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Distribution of Seagrasses, and Their Fish and Penaeid Prawn Communities, in Cairns Harbour, a Tropical Estuary, Northern Queensland, Australia

Robert G. Coles, Warren J. Lee Long, Reg A. Watson and Kurt J. Derbyshire

Northern Fisheries Centre, PO Box 5396, Cairns, Qld 4870, Australia.

Abstract

From aerial photography (July 1987) and diving surveys (February 1988), 876 ha of seagrasses (eight species) were mapped in Cairns Harbour, tropical north-eastern Queensland. *Zostera capricorni* was the most common seagrass species and had the greatest biomass at 79 g m^{-2} dry weight of stems and leaves and 180 g m^{-2} dry weight of roots and rhizomes. The maximum shoot density found was 4798 shoots m^{-2} of *Halodule pinifolia*, the second most common species. Seagrasses were found only between 0·5 and 5·0 m below mean sea level. *Zostera capricorni* was found at the shallowest depths, *Halodule pinifolia* at the deepest depths. Twenty species of penaeid prawns, nine of which are marketed commercially, were sampled from the seagrass beds. Abundances of prawns of commercial species were significantly greater on seagrass-covered substrata than on nonvegetated substrata. Overall, 5614 mostly small or juvenile fish, representing 134 taxa, were sampled from seagrasses in Cairns Harbour. The most numerous fish species were a goby, *Yongeichthys criniger*, and a pony fish, *Leiognathus splendens*. Only 15 species were highly valued as recreational fish, and only 11 species were highly valued as commercial fish. Of the fish species, five (4%) were highly valued species of both groups. The density of fish on the seagrass beds was estimated to be 8809 fish ha^{-1}.

Introduction

Extensive seagrass meadows are found in nearshore tropical waters throughout the world (den Hartog 1970). Although the potential for loss of seagrass habitat in coastal waters has been recognized (Larkum 1976; Poiner and Roberts 1986), ecological research in northern Australian waters remains surprisingly sparse. The difficulties of working in remote coastal areas of low human population densities, high water turbidities and large tidal ranges have prevented detailed projects from being undertaken in northern Australia. den Hartog's (1970) revision of seagrass taxonomy provided a foundation for recent seagrass research in the northern Queensland region. Fourteen species of seagrass have now been identified in north-eastern Queensland, and a general knowledge of their distribution patterns has been documented (Coles *et al.* 1989).

Long-term studies at Townsville (Birch and Birch 1984) and a survey of species in the Torres Strait (Bridges *et al.* 1982) have provided information on the role of disturbance and emersion in the control of seagrass species' depth ranges and the distribution of seagrass species in the tropics. A reasonable history of studies of crustacean and fish communities of temperate-region seagrass habitats (see reviews by Bell and Pollard 1989; Howard *et al.* 1989; Klumpp *et al.* 1989) is not, however, paralleled in the northern tropics of Australia, so that there still exists only a rudimentary knowledge of the faunal communities of Australian tropical seagrasses.

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Recognition of the economic value of seagrasses as nursery grounds for juvenile penaeid prawns (Staples 1984; Coles and Lee Long 1985) has led to more extensive studies of seagrass distribution in northern Queensland (e.g. Coles *et al.* 1987), where catches of fish and prawns in beam-trawl samples were also examined. Blaber (1980) documented the fish in seine- and gill-net samples from Cairns Harbour, and some seagrass habitats were sampled in his study. The incidence of fish in seagrass beds of south-eastern Asia was summarized by Fortes (1989). These studies give a broad-scale picture of the extent and distribution of prawn and fish populations in tropical seagrasses.

The Cairns Harbour and Trinity Inlet System (Fig. 1) are typical of mangrove-lined bay and inlet systems in northern Queensland, Australia. This paper reports an investigation of the seagrasses of Cairns Harbour and their fish and prawn populations. The study provides a baseline record of seagrass distribution and associated faunal communities for the harbour.

Materials and Methods

Study Area

Cairns Harbour in northern Queensland (16°55′S,145°47′E) is a wide, shallow bay at the head of a tidal estuary (Fig. 1). The bay and estuary are mangrove-fringed except at the rocky outcrop of False Cape, at places where harbour facilities have been developed, and adjacent to the Cairns city esplanade retaining wall. The study area extended from Ellie Point in the west to Cape Grafton in the east (Fig. 1).

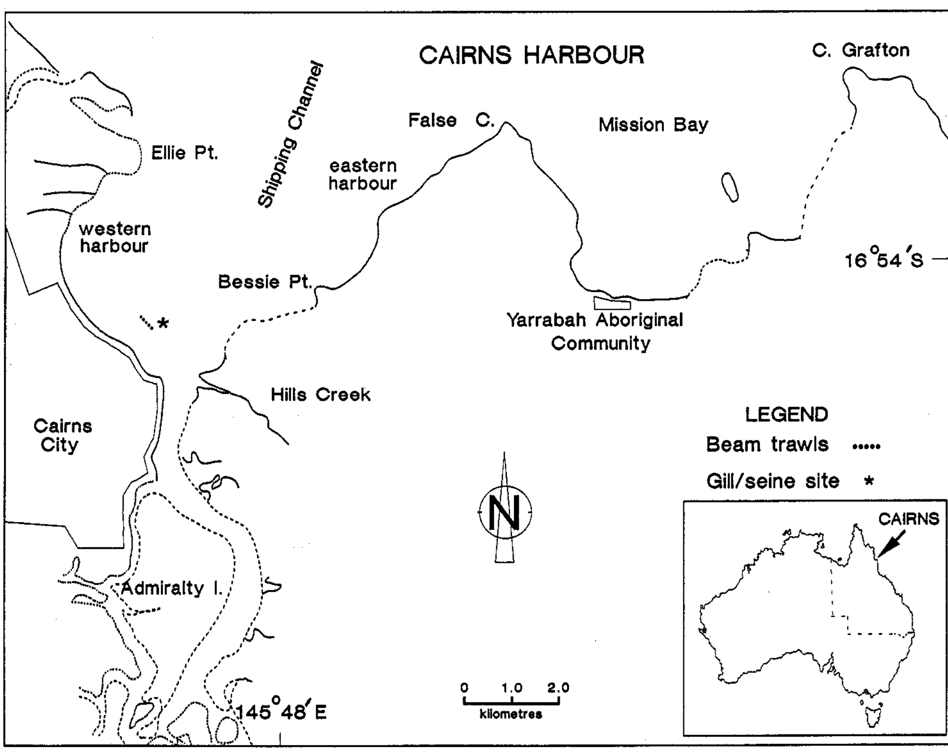

Fig. 1. Cairns Harbour, Queensland, Australia, showing beam-trawl sampling sites for prawns and fish and seine- and gill-net sites for fish samples.

Physical Parameters

Turbidity was measured with a Hach turbidimeter for water samples taken from the foreshore adjacent to the Cairns city esplanade at the time of high tide once each week from January 1988 to November 1989. Salinity and temperature were recorded at trawl sites at high tide at night at the time of new moons each month from 1980 to 1987. Salinity was measured with a Reichert refractometer, temperature with a mercury thermometer. Water depth at seagrass survey diving sites was measured with a recording depth sounder and corrected to mean sea level by using time-of-day and tidal-plane data for the Cairns port.

