

ENCOUNTER 2002 EXPEDITION TO THE ISLES OF ST FRANCIS, SOUTH AUSTRALIA: REEF FISHES

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Summary

SHEPHERD, S. A. & BROOK, J. B. (2003) Encounter 2002 expedition to the Isles of St Francis, South Australia: Reef fishes. *Trans. R. Soc. S. Aust.* **127**(2), 269–279, 28 November 2003.

Reef fish populations of the Isles of St Francis were surveyed by visual census along transects from 5–20 m depth and over a range of exposures to swell. Overall mean densities of ~0.5 m⁻² were recorded divided among 5 groups: (1) mid-water species, mainly planktivores and macrophage carnivores; (2) species associated with soft bottoms or seagrasses; (3) reef-dwelling species, mainly benthic carnivores and herbivores, that swim within 1–2 m of the algal canopy; (4) reef-dwelling species living under the algal canopy or close to reef structures, and comprising benthic carnivores, omnivores and herbivores; and (5) cryptic or cave-dwelling species, mostly carnivores or planktivores. The very high abundance of fishes recorded, termed the offshore island effect, is hypothesised to be due to high local reef productivity, a high carbon subsidy from the surrounding seas, and low fishing pressure. Juveniles of some species recruited in particular habitats defined by depth and exposure, and abundances of post-juveniles varied along depth and exposure gradients. The patterns of distribution suggest, in the case of wrasses and leatherjackets, habitat partitioning among similar co-occurring species, in the case of the herring gale, differential food abundance, and, in the case of the seaflyfin, a gradient in topographic complexity.

KEY WORDS: Reef fishes; wrasses; leatherjackets, southern Australia; trophic fish groups; fish distribution patterns; fish abundance patterns; offshore island effect.

Introduction

Shallow temperate reefs are known to be highly productive systems yet the structure and composition of fish assemblages are virtually unknown in South Australia, although knowledge has advanced elsewhere in southern Australia on fishes of shallow reefs (reviewed by Jones & Andrew 1990; Barrett 1995; Turner & Norman 1998; Curley *et al.* 2002). The only published accounts of coastal reef fishes in South Australia are those of Kuter (1983) and Branden *et al.* (1986) who compared two fish census techniques in the Investigator Group of Islands.

The Encounter 2002 expedition to St Francis Isles in the eastern Great Australian Bight from 16–26 February (Robinson *et al.* 2003) gave the opportunity to survey the fishes of these offshore islands. Coastal reef fishes have been heavily exploited in southern Australia for many decades by spearfishers (Johnson 1985a,b) and anglers, so that pristine abundances of fish are now rare. The Isles of St Francis are very lightly fished by one or two fishers from Ceduna, and the fish assemblages, like those of the Investigator Group, may be considered representative of natural assemblages once common on mainland coasts.

It is known that water movement and depth gradients influence the composition of reef fish assemblages as well as macrophyte communities (Shepherd & Womersley 1976) in which fish reside and recruit (Jones 1988; Jenkins & Wheatley 1998). The purpose of this study was to quantify the abundance and size structure of reef fishes along depth and water movement gradients in a relatively pristine environment, and so gain insights into juvenile habitats, and abundances of adults on coastal reefs around offshore islands. Secondary purposes were to gather data for future regional ecosystem modelling, and for the selection of marine reserves in Nuyts Archipelago.

Methods

The Isles of St Francis are exposed to strong prevailing south-westerly swell as well as seas from the south-east generated by strong south-easterly winds during the late summer (Shepherd & Womersley 1976). The annual sea surface temperature range is from 14–20°C with cooler bottom waters during upwelling periods. Light penetration is generally high and corresponds to that for Type II oceanic water of Jerlov (1968) (see Turner & Cheshire 2003).

Rocky substratum is of moderate to steeply sloping granite rock or rhyolite (Robinson *et al.* 1996; Ferris 2003), comprising jointed blocks 1–5 m in size, forming between and under them numerous crevices

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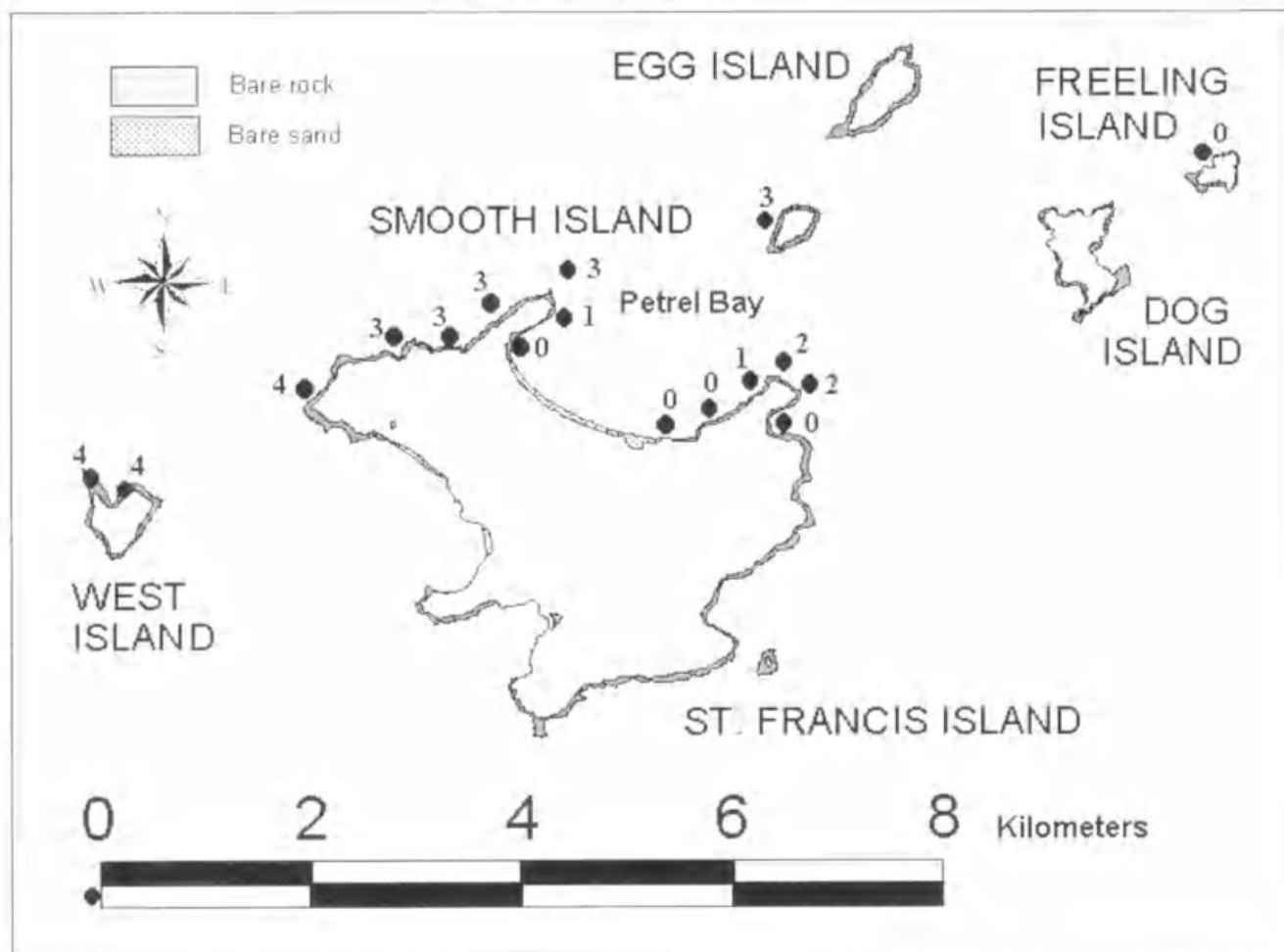


