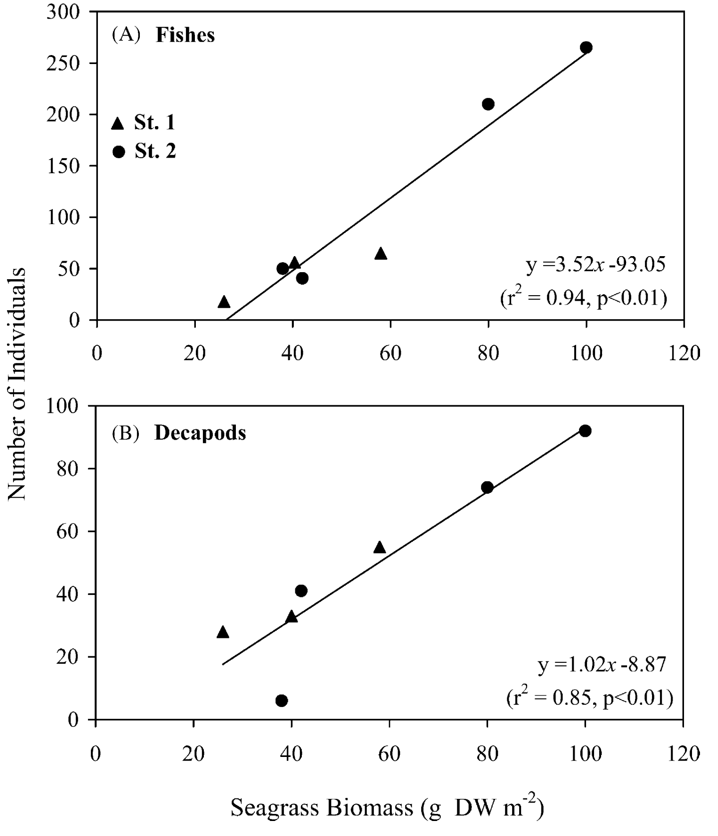

Fig. 5. Relationships between fish (A) and decapod abundance (B) and seagrass biomass at two stations in Cockle Bay. Station means across seasons are plotted.

dominant. Broad-scale surveys of fish communities in seagrass beds from other regions of Queensland suggest a similar community structure. The genera *Leiognathus* and *Pelates* also dominated the fish communities of seagrass beds from Cairns to Bowen (Coles et al., 1992), inside Cairns Harbour (Coles et al., 1993) and on Groote Eylandt, Northern Australia (Blaber et al., 1992). These fish groups are of commercial and recreational importance. For example *Pelates* (Teraponidae) is valued as live bait in Queensland, and the family Sillaginidae is harvested as a food fish (Coles et al., 1992). Compared with the seagrass beds of tropical Australia, the temperate areas such as Western Port Bay, Victoria (Edgar and Shaw, 1995a) had more fish species (59) and a different species composition. For example, small non-commercially important groups such as Gobiidae, Syngnathidae, and Clinidae, and the commercially important *Meuschenia freycineti*, *Hyporhamphus melanochir*, *Engraulis australis*, and *Sardinops neopichardus* dominate temperate Australian seagrass beds. Several studies show that Gobiidae are distributed widely in coastal areas regardless of climate and factors such as seagrass composition, temperature, and biological variables (Blaber et al., 1992; Coles et al., 1992, 1993).

The 55 decapod species collected from the seagrass beds of Cockle Bay were mostly shrimps. Rhychocinetidae and Atyidae were the dominant families followed by Palaemonidae, Penaeidae, and Hippolytidae. Studies of the tropical seagrass beds of Green Island, Queensland showed that Processidae, Palaemonidae, Hippolytidae, Sergestidae, and Penaeidae were dominant in that order (Mellors and Marsh, 1993). Temperate Australian seagrass decapod communities, such as in Western Port Bay in Southeastern Australia, were dominated by Palaemonidae, Crangonidae, Hippolytidae, and Pandalidae (Howard, 1984). Caridean shrimps in particular were in high abundance, as well as Palaemonidae and Hippolytidae. These groups were abundant in seagrass beds regardless of locations, sampling gear used and climate. Brook (1977) and Gore et al. (1981) reported that the caridea fauna was dominated by Hippolytidae in seagrass systems in Florida.

