Ecosystem monitoring inside and outside proposed Sanctuary Zones within the Encounter Marine Park - 2005 baseline surveys

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Summary

Densities of fishes, macroinvertebrates and plants on subtidal rocky reefs within the Encounter Marine Park (EMP) were surveyed at 32 sites in March 2005. At the time of survey, a draft zoning plan for the EMP had just been released for consultation. Data obtained during 2005 thus represents baseline conditions, although the zones in which the surveyed sites are situated may change following public consultation. Any such change in boundaries is expected to be relatively minor, with little effect on the overall distribution of sites inside and outside Sanctuary zones.

Monitoring surveys utilised the same underwater visual census techniques as used in monitoring programmes operating concurrently in Tasmania, New South Wales, Victoria and Western Australia, as well as previously in South Australia (Investigator Strait in 2004), forming part of a continental-scale study of the effectiveness of marine protected areas (MPAs).

Because a wide range of species have been examined, ecosystem shifts as well as changes in the abundance of targeted fishery species will be detectable following the protection of areas from fishing. The selection of 16 sites within each management zone type provides sufficient replication to detect biologically meaningful change for common species and species richness indicators.

Once fishing restrictions pertaining to different management zones are adequately enforced, surveys should be repeated on an annual basis until differences between zones stabilise. Such a monitoring scheme would not only provide time-series information on trends in the abundance of species of interest in different zones, but also information on indirect impacts of rock lobster, abalone fishing and general recreational and commercial fishing on ecosystems; and regional change associated with such factors as climate change. If insufficient funding is available for annual monitoring, then we recommend that surveys be undertaken every two years.

1. Introduction

Partly as a consequence of widespread losses in inshore biodiversity and declining confidence with traditional single-species approaches to fisheries management, a growing number of fully protected or “no-take” marine protected areas (MPAs) are being proclaimed worldwide (Roberts and Hawkins, 2000). In Australia, a core component of marine conservation planning during the past decade has been the development of a national representative system of marine protected areas (ANZECC, 1999). The ecology and taxonomy of marine species are poorly known compared to terrestrial species, hence single species management is arguably more difficult and habitat protection more desirable when dealing with communities in the marine realm (Fairweather and McNeill, 1993; Roberts and Polunin, 1993; Sobel 1993).

MPAs are also increasingly proposed for fishery enhancement, fishery insurance and fishery research purposes (Davis, 1981; Roberts and Polunin, 1991; Dugan and Davis, 1993). Most government agencies now recognise that ecologically-sustainable development requires management of ecosystems as well as individual species, because the removal of a resource will have flow-on effects on other species (Zann, 1995; Jennings and Kaiser, 1998).

Concurrent with the implementation of the national representative system of MPAs comes the need for effective monitoring programs to assess the ability of MPAs to achieve management aims. While the current focus of MPA planning and implementation is the conservation of biodiversity, MPA’s potentially provide a wide range of important functions. These include acting as baseline reference areas for assessing the success of current conservation and fisheries management strategies in coastal ecosystems, and assisting fisheries management through protection of spawner biomass, conservation of critical habitats, and acting as research areas, including for studies not possible elsewhere. Only by empirically investigating changes that occur in MPAs following protection can we assess the true value of MPAs.

In order to properly determine whether changes observed within MPAs are the result of protection rather than natural variation in space and time, scientifically-credible baseline surveys within and adjacent to proposed MPAs are needed prior to protection from fishing, with subsequent surveys at biologically meaningful time intervals. Ideally, baseline surveys should be conducted over several years to assess the scale of inter-annual variability before the MPA is declared.

In the present report, we describe results of surveys in the proposed Encounter Marine Park (EMP) in March 2005. These surveys describe baseline conditions in the EMP. A draft zoning plan for the EMP was released for a three month consultation period at the time that the surveys were performed, but the final boundaries of the internal zones have yet to be finalised prior to legal gazettal.

The EMP surveys comprise one component of a larger investigation of effects of protection from fishing in temperate Australian MPAs. The larger project, coordinated by the Tasmanian Aquaculture and Fisheries Institute, has so far involved baseline and MPA surveys in Jervis Bay (NSW), Wilsons Promontory (Vic), Port Phillip Heads (Vic), Investigator Strait (SA), Jurien Bay (WA), Maria Island (Tas), Tinderbox (Tas), Kent Group (Tas), Port Davey (Tas), Bicheno (Tas) and Ninepin Point (Tas). All surveys have involved fished reference sites and utilised similar methodology, allowing direct comparison of results between differing locations, designs and management strategies. This information will be pivotal for planning to ensure MPAs fulfil their desired roles effectively.

