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Adult male and female blue groper Photo: Thierry Laperousaz

Juvenile blue groper Photo: David Muirhead

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SUMMARY
The abundance of the western blue groper (WBG), *Achoerodus gouldii*, was examined on near-shore rocky coasts of southern Eyre Peninsula. Densities of juveniles (< 20 cm), sub-adults (20-60 cm) and adults (>60 cm) were obtained at 19 sites in different conditions of depth, exposure to swell, and rocky bottom relief. In all, 551 WBG were seen on 91 transects each covering an area of 500 m^2. Juvenile densities were generally in the range 0-2 per 500 m^2, sub-adult densities were 0.2 – 7 per 500 m^2 and adults <0.5 per 500 m^2. Two hotspots of recruitment were discovered; these were in Memory Cove and behind the reef at Pt Avoid. Juveniles were restricted to shallow, sheltered waters to depths of about 5 m adjacent to exposed coasts. Sub-adults were common in slightly deeper water, and adults occurred mainly on exposed coasts adjacent to depths of 10 m or more. Extensive overlap occurred between juvenile, sub-adult and adult habitat. Habitat attributes of depth and exposure to swell were correlated with WBG abundance. At two sites where granitic and calcarenite substrata co-occurred, there was no relation between WBG abundance and substratum type. From size-frequency data it can be inferred that juvenile habitat is close inshore, and that, with increasing size, fish move into adjacent deeper and more exposed habitats.

INTRODUCTION
This is the fourth report in the series on the distribution and abundance of the western blue groper (WBG), *Achoerodus gouldii*, on South Australian coasts. Earlier reports (Shepherd *et al.* 2002, Shepherd & Brook 2003, 2004) described the biology and ecology of the species, and gave abundance data for Kangaroo I., southern Yorke Peninsula, and western Eyre Peninsula. This study extends the above surveys to southern Eyre Peninsula, thus completing the surveys planned for the exposed coasts of central and western South Australia. An earlier study (Shepherd & Brook 2003) suggested that WBG recruited into shallow water adjacent to more exposed, deeper habitat. This study further examined that hypothesis by obtaining abundance data from sheltered to exposed habitats. Ancillary data collected on the abundance of other reef fishes will be presented elsewhere.

METHODS
We used the standard visual census technique (Barrett & Buxton 2002) to estimate the size and number of all fish species within 2.5 m of a 100 m line set at the given depth (see Shepherd & Brook 2003 for further details). Divers/snorkellers swam along the line about 1 m above the algal canopy and recorded the length of every species within

the swathe 5 m wide. At some sites, after team members were trained to swim 100 m at a constant speed in 10 min., we used timed swims of 10 min. instead of laying a transect line, thus providing considerable savings in time. In all, we completed 91 transects at 19 sites from 12-17 December 2004 (Fig. 1), with 4-6 transects per site. The sites chosen covered a range of habitats from sheltered to exposed, and from low (<0.5 m) to high (>2 m) relief. At each site we sought to maximise spatial coverage, but the number of sites and replicates per site depended on the time available. All divers were experienced in recognition of fish species, and those inexperienced in estimating length were trained early in the survey.

The data were recorded on waterproof data sheets fixed to underwater slates (see earlier reports for greater details of method). Characteristics of the habitat surveyed were noted in terms of substratum type, relief, and dominant canopy algal species. As in the previous studies, the aspect of the site and the dominant algae present were used in a subjective assessment of the exposure index (EI), which ranged from 0 (extreme shelter) to 4 (fully exposed to swell) (see Table 1). Species used in this EI assessment (after Shepherd & Womersley 1981) were: *Acrocarpia paniculata* (EI=4); *Cystophora moniliformis, C. siliquosa* (EI=3); *C. subfarcinata, C. monilifera* (EI=1-2); *Scaberia, Sargassum* spp. (EI=0). Substratum complexity on a scale 0-3 was estimated crudely from the average vertical reef relief of the transect area (see caption to Table 1).