Seagrasses

Seagrass habitats were mapped by using both commercially available aerial photographs (taken July 1987) and diving surveys (February 1988). Aerial photographs were most accurate for mapping seagrass habitats that were exposed at low tide, but diver observations and samples were necessary in areas of deep and/or turbid water or low-density growth. Habitats visible in aerial photographs were verified during diving surveys and during low-level helicopter flights.

Bottom habitat was observed and recorded at 27 single-point sites and at 138 sites approximately 80 to 370 m apart along transects across the study area (Figs 2*a* and 2*b*). The positions of sites and transects were fixed by using radar with a variable-range marker. Tropical coastal seagrass beds do not have an easily defined edge, and isolated shoots of seagrass may be found over a wide area of bottom. Only seagrass beds with a bottom cover estimated to be greater than 10% were included as seagrass habitat in this study.

At each site, at least 5 m^2 of bottom were examined for the presence of seagrass. Much larger areas were investigated if visibility was good. If seagrass was found, two square quadrats, each enclosing 0·25 m^2, were placed on the bottom to obtain partially random samples (Kershaw 1980), and the seagrass within the quadrats was collected for biomass studies. Each quadrat sample collected consisted of all seagrass plant material, including roots and rhizomes, to a depth of 5 to 10 cm in the substratum. Where the seagrass bed was continuous over a large area, additional samples were collected for depth records and for distributional and taxonomic purposes. Areas of seagrass were plotted on maps and measured with a Paton planimeter.

In the laboratory, each quadrat sample was washed and sorted into component species, using the key described by Kuo and McComb (1989). Samples were not treated with acid because there was little contamination with epiphytes or sediment. Total numbers of shoots were recorded for each species in each quadrat. For each species at a site, a subsample of 50 shoots was divided into above-ground (stems and leaves) and below-ground (roots and rhizomes) portions. This material was dried for 48 h at 80°C, and dry weights were obtained and expressed in grams per square metre. Two morphological types of *Halodule uninervis* were recognized and treated separately in laboratory analysis: wide (leaf blade width $>1\cdot5$ mm) and thin (blade width $<1\cdot5$ mm).

Penaeid Prawns

Samples of prawns were collected at the time of high tide at night, using a beam trawl that was towed behind a 4·3-m outboard-powered dinghy. The beam trawl was 1·5 m wide and 0·5 high and was fitted with a 2-mm-mesh net and cod-end. It was towed at a speed of approximately 0·5 m s^{-1} for 2·5 min, as described by Coles and Lee Long (1985).

From August 1980 to January 1987, four trawl samples were taken once each lunar month within two nights of the time of the new moon at a permanent site on seagrass (predominantly *Zostera capricorni*, 50 to 100% bottom cover) in the western harbour (Fig. 1). In April 1988, 18 beam-trawl samples were taken on seagrass-covered bottom (predominantly *Zostera capricorni*, 50 to 100% bottom cover) near the permanent prawn-sampling site and 10 trawl samples were taken on nearby sites with a bare mud substratum (Fig. 1). Measurements of the carapace length (CL) of all prawns caught were made with dial calipers. Only those prawns with a CL greater than 3 mm were identified to species (because of taxonomic difficulties below this size—see Dall 1957; Grey *et al.* 1983) and sexed.

Fish

Fish from seagrass habitats were collected at the permanent prawn-sampling site (Fig. 1) in Cairns Harbour, using three types of gear to obtain a comprehensive species list for the site:

(1) Beam trawls, as used for sampling prawns, were also used for sampling fish and estimating fish density in seagrass beds. Trawls were taken close to the time of high tide at night, with the beam

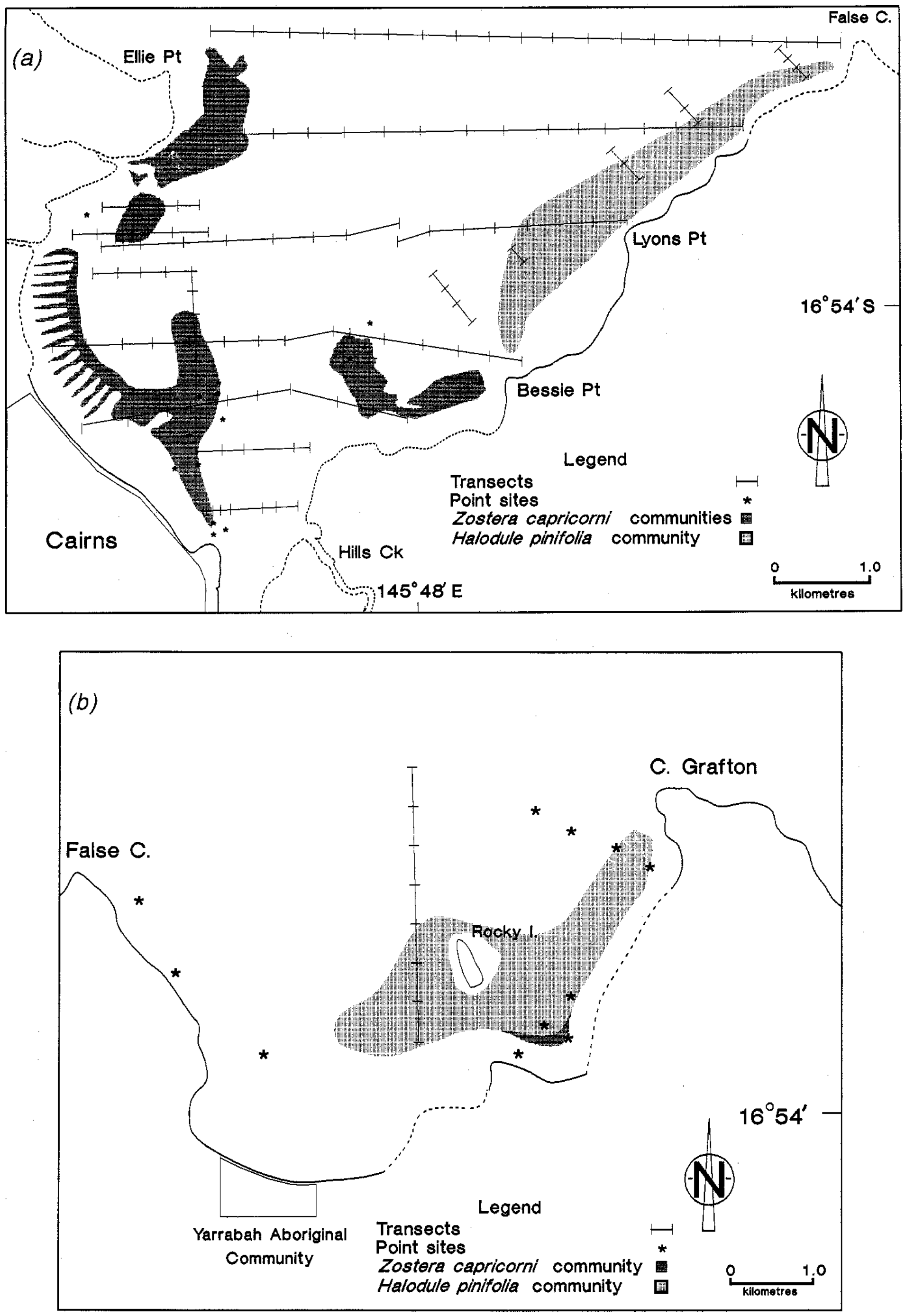

Fig. 2. Seagrass sampling sites and the distribution of seagrass beds in 1988 in (*a*) western and eastern Cairns Harbour and (*b*) Mission Bay.

trawl being towed at approximately 0·5 m s^{-1} for 2·5 min. In all, 30 samples were taken between 18 and 29 April 1988.