The area of the EMP and surrounding waters surveyed extends from Granite Island in Encounter Bay around the Fleurieu Peninsula to a point just south of Myponga, as well as the eastern coast of Kangaroo Island. Approximately half of the 32 sites are located within five of the 16 proposed highly protected Sanctuary Zones in which fishing is prohibited. The remainder of sites lie within Habitat Protection Zones, Special Purpose Area Zones or outside the EMP, where recreational fishing, and most or all forms of commercial fishing, are allowed.

Underwater visual censuses of fish, large mobile invertebrates and macroalgae were undertaken at these sites. The survey methodology covers these major groups to provide as much quantitative information on as many species as possible in the limited dive time available. This methodology is aimed at not only detecting changes in heavily exploited species, but also any cascading ecosystem effects of fishing on other ecosystem components, as well as patterns of long-term regional change.

2. Methods

2.1 Sites

Five categories of management zone provide different levels of protection in the EMP (DEH 2005):

Restricted Access Zones

Objective: To provide protection and conservation for unique and biologically significant habitats within a marine park, by restricting access.

Sanctuary Zones

Objective: To provide protection and conservation for habitats and biodiversity within a marine park, where the removal or harm of plants, animals or marine products is prohibited.

Habitat Protection Zones

Objective: To provide protection for species and habitats within a marine park, whilst allowing activities and uses that do not harm habitats or the functioning of ecosystems.

General Managed Use

Objective: To provide protection for species and habitats within a marine park, whilst allowing ecologically sustainable use.

Special Purpose Areas

Objective: To provide for specific activities or uses within a marine park.

For the purpose of this study, two different categories were used to partition the sampling regime:

> **Inside**: areas within Sanctuary Zones or Restricted Access Zones. Fishing will be prohibited within these areas
>
> **Outside**: areas within the other three zone types or outside the EMP. Recreational and most or all forms of commercial fishing will be allowed within these areas.

A total of 28 locations were investigated during an 11 day period from 8th to 18th March 2005 (Fig. 1, Table 1). Four locations were surveyed at two depths, which are here considered separate ‘sites’ because differences between biotic communities at the two depths within a site were generally of comparable magnitude or greater than differences between locations sampled at the same depth. Sites examined were in three general regions within the EMP:

- moderately sheltered reefs at 5 m depth within Gulf St Vincent (GSV)
- moderately sheltered reefs at 5 m and 10 m depth on the north coast of Kangaroo Island (KI)
- reefs exposed to oceanic swell at 5 m and 10 m depth on the south coast of Fleurieu Peninsula, in and near Encounter Bay (EB)

Sites were selected to provide a balance between the Inside and Outside area categories defined above as determined from the draft zoning plan released at the beginning of the study. Site locations were chosen with the constraint that they needed to contain reef habitat of sufficient size for placement of a 200 m length transect. Sixteen sites were surveyed in each of the Inside and Outside area categories.