Fig. 1. Map of the Isles of St Francis showing the location of sites sampled (●) with exposure index value in brackets.

and occasional caves. Calcareous substrata, comprising continuous or fractured aeolianite reef to -5 m deep, occur on the southern shores of Petrel Bay and on the north side of Freeling Island and provide a topographically complex habitat (Womersley & Baldock 2003). Generally, rocky bottom meets the sand at about 10 m depth on sheltered shores, increasing to 25–30 m on fully exposed coasts. Overall, topographic complexity, while it varied on a small scale, at the scale of sampling in this study (100–200 m) varied little between sites, but declined somewhat with depth as block and boulder sizes decreased.

Dive sites were classified subjectively according to exposure to swell and given an exposure index (EI) ranging from 0–4 to encompass the range of water movement from extreme shelter to extreme exposure to southwest swell (modified from the classificatory procedure of Barrett *et al.* 2001). In all, 17 sites were selected to cover the full EI range (0–4) from depths of 5–20 m at 5 m depth intervals. Dives were within

1 (rarely 2) m of the nominated depth. However, prevailing swell and southerly winds largely restricted dive sites to those with a northerly aspect, and in consequence restricted the statistical analyses possible.

We used the standard visual census method (Barrett & Buxton 2002) to estimate the size and number of fish of all species observed other than small cryptic species. The diver swam with a reel and 50 m line on a given depth contour, and recorded all fish within a 5 m swathe to a height of about 5 m in the water column. The diver swam about 1 m above the algal canopy at a constant speed and did not attempt to search for small (<10 cm) cryptic species under the algal canopy, but did record juveniles of

TABLE 1. Distribution of censuses on depth and exposure index gradients. Exposure indices range from 0–4 over a depth range from 5–20 m.

Depth (m)	Exposure Index				
	0	1	2	3	4
5	3	5	3	3	4
10	5	6	2	4	4
15	-	-	3	2	-
20	-	-	1	3	5

¹ Edyvane, R. S. & Baker, J. L. (1999) Marine heritage values of the St Francis Isles and Investigator Isles, South Australia. SARDI Final report to Australian Heritage Commission, 36 p + figures.



Fig. 2. Schematic diagram of the spatial organization of reef fishes in the water column. Group 1 is pelagic or mid-water species. Group 2 is species living in seagrass or on soft bottoms. Group 3 is species with restricted range on rocky substrata that swim within 1 m of the algal canopy. Group 4 is species with localised range that live under the algal canopy. Group 5 is cryptic species living in crevices. See text for further details.

larger species seen in crevices and caves within the area covered by the swathe. Estimates of fish sizes were recorded in 5 cm size classes to 40 cm size, then in the size classes 40–50 cm, 50–70 cm and >70 cm, (in the last group we estimated the size of each fish). Divers were previously trained and experienced in underwater fish surveys. There were 2–4 replicate censuses per site at each available depth interval, as recommended by Branden *et al.* (1986), except when divers were restricted by diving time limits. Underwater visibility was usually 10–15 m, but during days of moderate swell with a lower visibility of ~8 m we conducted censuses in Petrel Bay at 5–10 m depth. In all, 53 transects, each covering 250 m², were done at the 17 sites shown in Fig. 1, distributed among the depths and EIs shown in Table 1.

Juveniles of some species, notably the labrids (*Notalabrus tetricus*, *Austrolabrus maculatus*, and *Ophthalmolepis lineolatus*), western talma, *Chelmonops curassus*, and scalyfin, *Parma victoriae*, were moderately common in some censuses. We used the 0–10 cm size class as an index of their abundance, except for blue groper, *Achoerodus gouldii*, where we used the 0–20 cm size class for juveniles and the 20–60 cm size class for sub-adults (after Gillanders 1997). The habitats of juveniles, where abundant, were defined in terms of location on the depth-EI gradient.

Abundances of 10 site-attached species with >49% occurrence in transects were examined for

correlations with depth (9 species) and EI (3 species). For three species of labrids with ontogenetic shifts in habitat we examined patterns for small and large size classes separately. Correlations were also examined between (1) the abundance of herring calf, *Odalus cyanomelas*, and biomass of its preferred food, *Ecklonia*, using biomass data from Shepherd & Womersley (1976) and Edyvane & Baker (1999)¹, and (2) the change in the sex ratio of the blue-throated wrasse, *N. tetricus*, with depth. This wrasse is a protogynous hermaphrodite (Shepherd & Clarkson 2001; Smith *et al.* 2003) and reaches sexual maturity as a female from 13–20 cm (Smith *et al.* 2003; G. J. Edgar pers. comm.). Assuming sexual maturity at 15 cm, we calculated female:male sex ratios for each transect, and examined the decline in the sex ratio with depth. In all, 20 correlations were calculated, so, by chance alone, one is expected to be significant at $P < 0.05$. Levels of significance at $P > 0.01$ should therefore be accepted with caution.

Correlations of species' abundances with depth, a continuous variable, were tested with parametric tests, and correlations with EI, measured on an ordinal scale, and with sex ratios, were tested with the Pearson rank non-parametric test (Conover 1980).

