Vlaams Instituut voor de
Zee / Vismijn
Pakhuizen 45-52
B-8400 Oostende
Belgie

ISN: 682212 PERIODIEK **OPGEHAALD** 2005-04-20

Referentie aanvrager: Impala erquest 1835341/756.vliz

Titelisn: 61160

Australian journal of marine and freshwater research Voortg. als:Marine and freshwater research, ISSN 1323-1650

Gewenst: 1984 **Fotokopie**

Leveren via Email **Email adres:** janh@vliz.be

Auteur:	**Titel van artikel:**	**Pagina's:**
Bell et al	Structure of a fish community ...	33-46

UB	MAG	NN04955	Vol. 1(1950)-38(1987)
RIVO			Vol. 1(1950)-45(1994)
RIVO			Vol. 1(1950)-45(1994)

Aust. J. Mar. Freshw. Res., 1984, **35**, 33–46

Structure of a Fish Community in a Temperate Tidal Mangrove Creek in Botany Bay, New South Wales

J. D. Bell,[A] *D. A. Pollard, J. J. Burchmore, B. C. Pease*[B] *and M. J. Middleton*

Division of Fisheries, Department of Agriculture New South Wales,
P.O. Box K220, Haymarket, N.S.W. 2000.
[A] Present address: School of Biological Sciences, Macquarie University, North Ryde, N.S.W. 2113.
[B] Present address: Shellfish Laboratory, Washington State Department of Fisheries,
P.O. Box 226, Brinnon, Washington 98320, U.S.A.

Abstract

The fish assemblage in the lower reaches of a temperate tidal mangrove creek entering Botany Bay near Sydney, New South Wales, was sampled using rotenone every second month between December 1977 and October 1980. Almost 17 000 fish (weight ~115 kg), belonging to 46 species and 24 families, were collected. Six species dominated the assemblage and another four were relatively common. Fourteen species, including four of the above, were economically important. These fishes made up 38% of individuals and 32% of biomass and were represented only by small juveniles. Nineteen species (41%) were temporary residents; these mainly comprised juveniles of large species that live elsewhere as adults. Fifteen species (33%), most of which only attain a small size (<100 mm), were assumed to be permanent residents. The remaining 12 species (26%) occurred in only one sample and were, therefore, classified as rare. The diversity (H') and evenness (J') of the fish community were low and showed little seasonality because a few species dominated the assemblage on an irregular basis. Numbers of species and of individuals varied seasonally and were significantly correlated. Peaks in these parameters lagged behind those in water temperature by 4 months and were largely the result of the relatively restricted recruitment periods of several abundant temporary resident species. The large numbers of juveniles and small species in the mangrove creek habitat were attributed to the availability of suitable shelter and food for such small fishes. Concerted use of the mangrove habitat by several abundant temporary resident species during the same general period each year appeared to be facilitated by the occupation of otherwise vacant feeding niches and some staggering of their peak recruitment periods. Exclusive use of this habitat by small juveniles of several species in Botany Bay confirms that mangrove habitats in temperate Australia, like some of those studied in tropical and subtropical regions, are important nursery areas for fishes inhabiting adjacent estuarine and inshore marine habitats as adults.

Introduction

Mangroves are protected to varying degrees in several Australian States, partly because they are believed to provide important habitats for fish. Although some data are now available on fish associated with mangroves in tropical Australia (Beumer 1978; Blaber 1980), this general belief is based largely on results of research undertaken in the south-eastern United States and Caribbean (e.g. Austin 1971; Odum and Heald 1972; see also summary in Clark 1977). Other than surveys by Wallace and van der Elst (1975) and Branch and Grindley (1979) in South Africa, little has been reported of fish communities associated with more temperate mangrove areas. The paucity of data from temperate Australian regions is surprising considering that mangroves form a conspicuous habitat in many temperate Australian estuaries and bays. For example, mangroves extend southwards to Corner Inlet, Victoria, (38°55′S.) on the east coast (Bird 1972), and make up 34% of the 132 ha of estuarine wetlands (seagrasses and mangroves) present in Pambula Lake, the southernmost estuary in New South Wales (R. West, personal communication).

0067-1940/84/010033$02.00

The aims of this study, therefore, were to determine the structure of the fish community inhabiting a temperate Australian mangrove creek, to assess the importance of such a creek as a nursery habitat for economically important fish species, and to describe some of its physical properties. To achieve these aims, we sampled and identified the fish species associated with a permanent mangrove creek entering Botany Bay, on the coast of central New South Wales, over a 3-year period and described the size and residence status of each species and the seasonality of the more abundant species. Variations in numbers of species and individuals, total biomass, the Shannon–Weiner diversity index, community evenness and relative abundance and occurrence of species throughout the study, were also described. The presence of very large numbers of several temporary resident species, particularly during April and June, provided the opportunity to examine mechanisms facilitating the overlapping use of the creek habitat by these species.