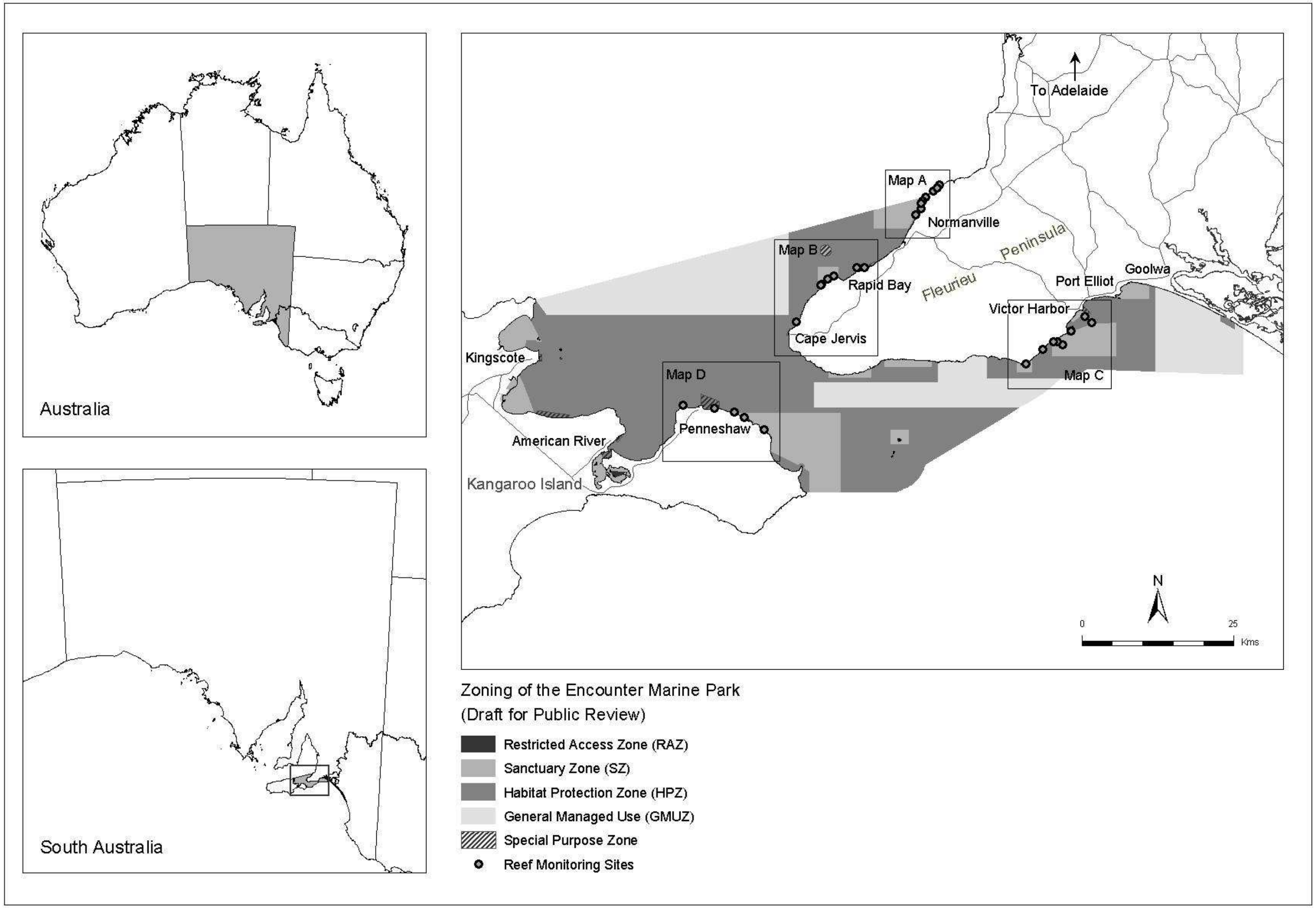

Fig. 1. (a) Encounter MP monitoring area.