Information on life habit was based on our observations, and nomenclature and diet of fishes were variously extracted from the publications of Edgar *et al.* (1982); Gomon *et al.* (1994); Edgar (1997); Hutchins & Swainston (1999); Andrew (1999) and Kuiter (2000).

Results

Structure of Fish Assemblages

We recognised five ecological groups of fish (cf. Harmelin 1988) according to life habit and behaviour (Fig. 2):

Group 1: pelagic or mid-water species that range widely and swim above reef habitats, usually in schools or small groups. They are mainly planktivores and macrophage carnivores.

Group 2: species that live and feed among seagrasses or on sandy bottom, but occasionally visit adjacent reef habitats. They are mainly benthic carnivores.

Group 3: demersal reef-dwelling species that swim within ~1–2 m of the algal canopy. They are benthic carnivores, omnivores and herbivores usually with home ranges that extend over tens of metres (e.g. wrasses) to kilometres (e.g. zebra fish, *Girella zebra*).

Group 4: reef-dwelling species living under the algal canopy or close to reef structures with some relief, and usually having small home ranges or

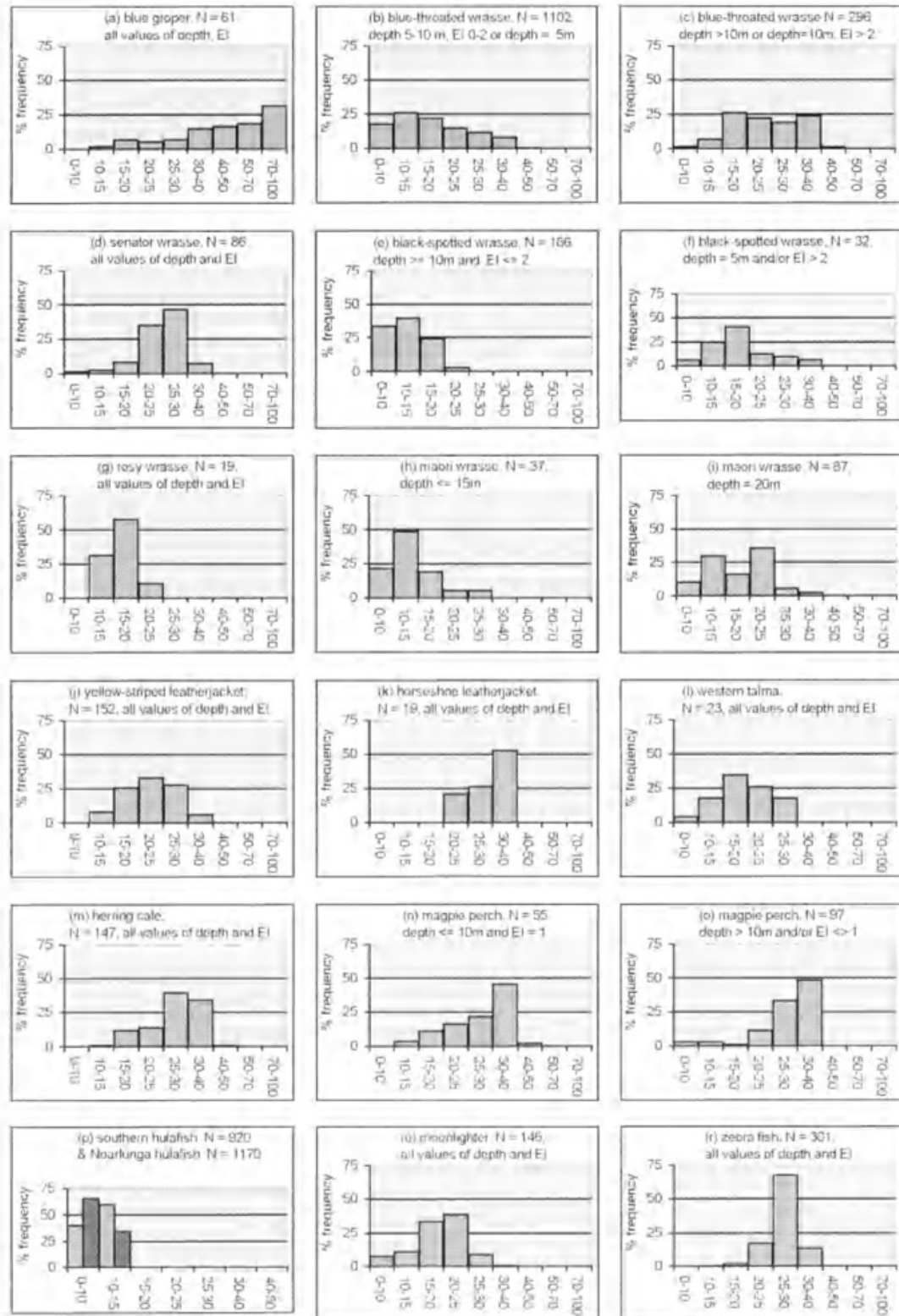


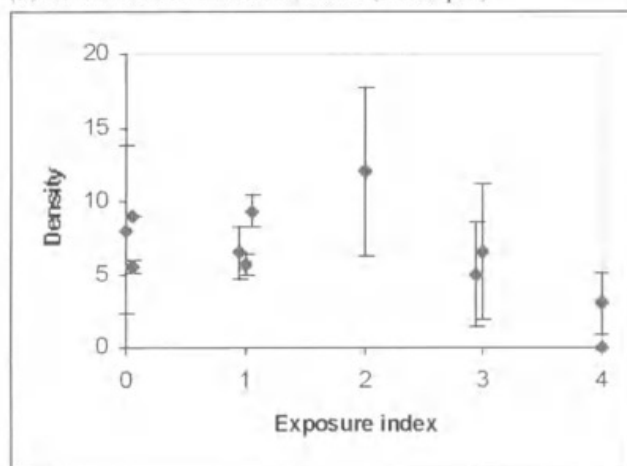
Fig. 3. Length-frequency distributions of commoner reef fishes. Data combined for all sites unless otherwise indicated.

a: blue groper; b: blue-throated wrasse - combined data for depth 5–10 m, EI 0–2 and 5 m EI 3–4 showing recruitment regions; c: blue-throated wrasse - combined data for remaining sites at 10–20 m and EI 3–4; d: senator wrasse; e: black-spotted wrasse - combined data for 10–20 m, EI 0–2 showing recruitment regions; f: black-spotted wrasse - combined data for sites at other depths and EI; g: rosy wrasse; h: maori wrasse - combined data for all sites 5–15 m depth showing recruitment regions; i: maori wrasse - combined data for all sites at 20 m depth; j: yellow-striped leatherjacket; k: horseshoe leatherjacket; l: western talma; m: herring cale; n: magpie perch - combined data for high density sites i.e. 5–10 m, EI 1; o: magpie perch - combined data for all depths at EI 2–4; p: Noarlunga hulafish (grey) and southern hulafish (black); q: moonlighter; r: zebra fish.