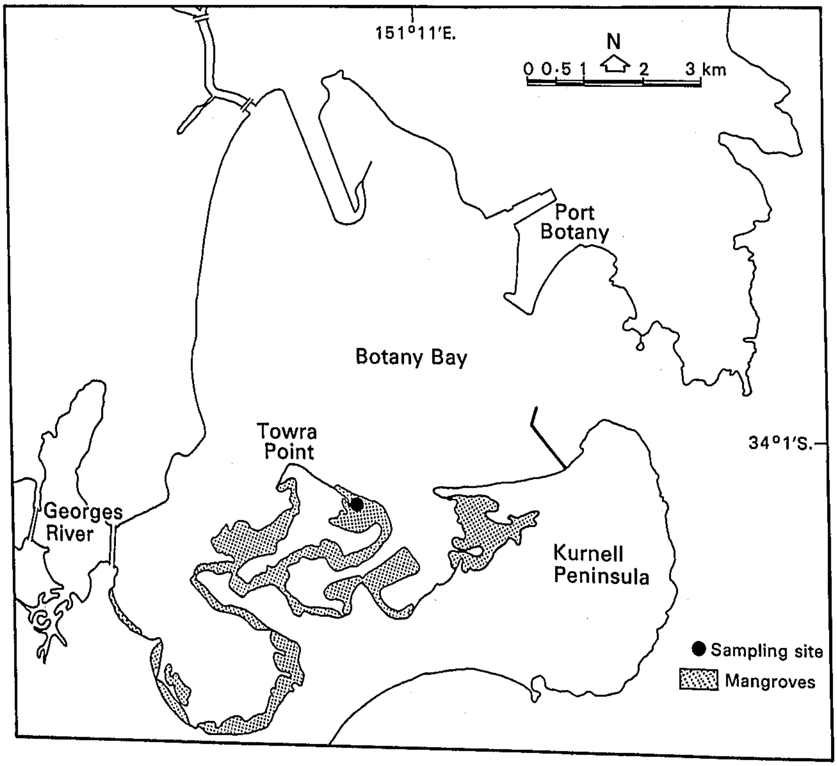


Fig. 1. Distribution of mangroves in Botany Bay, and location of natural drainage creek used as sampling site.

Materials and Methods

Study Area

This study was carried out in part of a 400-ha *Avicennia marina* mangrove forest on the southern shores of Botany Bay (34°1'S.,151°11'E.) to the south of Sydney (Fig. 1). These mangroves are inundated during high tides and creeks drain water from the mangrove flats as the tide ebbs. The largest of the drainage creeks provide permanent fish habitats in this intertidal environment and also function as pathways for fish leaving the inundated mangrove flats.

Samples were collected from the lower 200 m of one of the longest (~1 km) drainage creeks where it was about 5 m wide, and where its bed (which was mostly sand) was 1·0–1·5 m below the surrounding mangrove flats. The creek generally held not less than 0·5 m of water at low tide, but at high water the banks were completely submerged, enabling fish to move over the adjacent mangrove flats. A moderate tidal current (~0·2 m s^{-1}) was generated within the creek during falling tides.

Collection and Analysis of Fish Samples

Fish were sampled from the mangrove creek during daytime every second month between December 1977 and October 1980, using nets and rotenone fish poison. A stop net with a stretched mesh size of 15 mm, similar to that used by Lasserre and Toffart (1977) and Shenker and Dean (1979), was used to completely block the mouth of the creek. The net was installed during ebb tide when the mangrove flats first became exposed. Sufficient rotenone to dislodge all fishes sheltering within the study area was then added to the creek 200 m upstream. The net collected both those species leaving the creek during ebb tide and those swept down the creek after being poisoned. Some fish killed by the rotenone sank to the creek bed and were collected with dip nets.

Water temperature (to the nearest $0 \cdot 1$°C) and salinity (to the nearest 1×10^{-3}) were measured concurrently with each sampling operation. On each occasion, sampling was carried out within the time period 1000–1500 h.

Fish from each sample were preserved in 10% (v/v) formalin. The overall length range [measured to the nearest millimetre of total length (TL) or length to caudal fork (LCF), as appropriate], total number and total biomass (to the nearest gram) of each species were determined in the laboratory. The length of each individual belonging to the more abundant economically important species was also measured to the nearest millimetre.

Data Analysis

Several parameters were used to describe the fish assemblage of the mangrove creek during each sampling period: number of species (richness), number of individuals, total biomass, the Shannon–Weiner diversity index (H') and the evenness index (J') (Pielou 1966). Pearson's correlation coefficient (r) was calculated between each water-quality parameter and each measure of community structure, and also between the various measures of community structure. As several community parameters were strongly seasonal but were negatively correlated with water temperature, a Box–Jenkins time-series analysis (Anderson 1976) was used to determine whether a time lag existed between them and water temperature.

To summarize changes in the relative abundance and occurrence of species over time, bimonthly samples were classified (using ln abundance) with the agglomerative polythetic classification program MULCLAS (Lance and Williams 1967), using the Canberra metric dissimilarity measure and a flexible sorting strategy. The dissimilarity matrix was then ordinated using the program GOWER (Williams 1976) and dissimilarities between samples were displayed on linear axes (eigenvectors).

The diets of abundant temporary resident species were determined by analysing their stomach contents using the estimated volumetric method (Pillay 1952). Similarities between the diets of these species were assessed using the Spearman rank correlation coefficient (r_s) (Siegel 1956).

Results

Environmental Parameters

Water temperatures in the mangrove habitat ranged from 12 to 28°C during the study, with maxima occurring during February and minima from June to August (Fig. 2). Salinity generally remained slightly higher than that of seawater ($\bar{x}$, $36 \cdot 0 \times 10^{-3}$; s.d. = $2 \cdot 5$) but in 1978, following periods of heavy rain, it fell to 33×10^{-3} and 28×10^{-3} during April and June, respectively. Temperature and salinity ranges were generally more extreme than those recorded by the State Pollution Control Commission (Anon. 1981) in other shallow habitats, and by Middleton *et al.* (1983) in *Zostera capricorni* seagrass beds (Fig. 2), in Botany Bay.

Numbers and Biomass of Fishes

A total of 16 905 fish (weighing $114 \cdot 9$ kg), belonging to 46 species and 24 families, was taken from the mangrove creek in the 18 bimonthly samples. As the study area was about 1000 m^2, the mean density of fish in the creek was $\sim 0 \cdot 94$ m^{-2} and the mean biomass $\sim 6 \cdot 4$ g m^{-2}. Abundance, biomass, length range, and life-history stage data (from Bell 1980; D. Hoese, personal communication) for each species are given in Table 1.