(2) Monofilament gill-nets 30 m long and 1·5 m deep and of three stretched-mesh sizes (3·0, 7·5 and 12·5 cm) were used to catch fast-swimming fish. Gill-nets were set for the period of high water at night when the seagrass site was immersed. Samples were taken on one night in each of the months of March, September and December 1988.

(3) A seine-net 30 m long with 2-cm stretched mesh was hauled through a single arc around a fixed point near the water's edge. Two daytime and two night-time seine-net samples were taken once in each of February, March, April and September 1988.

Standard lengths and weights of all fish were recorded. A value classification was assigned to each species to designate its importance to various user groups, including commercial, recreational, aquarium and traditional fishers, in the Cairns region.

Results and Analysis

Physical Environment

Turbidities were highest during the late-summer (January to April) monsoonal wet season, remaining lower and more stable through the remainder of the year (Fig. 3). A harbour-dredging programme was conducted for approximately four weeks in June and July each year. Aerial observations indicated that dredge plumes did not normally disperse outside the main shipping channel during those periods.

Between 1980 and 1987, water salinity ranged between 20 and 37 on the Practical Salinity Scale, with the largest range in January (Fig. 4*a*). The water temperature recorded at night was lowest in July at 22°C and highest in January at 33°C (Fig. 4*b*).

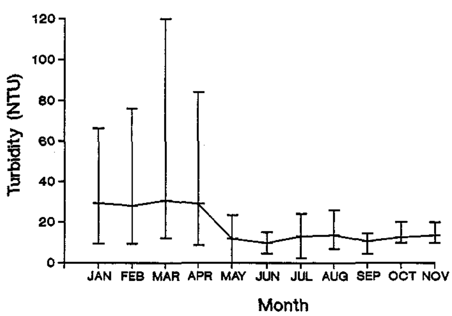

Fig. 3. Means and ranges of turbidity (NTU) in western Cairns Harbour between 1988 and 1989, based on four measurements per month.

Seagrasses

In all, 876 ha of seagrass were mapped: 230 ha in the western harbour between Ellie Point and the entrance to Trinity Inlet and 270 ha in the eastern harbour between the inlet entrance and False Cape (Fig. 2*a*), and 376 ha in Mission Bay (Fig. 2*b*). Eight species were present: *Zostera capricorni*, *Halodule pinifolia*, *Halophila ovalis*, *Cymodocea serrulata*, *Halodule uninervis*, *Cymodocea rotundata*, *Thalassia hemprichii* and *Halophila decipiens*. *Zostera capricorni* was the most common species, found at 22 sampling sites, followed by *Halodule pinifolia* and *Halophila ovalis* at 15 and 12 sampling sites, respectively (Fig. 5). An alga, *Caulerpa sertularioides*, was found within predominantly seagrass communities; it possesses external morphological features superficially similar to those of some seagrasses and could be confused for a seagrass in aerial observations or by a diver in conditions of low water visibility.

Depth ranges of the seagrass species overlapped (Fig. 6). All species were found below mean sea level, and most records of seagrass were from between 0·5 and 1·7 m below mean sea level (between 1·0 m and −0·2 above Cairns Harbour port datum). Only *Halodule*

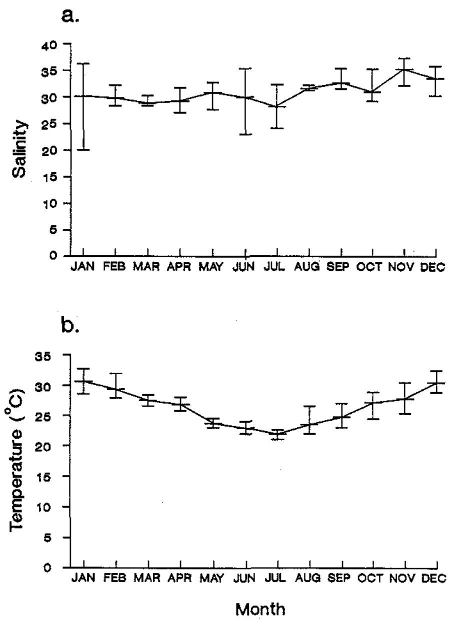

Fig. 4. Means and ranges of (*a*) surface salinity and (*b*) temperature in western Cairns Harbour between 1980 and 1987, based on three measurements per month.

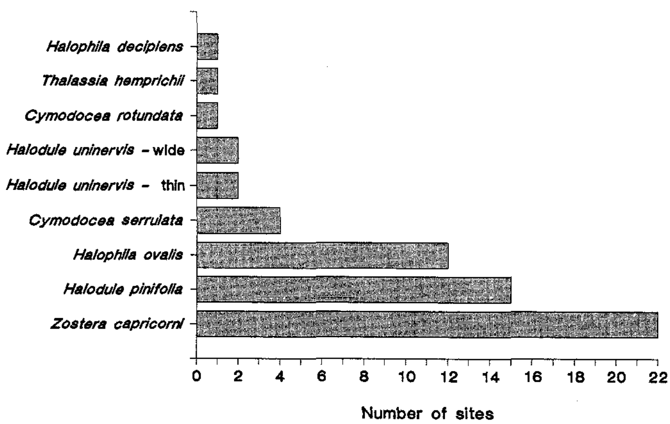

Fig. 5. Number of sites at which each seagrass species was found in Cairns Harbour.

pinifolia was found in deeper water, ranging down to 5 m below mean sea level. *Zostera capricorni* was found at 0·5 m below mean sea level, the highest intertidal depth at which seagrass was found in our survey.

The maximum shoot density obtained for any species was 4798 shoots m^{-2} of *Halodule pinifolia* (Fig. 7*a*). The largest biomass recorded was for *Zostera capricorni* at 79 g m^{-2} dry weight of stems and leaves and 180 g m^{-2} dry weight of roots and rhizomes (Figs 7*b* and 7*c*).