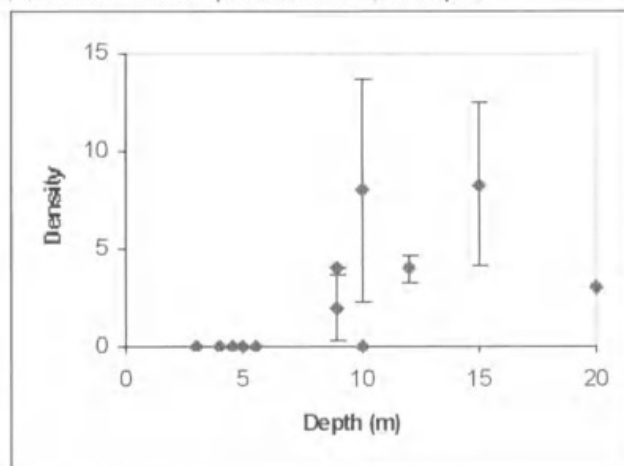
TABLE 2. List of species recorded in censuses according to ecological group. Mean density in occupied transects is given for each species in numbers/250 m² and mean size in cm. % occ. is the percentage of all transects in which the species was recorded. FT is feeding type. C=carnivore; P=planktivore; O=omnivore; BC=benthic carnivore; H=herbivore. Exposure index = EI. S.E. = standard error. Overall mean densities for each group for all transects are given in bold.

Common name	Scientific name	FT	Density (se) EI 0-2	Density (se) EI 3-4 (cm) (s.e)	Mean Size	% occ.
Group 1						
Blue morwong	<i>Nemodactylus valenciennesi</i>	BC	1.0	0	45.0	3.8
Long-finned pike	<i>Dinolestes lewini</i>	C	0	14.8 (12.1)	16.5 (0.9)	17.0
Snook	<i>Sphyræna novaehollandiae</i>	C	8.4 (3.6)	0	45.0	13.2
Sea sweep	<i>Scorpiæ aequipinnis</i>	P	7.2 (2.7)	6.0 (1.6)	19.8 (0.7)	28.3
Banded sweep	<i>Scorpiæ georgianus</i>	P	2	3.0 (1.8)	22.5 (1.4)	11.3
Butterfly perch	<i>Caesioperca lepidoptera</i>	P	4.7 (0.7)	29.2 (14.3)	24.4 (0.3)	15.1
Barber perch	<i>Caesioperca rasor</i>	P	19.5 (7.4)	16.8 (3.0)	16.0 (0.2)	37.7
Old wife	<i>Enoplosus armatus</i>	P	15.7 (5.9)	4.3 (1.8)	21.5 (0.4)	41.5
Tommy ruff	<i>Arripis georgiana</i>	P	15.0	4.0	17.5 (1.6)	3.8
Mean density 19.4						
Group 2						
Silver (white) trevally	<i>Pseudocaranx dentex</i>	BC	93.2 (54.2)	7.5 (1.4)	21.7 (0.3)	17.0
Red mullet (goat fish)	<i>Upeneichthys vlamingii</i>	BC	2.2 (0.2)	3.3 (1.3)	21.0 (1.1)	17.0
Yellowfin whiting	<i>Sillago schomburgkii</i>	BC	9.4 (3.0)	0	17.5 (0.7)	9.4
King George whiting	<i>Sillaginodes punctata</i>	BC	2	0	17.5	1.9
Sand (skipjack) trevally	<i>Pseudocaranx wrightii</i>	BC	0	36	15.0 (0.6)	1.9
Southern silver belly	<i>Parupuleia melbourneensis</i>	BC	1.0 (0)	2.0 (1.0)	12.5 (1.5)	5.7
Mean density 10.4						
Group 3						
Western blue groper	<i>Achoerodus gouldii</i>	BC	2.7 (0.7)	2.2 (0.3)	53.0 (3.2)	49.1
Long snouted boarfish	<i>Pontacropsis recurvirostris</i>	BC	0	1	60.0	1.9
Dusky morwong	<i>Dactylophora nigricans</i>	H	1.2 (0.2)	2	49.7 (5.4)	9.4
Silver drummer	<i>Kyphosus sydneyanus</i>	H	1.8 (0.8)	1.3 (0.2)	40.9 (1.6)	22.6
Harlequin fish	<i>Othos dentex</i>	C	1.0 (0)	1.0 (0)	40.0 (5.0)	3.8
Blue devil	<i>Paraplesiops melanocephalus</i>	BC	1.0 (0)	1.0 (0)	31.7 (2.2)	5.7
Magpie perch	<i>Cheilodactylus nigripes</i>	BC	3.7 (0.4)	2.7 (0.3)	27.9 (0.6)	90.6
Zebra fish	<i>Girella zebra</i>	H	5.1 (1.1)	9.4 (4.0)	27.4 (0.3)	73.6
Luderick	<i>Girella tricuspidata</i>	O	0	2.0 (0)	27.5	5.7
Brown-spotted wrasse	<i>Notolabrus parilis</i>	BC	1	0	27.5	1.9
Blue-throated wrasse	<i>Notolabrus tetricus</i>	BC	34.4 (3.9)	17.4 (2.8)	22.5 (0.2)	98.1
Pretty polly	<i>Dotalabrus aurantiacus</i>	BC	1.3 (0.3)	3.0 (2.0)	18.3 (1.2)	9.4
Maori wrasse	<i>Oplithalmolepis lineolatus</i>	BC	3.8 (0.7)	8.6 (1.7)	17.2 (0.6)	37.7
Rosy wrasse	<i>Pseudolabrus psittaculus</i>	BC	1.9 (0.4)	3.0 (1.0)	16.7 (0.8)	17.0
Western writher	<i>Acanthistius serratus</i>	C	1	0	22.5	1.9
Yellowstripe leatherjacket	<i>Meschenia flavolineata</i>	O	4.1 (1.1)	5.1 (0.7)	22.4 (0.5)	62.3
Horseshoe leatherjacket	<i>Meschenia hippocrepis</i>	BC	2.0 (0.3)	2.3 (0.6)	29.4 (0.9)	30.2
Stars/stripe leatherjacket	<i>Meschenia venusta</i>	O	0	1.3 (0.2)	22.5 (1.2)	17.0
Blue-lined leatherjacket	<i>Meschenia galii</i>	O	0	1	22.5	1.9
Rough leatherjacket	<i>Scorpaenichthys granulosus</i>	O	1	0	27.5	1.9
Degen's leatherjacket	<i>Thamnaconus degeni</i>	BC	0	1	17.5	1.9
Toothbrush leatherjacket	<i>Acanthaluteres vittiger</i>	BC	1	0	22.5	1.9
Blue-tailed leatherjacket	<i>Eubalichthys cyanoura</i>	BC	0	2	25.0 (2.0)	1.9
Western talmu	<i>Chelmonops curvatus</i>	BC	1.8 (0.2)	2.1 (0.2)	19.2 (1.0)	30.2
Western footballer	<i>Nearyptis obliquus</i>	H	2.0 (0)	3.8 (1.5)	14.2 (0.6)	11.3
Mean density 43.1						
Group 4						
Herring eale	<i>Oxysoma cyanomelas</i>	H	3.8 (0.5)	3.9 (0.5)	27.2 (0.5)	71.7
Senator wrasse	<i>Pictilabrus latidorsus</i>	BC	2.2 (0.3)	3.1 (0.4)	24.2 (0.6)	64.2
Victorian scalyfin	<i>Parma victoriae</i>	H	2.3 (0.3)	2.2 (0.3)	22.0 (0.6)	60.4
Moonlighter	<i>Tilodon sexfasciatus</i>	BC	3.5 (0.7)	3.8 (0.6)	19.1 (0.5)	75.5
Rainbow eale	<i>Oxysoma acroptilus</i>	BC	1.5 (0.5)	0	17.5 (2.9)	3.8
Snakeskin wrasse	<i>Eupetrichthys angustipes</i>	BC	1.7 (0.3)	0	15.8 (1.3)	5.7
Black-spotted wrasse	<i>Austrolabrus maculatus</i>	BC	11.1 (2.6)	3.0 (0.7)	15.7 (0.4)	50.9
Shaw's cowlfish	<i>Aracana aurita</i>	BC	2.0 (0)	1.0 (0)	12.5	5.7
Long-rayed weed whiting	<i>Siphonognathus radiatus</i>	BC	2.0 (0)	0	7.5	1.9
Weed whiting	<i>Haletta semifasciata</i>	BC	0	20	5.0 (0.8)	1.9
Pencil weed whiting	<i>Siphonognathus beddomei</i>	BC	1.0 (0)	23.0 (17.0)	10.0 (0.9)	5.7
Mean density 13.3						
Group 5						
Orange-lined bullseye	<i>Pempheris sp.</i>	C	1	0	12.5	1.9
Common bullseye	<i>Pempheris multiradiata</i>	C	3.0 (0.6)	4.0 (0)	13.8 (0.7)	7.6
Southern hulafish	<i>Trachinops caudimaculatus</i>	P	64.0 (17.9)	70.0 (21.2)	10.7 (0.1)	26.4
Noarlunga hulafish	<i>Trachinops noarlungae</i>	P	75.0 (25.0)	85.0 (22.3)	8.2 (0.1)	26.4
Mean density 39.1						
Total density 125.3						