Table 1. Abundance and biomass data for fish species inhabiting a mangrove creek entering Botany Bay

Family and species	Abundance	% Abundance[B]	Biomass (g)	% Biomass[B]	Length range (mm)	Residence status[C]	Life-history stage[D]
Anguillidae							
Anguilla australis	5	+	4397	3·8	500–950	T (LT)	J, A
Anguilla reinhardtii	26	0·2	41 262	35·9	49–1200	T (LT)	J, A
Ophichthidae							
Ophisurus serpens	9	+	164	0·1	220–470	T (LT)	J
Plotosidae							
Cnidoglanis macrocephalus	3	+	1	+	37–39	R	J
Atherinidae							
Pranesus ogilbyi	1	+	1	+	31	R	J
Pseudomugil signifer	1947	11·5	287	0·3	9–38	P	J, A
Syngnathidae							
Urocampus carinirostris	1	+	1	+	63	R	A
Scorpaenidae							
Centropogon australis	6	+	8	+	11–60	T (LT)	J
Platycephalidae							
Platycephalus fuscus[A]	8	+	17	+	26–97	T (LT)	J
Ambassidae							
Priopidichthys marinanus	2	+	5	+	44–61	R	A
Velambassis jacksoniensis	5382	31·8	1078	0·9	7–55	T (ST)	J, A
Serranidae							
Epinephelus daemeli	4	+	2	+	27–39	T (LT)	J
Theraponidae							
Pelates sexlineatus	1	+	4	+	71	R	J
Therapon jarbua	3	+	7	+	29–64	T (LT)	J
Sillaginidae							
Sillago ciliata[A]	76	0·5	71	+	19–100	T (LT)	J
Pomatomidae							
Pomatomus saltatrix[A]	1	+	1	+	27	R	J
Gerreidae							
Gerres ovatus[A]	1071	6·3	787	0·7	10–52	T (LT)	J
Sparidae							
Acanthopagrus australis[A]	400	2·4	1654	1·4	14–112	T (LT)	J
Rhabdosargus sarba[A]	9	+	2	+	11–24	T (LT)	J
Monodactylidae							
Monodactylus argenteus	159	0·9	91	+	12–46	T (LT)	J

Kyphosidae							
Girella tricuspidata[A]	*3145*	*18·6*	29 850	26·0	17–200	T (LT)	J
Microcanthus strigatus	*2*	+	2	+	24–27	R	J
Scatophagidae							
Selenotoca multifasciata	1	+	2	+	34	R	J
Mugilidae							
Liza argentea[A]	1525	9·0	3639	3·2	10–170	T (ST)	J
Mugil cephalus[A]	28	0·2	442	0·4	24–138	T (ST)	J
Myxus elongatus[A]	71	0·4	446	0·4	22–123	T (ST)	J
Blennidae							
Omobranchus anolius	16	+	18	+	46–81	P	A
Gobiidae							
Acanthogobius flavimanus	5	+	116	0·1	95–192	P?	J, A
Arenigobius bifrenatus	1	+	1	+	18	R	J
Arenigobius frenatus	20	0·2	50	+	11–89	P	J, A
Bathygobius krefftii	17	0·1	5	+	16–50	P	J, A
Favonigobius exquisitus	368	2·2	85	+	10–87	P	J, A
Favonigobius lateralis	121	0·7	34	+	13–43	P	J, A
Favonigobius tamarensis	63	0·4	17	+	13–82	P	J, A
Gobiopterus semivestita	481	2·8	42	+	17–35	P	J, A
Mugilogobius paludis	150	0·9	25	+	12–39	P	J, A
Mugilogobius stigmaticus	31	0·2	7	+	11–36	P	J, A
Pandaculus lidwilli	8	+	1	+	10–14	P	A
Pseudogobius olorum	80	0·5	14	+	10–38	P	J, A
Redigobius macrostomus	492	2·9	69	+	7–44	P	J, A
Eleotridae							
Gobiomorphus australis	6	+	74	+	62–119	P	A
Bothidae							
Pseudorhombus arsius[A]	4	+	16	+	48–110	T (LT)	J
Pseudorhombus jenynsii[A]	1	+	1	+	66	R	J
Monacanthidae							
Meuschenia freycineti[A]	3	+	130	0·1	135–149	R	J
Scobinichthys granulatus[A]	1	+	13	+	95	R	J
Tetraodontidae							
Torquigener hamiltoni	1150	6·8	29 924	26·1	27–142	T (LT)	J, A

[A]Species of economic importance. [B]+ <0·1%. [C]P, permanent resident; T (LT), long-term temporary resident; T(ST), short-term temporary resident; R, rare species. [D]J, juvenile; A, adult.