Fish collected from the Cockle Bay seagrass beds appeared to be dominated by small fish and juveniles of most species. This indicated that the seagrass beds of Cockle Bay function as nursery areas. Such conclusions are in general agreement with other studies of tropical seagrass beds (Adams, 1976; Weinstein and Heck, 1979; Blaber et al., 1992; Coles et al., 1993; Hutomo and Peristiwady, 1996; Nagelkerken et al., 2002). A significantly greater abundance of decapod juveniles than that of adults in our study site at Cockle Bay confirmed that also these species were likely to be dependent on seagrass beds for shelter and survival during the early life cycle stages (Coles and Lee Long, 1985; Turnbell and Mellors, 1990; Haywood et al., 1995; Vance et al., 1996).

Temporal variation in species composition and abundance appear to be considerable for both fish and decapod communities utilizing tropical seagrass beds. In Cockle Bay, the number of individuals was highest in April 1999 and October 1999 and biomass was high in April 1999 and March 2000. These peaks in abundance corresponded closely with peak seagrass biomass and prey availability. Temporal variation of seagrass biomass in Cockle Bay was marked. When seagrass biomass increased from April 1999, the number of fish and decapod individuals also increased and numbers declined with decreases in seagrass biomass from March 2000. Several other studies have demonstrated a positive correlation between faunal richness and abundance and the aboveground biomass of seagrass beds (Nelson, 1981; Leber, 1985; Bell and Pollard, 1989; Connolly et al., 1999). Features of seagrass beds such as shoot density and length can influence faunal abundance, and this has been shown best with decapods. The density of caridean shrimps was significantly associated with seagrass biomass, although the abundance of penaeids shrimps was not correlated in this way at Green Island, Northern Queensland (Mellors and Marsh, 1993).

Prey availability may also be an important factor influencing faunal abundance in tropical seagrass beds. High seagrass standing crop provides good shelter and food resources for small organisms such as epiphytic epifauna (Amphipods, Isopods, Tanaids, etc.). Smaller individuals of the dominant fish species of Cockle Bay (*S. maculata burrus*, *Lethrinus* sp. and *P. sexlineatus*) fed mainly on small gammarid amphipods and isopods (Kwak, unpublished data). The temporal abundance of epiphytic epifauna coincided with these groups of dominant fishes during the study period. These common fish species changed diets from gammarid amphipods and copepods to decapods such as caridean shrimps and crabs (and polychaetes) as they increased in size (Kwak, unpublished data). The caridean shrimps were the most common decapods in Cockle Bay and their temporal pattern of abundance was very similar to that of fishes. Hence we suggest that the high abundance of epiphytic epifauna and caridean shrimps was responsible for the maintenance of fish abundance through predator–prey interactions in these seagrass beds.

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References

Adams, S.M., 1976. The ecology of eelgrass, *Zostera marina* (L.), fish communities. I. Structural analysis. J. Exp. Mar. Biol. Ecol. 22, 269–291.

Baelde, P., 1990. Differences in the structures of fish assemblages in *Thalassia testudinum* beds in Guadeloupe, French West Indices, and their ecological significance. Mar. Biol. 105, 163–173.

Bell, J.D., Pollard, D.A., 1989. Ecology of fish assemblages and fisheries associated with seagrasses. In: Larkum, A.W.D., McComb, A.J., Shepherd, S.D. (Eds.), Biology of Seagrasses. A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier Science Publishers B. V., New York/Amsterdam, pp. 565–597 (chapter 17).

Birch, W.R., Birch, M., 1984. Succession and pattern of tropical intertidal seagrasses in Cockle Bay, Queensland, Australia: A decade of observations. Aquat. Bot. 19, 343–368.

Blaber, S.J.M., Brewer, D.T., Salini, J.P., Kerr, J.D., Conacher, C., 1992. Species composition and biomasses of fishes in tropical seagrasses at Groote Eylandt, Northern Australia. Estuar. Coast. Shelf Sci. 35, 605–620.

Brook, I.M., 1977. Trophic relationships in a seagrass community (*Thalassia testudinum*) in Card Sound, Florida: fish diets in relation to macrobenthic and cryptic faunal abundance. Trans. Am. Fish. Soc. 106, 219–229.

Coles, R.G., Lee Long, W.J., 1985. Juvenile prawn biology and the distribution of seagrass prawn nursery grounds in the Southeastern Gulf of Carpentaria. In: Rothlisberg, P.C., Hill B.J., Staples D.J. (Eds.),. Second Australian National Prawn Seminar NPS2. Cleveland, Australia, pp. 55–60.