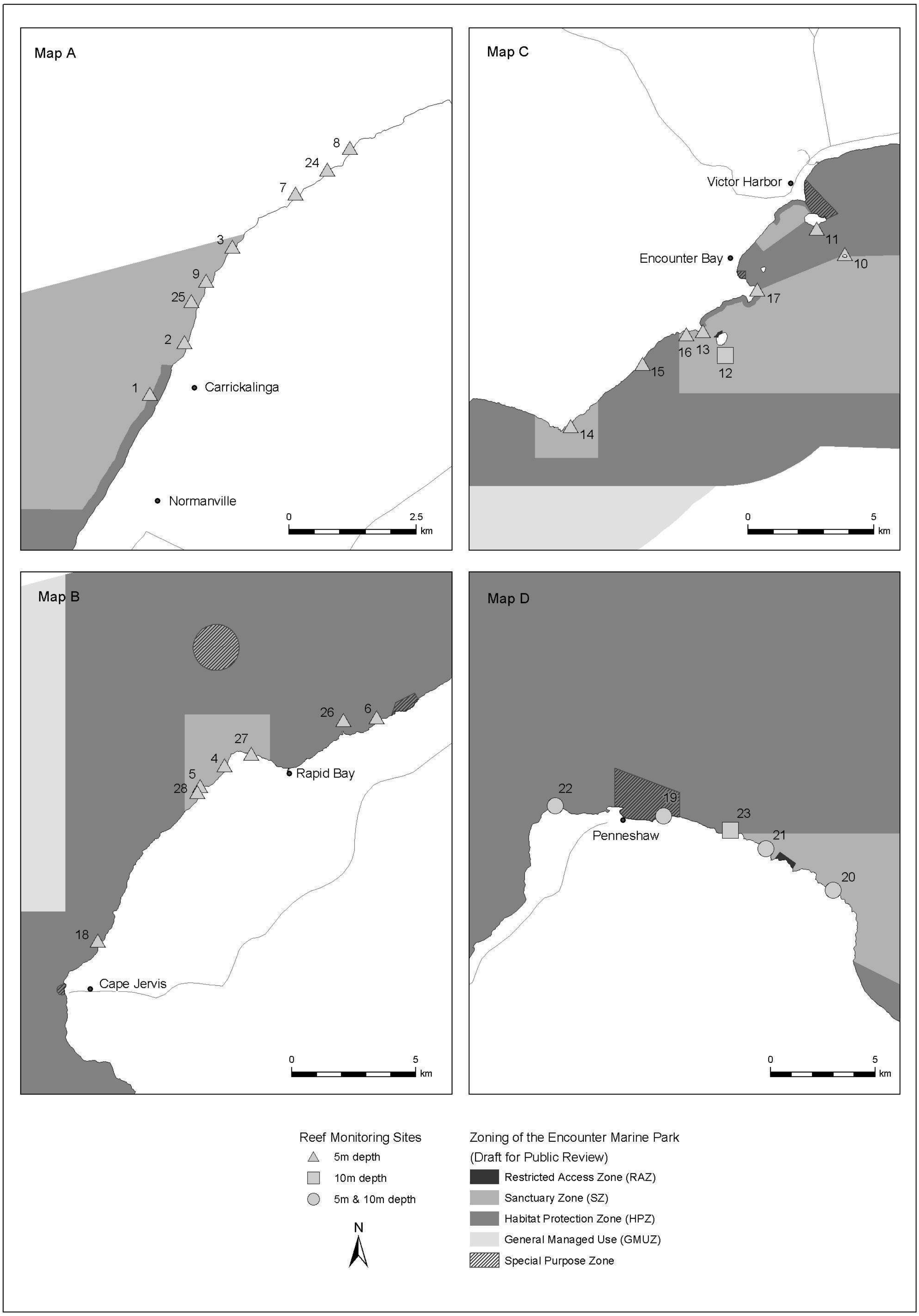

Fig. 1. (b) Location of sites surveyed within the Encounter MP.

Table 1. Site details for locations surveyed in Encounter, with underwater visibility at time of survey.

Site No	Location Name	Depth (m)	Latitude	Longitude	DEH Zone	Reg -ion	Category	Date	Vis (m)
1	Carrickalinga Toilet	4-5m	35.42445	138.31901	Habitat	GSV	Outside	8/03/2005	7
2	Haycock Point	5m	35.41574	138.3279	Sanctuary	GSV	Inside	8/03/2005	
3	Carrickalinga Head	5m	35.398	138.33591	Sanctuary	GSV	Inside	8/03/2005	
4	Rapid Head Cliffs	5m			Sanctuary	GSV	Inside	9/03/2005	10
5	Rapid Head South	5m	35.53145	138.1519	Sanctuary	GSV	Inside	9/03/2005	10
6	Sunset Cove South	5m	35.50467	138.22924	Habitat	GSV	Outside	9/03/2005	12
7	Myponga South	5m	35.38821	138.34923	Out of Park	GSV	Outside	11/03/2005	8
8	Myponga Point	5m	35.37988	138.36068	Out of Park	GSV	Outside	11/03/2005	10
9	Dodd's Beach	5m	35.40416	138.33043	Sanctuary	GSV	Inside	11/03/2005	10
10	Seal Is	5m	35.57618	138.64429	Habitat	EB	Outside	12/03/2005	5
11	Outside Granite Island	5m	35.56754	138.63158	Habitat	EB	Outside	12/03/2005	6
12	West Island Outer	10m	35.61029	138.59289	Sanctuary	EB	Inside	12/03/2005	5
13	Kings Head	5m	35.60551	138.58308	Sanctuary	EB	Inside	12/03/2005	6
14	Newland Head	5m	35.64094	138.52662	Sanctuary	EB	Inside	13/03/2005	7
15	Flat Irons	5-7m	35.61781	138.55721	Habitat	EB	Outside	13/03/2005	8
16	Kings Head North	5m	35.60676	138.57594	Sanctuary	EB	Inside	13/03/2005	7
17	The Bluff	5m	35.58996	138.60645	Habitat	EB	Outside	13/03/2005	6
18	Morgans	5m	35.58845	138.10838	Habitat	GSV	Outside	14/03/2005	9
19	Hoggs Point	10m, 5m	35.71974	137.96448	Special	KI	Outside	14/03/2005	9
20	Snapper North	10m, 5m	35.74983	138.05538	Sanctuary	KI	Inside	15/03/2005	8
21	Cable Hut	10m, 5m	35.73268	138.0191	Sanctuary	KI	Inside	15/03/2005	7
22	Kangaroo Point	10m, 5m	35.71667	137.9071	Habitat	KI	Outside	16/03/2005	8
23	Penneshaw East	10m	35.72509	138.00006	Habitat	KI	Outside	16/03/2005	6
24	Ripple Rock	5m	35.38386	138.3559	Out of Park	GSV	Outside	17/03/2005	12
25	Cock-up Rocks	5m			Sanctuary	GSV	Inside	17/03/2005	10
26	Second Valley	5m	35.50594	138.21446	Habitat	GSV	Outside	17/03/2005	12
27	Rapid Head North	5m	35.51922	138.17416	Sanctuary	GSV	Inside	18/03/2005	14
28	Rapid Head Windmill	5m	35.53085	138.15289	Sanctuary	GSV	Inside	18/03/2005	12