Density data for WBG are presented in three length classes: juveniles <20 cm, sub-adults 20-60 cm, and adults >60 cm (after Gillanders 1997). The size categories do not have biological significance; however, the colour of juveniles changes from pale brown to greenish at 20-30 cm, and that of large fish changes from green to greenish-blue (for females), and to a deeper blue (for males), at a size of 55-60 cm, which is about the putative size at sexual maturity.

Site descriptions

Southwestern Eyre Peninsula is exposed to strong SW swell, but promontories and inlets provide shores with a range of exposures ranging from strong to sheltered. In contrast, the shores of Thorny Passage are sheltered and subject only to wind waves with short fetch. The substratum at sites was either Precambrian crystalline bedrock (here termed granite) with generally few crevices or cryptic habitat, or calcarenite, eroded to form a friable, coarsely grained rock with abundant cryptic habitat (Edyvane 1999). The following sites were surveyed.

Sites 1, 2, 3. At Point Drummond transects ran from about 100-300 m south of the boat ramp, parallel to the shore and seaward of several reefs projecting above low water mark (Site 1), near-shore off the boat-ramp (Site 2) and in a shallow bay on the exposed western side of the point (Site 3).

Sites 4, 5. At Point Avoid transects ran on the SE sheltered side (Site 4) and the NW exposed side (Site 5) of the reef connecting Point Avoid with Golden I.

Sites 6, 7, 8, 9. At Redbanks transects ran westward along the granitic promontory (Site 6), northward to the bommie 200 m offshore (Site 7), east toward the corner of the bay (Site 8), and near-shore (Site 9) from the point of entry on the northern sheltered side of the westerly pointing promontory.

Sites 10a, 10b, 11, 12. At Wanna transects ran from an entry point on the granite platform opposite the unnamed islet located 400 m offshore. At Site 10 a,b transects ran sequentially southward close to shore, at Site 11 in the same direction, but deeper, and at Site 12 along the inner margin of the islet.

Sites 13, 14, 15, 16. At Memory Cove, transects ran along the northern margin of the bay (Site 13), and sequentially on the southern margin close to the beach at 2-3 m depth (Site 14), about 200 m further east at 5 m depth (Site 15), and a further 200 – 300 m eastwards at 10 m depth (Site 16).
Site 17. At Taylor Landing transects ran south of the boat ramp close to shore over calcarenite outcrops.
Site 18. At McLaren Point transects ran south of the Point over granite substratum with seagrass patches.
Site 19. At Cape Donington transects ran from the most easterly point of the Cape, north and west around the Cape.

RESULTS

The sites examined, their substratum, estimated exposure index and dominant canopy species are summarised in Table 1. Cover of canopy algal species at Sites 1-11 was high, usually 70-100%, and at the remaining sites was mostly 50-80%.

Abundance and size of WBG

The mean densities of juveniles, sub-adults and adults at all sites are given in Table 2, with data on the number of transects per site. Juveniles were generally in low abundance (< 1 per 500 m^2) at all sites, except in Memory Cove and at the sheltered SE Pt Avoid, where they were 4-16 per 500 m^2. Sub-adult densities were generally in the range 1-7 per 500 m^2, with spikes of higher densities in Memory Cove and SE Pt Avoid. The spikes were caused by the presence of WBG aggregations in one or two transects at these sites, giving large variances to the means.

Next we examined the relation between WBG abundance and the habitat variable, Exposure Index (EI) for all sites combined. The density of juveniles and sub-adults combined (D), in numbers.500 m^{-2}, declined significantly with increasing EI (Fig. 2). The following regression was fitted to the data
:

$$D = 10.3 - 2.5\ EI \quad (N = 90; R^2 = 0.130; P < 0.01)$$

Juveniles were recorded mainly in sheltered habitats, but with increasing size, were found in places of increased exposure. Adults were in low density, and only recorded at Redbanks and Wanna at EI values of 2-3 near deeper water (> 10 m).