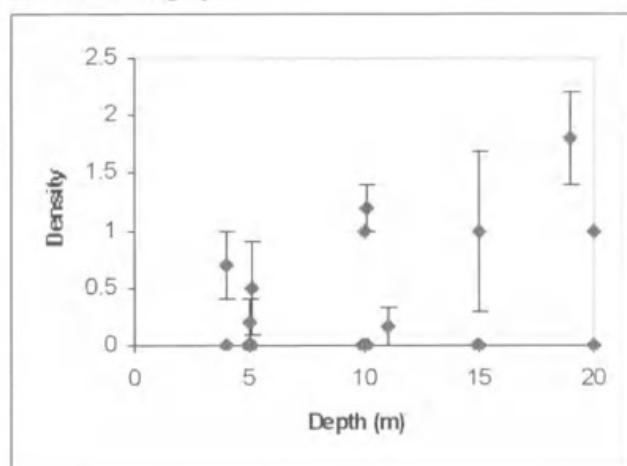
(a) Juvenile blue-throated wrasse (5m depth)



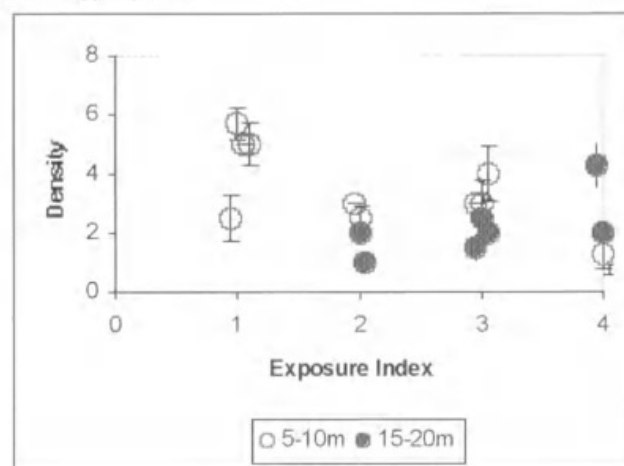
(b) Juvenile black-spotted wrasse (5m depth)