The two most common seagrass species in Cairns Harbour each formed almost monospecific meadows: *Zostera capricorni*, predominant in the western harbour and inshore at Mission Bay, and *Halodule pinifolia*, predominant in the eastern harbour and deeper areas of Mission Bay. *Halophila ovalis* was found in low abundance or in patches within meadows

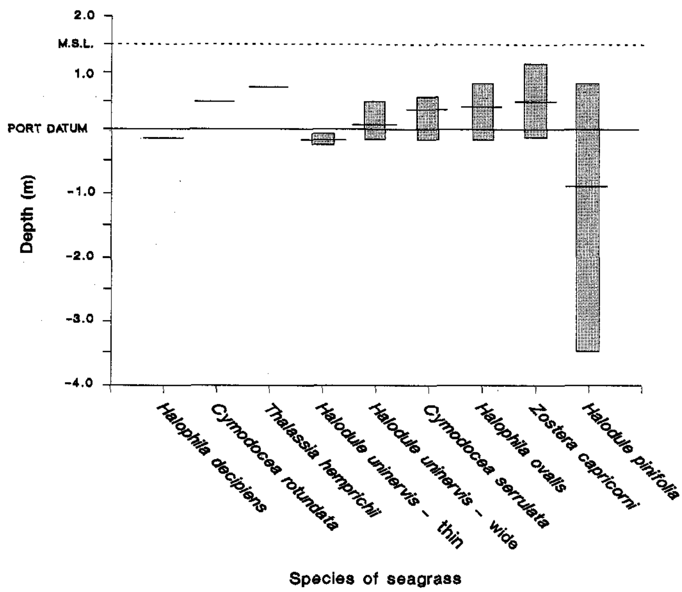

Fig. 6. Depth ranges of seagrass species in Cairns Harbour. M.S.L., mean sea level.

of *Zostera capricorni* or *Halodule pinifolia*. *Cymodocea serrulata*, *Halodule uninervis*, *Cymodocea rotundata*, *Thalassia hemprichii* and *Halophila decipiens* were found mostly in the western harbour at or beyond the seaward edge of *Zostera capricorni* meadows.

The major meadows of *Zostera capricorni* in the western harbour were bordered on the seaward side by sandbars that were exposed at low-water neap tides. These sand bars appeared to impede drainage of water from the *Zostera* meadows at low tide (protecting them from drying) and to provide some buffer protection from onshore waves.

Penaeid Prawns

Twenty species of penaeid prawns were collected from the Cairns Harbour seagrass meadows (Table 1). Nine of these species are marketed commercially. The most common of the commercial species were the tiger prawns *Penaeus esculentus* and *P. semisulcatus* and the endeavour prawn *Metapenaeus endeavouri*. All of these prawns were immature, the majority being less than 10 mm CL.

There were differences in species composition, and significant differences in abundance, between vegetated and nonvegetated substrata (Table 2). The number of commercially important prawns was significantly greater on vegetated bottoms (Kruskal–Wallis one-way analysis of variance, $P<0\cdot01$).

Data pooled across years showed that January was the month of greatest abundance of juvenile *P. esculentus* (Fig. 8). *Penaeus semisculcatus* abundances peaked in February. Both tiger prawn species had relatively short periods of high abundance in seagrass meadows, at about the time of the monsoon season each year. In contrast, *M. endeavouri* appeared to have a more prolonged period of peak abundance, from January to July.

Fish

In all, 134 taxa of fish were recorded from Cairns Harbour. Sizes ranged from 7 to 625 mm in standard length. The average length of fish caught was 32 mm, and most of the fish caught were immature (Table 3). In April 1988, the density of beam-trawl-caught fish,

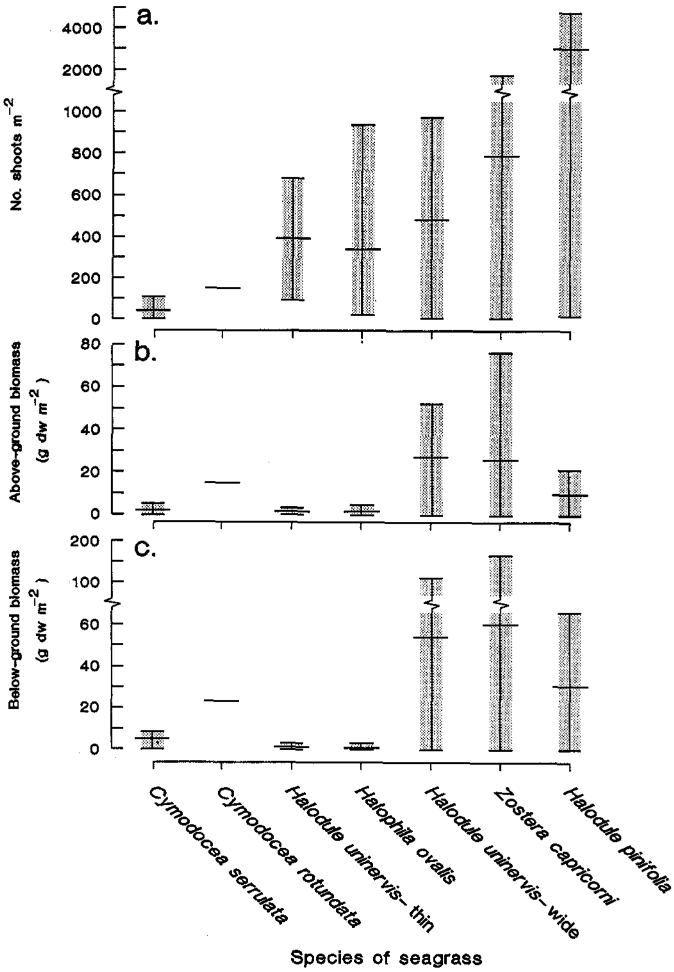

Fig. 7. Means and ranges of (*a*) shoot density, (*b*) above-ground biomass and (*c*) below-ground biomass for seagrass species sampled in Cairns Harbour.

at the seagrass site adjacent to the esplanade in Cairns Harbour, was estimated to be 8809 fish ha^{-1}. Of the 5614 fish collected by all sampling methods, the two most numerous species were a goby, *Yongeichthys criniger*, and a pony fish, *Leiognathus splendens* (Table 3). The largest individual fish was a shark of the genus *Carcharhinus*. The greatest biomass other than sharks was contributed by the salmons *Polydactylus sheridani* and *Eleutheronema tetradactylum*, the queenfish *Scomberoides commersonianus*, and the catfish *Arius proximus* (Table 3).