At Redbanks and Wanna (Sites 6-12), both granitic and calcarenite substrata were present, the former in generally somewhat more exposed situations. There were 18 transects on granite and 17 on calcarenite. Mean WBG density on the two substratum types was almost identical (1.37 (s.e. 0.25).500m^{-2} on calcarenite and 1.44 (s.e. 0.31).500 m^{-2} on granite. However, the size frequency distributions of WBG differed significantly between the two substratum types ($\chi^2 = 17.4$; P<0.001), with a greater size range of juveniles and sub-adults on calcarenite, and more adults on granite. The two substratum types did not differ in mean substratum complexity values (t=0.27; ns), but did differ significantly in the mean Exposure Index (t=3.54; P<0.002); for calcarenite mean EI was 2.63 (s.e. 0.15), and for granite mean EI was 3.47 (s.e. 0.12).

Length-frequency distributions (N = 451) of WBG at different EI values for all sites combined are shown in Figure 2. It is evident that, on the EI gradient, the proportional abundance of juveniles and sub-adult WBG declines causing an increase in mean size

Table 1. Habitat features of survey sites on southern Eyre Peninsula. Estimated range of exposure indices given is from: 4 – fully exposed to SW swell; 3 – moderately exposed to swell; 2 – moderately sheltered; 1 - very sheltered; 0 - extreme shelter. Substratum complexity (SC) is: 0 – flat rock, sometimes with fine sediment, holes or crevices rare; 1 - rock to 1 m relief with some crevices; 2 - reef of moderate relief (1-2 m) with numerous crevices; 3 – reef of high relief (>2m) with many crevices and caves.

Site No.	Site (Lat. Long.)	Depth (m)	Substratum & Exposure	Algal dominants
1	**Pt Drummond (S1)** 34° 15.538′ S; 135° 16.136′ E.	3-4	Granitic SC=1 EI=2	*Acrocarpia, C.moniliformis, C. subfarcinata*
2	**Pt Drummond (S2)** 34° 15.403′ S; 135° 16.266′ E.	2	Granitic SC=0-1 EI=1	*C.moniliformis, C. subfarcinata, C. monilifera*
3	**Pt Drummond (W)** 34° 9.226′ S; 135° 15.262′ E.	4-5	Granitic SC=1 EI=3	*Ecklonia Acrocarpia, Caulerpa* spp., *C. moniliformis, C. subfarcinata*
4	**SE Point Avoid** 34° 41.622′ S; 135° 19.770′ E.	2-3	Calcarenite. SC=3 EI=2	*Cystophora monilifera, C. moniliformis,*
5	**SW Point Avoid** 34° 41.622′ S; 135° 19.507′ E.	3-4	Calcarenite SC=3 EI=4	*Ecklonia, Acrocarpia*
6	**Redbanks** (west) 34° 55.134′ S; 135° 19.507′ E.	2-4	Granite SC=2 EI=3	*Acrocarpia, Ecklonia, C. siliquosa, C. subfarcinata, C.moniliformis*
7	**Redbanks** (north) 34° 55.081′ S; 135° 36.961′ E.	4-5	Granite SC=2 EI=4	*Acrocarpia, C. siliquosa, C. subfarcinata, C.moniliformis*
8	**Redbanks** (east) 34° 55.134′ S; 135° 37.190′ E.	2-4	Calcarenite SC=2 EI=2	*Ecklonia,C. siliquosa, C. subfarcinata, C.moniliformis*
9	**Redbanks** (inshore) 34° 55.135′ S; 135° 37.026′ E.	2-4	Granite SC=2 EI=2	As above
10a	**Wanna** (near-shore) 34° 53.925′ S; 135° 51.433′ E.	2-3	Calcarenite SC=2 EI=3	*Ecklonia, C. subfarcinata, C.moniliformis*
10b	**Wanna** (south) 34° 54.059′ S; 135° 51.458′ E.	3	Calcarenite (SC=2) EI=3	As above
11	**Wanna** (5 m depth) 34° 53.968′ S; 135° 51.433′ E.	5	Calcarenite SC=2 EI=3	As above
12	**Wanna** (near islet) 34° 54.059′ S; 135° 51.333′ E.	5	Granite SC=2 EI=3	*Ecklonia Acrocarpia, C. siliquosa*
13	**Memory Cove** (N) 34° 57.661′ S; 135° 59.342′ E.	3-5	Granite SC=1 EI=1	*Ecklonia, Cystophora monilifera, C. moniliformis*
14	**Memory Cove** (S2) 34° 57.742′ S; 135° 59.540′ E.	2-3	Granite SC=1 EI=0	*Ecklonia, C. monilifera, C. moniliformis, C. subfarcinata*