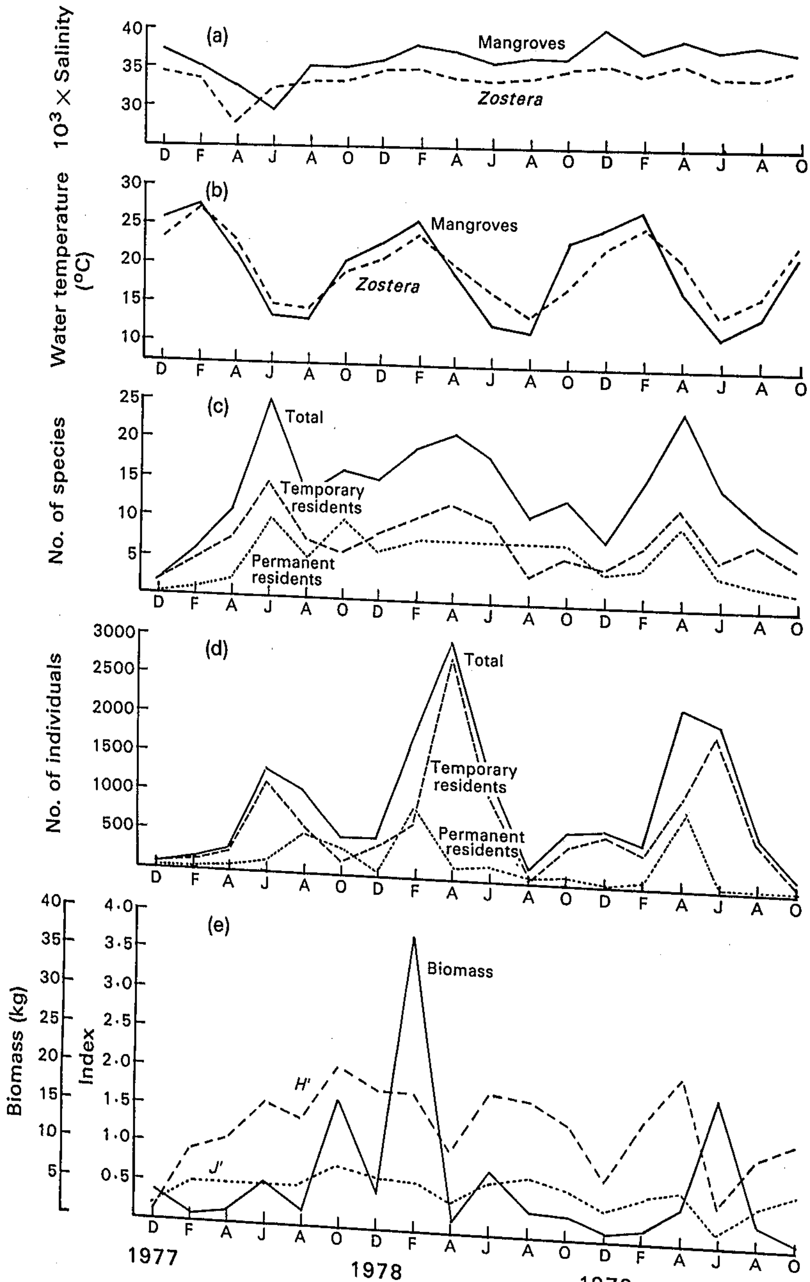


Fig. 2. Bimonthly variations between December 1977 and October 1980 in physical and biological parameters of mangrove creek. (*a*) Salinity. (*b*) Water temperature. In (*a*) and (*b*), data from the shallow water *Zostera capricorni* seagrass habitat in Botany Bay studied by Middleton *et al.* (1983) are included for comparison with those from the mangrove creek. (*c*) Number of species. (*d*) Number of individuals. (*e*) Total biomass and the Shannon-Weiner (H') and evenness (J') indices.

Six species, *Velambassis jacksoniensis* (31·8%), *Girella tricuspidata* (18·6%), *Pseudomugil signifer* (11·5%), *Liza argentea* (9·0%), *Torquigener hamiltoni* (6·8%), and *Gerres ovatus* (6·3%), dominated the number of fish in the assemblage. However, another four species, *Redigobius macrostomus* (2·9%), *Gobiopterus semivestita* (2·8%), *Acanthopagrus australis* (2·4%) and *Favonigobius exquisitus* (2·2%), were also relatively common. Community biomass was dominated by *Anguilla reinhardtii, Girella tricuspidata* and *Torquigener hamiltoni* (Table 1).

Fourteen species, comprising 38% of total numbers and 32% of total biomass, were of some economic importance (Table 1). The mean lengths of the four most abundant of these species (*Girella tricuspidata, Liza argentea, Gerres ovatus* and *Acanthopagrus australis*) were well below those of mature individuals, i.e. most were small juveniles of the 0+ age group (Table 2). The remaining economically important species also occurred only as small juveniles and nearly all of the other species were represented to some extent in the samples by juveniles (Table 1).

Table 2. Mean ($\bar{x}$) lengths to caudal fork (LCF) of most abundant economically important fish species

s.d., standard deviation; *n*, number of fish

Fish species	$\bar{x}$ LCF (mm)	s.d.	*n*	Length at first maturity (mm)[A]
Gerres ovatus	28·4	7·5	1071	125
Acanthopagrus australis	46·6	24·0	400	205
Liza argentea	44·0	28·9	1525	280
Girella tricuspidata	74·4	27·2	1575	190

[A] From Bell (1980).

Residence Status

Fish species were classified as permanent residents, temporary residents or rare species on the basis of their occurrence and abundance, and on unpublished records of the species' life histories. Species likely to remain in the mangrove habitat throughout their lives were regarded as permanent residents, whereas temporary residents included fishes that regularly used the creek but normally only remained there for a portion of their life history (usually only as juveniles). Two patterns of temporary residence were recognized among species, *viz*, 'long-term' species whose individuals seemed to remain in the creek for extended seasonal periods (≥4 months) and generally showed an increase in mean length during their stay, and 'short-term' species, represented by species that, because of the great variation in the size of individuals in successive samples, were believed to visit and leave the creek frequently (unpublished data). Rare species were those that occurred in low numbers (<4) in only one sample. Fifteen species (33%) appeared to be permanent residents of the mangrove creek, and 19 species (41%) were temporary residents (Table 1). Most temporary residents were juveniles and were 'long-term' species. However, the relatively mobile *Velambassis jacksoniensis* and juveniles of the Mugilidae (mullets) were classified as 'short-term' species (Table 1). Twelve species (26%) were rare. Temporary residents dominated the community in terms of number of individuals (77%) and total biomass (99%).

Community Structure

Number of species

The number of species present in the mangrove creek followed a cyclical pattern throughout the study, with peak values occurring some time after maximum water temperature (Fig. 2). Time-series analysis showed that these parameters were significantly correlated ($P<0 \cdot 05$) with a time lag of 4 months (Table 3). There was no significant correlation between number of species and salinity ($r = -0 \cdot 297$, n.s.), presumably because salinity showed no seasonality (Fig. 2).

Number of individuals

The number of individuals showed similar seasonality to that displayed by the number of species (Fig. 2) and both were significantly correlated ($r = 0 \cdot 746$, $P<0 \cdot 001$). Time-series analysis showed that number of individuals was also significantly correlated ($P<0 \cdot 05$) with the water temperature recorded 4 months earlier (Table 3). Salinity and number of individuals were not significantly correlated ($r = 0 \cdot 117$).