Taxa were classified according to their value as commercial, recreational, aquarium or traditionally hunted fish. Fifteen species are valued highly as recreational fish, and a further 20 are of low value (kept if caught); 99 (74%) of the fish species sampled from Cairns Harbour are of no direct value as recreational fish. Eleven species are highly valued as commercial fish, with a further eight species being of low value (kept if caught); 115 (86%) of the species present are of no commercial value. Of the 134 taxa, only five (4%) are highly valued as both commercial and recreational fish. Seventeen (13%) of the fish species

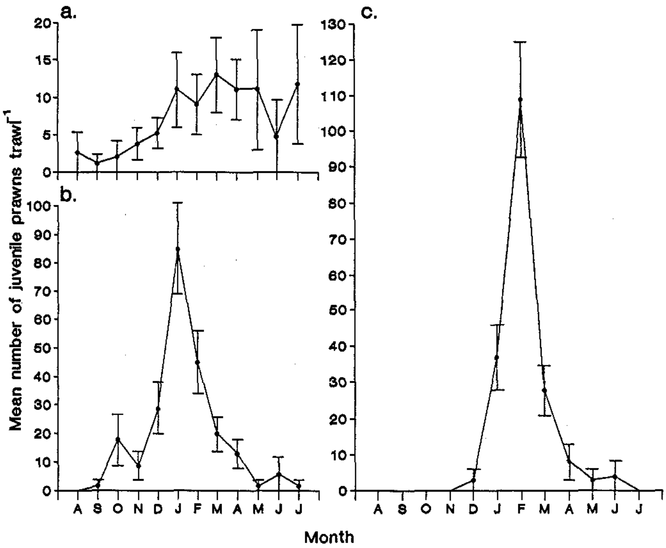

Fig. 8. Means and standard errors of numbers of juvenile prawns of (*a*) *Metapenaeus endeavouri*, (*b*) *Penaeus esculentus* and (*c*) *P. semisulcatus* caught in each month in Cairns Harbour. Data are for 1980 to 1987.

Table 1. Species of penaeid prawns and the numbers caught in beam-trawl samples in Cairns Harbour between 1980 and 1987

Species		Total number
Common name	Scientific name	(276 trawls)
Brown tiger prawn	*Penaeus esculentus*[A]	2153
Grooved tiger prawn	*Penaeus semisulcatus*[A]	1759
Western king prawn	*Penaeus latisulcatus*[A]	44
Banana prawn	*Penaeus merguiensis*[A]	19
Leader prawn	*Penaeus monodon*[A]	6
Red-spot king prawn	*Penaeus longistylus*[AB]	3
Red-legged banana prawn	*Penaeus indicus*[AB]	2
True endeavour prawn	*Metapenaeus endeavouri*[A]	2307
York prawn	*Metapenaeus eboracensis*	713
Red endeavour prawn	*Metapenaeus ensis*[A]	269
Western school prawn	*Metapenaeus dalli*[B]	74
Greasyback prawn	*Metapenaeus bennettae*[B]	46
Brown rough prawn	*Trachypenaeus fulvus*	246
Hardback prawn	*Trachypenaeus anchoralis*	11
Coral prawn	*Metapenaeopsis novaeguineae*	15
Southern velvet prawn	*Metapenaeopsis palmensis*	12
Coral prawn	*Metapenaeopsis rosea*	1
Orange prawn	*Atypopenaeus formosus*	6
Periscope prawn	*Atypopenaeus stenodactylus*	1
Coral prawn	*Parapenaeopsis cornuta*	1
Total		7688

[A] Species of major economic importance in northern Australia.
[B] Identification uncertain due to small size.

Table 2. Total abundance and mean (±s.e.) numbers per trawl of commercial penaeid prawn species caught on vegetated and nonvegetated substrata in Cairns Harbour

Number of trawls	Substratum	Commercial species	Total number of individuals	Average number per trawl
18	Seagrass:	*Penaeus esculentus*	117	6·5±1·9
	Zostera capricorni,	*Penaeus semisulcatus*	453	25·2±6·4
	50–100% bottom cover	*Metapenaeus endeavouri*	148	8·3±1·4
		Metapenaeus ensis	33	1·8±0·6
		Penaeus merguiensis	3	0·2±0·1
		Total	754	
10	Bare mud	*Penaeus esculentus*	1	0·1±0·1
		Penaeus semisulcatus	50	5·0±3·4
		Metapenaeus endeavouri	26	2·6±1·8
		Metapenaeus ensis	10	1·0±0·4
		Penaeus latisulcatus	1	0·1±0·1
		Penaeus merguiensis	1	0·1±0·1
		Total	89	

are considered to be of high value as aquarium fish, and three species are important as baitfish, with 16 other species being used as baitfish if caught. Three species are also traditionally targeted by Aboriginal and Islander people in the region.

Discussion

Seagrass Distribution

The estimated area of 876 ha of seagrass in Cairns Harbour is equivalent to 0·004% of the total 2464 km^2 of seagrass habitat estimated to exist in coastal waters between Townsville and Cape York (Lee Long *et al.* 1993). Although the Cairns Harbour seagrasses represent only a small proportion of the total area of seagrass along the tropical Queensland coast, they are important as the only large seagrass area in the immediate coastal region (Lee Long *et al.* 1993).

Maps of seagrass habitat derived from aerial photographs have associated errors that depend on the scale of the photographs and final maps and on tracing and interpretation of photographic images. Errors may also occur in defining the edges of a seagrass meadow by diving survey, particularly in turbid water such as occurs along the seaward edges of Cairns Harbour seagrass meadows. Errors were minimized in this study by combining numerous diving observations with information from aerial photographs (see Figs 2*a* and 2*b*), checking with photos from low-level helicopter flights, and including only seagrass densities greater than 10% bottom cover.

Fourteen seagrass species have been identified in eastern tropical Queensland coastal and reef-lagoon waters (Coles *et al.* 1989). More than half of these species were present in the muddy foreshore region of Cairns Harbour. Seagrass species such as *Thalassia hemprichii*, which is commonly found on reef platforms, and *Cymodocea serrulata*, which, except on the eastern Queensland coast (Coles *et al.* 1987), is uncommon where freshwater runoff occurs (Poiner *et al.* 1987), were found in Cairns Harbour, but in low abundance. There is no river system providing permanent freshwater runoff into Cairns Harbour. Low salinities normally occur only in the period from December to March; salinity is otherwise relatively constant, around that of normal sea water, for most of the year. In previous studies, we found only *Zostera capricorni* and *Halodule uninervis* (wide-leafed form) where freshwater influence is more prolonged, i.e. in the mouths of some creeks and rivers of northern and eastern Queensland (Coles *et al.* 1987).

Table 3. Taxa, value classifications and size and abundance data for fish collected in Cairns Harbour
Asterisks indicate identifications confirmed by the Queensland Museum Fish Section. Value codes: A, targeted aquarium species (17 species); a, incidental aquarium species (33); B, target baitfish species (3); b, incidental baitfish species (16); C, targeted commercial species (11); c, incidental commercial species (8); R, targeted recreational species (15); r, incidental recreational species (20); T, targeted traditional (Aboriginal/Islander) species (3); t, incidental traditional (Aboriginal/Islander) species (0); –, no fishery value (30); ?, unknown value (13). Net types: B, beam trawl; G, gill-nets; S, seine-net