2.2 Reef monitoring protocol and its rationale

The creation of a mosaic of management zones in the seascape through the declaration of marine protected areas (MPAs) represents an ecological human exclusion experiment at a vast spatial scale (Walters & Holling 1990). The EMP monitoring method described below was developed to capitalise on this experiment (Edgar & Barrett 1999). It involves underwater visual census of densities of fishes, invertebrates and plants along 200 m transects at replicate sites to quantify biological changes in different management zones.

We consider that visual census techniques provide the most effective technique for monitoring species at shallow-water sites in MPAs because they are non-destructive and permit the collection of large amounts of data on a broad range of species within a short dive period. MPA monitoring programs need to cover a range of taxa because, in addition to heavily-exploited species that are predicted to recover in new MPAs, significant secondary effects of fishing may occur that would otherwise go undetected.

Sites investigated are fixed between surveys, with sampling repeated in the same month in different years to minimise seasonal effects. The 200 m transect distance is subdivided into four contiguous 50 m long blocks, each of which is 10 m wide in censuses for mobile fishes, 1 m wide for censuses of mobile macro-invertebrates and cryptic fishes, and comprised five positions set at 10 m intervals for plants and sessile invertebrates.

This ‘extended-transect’ sampling design was selected to maximise the amount of information gathered at each site by three divers, each with a single tank of air. Three sites can be surveyed per day, weather conditions permitting. Pilot trials indicated that if divers reduced the amount of information collected per site, for example by surveying two rather than four 100 m long blocks, then site coverage would not have increased greatly because of the lengthy time required to move between sites (pull anchor, gear up for diving, set transect lines). Collection of additional information at each site would require either more dive personnel or reduced site coverage.

The overriding consideration when planning the monitoring design was that temporal change in protected zones provided the primary focus of study. Consequently, spatial variation at the site level that interferes within the detection of the temporal signal was minimised as much as possible. This was done by censusing fixed sites through time, surveying species along set depth contours, sampling in the same season in different years, and aggregating data over a long distance (200 m) per site to smooth fine scale variation.

The collection of data from four 50 m long blocks is best viewed as an approach to increase the precision of estimates of mean values for a 50 m block at a site. Information on spatial substructure within sites – in the form of data from the four contiguous 50 m-long transects – was not obtained to assess variance within sites. Rather the 200 m transect was subdivided into four blocks because:

1. Data are more easily compared with results of other investigators, who often use transect lengths of 50 m.

2. Different divers can collect information in different 50 m sections of the 200 m length, allowing equitable distribution of dive time regardless of number of divers, and permitting analysis of between-diver effects.

3. If greater precision at a site is required, for example if rock lobster numbers are highly spatially-variable but are of great interest, then extra 50-m blocks can be added. Similarly, the number of 50-m blocks can be reduced if dive time is limited, such as when surveying deep sites. In both cases, data at the 50-m block scale remain directly comparable with data for other sites.

4. Site data can be partitioned to allow inter-site comparisons of particular habitat types. For example, if a sea urchin barren extends for the first 70 m of a transect followed by 130 m of *Sargassum*, then the first 50 m block provides data on species assemblages in sea urchin barrens, the second 50 m block data on ecotonal zones, and the third and fourth blocks data on fucoid algal habitats. Differences in effects of MPA protection in urchin barrens versus algal habitat can be assessed using these data.