Table 3. Box–Jenkins time-series analyses between water temperature and various community parameters and abundances of several of the most abundant temporary resident species
*Significant positive correlation at $P<0 \cdot 05$, **$P<0 \cdot 01$

Time lag in water temperature (months)	Pearson's correlation coefficient for water temperature and: No. of individuals	No. of species	Abundance of *Gerres ovatus*	Abundance of *Acanthopagrus australis*	Abundance of *Girella tricuspidata*
−12	−0·087	0·031	−0·061	−0·174	−0·436
−10	−0·586	−0·343	−0·542	−0·573	−0·407
− 8	−0·407	−0·362	−0·452	−0·448	0·138
− 6	0·188	0·158	0·086	0·264	0·360
− 4	0·512*	0·480*	0·358	0·732**	0·429
− 2	0·331	0·277	0·476*	0·562*	−0·187
0	−0·352	−0·410	−0·203	−0·370	−0·499
+ 2	−0·632	−0·615	−0·578	−0·755	−0·280
+ 4	−0·331	−0·179	−0·376	−0·312	0·185
+ 6	0·189	0·261	0·242	0·319	0·153
+ 8	0·403	0·351	0·291	0·557*	0·104
+10	0·297	0·051	0·278	0·277	−0·054
+12	−0·150	−0·232	−0·108	−0·246	−0·116

Other community measures

Total biomass varied considerably throughout the study (Fig. 2); higher biomass was usually related to the occurrence of more larger species or individuals. For example, total biomass was significantly correlated with the numbers of the large eel *Anguilla reinhardtii* ($r = 0 \cdot 847$, $P<0 \cdot 001$) and the abundance of the relatively large and common toadfish, *Torquigener hamiltoni* ($r = 0 \cdot 815$, $P<0 \cdot 001$).

The H' and J' species diversity measures showed no seasonal patterns (Fig. 2) and were not significantly correlated with either water temperature or salinity. H' and J' had comparatively low mean values of 1·33 (±0·53) and 0·51 (±0·17), respectively, during the study period and were reduced on several occasions as a result of the capture of only a small number of species (e.g. December 1977) and/or because relatively few species dominated the catch (e.g. April 1979 and June 1980).

Relative abundance and occurrence of individuals

The ordination, which explained 31% of the variance in the data on the first two eigenvectors, produced two main groups of samples (Fig. 3). The April and June samples, characterized by high numbers of species and of individuals of temporary residents (Fig. 2), separated clearly from all other samples. The results of the classification generally confirmed the pattern shown by the ordination.

Seasonality of species

Bimonthly abundances of the 10 most abundant species are shown in Fig. 4. The four species in this group that were 'long-term' residents had consistent periods of abundance and absence/scarcity during each year. *Torquigener hamiltoni* reached peak abundances from October through April and was either absent or present in only low numbers from June through August. The abundance of *T. hamiltoni* was positively correlated with water temperature, however, the relationship was not significant ($r = 0 \cdot 331$). *Gerres ovatus* and *Acanthopagrus australis* attained highest abundances during April or June and were

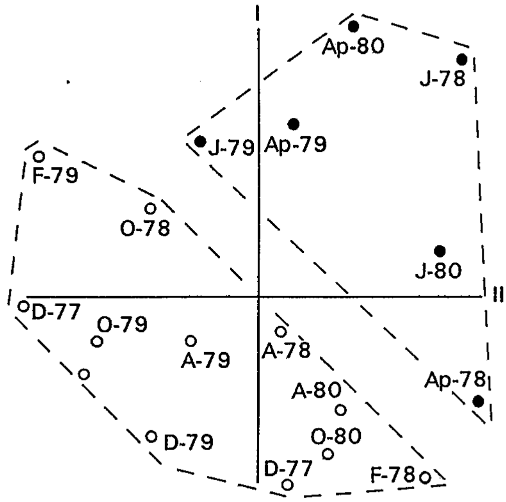


Fig. 3. Ordination of abundance data for each sample plotted against eigenvectors I and II. Samples are labelled by month and year: ● April and June samples; ○ August to February samples.

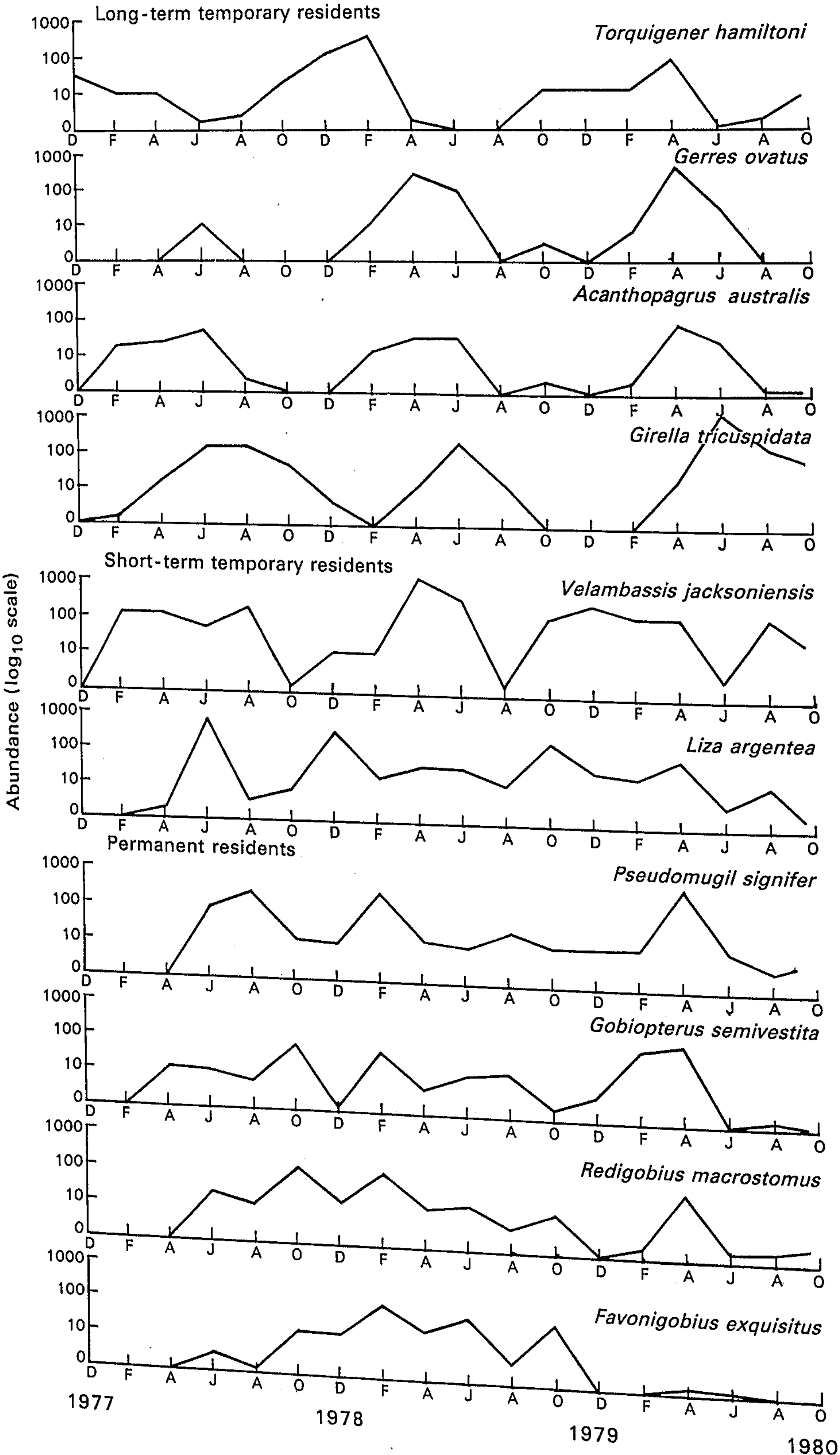
uncommon in, or absent from, the creek from August through December. Time-series analysis showed that abundances of *G. ovatus* and *A. australis* were most highly correlated with water temperatures recorded 2 and 4 months earlier, respectively (Table 3). The abundance of *Girella tricuspidata* was also best correlated (although not significantly) with water temperature recorded 4 months earlier (Table 3). However, *G. tricuspidata* was normally present in large numbers during a slightly later and more extended period (April–October) than *Acanthopagrus australis* and was generally only uncommon or absent during December and February.