Family	Species	Code	Length range (mm)	Average length (mm)	Total weight (g)	Total number	Net type
AMBASSIDAE	*Ambassis nalua**	a	19-90	40	632.2	217	B,S
	*Ambassis gymnocepahuls**	a	36-50	42	18.5	9	B
APOGONIDAE	*Apogon quadrifasciatus*	a	31	31	1.1	1	B
	Apogon ellioti	a	35-45	40	5.5	2	B
	Apogon sp.1*	a	23-32	26	3.1	4	B
	Foa brachygramma	a	16-41	35	33.1	18	B
ARIIDAE	*Arius* cf. *argyropleuron*	Ar	245-255	251	1335.0	4	G
	Arius macrocephalus	Ar	235-260	247	1327.0	4	G
	Arius proximus	Ar	415	415	1928.0	1	G
ATHERINIDAE	*Atherinomorus endrachtensis**	b	41-53	46	12.0	8	B
BELONIDAE	*Strongylura strongylura**	br	220	220	15.7	1	S
BOTHIDAE	*Engyprosopon grandisquama*	a	31-33	32	1.0	2	B,S
CALLIONYMIDAE	*Callionymus* sp.1	A	25	25	0.2	1	B
	Repomuscenus belcheri	A	45	45	1.0	1	B
CARANGIDAE	*Caranx* sp.1	cr	49	49	3.0	1	S
	Scomberoides commersonianus	CR	235-342	305	2094.0	5	G
	Scomberoides tol	-	268	268	239.0	1	G
CARCHARHINIDAE	*Carcharhinus* cf. *sorrah*	?	510-625	573	13037.0	12	G
	Carcharhinus sealei	Cr	420-440	430	904.0	2	G
CENTRISCIDAE	*Centriscus scutatus*	A	63-74	67	0.8	3	B
CENTROPOMIDAE	*Psammoperca waigiensis**	Ar	73-85	79	215.0	2	B
CHAETODONTIDAE	Chaetodontidae sp.1*	A	13	13	0.2	1	B
CLUPEIDAE	*Anodontostoma chacunda*	b	57-88	77	169.0	12	B
	*Escualosa thoracata**	?	21-46	15	21.1	36	B
	Herklotsichthys koningsbergeri	B	69	69	7.6	1	B
	*Herklotsichthys quadrimaculatus**	b	17-25	22	2.0	16	B
	Herklotsichthys sp.1*	?	92-106	98	139.2	6	G
	*Nematolosa come**	b	95-190	151	1305.9	11	G
CONGRIDAE	*Conger labiatus*	ar	235	235	14.1	1	B
CYNOGLOSSIDAE	*Cynoglossus puncticeps*	a	15-87	47	62.0	43	B,S
	Cynoglossus sp.1	a	37	37	0.6	1	B
	Paraplagusia guttata	a	42-130	74	17.3	3	S
DASYATIDIDAE	*Himantura granulata*	Ar	-	-	813.0	1	S
ELOPIDAE	*Elops australis*	r	435	435	850	1	G
	Megalops cyprinoides	r	415	415	1372.0	1	G
ENGRAULIDAE	Engraulidae spp.	-	9-33	14	22.1	142	B
	Stolephorus devisi	-	27-42	29	0.9	3	B
	*Stolephorus indicus**	-	25-34	29	0.9	3	B
	Stolephorus cf. *tysoni**	-	10-57	19	89.4	285	B
	Stolephorus spp.	-	14-33	22	25.7	161	B
	*Thryssa hamiltonii**	-	32-158	88	248.9	16	B
	Thryssa sp.1	-	20-40	26	3.2	13	B
	Thryssa spp.	-	20-27	23	0.7	5	B
EPHIPPIDAE	*Drepane punctata*	AR	121-215	168	711.0	2	B
	Zabidius novemaculeatus	Ar	16-24	20	1.2	4	B

Table 3 (*continued*)

Family	Species	Code	Length range (mm)	Average length (mm)	Total weight (g)	Total number	Net type
GERREIDAE	*Gerres abbreviatus*	b	154-166	160	391	2	B
	*Gerres argyreus**	b	67	67	10.1	1	G
	*Gerres filamentosus**	b	99-145	115	191.4	3	B
	Gerres poieti	b	33-60	50	15.2	3	B,S
GOBIIDAE	*Drombus halei**	-	24-40	31	5.0	8	B
	*Glossogobius biocellatus**	-	40-51	45	6.0	4	B
	Gobiidae sp.1 *	-	8-35	13	55.1	225	B
	Gobiidae sp.2	-	10-28	19	3.1	20	B
	Gobiidae sp.3	-	18-35	29	2.4	5	B
	Gobiidae spp.	-	7-29	10	7.9	113	B
	*Oxyurichthys ophthalmonema**	-	35-74	53	12.5	4	B
	Yongeichthys criniger	-	7-83	12	131.0	1087	B,S
HAEMULIDAE	Haemulidae sp.1	?	14-31	23	0.2	2	B
	*Pomadasys kaakan**	R	13-290	96	920.1	7	B,S
	*Pomadasys maculatum**	a	9-40	14	16.2	129	B,S
	Pomadasys opercularis	R	35-205	109	781.3	9	B,G,S
	Pomadasys sp.1	?	12-22	17	1.2	6	B
HEMIRHAMPHIDAE	*Arrhamphus sclerolepis**	bC	27-119	73	55.4	11	B
	Hyporhamphus australis	BC	25-111	59	10.1	3	B
	*Hyporhamphus quoyi**	bC	34-135	80	126.1	20	B
	Rhynchorhampus georgi	bC	25	25	0.1	1	B
LACTARIIDAE	*Lactarius lactarius*	?	238	238	342.0	1	G
LEIOGNATHIDAE	*Gazza minuta*	-	30-60	36	16.7	11	B
	*Leiognathus bindus**	-	38-45	42	7.2	3	B
	Leiognathus decorus	-	8-76	34	203.6	117	B,G,S
	Leiognathus equulus	-	13-150	57	572.5	21	B
	*Leiognathus splendens**	-	10-65	15	722.2	659	B,G,S
	Leiognathus sp.1	-	7-11	7	1.1	31	B
	Leiognathus spp.	-	7-12	9	4.4	129	B
	Secutor ruconius	-	7-66	17	137.9	326	B
LETHRINIDAE	*Lethrinus lentjan**	ar	25-132	64	307.0	34	B,S
	Lethrinus sp.1	?	15-84	21	71.9	103	B,S
	Lethrinus spp.	?	16-26	19	1.4	6	B
LUTJANIDAE	*Lutjanus erythropterus*	CR	48	48	4.1	1	B
	Lutjanus fulviflammus	ar	17-117	49	466.1	55	B,S
	*Lutjanus russelli**	aCR	27-97	49	46.2	6	B,S
	Lutjanus sp.1	?	18	18	0.2	1	B
MONACANTHIDAE	*Monacanthus chinensis*	A	15-26	26	5.4	18	B
MUGILIDAE	*Liza vaigiensis*	b	225	225	390.0	1	S
	*Mugil georgii**	BT	57-205	147	1079.0	11	S
	Valamugil seheli	bC	152	152	81.8	1	S
MULLIDAE	*Upeneus* sp.1 *	a	22-86	44	32.3	9	B,S
MURAENIDAE	*Gymnothorax* sp.1	A	83-160	109	8.7	7	B
PARALICHTHYIDAE	*Pseudorhombus arsius*	a	31-40	36	2.0	2	S
	Pseudorhombus elevatus	a	16-125	49	108.1	20	B,S
PLATYCEPHALIDAE	*Cymbacephalus nematophthalmus*	cr	19-131	82	187.8	12	B,S
	Inegocia isacanthus	?	23-49	36	1.5	2	B
	Platycephalidae spp.	?	10-51	34	2.1	3	B
	Platycephalus fuscus	cR	41-46	44	1.7	2	B
	Platycephalus indicus	cR	175-395	285	745.4	2	B,G
	Suggrundus sp.1	?	33	33	0.4	1	B
POLYNEMIDAE	*Eleutheronema tetradactylum*	cR	335-505	420	3006.0	2	G
	Polydactylus heptadactylus	-	24-33	29	1.3	2	B
	Polydactylus multiradiatus	r	13-52	33	10.7	22	B
	Polydactylus sheridani	CR	225-375	287	4200.0	9	G
	Polydactylus sp.1	?	16-24	19	0.6	4	B