The extended-transect design represents a compromise between power and generality, lying intermediate along the spectrum from more general site studies that involve random replicate transects at each site, and more powerful studies with a single fixed-transect permanently attached to the seabed.

The extended-transect design is considerably more powerful than a random-transect design, but with less generality in associated statistical tests. Although an understanding of within-site variation can be critical for studies with other aims, individual sites had no intrinsic importance in this MPA study. Our interest was focused on within- and between-zone effects, with sites providing replicate information for analyses. Advantages of random-transect methods over our method are: (i) sites encompass a greater total area of seabed because a range of depths are surveyed at each site rather than a single depth contour, increasing generality, and (ii) information is gathered on spatial variance within sites. However, for a study of MPA effects, we considered that these advantages were outweighed by disadvantages. These include: (i) spatial noise associated with randomised placement of transects that obscures the fundamental temporal signal, (ii) lost diving time during periods when divers move to the start of different replicate transects, resulting in reduced data collection per site, (iii) difficulties in truly randomising transect placement, and spatial biases associated with haphazard placement, and (iv) confounding with depth as a consequence of some sites being relatively flat with little depth range, and others being steeply-sloping and encompassing a large depth range. Depth is better included as an explicit variable within analyses rather than contributing to spatial noise between replicates.

A design involving transects that are permanently attached to the seabed would be more powerful at detecting temporal effects than our design, but at some minor cost in generality and at considerable extra cost in dive time. The cost in generality for a physically-fixed transect design relates to the fact that our transects were relocated on each sampling event within a band that extended ca. 1 m in depth (due in large part to different tidal heights at the time of each survey) and ca. 20 m in horizontal extent (due to imprecision in site relocation). Thus, some spatial 'noise' is added to the temporal 'signal' in our design, reducing power but also reducing the possibility that overall conclusions are affected by anomalous siting of a transect.

The major reasons for not utilising a physically-fixed transect were twofold. Firstly, we recognised aesthetic values associated with diving in MPAs, and considered that 200 m long ropes or chains permanently attached to the seabed in sanctuary zones, or permanent star picket markers, would represent a visual intrusion to recreational divers. The presence of a permanent transect line, including wave-induced movement that abrades plants, could also potentially affect the habitat and thus the ecosystem components censused along the transect.

Secondly, despite the theoretical increase in power to detect temporal signal for physically-fixed transect designs, power is adversely affected in a practical sense by reduced replication. Considerable dive time is required initially to set up permanent transect lines and seabed markers. If transect lines are left attached between surveys, then they need maintenance, perhaps with replacement after two or three years. If lines are strung on each survey between permanent markers such as star pickets, then dive time is reduced by the extra time required to set the line after locating markers, some of which may disappear between annual surveys.

2.3 Census methodology

At each reef site the abundance and size structure of large fishes, the abundance of cryptic fishes and benthic invertebrates, and the percent cover of macroalgae, corals and other cover-forming invertebrates, were each censused separately along four 50 m long transects (Edgar & Barrett, 1999; Barrett & Buxton, 2002). The transect lines were laid end to end along a fixed depth contour.

For fish transects, the density and estimated size-class of fish within 5 m of each side of the line were recorded on waterproof paper, with the diver swimming up the offshore side of the line and then back along the inshore side while at the centre of a 5 m wide lane. Size-classes of total fish length used in the study were 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 375, 400, 500, 625, 750, 875 and 1000+ mm. Lengths of fish >1 m length were individually estimated.

Double counting of individual fish sometimes occurred when the diver returned along the inshore side of the transect line. Nevertheless, such double counts have little importance if the inshore and offshore 50 m x 5 m blocks are considered as two separate (albeit non-independent) estimates for the 50 m transect length. The reason that fish were counted on the return leg regardless of whether they were recognised as having been counted on the initial leg was that if this had not been done then return counts would be lower than initial counts, and mean total density estimates not comparable with 50 m x 5 m density estimates of workers elsewhere. Return counts were undertaken to allow greater precision of site estimates with little extra underwater time – transect lines already having been set.