The remaining common species, including the 'short-term' temporary residents *Velambassis jacksoniensis* and *Liza argentea* and several permanent residents, were relatively abundant in most samples (Fig. 4) and showed little seasonality in their abundances. Juveniles of several less abundant fishes in the assemblage (*Centropogon australis, Platycephalus fuscus, Epinephelus daemeli, Therapon jarbua, Sillaga ciliata* and *Monodactylus argenteus*) also demonstrated a regular pattern of occurrence 2–4 months after maximum water temperature and absence during months of increasing and maximum temperatures.

Feeding Habits

The diets of the most abundant temporary resident species are shown in Table 4. *Gerres ovatus* had a carnivorous diet. It consumed principally soft-substrate benthic organisms such as harpacticoid copepods and polychaetes. *Acanthopagrus australis* was also a benthic feeder and predominantly carnivorous but was more of a generalist than *Gerres ovatus*;

Fig. 4


Long-term temporary residents
Torquigener hamiltoni
Gerres ovatus
Acanthopagrus australis
Girella tricuspidata
Short-term temporary residents
Velambassis jacksoniensis
Liza argentea
Permanent residents
Pseudomugil signifer
Gobiopterus semivestita
Redigobius macrostomus
Favonigobius exquisitus
Abundance (log10 scale)
1000
100
10
0
D F A J A O D F A J A O D F A J A O
1977
1978
1979
1980

its diet included organisms associated with the sediment and with mangrove roots. *Torquigener hamiltoni* was a macrophagic carnivorous feeder, consuming principally decapods (mainly brachyuran crabs), cirripedes (barnacles) and gastropods associated with mangrove roots. *Girella tricuspidata* was also a benthic feeder; however, it was mainly herbivorous, consuming algae attached to mangrove roots, some detritus and cirripedes.

Table 4. Diets of most abundant temporary resident species

Food type	Estimated volume (%) in diet of					
	Velambassis jacksoniensis	*Gerres ovatus*	*Acanthopagrus australis*	*Torquigener hamiltoni*	*Liza argentea*	*Girella tricuspidata*
Epiphytic algae	—	—	6·2	—	19·3	68·8
Polychaeta	2·4	32·8	19·1	1·0	1·5	—
Gastropoda	—	—	—	6·3	—	—
Benthic Copepoda	83·3	53·6	13·3	—	15·1	0·9
Amphipoda	0·9	—	15·0	—	0·9	1·0
Decapoda	2·0	—	22·0	74·5	—	—
Cirripedia (adults)	1·5	—	2·4	14·0	—	7·0
Planktonic Crustacea	9·6	—	—	—	—	—
Other Crustacea	—	2·9	5·9	—	5·4	1·7
Insecta	—	2·4	—	—	37·5	—
Teleostomi	—	—	7·7	—	—	—
Other fauna	0·3	7·1	7·5	—	1·5	4·4
Detritus	—	—	0·9	2·7	16·0	16·2
Sand	—	1·2	—	—	2·8	—
No. of stomachs examined	50	91	177	60	219	175
No. of stomachs empty	10	49	17	21	28	37
Length range (mm)	17–55	12–52	14–112	79–139	10–164	17–124
Years sampled	1979–1980	1978–1979	1978–1979	1979–1980	1978–1979	1978–1979

Liza argentea was omnivorous and appeared to feed throughout the water column, taking large numbers of insects blown from the mangrove foliage onto the surface of the water and also substantial quantities of copepods, detritus and epiphytic algae. *Velambassis jacksoniensis* had a limited microphagic diet that consisted mainly of benthic copepods but also included planktonic crustaceans.

Table 5. Matrix of Spearman rank correlation coefficients between diets of most abundant temporary resident species

*$P<0·05$

	Gerres ovatus	*Acanthopagrus australis*	*Liza argentea*	*Girella tricuspidata*	*Velambassis jacksoniensis*	*Torquigener hamiltoni*
Gerres ovatus	1·0	0·089	−0·038	−0·702*	0·163	−0·773*
Acanthopagrus australis		1·0	−0·501	−0·780*	0·238	−0·123
Liza argentea			1·0	0·102	−0·577	−0·680*
Girella tricuspidata				1·0	−0·793*	−0·336
Velambassis jacksoniensis					1·0	−0·430
Torquigener hamiltoni						1·0

The differences between the diets of these species are shown in Table 5. Of the 15 pair-wise dietary comparisons using r_s, 11 resulted in negative correlations, five of which were significant at the 5% level. There were no significant correlations (similarities) between the diets of any two species.