Table 3 (*continued*)

Family	Species	Code	Length range (mm)	Average length (mm)	Total weight (g)	Total number	Net type
SCIAENIDAE	*Nibea soldado**	cR	40-250	117	1662.3	10	B,G
	*Otolithes ruber**	r	300	300	398	1	G
SCORPAENIDAE	*Paracentropogon longispinis*	A	26-42	35	4.5	3	B
SERRANIDAE	*Centrogenys vaigiensis*	A	15-41	26	7.1	7	B
SIGANIDAE	*Siganus canaliculatus*	a	19-72	39	90.3	35	B,S
	*Siganus fuscescens**	a	18-39	25	5.3	15	B
	*Siganus guttatus**	AT	19-60	30	17.0	14	B,S
	Siganus spinus	aT	18-32	21	7.2	40	B
	Siganus spp.	a	17-32	20	9.4	56	B
SILLIGANIDAE	*Sillago maculata**	bR	32-84	50	8.6	3	B,S
	*Sillago sihama**	bR	22-200	60	142.7	17	B
	Sillago spp.	r	8-37	21	16.5	103	B
SOLEIDAE	*Dexilichthys muelleri*	a	180-190	185	321.0	2	B,S
SPARIDAE	*Acanthopagrus berda*	CR	140-225	173	757.5	3	G
SPHYRAENIDAE	*Sphyraena jello*	cR	33	33	0.1	1	B
SPHYRNIDAE	*Sphyrna lewini*	cr	560	560	812.0	1	G
SYNGNATHIDAE	*Hippichthys cyanospilus**	-	46-105	83	14.9	36	B
SYNODONTIDAE	*Saurida nebulosa**	r	103-122	113	31.2	2	S
TERAPONIDAE	*Pelates quadrilineatus*	-	10-75	22	360.1	571	B,S
	Terapon puta	-	9-65	35	289.5	201	B,S
	Terapon spp.	-	10-14	12	0.6	24	B
TETRABRACHIIDAE	*Tetrabrachium ocellatum*	A	18-41	33	7.2	3	B
TETRAODONTIDAE	*Amblyrhynchotes spinosissimus*	a	9-11	10	1.2	5	B
	Arothron hispidus	a	12-25	18	2.1	2	B
	Arothron immaculatus	a	13-82	29	165.8	39	B,S
	Canthigaster margaritatus	a	31	31	1.5	1	B
	Chelonodon patoca	a	28-35	32	6.6	3	B,S
	Torquigener sp.1*	a	11-17	14	0.8	3	B
	Torquigener sp.2*	a	15-16	16	0.5	2	B
	Torquigener spp.	a	11-17	14	0.8	3	B
TRIACANTHIDAE	*Triacanthus biaculeatus*	a	135	135	45.4	1	S
	*Tripodichthys angustifrons**	a	7-27	16	6.9	29	B,S
UNIDENTIFIED	unidentified larvae	?	11-25	18	0.8	14	B
TOTAL			**7-625**	**32**	**47947.0**	**5614**	

Seagrasses occurred within a limited range of depths, with ranges for most species overlapping. *Thalassia hemprichii*, *Zostera capricorni*, *Halophila ovalis* and *Halodule pinifolia* were found up to nearly 1 m above port datum. The tidal range in the harbour can be 3·5 m, and the upper limit of seagrass distribution is most likely controlled by exposure to drying at low tides. Small pools and channels are common on the mud-flats of the harbour. Seagrass species found at the upper depth range were mainly in these depressions, where water remained at low tides. Small-leafed species such as *Halophila ovalis* and *Halodule pinifolia* were found outside these depressions only in places where the muddy sediment remained moist and the plants were protected from drying.

Only one species, *Halodule pinifolia*, was found in places deeper than 2 m below mean sea level, where irradiances were low. This species and *Halodule uninervis* (thin-leafed form) are common pioneering species in north-eastern Australia and are often associated with prawn nursery grounds (Coles *et al.* 1987; Poiner *et al.* 1987). Seagrasses in Cairns Harbour were more restricted in their depth ranges than were seagrasses at other localities sampled along the Queensland eastern coast (Coles *et al.* 1987). Seagrasses in the harbour ranged from 0·50 to 5·0 m below mean sea level. These same species occupied a depth range of 0 to 10 m below mean sea level at other sites along the coast (Coles *et al.* 1987). It is likely that low light intensities due to turbidity are the reason for the reduced depth range in Cairns Harbour.

Zostera capricorni was the most common species collected, and it formed almost monospecific meadows in the western harbour and shallow parts of Mission Bay. Biomass estimates for *Zostera capricorni* here are amongst the highest recorded for this species from other surveys between Cape York and Hervey Bay (Lee Long *et al.* 1993). Cairns is near the most northerly location we recorded for this species in other recent surveys of the coast (Coles *et al.* 1987; Lee Long *et al.* 1993), although den Hartog (1970) recorded small pieces of *Zostera capricorni* from Thursday Island in the Torres Strait. The high biomass and frequency of occurrence of *Zostera capricorni* near its geographical limit make it difficult to identify the physical and biological factors that affect its geographical distribution. Further north, dense stands of *Cymodocea serrulata* are common in shallow coastal estuaries (Coles *et al.* 1987), and this species may replace *Zostera capricorni* as a climax community species in northern waters and where freshwater runoff is infrequent.

The *Zostera capricorni*-dominant meadows in the western harbour and the predominantly *Halodule pinifolia* meadows in the eastern harbour and Mission Bay represent two separate communities in Cairns Harbour. Only long-term monitoring will reveal whether the communities dominated by *H. pinifolia* (a typically pioneering species) will be succeeded by other species.

Penaeid Prawns

For the major commercial species in our samples, the paucity of prawns with a carapace length greater than 10 mm indicates that the adults most likely follow the generalized penaeid prawn life cycle described by Kirkegaard (1975) and move offshore to the deeper-water fishing grounds. A significantly greater abundance of juvenile commercial penaeid prawns on vegetated substrata than on nonvegetated substrata in Cairns Harbour confirms that during the early part of their life cycle these species are likely to be dependent on inshore seagrass habitats for shelter and survival (Staples 1984; Coles and Lee Long 1985). The tiger and endeavour prawn species found in Cairns Harbour are economically important species in most of the mixed-species trawl fisheries of northern Australia. Estimated annual yields from Cairns Harbour seagrasses of the three major commercial prawn species—*P. esculentus*, *P. semisulcatus* and *M. endeavouri*—were 178 t $year^{-1}$ with a landed value of \$A1·2 million annually (Watson *et al.* 1993). To place the value of these seagrass resources in a wider perspective, the estimated landed value of prawns from the Queensland eastern-coast prawn fishery is likely to be in excess of \$A55 million each year (Anon. 1991).