Coles, R.G., Lee-Long, W.J., Helmke, S.A., Bennet, R.E., Miller, K.J., Derbyshire, K.J., 1992. Seagrass beds and juvenile prawn and fish nursery grounds. Cairns to Bowen. Inf. Ser. Dep. Primary Ind. Qld. Brisbane, Australia. Department Primary Industry Ql92012, pp. 1–64.

Coles, R.G., Lee-Long, W.J., Watson, R.A., Derbyshire, K.J., 1993. Distribution of seagrass and their fish and penaeid communities, in Cairns Harbour, a tropical estuary, Northern Queensland, Australia. Aust. J. Mar. Freshwater Res. 44, 193–210.

Connolly, R., Jenkins, G., Loneragan, N., 1999. Seagrass dynamics and fisheries sustainability. In: Butler, A., Jernakoff, P. (Eds.), Seagrass in Australia: Strategic Review and Development of an R & D Plan. CSIRO publishers, Collingwood, pp. 24–64 (chapter 2).

Edgar, G.J., Shaw, C., 1995a. The production and trophic ecology of shallow-water fish assemblages in Southern Australia. I. Species richness, size-structure and production of fishes in Western Port Bay, Victoria. J. Exp. Mar. Biol. Ecol. 194, 53–82.

Edgar, G.J., Shaw, C., 1995b. The production and trophic ecology of shallow-water fish assemblages in southern Australia. II. Diets of fishes and trophic relationships between fishes and benthos at Western Port, Victoria. J. Exp. Mar. Biol. Ecol. 194, 83–102.

Gloerfelt-Tarp, T., Kailola, P.J., 1985. Trawled Fishes of Southern Indonesia and North-western Australia. ADAB, Australia DGF, Indonesia GTZ, Federal Republic of Germany.

Gore, R.H., Gallaher, E.E., Scotto, L.E., Wilson, K.A., 1981. Studies on decapod Crustacea from the Indian River region of Florida. XI. Community composition, structure, biomass and species-areal relationships of seagrass and drift algae-associated macrocrustaceans. Estuar. Coast. Shelf Sci. 12, 485–508.

Grey, D.L., Dall, W., Baker A., 1983. A guide to the Australian Penaeid Prawns. Department of Primary Production of the Northerns Territory: Darwin, 140 pp.

Hamdorf, I., Kikman, H., 1995. Status of Australian seagrass. Issues Paper-March 1995. Fisheries Pollution and Marine Environment Committee Issues Paper, pp. 1–32.

Haywood, M.D.E., Vance, D.J., Loneragan, N.R., 1995. Seagrass and algal beds as nursery habitats for tiger prawns (*Penaeus semisulcatus and P. esculentus*) in a tropical Australian estuary. Mar. Biol. 122, 213–223.

Heck, K.L., Weinstein, M.P., 1989. Feeding habits of juvenile reef fishes associated with Panamanian seagrass meadows. Bull. Mar. Sci. 45, 629–636.

Hemminga, M.A., Duarte, C.M., 2000. Seagrass Ecology. Cambridge University Press, 298 pp.

Holthuis, L.B., 1993. The Recent Genera of the Caridean and Stenopodidean shrimps (Crustacea, Decapoda). National Natuurhistorisch Museum, Leiden, 328 pp.

Howard, R.K., 1984. The trophic ecology of caridean shrimps in an eelgrass community. Aquat. Bot. 18, 155–174.

Hutomo, M., Peristiwady, T., 1996. Diversity, abundance and diet of fish in the seagrass beds of Lombok Island, Indonesia. In: Kuo, J., Philips, R.C., Walker, D.I., Kirkman, H. (Eds.), Seagrass Biology: Proceeding of an International Workshop. Rottnest Island, Western Australia, pp. 205–212.

Jenkins, G.P., Milward, N.E., Hartwick, R.F., 1984. Food of larvae of Spanish mackerels, genus *Scomberomorus* (Teleostei: Scombridae), in shelf waters of Great Barrier Reef. Aust. J. Mar. Freshwater Res. 35, 477–482.

Jenkins, G.P., Milward, N.E., Hartwick, R.F., 1985. Occurrence of larvae of Spanish mackerels, genus *Scomberomorus* (Teleostei: Scombridae), in shelf waters of Great Barrier Reef. Aust. J. Mar. Freshwater Res. 36, 635–640.