Fig. 4. Seasonality of most common species in fish assemblage from mangrove creek between December 1977 and October 1980.

Discussion

The fish assemblage in mangroves in Botany Bay has several features in common with those in other mangrove areas (e.g. Austin 1971; Odum and Heald 1972; Lasserre and Toffart 1977; Yãnez-Arancibia *et al.* 1980). It has relatively few species, a high proportion of which are economically important, and is dominated by juvenile Gerreidae, Sparidae and Mugilidae and other generally small species from the families Atherinidae, Ambassidae and Gobiidae. Thus, the community is characterized by a relatively low diversity (H') and evenness (J'). Another property of this assemblage, previously described for both mangrove (Galzin *et al.* 1981) and salt marsh (Subrahmanyam and Drake 1975) habitats, is the high proportion of temporary residents occurring as juveniles (reasons for this are discussed later).

The relatively higher numbers of species and individuals present around April and June each year are distinctive features of this fish assemblage. The ordination analysis, and the seasonality data, show that these pulses in numbers of species and individuals were largely due to juvenile recruitment of 'long-term' temporary residents such as *Gerres ovatus, Acanthopagrus australis, Girella tricuspidata, Platycephalus fuscus* and *Sillago ciliata.* These species spawn in the vicinity of Botany Bay when water temperatures are at a maximum (Bell 1980; Anon. 1981), and the significant time lag between these maximum water temperatures and the peak occurrence of species and recruitment of juveniles presumably represents the time necessary for the larval development and movement of these species to the mangrove creek habitat. Subsequent decreases in numbers of both species and individuals were mainly due to their emigration to other estuarine habitats (Bell 1980; Anon. 1981).

Salinity and temperature tolerances vary considerably between different estuarine fish species (Kinne 1967; Whitfield *et al.* 1981), and between size classes within a given species (Holliday 1971; Richards *et al.* 1977). This has led to the hypothesis that spatial distribution of fish in estuaries is largely mediated by responses to these parameters (Weinstein 1979). Similarly, Austin (1971) suggested that higher salinity tolerances by juveniles accounted for their abundance, and the absence of adults, in Puerto Rican mangrove habitats. Thus structural similarities between the fish assemblage in the mangrove creek in Botany Bay and those in other mangrove areas may be a reflection of the ability of both the species and juvenile size classes present to withstand the relatively extreme temperature and salinity regimes of these shallow habitats.

Investigations of habitat preferences by juvenile fish in a variety of habitats in Botany Bay (Bell 1980, Anon. 1981) revealed that high numbers of small juvenile (<50 mm TL) *Gerres ovatus, Acanthopagrus australis* and *Liza argentea* were associated only with mangrove habitats and that juvenile *Girella tricuspidata* had a strong preference for these habitats after an initial settlement phase in *Zostera capricorni* seagrass beds. The above observations, along with the high numbers of these four species in the mangrove creek, imply that they actively seek this habitat during an early stage in their life history. Despite its more extreme physical environment, the mangrove creek is beneficial to juvenile fish in providing suitable shelter and food.

The mangrove creek affords shelter to small fishes because it is too shallow for most larger piscivorous fish. The two *Anguilla* species were the only fish in the creek large enough to be potential predators and may not be important in this context as they were found to be feeding mainly on crabs (unpublished data). The pneumatophores and exposed roots of mangroves lining the creek banks provide further shelter from predators, such as birds, and an increased surface area for epiphytic food organisms. Plankton and vagile invertebrates are channelled through drainage creeks during ebb tide and, therefore, it is likely that these creeks provide a greater availability of such food types than other 'open-water' estuarine habitats.

Wallace and van der Elst (1975) suggested that the provision of shelter by the complex root system of *Avicennia* sp. accounted for the association of juvenile fish with these mangroves in South Africa. However, since large areas of apparently suitable shelter in the form of the robust seagrass *Posidonia australis* (which also supports few piscivorous fish; Middleton *et al.* 1983) were available in Botany Bay, the almost exclusive occurrence of small juveniles of species like *Gerres ovatus* and *Acanthopagrus australis* in the mangrove creek indicates that feeding requirements may also be important criteria in habitat selection by these fishes. The dietary data indicate that these two species may require areas of exposed soft substrate on which to feed. Such exposed areas are common amongst mangroves but not amongst *Posidonia australis* shoots.

Another characteristic of this mangrove fish assemblage is that high densities of temporary residents were maintained in the creek for several months. Differences in diurnal–nocturnal activity patterns (Shenker and Dean 1979), partitioning of food resources (Beumer 1979) and staggered recruitment periods (Subrahmanyam and Coultas 1980) are all factors reported to facilitate coexistence of abundant species in fish assemblages in estuarine creeks. In the absence of night-time samples and data on food evacuation rates for each species, we cannot strictly determine whether the abundant temporary residents in the mangrove creek in Botany Bay feed at different times. However, our data indicate that these species may feed at comparable times (i.e. most individuals of each species contained stomach contents during the daytime, see Table 4). The data do show that all of these species had different diets. This suggests that there is no obvious competition for feeding periods or food among the abundant temporary residents. We submit that the coexistence of the temporary residents may be due to their occupation of niches that were vacant before their recruitment. Such niches presumably exist because the shallow nature and relatively extreme milieu of the mangrove habitat deter other species from using it. Staggering of recruitment and emigration periods, which occurred to a limited degree among the four most abundant 'long-term' temporary residents, may reduce overlap in their use of the one resource likely to be in short supply during years of highly successful recruitment by all species, i.e. suitable subtidal shelter in the vicinity of the mangrove flats.

Whereas the relative importance of food and shelter to the juvenile fish of the mangrove habitat in Botany Bay remains to be more precisely elucidated, it is clear that this area provides a nursery for economically important species. The regular and apparently exclusive use of mangrove habitats as nursery areas by some species indicates that availability of mangroves could be a limiting factor in their recruitment success. Mangroves are widespread in temperate Australia and the real importance of this habitat as a fish nursery area will only be evident after further research to determine whether the patterns of fish use observed in this study are typical of these other temperate mangrove habitats.