The number of prawns of commercial species found in the samples from trawls over bare mud was larger than expected. Previous research (Coles and Lee Long 1985) showed very low numbers on nonvegetated bottoms. It is very likely that the trawls over bare mud include prawns moving off the adjacent seagrass meadows.

The abundance of prawns in the seagrass meadows may vary from site to site. Within-meadow variation of prawn abundance was not investigated in this study but may be significant even across a homogeneous habitat. Preliminary surveys of juvenile prawns on seagrasses throughout Queensland coastal, island and reef habitats showed differences in the abundance of each species between localities (e.g. Coles *et al.* 1987). Spatial variation in the abundance of juvenile prawns in seagrass meadows may have consequences for the priority that managers might give to protecting different areas of seagrass. This is of particular concern in areas such as Cairns Harbour, where impacts from expanding tourism, urban and industrial development are imminent.

The marked seasonal nature of the abundance patterns of juvenile tiger prawns (*P. esculentus* and *P. semisulcatus*) was not observed for the true endeavour prawn (*M. endeavouri*). Abundances of all three species were high in monsoonal summer months, the period of low salinity and high turbidity. Moderately higher abundances of postlarval and juvenile *P. monodon* and *P. monoceros* were detected during the monsoon season in the Enmore estuary, Madras, India (Vasudevan and Subramonian 1985). The influence of monsoonal wet-season events on the survival of juvenile prawns may be important in affecting the sizes of subsequent adult stocks. A better understanding of the impacts of monsoonal freshwater flushes on the survival and movement of juvenile penaeid prawns and on the seagrass habitat in which they live might help to explain the typical year-to-year fluctuations (Garcia and Le Reste 1981) in the sizes of adult stocks in penaeid prawn fisheries.

Fish

Fish species richness (i.e. the number of species in samples) for Cairns Harbour seagrass meadows is similar to that recorded from other tropical Indo-Pacific seagrass habitats, although differences in sampling gear makes comparisons with other studies difficult. Fortes (1989) recorded 123 species, representing 51 families, from seagrass meadows in the Philippines. The size range and abundance of fish trawled on seagrass meadows between Cairns and Bowen (Coles *et al.* 1990) and at Mornington Island in the Gulf of Carpentaria (Queensland Department of Primary Industries, unpublished data) are similar to those reported here, although some different species occur. This suggests that other seagrass-vegetated bays and estuaries in coastal tropical Queensland may support similar types of fish faunas and may be important to recreational and commercial fisheries.

The fish fauna on the seagrass meadows appeared to be dominated by small fish and juveniles of most species. Larger juvenile and adult fish are regularly taken within Cairns Harbour by fishers. Pelagic fish such as mackerels may also inhabit the seagrass meadows at certain times of the year, but their transient habits result in poor representation in our samples. Blaber (1980) noted that, as a nursery habitat for fish, the bay (Cairns Harbour) was less important than the mangrove-lined estuary (Trinity Inlet) that drains into the bay. He found that piscivores represented a large proportion of fish in his seine- and gill-net samples, and he proposed that this abundance of piscivores and a shortage of calm waters made the bay (harbour) area less ideal for juveniles of many marine species. We found that juveniles were abundant in Cairns Harbour samples. Furthermore, only 25% of fish taxa caught in our study were recorded by Blaber (1980). These differences most likely arise because our sample sites were restricted to seagrass habitats and because, in addition to seine- and gill-nets, we used beam trawls, which catch smaller fish.

The families Ariidae, Carcharhinidae, Haemulidae, Lethrinidae, Lutjanidae, Platycephalidae, Polynemidae, Sciaenidae, Sparidae and Sphyraenidae were represented above the seagrass, but more commonly as juveniles than as adults. Many of the species from these families are likely to be important predators on the population of juvenile penaeid prawns in the seagrass meadows. Large predator species were mostly caught in gill-nets. *Scomberoides commersonianus*, *Arius proximus*, *Polydactylus sheridani* (common at our site) and *Lates calcarifer* accounted for the majority of prawn predation in another tropical Australian estuary, the Embley River, Weipa (Salini *et al.* 1990). *Cymbacephalus nematophthalmus* and *Centrogenys vaigiensis*, both represented in our samples, were the most important penaeid prawn predators identified by Derbyshire and Dennis (1990) in seagrass meadows on Warrior Reef, Torres Strait.

A study of the 'residency' status of fish in the Cairns Harbour seagrass meadows would be useful for a full understanding of the fish assemblages. Classifications of species into groups as proposed by Kikuchi (1966) or discussed by Bell and Pollard (1989) would be helpful, but for many species this can be done only after repeated sampling of a seagrass meadow. Much of the seagrass in Cairns Harbour is exposed at low tides, so it is used by most fish species on a tide-related basis. We concur with Robertson (1980) and Bell and

Pollard (1989), who highlighted the need for an expansion of the usual classifications of fish residency to include this type of use of seagrass habitats.

Few of the 134 fish taxa collected from Cairns Harbour seagrasses constitute part of an organized fishery with an appropriate marketing infrastructure. Some of the species are of considerable importance as aquarium fish, baitfish or recreational fish, and a relatively small proportion (4%) are sought by both commercial and recreational fishers. The high densities of small fish on these seagrass meadows may, however, be significant as both direct and indirect food sources for species of commercial and recreational importance. The total area of seagrass habitat in Cairns Harbour would therefore most likely support an important component of the local fin-fish production in Cairns Harbour.

Reef fish species were poorly represented in the Cairns Harbour seagrass habitat. Similarly, in a beam-trawl survey of seagrass meadows between Cairns and Bowen, only four species occurred that are recorded in Russell's (1983) check-list of fishes of the Capricornia section of the Great Barrier Reef Marine Park (Coles *et al.* 1990). Amesbury (1988) found very few juveniles or adults of coral-reef fish species on coastal seagrass habitats in Papua New Guinea. It seems unlikely that there is significant interaction between coastal seagrass-meadow fish populations and those of coral reefs.

Cairns Harbour Environment

Cairns is a rapidly expanding provincial city and tourist destination. The city, seaport and international airport are immediately adjacent to the mangroves, seagrasses and mud-flats of the western and eastern harbour. Increasing urban and industrial runoff into the harbour may have detrimental effects on the seagrass habitats and on the valuable crustacean and fish communities that they support. The potential for loss of seagrass habitat and the fisheries resources that are dependent on them is paralleled in many other bays and estuaries on the Queensland coast as provincial centres develop. Careful management of the nearshore zone in these regions will be necessary to ensure that coastal development coexists with natural marine habiats.

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