Klumpp, D.W., Howard, R.K., Pollard, D.A., 1989. Trophodynamics and nutritional ecology of seagrass communities. In: Larkum, A.W.D., McComb, A.J., Shepherd, S.D. (Eds.), Biology of Seagrasses. A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier Science Publishers B. V., New York/Amsterdam, pp. 394–437 (chapter 13).

Lanyon, J., 1984. Guide to the indentification of seagrasses in the Great Barrier Reef Region. Great Barrier Reef Marine Park Authority, Special Publication Series (3), 53 pp.

Leber, K.M., 1985. The influence of predatory decapods, refuge, and microhabitat selection on seagrass community. Ecology 66, 1951–1964.

Lee Long, W.J., Mellors, J.E., Coles, R.G., 1993. Seagrasses between Cape York and Hervey Bay, Queensland, Australia. Aust. J. Mar. Freshwater Res. 44, 19–31.

Marsh, H., Channells, P.W., Heinsohn, G.E., Morrissey, J., 1982. Analysis of stomach contents of dugongs from Queensland. Aust. Wildl. Res. 9, 55–67.

McNae, W., 1966. Mangroves in eastern and southern Australia. Aust. J. Bot. 14, 67–104.

Mellors, J.E., Marsh, H., 1993. Relationship between seagrass standing crop and the spatial distribution and abundance of the natantian fauna at Green Island, Northern Queensland. Aust. J. Mar. Freshwater Res. 44, 183–191.

Nagelkerken, I., Roberts, C.M., Van der Velde, G., Dorenbosch, M., Van Riel, M.C., Nienhuis, P.H., 2002. How important are mangroves and seagrass beds for coral-reef fish? The nursery hypothesis tested on an island scale. Mar. Ecol. Progr. Ser. 244, 299–305.

Nelson, W.G., 1981. The role of predation by decapod crustaceans in seagrass ecosystems. Kier. Meeres. Sond. 5, 529–536.

Robertson, A.I., Duke, N.C., 1990. Mangrove fish-communities in tropical Queensland, Australia: spatial and temporal patterns in densities, biomass and community structure. Mar. Biol. 104, 369–379.

Robblee, M.B., Zieman, J.C., 1984. Diel variation in the fish fauna of a tropical seagrass feeding ground. Bull. Mar. Sci. 34, 335–345.

Rozas, L.P., Minello, T.J., 1998. Nekton use of salt marsh, seagrass, and nonvegetated habitats in a South Texas (USA) Estuary. Bull. Mar. Sci. 63, 481–501.

Sheaves, M.J., 1995. Large lutjanid and serranid fishes in tropical estuaries: are they adults or juveniles? Mar. Ecol. Progr. Ser. 129, 31–40.

Simpfendorfer, C.A., Milward, N.E., 1993. Utilisation of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrnidae. Environ. Biol. Fish 37, 337–345.

Sokal, R.R., Rohlf, F.J., 1981. Biometry: The principle and practice of statistics in biological research, second ed. Freeman, New York.

Turnbell, C.T., Mellors, J.E., 1990. Settlement of juvenile *P. esculentus* on nursery grounds in Torres Strait. In: Mellors, J.E. (Ed.), Torres Strait Prawn Project: A Review of Research 1986–1988. Qld Department Primary Industries Information Series Ql90018, pp. 29–37.

Vance, D.J., Haywood, M.D.E., Heales, D.S., Staples, D.J., 1996. Temporal and annual variation in abundance of postlarval and juvenile grooved tiger prawn, *Penaeus semisulcatus* (Decapods: Penaeidae), and environmental variation in the Embley River, Australia: a six-year study. Mar. Ecol. Progr. Ser. 135, 43–55.

Weinstein, M.P., Heck Jr., K.L., 1979. Ichthyofauna of seagrass meadows along the Caribbean Coast of Panama and in the Gulf of Mexico: composition, structure and community ecology. Mar. Biol. 50, 97–107.

Williams, D.McB, Cappo, M., 1990. Life-histories of clupeids in North-eastern Australia: Preliminary data. In: Blaber, S.J., Copland, J.W. (Eds.), Tuna baitfish in the Indo-Pacific region. Proceedings of a workshop. December 11–13 1989, 30, ACIAR, Canberra, pp.70–74.