Acknowledgments

Technical staff at the Division of Fisheries, particularly P. Mort, J. Messersmith and G. Allan, helped sort and measure fish specimens, and D. Hoese and H. Larson of the Australian Museum confirmed the identifications of several gobies. T. Lau and A. Collins provided assistance with the analysis of data and members of the Division of Fisheries' Editorial Committee, M. Westoby and two anonymous referees made helpful criticisms of this manuscript.

References

Anderson, O. D. (1976). 'Time Series Analysis and Forecasting, the Box–Jenkins Approach.' (Butterworths: London.)

Anon. (1981). The ecology of fish in Botany Bay—biology of commercially and recreationally important species. State Pollution Control Commission of New South Wales. Rep. No. BBS23B.

Austin, H. M. (1971). A survey of the ichthyofauna of the mangroves of western Puerto Rico during December, 1967–August, 1968. *Caribb. J. Sci.* **11**, 27–39.

Bell, J. D. (1980). Aspects of the ecology of fourteen economically important fish species in Botany Bay, New South Wales, with special emphasis on habitat utilisation and a discussion of the effects of man-induced habitat changes. M.Sc. Thesis, Macquarie University.

Beumer, J. P. (1978). Feeding ecology of four fishes from a mangrove creek in north Queensland, Australia. *J. Fish. Biol.* **12**, 475–90.

Bird, E. C. F. (1972). Mangroves on the Australian coast. *Aust. Nat. Hist.* **17**, 167–71.

Blaber, S. J. M. (1980). Fish of the Trinity Inlet system of north Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. *Aust. J. Mar. Freshw. Res.* **31**, 137–46.

Branch, G. M., and Grindley, J. R. (1979). Ecology of southern African estuaries, Part XI. Mngazana: a mangrove estuary in Transkei. *S. Afr. Tydskr. Dierk.* **14**, 149–70.

Clark, J. R. (1977). 'Coastal Ecosystem Management, a Technical Manual for the Conservation of Coastal Zone Resources.' (Wiley-Interscience: Sydney.)

Galzin, R., Toffart, J. L., Louis, M., and Guyard, A. (1981). Contribution à la connaissance de la faune ichtyologique du Grand Cul de Sac Marin en Guadeloupe. *Cybium* **6**, 85–99.

Holliday, F. G. T. (1971). Salinity: fishes. In 'Marine Ecology'. (Ed. O. Kinne.) Vol. 2, pp. 997–1033. (Wiley-Interscience: Sydney.)

Kinne, O. (1967). Physiology of estuarine organisms with special reference to salinity and temperature: general aspects. In 'Estuaries'. (Ed. G. H. Lauff.) Am. Assoc. Adv. Sci. Publ. No. 83, pp. 525–40.

Lance, G. N., and Williams, W. T. (1967). Mixed data classificatory programs. I. Agglomerative systems. *Aust. Comput. J.* **1**, 15–20.

Lasserre, G., and Toffart, J. L. (1977). Echantillonnage et structure des populations ichtyologiques des mangroves de Guadeloupe en septembre 1975. *Cybium* **2**, 115–27.

Middleton, M. J., Bell, J. D., Burchmore, J. J., Pollard, D. A., and Pease, B. C. (1983). Structural differences in the fish communities of *Zostera capricorni* and *Posidonia australis* seagrass meadows in Botany Bay, New South Wales, Australia. *Aquat. Bot.* (In press.)

Odum, W. E., and Heald, E. J. (1972). Trophic analyses of an estuarine mangrove community. *Bull. Mar. Sci.* **22**, 671–738.

Pielou, E. C. (1966). Shannon's formula as a measure of specific diversity. Its use and misuse. *Am. Nat.* **100**, 463–5.

Pillay, T. V. R. (1952). A critique of the methods of study of food of fishes. *J. Zool. Soc. India* **4**, 185–200.

Richards, F. P., Reynolds, W. W., and McCauley, R. S. (1977). Temperature preference studies in environmental impact assessments: an overview with procedural recommendations. *J. Fish. Res. Board Can.* **34**, 728–61.

Shenker, J. M., and Dean, J. M. (1979). The utilisation of an intertidal salt marsh creek by larval and juvenile fishes: abundance, diversity and temporal variation. *Estuaries* **2**, 154–63.

Siegel, S. (1956). 'Nonparametric Statistics for the Behavioural Sciences.' (McGraw-Hill Kogakusha: Tokyo.)

Subrahmanyam, C. H., and Coultas, C. L. (1980). Studies on the animal communities in two north Florida salt marshes. Part III. Seasonal fluctuations of fish and macroinvertebrates. *Bull. Mar. Sci.* **30**, 790–818.

Subrahmanyam, C. B., and Drake, S. H. (1975). Studies on the animal communities in two north Florida salt marshes. Part I. Fish communities. *Bull. Mar. Sci.* **25**, 445–65.

Wallace, J. H., and van der Elst, R. P. (1975). The estuarine fishes of the east coast of South Africa. IV. Occurrence of juveniles in estuaries. V. Ecology, estuarine dependence and status. Oceanogr. Res. Inst. (Durban) Invest. Rep. No. 42.

Weinstein, M. P. (1979). Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fish. Bull. U.S.* **77**, 339–57.

Williams, W. T. (1976). 'Pattern Analysis in Agricultural Science.' (CSIRO: Melbourne.)

Whitfield, A. K., Blaber, S. J. M., and Cyrus, D. P. (1981). Salinity ranges of some southern African fish species occurring in estuaries. *S. Afr. Tydskr. Dierk.* **16**, 151–5.

Yãnez-Arancibia, A., Linares, F. A., and Day, J. W., Jr (1980). Fish community structure and function in Terminos Lagoon, a tropical estuary in the southern Gulf of Mexico. In 'Estuarine Perspectives'. (Ed. V. S. Kennedy.) pp. 465–82. (Academic Press: New York.).

Manuscript received 3 October 1982, accepted 26 July 1983