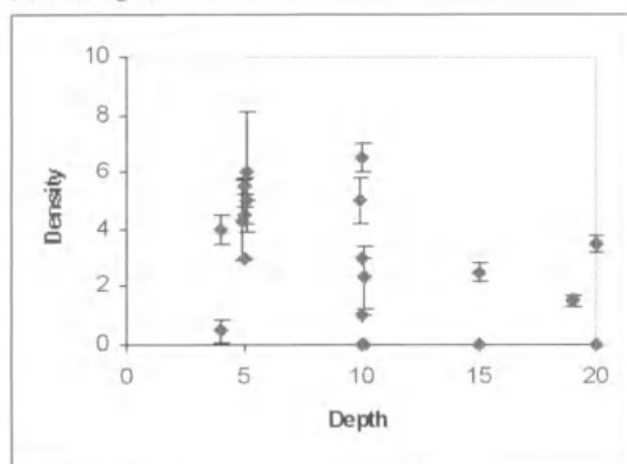
(c) Adult blue groper



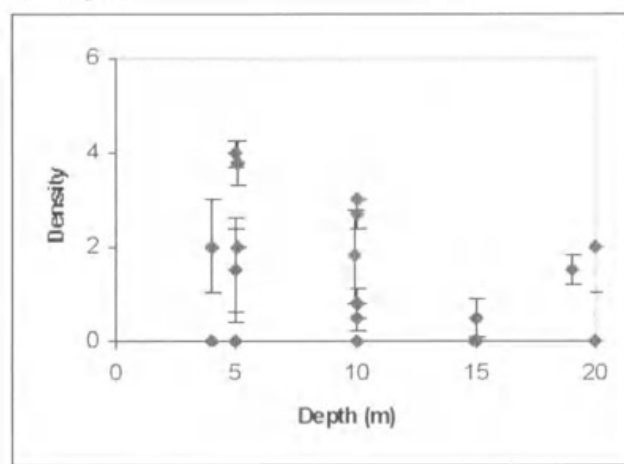
(d) Magpie perch



(e) Herring cale



(f) Scalyfin

Fig. 4. Plots of mean densities of six species of fish (numbers, 250 m⁻²) vs depth or exposure index.

a: juvenile blue-throated wrasse, *N. tetricus* (5 m depth only); b: juvenile black-spotted wrasse, *A. maculatus* at EI = 2; c: adult (> 60 cm) blue groper, *A. gouldii*; d: magpie perch, *C. nigripes*, 5–10 m depth (○); 15–20 m depth (●); e: herring cale, *O. cyanomelas*; f: Victorian scaly fin, *P. victorae*.

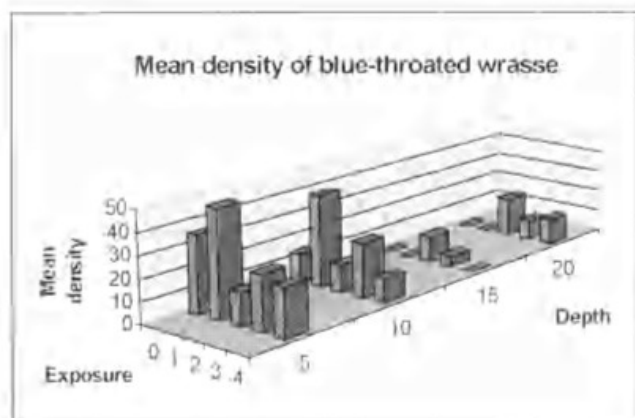


Fig. 5. A plot of mean density of the blue-throated wrasse, *N. tetraodon* (numbers/250 m²) vs depth (m) and exposure index. Zero values indicate either that no samples were taken (EI=4 at 15 m depth) or those depth/EI combinations were absent (EI=0-1 at 15-20 m depth).

territories extending from a few to tens of metres. They comprise herbivores, benthic carnivores and omnivores.

Group 5: cryptic or cave-dwelling species, active mainly at night. They are planktivores or carnivores.

The 55 fish species recorded by us on the transects are listed by group in Table 2 in approximate order of decreasing fish size with data on mean densities in occupied transects on sheltered (EI 0-2) and exposed (EI 3-4) coasts, and mean sizes and percentage of occupied transects. Length-frequency distributions, in some cases aggregated for particular depths and EIs, of the commoner species are shown in Fig. 3. Only two species with >50% occurrence in transects, the blue-throated and the black-spotted wrasses, *N. tetraodon* and *A. maculatus*, showed a significant difference in overall density on the exposure gradient (Table 2).

The overall mean density of fishes was 125.3 per 250 m² (i.e. ~0.5 m⁻²), of which 45% comprised Groups 3 and 4, the benthic feeders, and 46.7% Groups 1 and 5, which feed in the water column. Herbivorous species (excluding leatherjackets, which may browse small amounts of algae), a subset of Groups 3 and 4, comprised 8.3% of the total number of fishes (Table 2).

Juveniles

Juveniles of a few species apparently recruited onto near-shore reefs and were found in restricted parts of the depth-EI gradient.

Blue groper juveniles (<20 cm), *A. gouldii*, were few and seen only at 5 m depth (mean density 0.28 s.e. 0.48). Blue-throated wrasse juveniles, *N. tetraodon*, were restricted to depths of 5 m or less, except at sheltered sites (EI 0-2) where they were also abundant at 10 m depth (Fig. 3b). At 5 m depth

their abundance declined significantly ($p=0.67$; $P<0.005$) with increasing exposure (Figs 3c, 4a). In contrast, juveniles of the black-spotted wrasse, *A. maculatus*, were rare at exposed sites (EI 3-4) (Fig. 3f), and at sheltered sites (EI 0-2) increased significantly ($r=0.47$; $P<0.05$) in density with increasing depth (Figs 3e, 4b). The juvenile maori wrasse, *O. lineolatus*, was patchy, and almost entirely restricted to 10-20 m depth at EI 3 with a mean density of 0.89 (s.e. 0.34) (Fig. 3h). Juveniles of the magpie perch, *C. nigripes* (Fig. 3g), snapper wrasse, *P. laticlavus* (Fig. 3d), and scalyfin, *P. victorinus*, were only found in depths of 5 m or less, whereas juveniles of the moonlighter, *T. seifasciatum* (Fig. 3q), were seen only at 10 m depth at EI=0-3, and juveniles of the western talma, *C. curiosus*, only at 15-20 m at EI=2 (Fig. 3l). Juvenile magpie perch, *C. nigripes*, and barber perch, *C. rasor*, were few and rarely seen.

Post-juveniles and Adults

GROUPS 1, 2 (PELAGIC/MID-WATER SPECIES, SANDY-BOTTOM SPECIES)

The common species, sea sweep, *S. aequipinnis*, and barber perch, *C. rasor*, were seen in small to large groups at all depths and exposures. A few species showed apparent preferences for particular exposures. Thus, silver trevally, *P. dentex*, and butterfly perch, *C. lepidoptera*, were seen only at reduced water movements, either on sheltered coasts or deep (20 m) on exposed coasts; two large schools (mean size 100) in Petrel Bay accounted for the high densities at EI=2 (Table 2). The long-finned pike, *D. lewini*, occurred only on exposed shores (EI=3-4).

Old wives, *E. armatus*, were in low abundance at all depths and exposures (mean density 0.8 s.e. 0.2), except for five schools (mean size 32.3 s.e. 3.4) at 10-18 m, EI=0-3.