Fish census data clearly are affected by a range of biases, including observer error and variation in behavioural responses of fish to divers (DeMartini & Roberts 1982; Thompson & Mapstone 1997; Kulbicki & Sarramega 1999). Such biases were investigated in part and discussed for the transect methods used here by Edgar *et al.*

(2004a). Despite the existence of census biases, we consider them to be largely systematic and not greatly confound interpretation of patterns because data will be used for relative comparisons between different management zones only. Care was taken to ensure that sampling effort for each diver was equitably distributed between the different management zone types.

Cryptic fishes and megafaunal invertebrates (large molluscs, echinoderms and crustaceans) were counted along the transect lines used for the fish survey by recording animals within 1 m of one side of the line (a total of four 1 m x 50 m transects). During transects, measurements were taken using vernier callipers of the maximum shell diameter of all abalone encountered and the carapace length of all rock lobsters that could be captured by hand.

The area covered by different macroalgal, coral, sponge and other attached invertebrate species was quantified by placing a 0.25 m^2 quadrat at 10 m intervals along the transect line and assessing the percent cover of the various plant species. Cover was determined by counting the number of times each species occurred directly under the 50 positions on the quadrat at which perpendicularly placed wires crossed each other (a total of 1.25 m^2 for each of the 50 m sections of transect line).

The position of each site was recorded using a hand held GPS (Scoutmaster) based on the WGS84 Datum System, with position recorded in degrees and decimal minutes. Site positions and site details are listed in Table 1. All data were entered onto an Excel spreadsheet and checked for errors.

2.4 Statistical analyses

The monitoring design can be considered as a replicated Before-After-Control-Impact (BACI) design (Green 1979) that can be analysed using repeated-measures ANOVA, with management zone (and in future studies, the year) as a fixed factor. Ideally, such a design is balanced with the same number of sites inside and outside each of the different management zones investigated (Underwood 2000). Nevertheless, much information on variation within and between zones is lost with an ANOVA approach because sites in all zones of the same type are considered equal. Variation between sites in biological response to protection from fishing (resulting from factors such as distance from the reserve boundary, or level of pre-existing fishing pressure) possesses intrinsic interest and should be recognised, rather than adding to noise between replicates. An additional disadvantage of ANOVA designs for long-term monitoring programs is that time components need to be blocked in some way.

We suggest that ANOVA is most useful as a statistical tool in the early stages of monitoring programs when little time series data are available post MPA declaration. ANOVA also provides the only practical method for assessing power in pilot studies, other than in the rare situation where the response variate to be examined can be predictively modelled.

Data are analysed here using one-way ANOVA to assess whether sites investigated within sanctuary zones are significantly different to sites outside before protection from fishing. Given that larger differences were generally found between biological assemblages at 5 m and 10 m depth within a site compared to differences between nearby sites at the same depth, we considered the 5 m and 10 m transects to be independent; hence 32 ‘sites’ are incorporated into ANOVAs.

Once several years of post MPA declaration data are available, curvilinear modelling techniques should comprise the most useful of available methods for investigating MPAs. Using non-linear regression, for example, one can quantify relationships between biological response to protection and variables such as time since MPA declaration, management zone size, distance from MPA boundary, reef habitat complexity, and fishing pressure prior to declaration of the MPA. Effect size is readily estimated as the difference between the value of a variable at any point in time and the mean of baseline values for that variable at the same site prior to MPA declaration.

Relative differences between the plant and animal communities at different sites were here examined graphically using non-metric multidimensional scaling (MDS). Data input to matrices for multivariate analyses were square root transformed to reduce the influence of the most abundant species, and converted to a symmetric matrix of biotic similarity between pairs of sites using the Bray-Curtis similarity index, which is relatively insensitive to data sets with many zero values. The usefulness of the two dimensional MDS display of biotic relationships is indicated by the stress statistic, which signifies a good depiction of relationships when <0.1 and poor depiction when >0.2 (Clarke, 1993).

3. Results and discussion

3.1 Biotic similarities between sites

Given that the primary aim of the monitoring program is to identify differences in fished areas versus protected areas, the range of floral and faunal communities in sanctuary areas ideally should encompass the range of communities at the fished sites investigated. If not then trends through time may be confounded because the different community types in fished and unfished zones may track different environmental factors, and hence diverge into the future for reasons unrelated to effects of fishing.

Overall biotic community differences between sites for fishes are depicted using MDS in Fig. 2, while densities of each fish species at different sites are listed in Appendix 1. Sites with high levels of biotic similarity lie adjacent to each other in Fig. 2, while sites with few similarities are positioned at distance.