15	**Memory Cove** (S5) 34° 57.742′ S; 135° 59.540′ E.	5	Granite SC=1 EI=0	*C. monilifera, C subfarcinata*
16	**Memory Cove**(S10) 34° 57.710′ S; 135° 59.934′ E.	10	Granite SC=1 EI=0	*C. monilifera, C. polycystidea, Sargassum* spp.
17	**Taylor Landing** 34° 51.425′ S; 135° 57.763′ E.	2-3	Calcarenite SC=1 EI=1	*C. moniliformis, Osmundaria*
18	**McLaren Point** 34° 47.838′ S; 136° 0.649′ E.	2-4	Granite SC=0.5 EI=1	*Scaberia, C. monilifera, Osmundaria*
19	**Cape Donington** 34° 43.568′ S; 135° 59.671′ E.	2-4	Granite SC=1 EI=1	*Ecklonia, C. monilifera, C. subfarcinata*

Table 2. Density (numbers.500 m^{-2}) of juvenile (<20 cm), sub-adult (20-60 cm), and adult WBG at 19 sites on southern Eyre Peninsula. N = number of replicate 500 m^2 samples. Standard errors (s.e.) in brackets.

Site	N	**Juveniles (s.e.)**	**Sub-adults (s.e.)**	**Adults (s.e.)**	**Total**
1. Pt Drummond (S1)	5	0.5 (0.4)	3.8 (0.8)	0	4.3
2. Pt Drummond (S2)	4	0.8 (0.6)	2.8 (0.9)	0	3.5
3.Pt Drummond (W)	5	0.1 (0.1)	7.1 (2.8)	0	7.2
4. SE Pt Avoid	5	4.0 (1.3)	8.8 (4.6)	0	12.8
5. SW Pt Avoid	5	1.2 (0.3)	2.8 (1.2)	0	4.0
6. Redbanks (west)	4	0.3 (0.3)	0	0	0.3
7. Redbanks (north)	5	0.4 (0.3)	1.4 (0.8)	0	1.8
8. Redbanks (east)	5	0	0.8 (0.3)	0.2 (0.2)	1.0
9. Redbanks (nr shore)	4	0	1.5 (0.8)	0	1.5
10a. Wanna (nr shore)	4	0.5 (0.3)	1.0 (0.6)	0.3 (0.3)	1.8
10b Wanna (south)	4	0	2.4 (1.5)	0.5 (0.2)	2.9
11. Wanna (5 m)	4	0	1.5 (0.8)	0	1.5
12. Wanna (nr islet)	5	0	0.2 (0.2)	0.2 (0.2)	0.4
13. Memory Cove (N)	4	4.8 (3.2)	14.0 (9.7)	0	18.8
14. Memory Cove (S_2)	6	13.6 (4.4)	8.1 (2.7)	0	21.7
15. Memory Cove (S_5)	4	15.6 (11.5)	3.9 (2.2)	0	19.5
16. Memory Cove(S_{10})	5	1.8 (0.8)	2.2 (0.7)	0	4.0
17. Taylor Landing	5	0	4.0 (0.9)	0	4.0
18. McLaren Point	4	1.7 (0.4)	6.5 (1.3)	0	8.2
19. Cape Donington	4	0	2.0 (0.9)	0	2.0
Total	91				

with increasing EI. The shift was not depth-related as all transects, except those at Site 16 in Memory Cove, were at depths of 2-5 m.

The effect of depth *per se* on abundance is shown by abundances of juveniles and sub-adults at Sites 14-16 in Memory Cove (Table 2). Densities were highest at 2-5 m depth, but declined sharply at 10 m depth, where rock gave way to *Posidonia* seagrass beds.