Two species were seen only in restricted geographic locations: the luderick, *G. trichospidata*, off western St Francis I. and the blue morwong, *N. valenciennesi*, in eastern Petrel Bay. Other species were too uncommon to draw any inferences about their distribution patterns.

GROUP 3 (ABOVE-CANOPY, REEF-DWELLING SPECIES)

Reef habitats at the study sites were dominated by species in this group. Some home-ranging species (Edgar *et al.* 1982, Barrett 1995) tended to occur at uniform densities at all exposures. Examples were the scalyfin, *P. victorinus*, herring gale, *O. cyanomelas* (Fig. 3m), and western talma, *C. curiosus* (Fig. 3l), which all typically occurred in pairs. The abundance of the blue groper, *A. gouldii* (Fig. 3a), changed with depth but not exposure. While sub-adults (20-60 cm) occurred at all depths and exposures (mean

density 0.5 s.e. 0.1), the density of adults (>60 cm) increased significantly ($r=0.45$; $P<0.001$) with increasing depth (Fig. 4c); mean adult density was 0.5 (s.e. 0.1).

The abundance of post-juvenile (>10 cm) blue-throated wrasse, *N. letricus*, the most abundant species recorded, declined significantly ($r=0.45$; $P<0.001$) with depth (Fig. 5) at all exposures. The mean female:male sex ratio declined significantly ($r=0.489$; $P<0.0001$) from 12.2:1 at 5 m depth to 5.6:1 at 20 m.

Post-juvenile maori wrasse, *O. lineolatus* (Fig. 3i), were abundant only at 20 m depth. Here mean density per transect was 8.7 (s.e. 1.3) compared 0.6 (s.e. 0.2) at all other depths (Fig. 3h); the difference was significant ($t=5.9$; $P<0.001$). Other wrasses were uncommon or restricted geographically or in depth. The wrasses, pretty polly, *D. aurantiacus*, brown-spotted wrasse, *N. parulus*, and rosy wrasse, *P. psittacus*, and the serramid, western wirrah, *A. verratus*, (except for a single record at 5 m at EI = 4), were only seen on reef near the sand line, and the snakeskin wrasse, *E. angustipes*, only in shallow water (<10 m) at Freeling I.

The magpie perch, *C. nigripes* (Fig. 3n,o), was in low abundance (mean density 1.0 s.e. 0.4) in extreme shelter (EI = 0), but common elsewhere. The species showed a curious reversing pattern of abundance in relation to exposure at EI = 1–4. At shallow depths (≤ 10 m) density declined significantly ($p=0.811$; $P<0.0001$) with increasing exposure, but in deeper water (15–20 m) increased significantly ($p=0.738$; $P<0.005$) with increasing exposure (Fig. 4d). The two most common leatherjackets, yellow-striped leatherjacket, *M. fluviolineolata* (Fig. 3j), and horseshoe leatherjacket, *M. hippocrepis* (Fig. 3k), occurred at all depths and exposures, and usually in pairs. The former was rare in extreme shelter (EI = 0) and below 10 m depth (mean density 0.7 s.e. 0.3), but abundant elsewhere (mean density 4.4 s.e. 0.7). The latter was rare in extreme exposure (EI = 4) but common elsewhere. The third-most common leatherjacket, stars and stripes leatherjacket, *M. ventata*, was restricted to strong exposure (EI = 3–4) at ≥ 10 m depth, except for one sighting elsewhere. The dusky morwong, *D. nigricans*, was seen only in Perrel Bay, and conversely, the western footbiller, *N. abliquus*, was almost entirely restricted to exposed coasts (EI = 3). The zebra fish, *G. zebra*, (Fig. 3r) was almost omnipresent in low numbers (mean density per transect 3.1 s.e. 0.5) except for two large schools (mean size 70) at 5 m depth at EI = 4. The silver drummer, *K. xydionotus*, occurred at all depths and exposures in small to large groups.

GROUP 4 (UNDER-CANOPY REEF-DWELLING SPECIES)

The black-spotted wrasse, *A. maculatus* (Fig. 3e,f),

was in low density at all depths and exposures (mean density 0.8 s.e. 0.3), except at EI = 0–2 at 10–20 m where mean densities (7.3 s.e. 4.7) were significantly higher ($t=4.3$; $P<0.001$). The senator wrasse, *P. latilavus* (Fig. 3d), was solitary or in pairs, and the moonlighter, *T. sexfasciatum* (Fig. 3q), was usually in small groups; neither showed any pattern along depth or exposure gradients.

Scalyfin, *P. victoriae*, and herring-eale, *O. cyanomelas* (Fig. 3m), were most abundant at 5 m depth and both declined significantly ($r=0.32$; $P<0.05$ in each case) with depth (Fig. 4e,f). The abundance of herring-eale, *O. cyanomelas*, was significantly correlated with *Ecklonia* biomass ($r=0.30$; $P<0.05$).

GROUP 5 (CRYPTIC AND CAVE-DWELLING SPECIES)

The two species of hulafish (Fig. 3p) were both largely restricted to 5–12 m depth range, but at different exposures. The southern hulafish, *T. caudimaculata*, was most abundant at EI = 1–2, and the Noarlunga hulafish, *T. noarlungae*, at EI = 3–4 (Table 2) near entrances to caves or under overhangs. Schools were monospecific, except off Smooth I., where mixed schools were present.

Discussion

Trophic Organisation

Our recognition of ecological groups based on behaviour and trophic categories is an oversimplification. First, the diet of some species changes with size (e.g. some juvenile herbivores may feed on amphipods) (Horn 1989); second, some species such as silver trevally, *P. dentex*, may switch between benthic and mid-water feeding (Russell 1983); and third, many species to a small extent transgress feeding categories. Nevertheless, the groups are a useful conceptual aid for defining the structure of fish assemblages and for inter-site comparisons. The categories we use are broadly similar to those used by Harmelin (1988) for the Mediterranean, although fish in different categories in our waters probably mingle more than in the Mediterranean due to the homogenising effect of stronger water movement on subtidal habitats on southern Australian coasts (SAS, pers. obs.).

The so-called 'offshore island effect' (Chirat *et al.* 1988) is characterised by a greater abundance of fish species and individuals compared with mainland coasts. Total mean densities of fishes (~ 0.5 m $^{-2}$) which we have recorded, are near the upper limit of those recorded by Branden *et al.* (1986) for the Investigator Group of Islands in the eastern Great Australian Bight (range 0.1–0.6 m $^{-2}$), and similar to those of Barrett & Edgar (1993) for the Kent Group in Bass Strait (~ 0.5 m $^{-2}$) and Russell (1977) for Goat I. in northern New Zealand (up to 1.2 m $^{-2}$). On the

south-eastern Australian mainland coast fish densities are much lower. In far eastern Victoria (Cape Howe to Gabo I.) mean densities were 0.19 m^{-2} (Edmunds *et al.* 2001), in central Victoria they ranged from 0.03–0.14 m^{-2} (Edmunds *et al.* 2000; Edmunds 2002) and in northern Tasmania from 0.14–0.2 m^{-2} (Barrett & Edgar 1993; Barrett & Wilcox 2001). The limestone patch reefs of south-west Western Australia had higher densities of ~0.8 m^{-2} (Howard 1989), but in that study the fish mainly sheltered in the patch reefs and fed in surrounding seagrasses. Overall, the St Francis Isles rank high, in terms of fish abundance, with other rich temperate Australasian regions.

A comparative examination of the ecologic-trophic groups of fish (Jones 1988) at various sites in Australasia suggests the source of this richness. In Russell's (1977) study in New Zealand, open water feeders, with a large subtropical component, comprised 78% and benthic feeders 15% of individuals, whereas on the Tasmanian mainland open-water feeders averaged only 42% and benthic feeders 58% of the total (Barrett & Edgar 1993). Conversely in the Kent Group open water feeders comprised ~70%, due largely to the high abundance of barber perch, *C. rasor*. Open water feeders comprised a high proportion (67–72%) in eastern Victoria and Wilsons Promontory (which has a fish fauna similar to that of the Kent Group), but a low proportion (12–18%) elsewhere with low overall densities. The Isles of St Francis, with nearly equal abundances of open water feeders and benthic feeders, are thus relatively high in both trophic groups. It is apparent that much of the variation in abundance between locations in Australasia is due to differences in numbers of open water feeders, rather than to benthic feeders. Why is this so?

Offshore islands are swept by ocean currents and are sometimes regions of local upwelling, so that local island reefs can capture the production of large surrounding oceanic areas (see Okey *et al.* 2003). The enhanced import of carbon not only supports an increased number of open water feeders, but also increases secondary and tertiary production in the resident fauna of reefs (Menge *et al.* 1997). Thus, our Groups 1, 2 and 5, representing planktivores, carnivores and soft bottom immigrants, depend largely on carbon imports from the surrounding seas or adjacent seagrasses and sandy bottom, whereas benthic feeders (Groups 3, 4) depend on the productivity of local reefs, albeit enhanced to some extent by oceanic imports (Bray *et al.* 1981). The often steeply sloping shores of offshore islands may also favour planktivores as they provide some shelter close to shore.

A subset of benthic feeders, the herbivores, has received more attention than other groups in Australasia. Jones & Andrew (1990) recorded 19–

44% of fishes as herbivores at four sites in south-eastern Australia and northern New Zealand, whereas Russell (1977) recorded only 5% as herbivores, and Barrett & Edgar (1993), Barrett & Wilcox (2001) and Edmunds (2002) and Edmunds *et al.* (2000, 2001) 5–10% for Victorian, northern Tasmanian and Bass Strait Island sites, and <1% for southern Tasmania. Our mean value of 8% is therefore about average for temperate reefs, and suggests that herbivores do not contribute to the offshore island effect.

An alternative, non-exclusive explanation for the 'off-shore island effect' is that fishing is much more intense on mainland coasts and reduces the abundance of fishes on coastal reefs. At present, Nuyts Archipelago is lightly fished with an annual take of ~5 t of blue-throated wrasse (*A. Suter* pers. comm.). Recreational (and to a small extent spear) fishing is generally common on mainland coasts and targets reef dwelling carnivores and some omnivores, but as yet we have no data on abundance of reef fishes or the intensity of recreational fishing on adjacent mainland coasts for evaluating this alternative hypothesis.

Species Abundance Patterns

While many texts on southern Australian fishes (see above) give qualitative information on depth and exposure preferences of juveniles and adults, this is the first such quantitative analysis for southern rocky coasts. In particular our data on juvenile and adult abundances of the numerous species in the family Labridae suggest microhabitat partitioning between them, although we cannot strictly distinguish between habitat preferences and differential survival of randomly settling juveniles (see Connell & Jones 1991). Juveniles of the blue-throated wrasse, *N. tetraeus*, the black-spotted wrasse, *A. maculatus*, and the maori wrasse, *O. lineolatus*, each occupied different parts of the depth

exposure gradients. The occurrence of other wrasses only at or near the sandline may reflect their use of reefs for shelter and adjacent sandy or seagrass habitats for feeding (see Howard 1989; Edgar *et al.* 1993). Our limited data on the shallow habitat of juvenile blue groper, *A. gouldii*, supports our other survey findings (unpublished data) that this species recruits into very shallow (< 2 m depth) rocky habitat on sheltered coasts, not sampled in this study. Size-frequency and abundance data (Fig. 3a–c; Figs 4c, 5) for the blue-throated wrasse and the blue groper, and changing sex ratios for the former species, suggest that their juveniles recruit into shallow, mainly sheltered, macro-algal habitats, and with increasing size migrate to adjacent deeper water. Differential juvenile and adult habitats are well known for many fishes (Gillanders *et al.* 2003).

Explanations of species' abundance patterns on depth and exposure gradients for other species are speculative although some principles are known. As noted by Ross (1986), when fishes co-exist in an area, food and then habitat are the resources most commonly partitioned between them. Thus, the differential occurrence of functionally related species, such as leatherjackets and hulafishes respectively, at particular depths and exposures may be due to habitat partitioning between species, as we have suggested for some wrasses. Changes in abundance of species with depth or exposure may reflect changes in abundance/presence of its preferred food, e.g. the herring eale and its preferred diet, *Ecklonia*, (see Andrew & Jones 1990; Jones 1999), changes in habitat e.g. magpie perch (see Connell 2002; Curley *et al.* 2002), or in topographic complexity e.g. the scalyfin, which is dependent on the presence of shelter holes (see Norman & Jones 1984; Lincoln Smith & Jones 1995).

Overall, as shown by our speculations, understanding of the ecology of most temperate reef fishes is still primitive, and much research needs to

be done if marine sanctuaries are to be optimally identified and sited within a managed marine ecosystem.

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