DISCUSSION

Overall, densities of WBG in this survey was similar to those recorded in the survey of western Eyre Peninsula (Shepherd and Brook 2004), and greater than the earlier surveys further east (Shepherd et al. 2002, Shepherd & Brook 2003). As in the earlier studies, the highest densities of juveniles and sub-adults were recorded in sheltered waters, and declined with increasing exposure. Adults were found only on exposed coasts adjacent to deeper water > 10 m depth. The unusually high densities of juveniles and sub-adults in Memory Cove and to a less extent in SE Pt Avoid, suggest that these sites are important nursery areas or 'hotspots' for WBG recruitment, which merit special protective measures. Comparably high densities have only been previously recorded at Smoothpool and Speeds on western Eyre Peninsula (Shepherd & Brook 2004). However, all estimates of density are almost certainly under-estimates as Shepherd (2005) showed that juveniles and sub-adults were emergent from cryptic habitat for only 35-40% and 55-60% respectively of daylight hours. The extent of under-estimation is unknown and likely varies from place to place.

The decline in abundance of juveniles and sub-adults with increasing exposure (Fig. 2) reinforces the earlier studies cited above, which concluded that juveniles settle in shallow, sheltered waters and move with increasing size to more exposed habitats.

We hypothesize that aspects of the coastal topography of sites are a main influence on juvenile and sub-adult abundance. Sheltered bays, such as Memory Cove, and the complex calcarenite reef structure between Pt Avoid and Golden I. (SE Pt Avoid) may provide sheltered habitat for juveniles, whereas exposed sites, such as Wanna and Redbanks, do not.

The steep decline in abundance at Sites 17-19 in Thorny Passage north of Memory Cove may be due to larval limitation or unsuitability of the habitat, or a combination of these factors. Surveys further north on eastern Eyre Peninsula and the near-shore islands, and also on western Yorke Peninsula at least as far north as Wardang I. would clarify the geographic distribution of WBG in lower Spencer Gulf, and possibly elucidate these questions.

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Fig. 1. Map of Southern Eyre Peninsula showing study sites

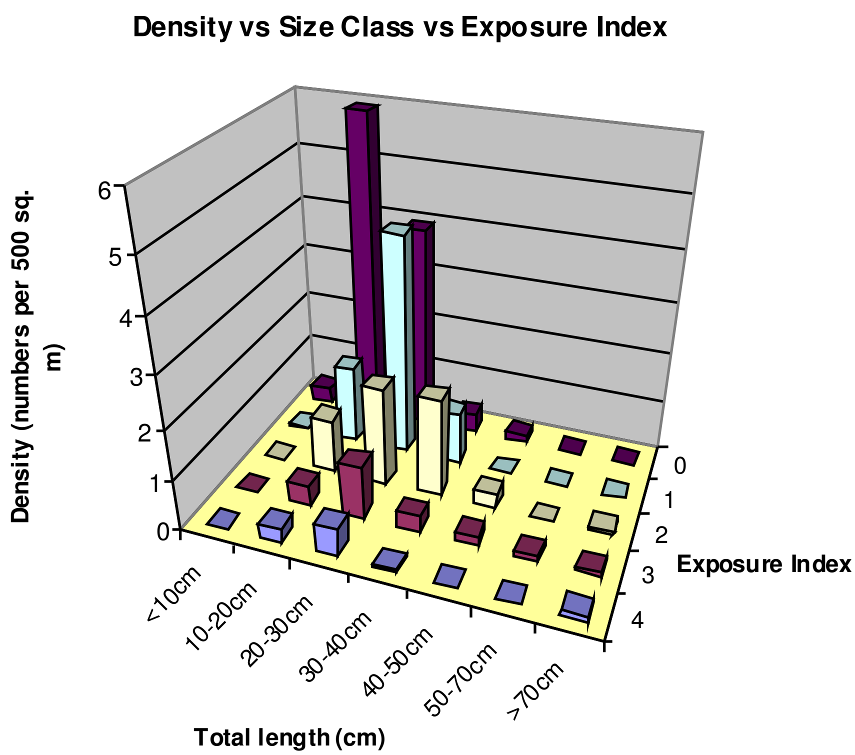

Figure. 2. Length frequency distributions of western blue groper for all sites in seven size groups at EI = 0,1,2,3 and 4. Densities are standardised to numbers per 500 m^2. WBG < 20 cm are designated juveniles, those 20-60 cm sub-adults, and those > 60 cm adults.