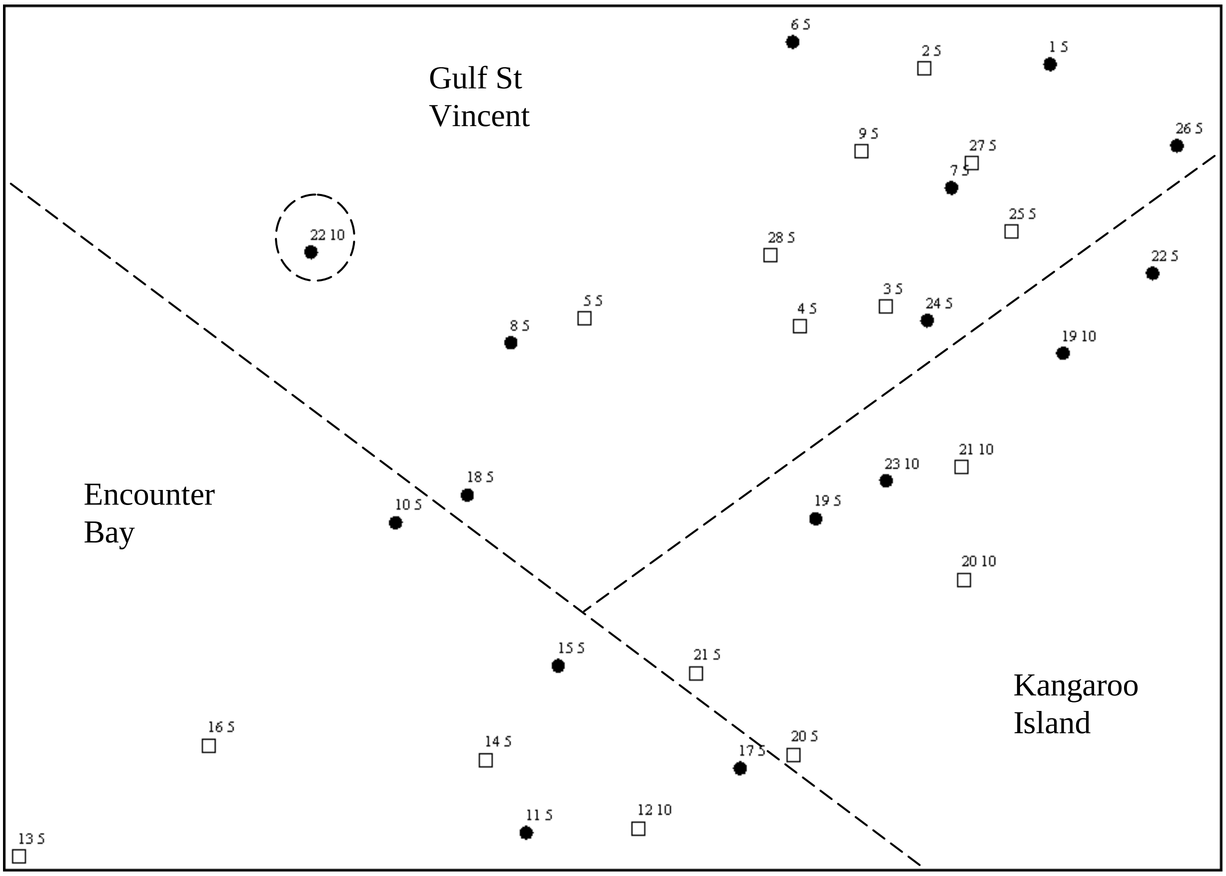

Fig. 2. Results of MDS showing relationships between sites for fish assemblages in 2005. Sites are coded by numbers listed in Table 1 and the depth. In the figure, the filled circles represent the “outside” control sites, and the squares represent sites “inside” Sanctuary Zones. The stress statistic is 0.12, indicating a good depiction of relationships between sites. The dashed lines partition the sites into the three general regions surveyed, apart from the 10 m survey at site 22, from Kangaroo Island (circled).

Patterns of biotic similarity between sites for invertebrates and plant and sessile animals were generally comparable to those for fishes (Figs 3 and 4). In general, “inside” and “outside” sites are well interspersed within these plots, indicating that sites monitored within sanctuary zones have similar biotic assemblages to external reference sites before MPA protection. Assemblages surveyed at Kings Head, a site with very little relief (sites 13 and 16), and the deep site at Kangaroo Head (site 22), which lay along the reef margin, were the most anomalous.

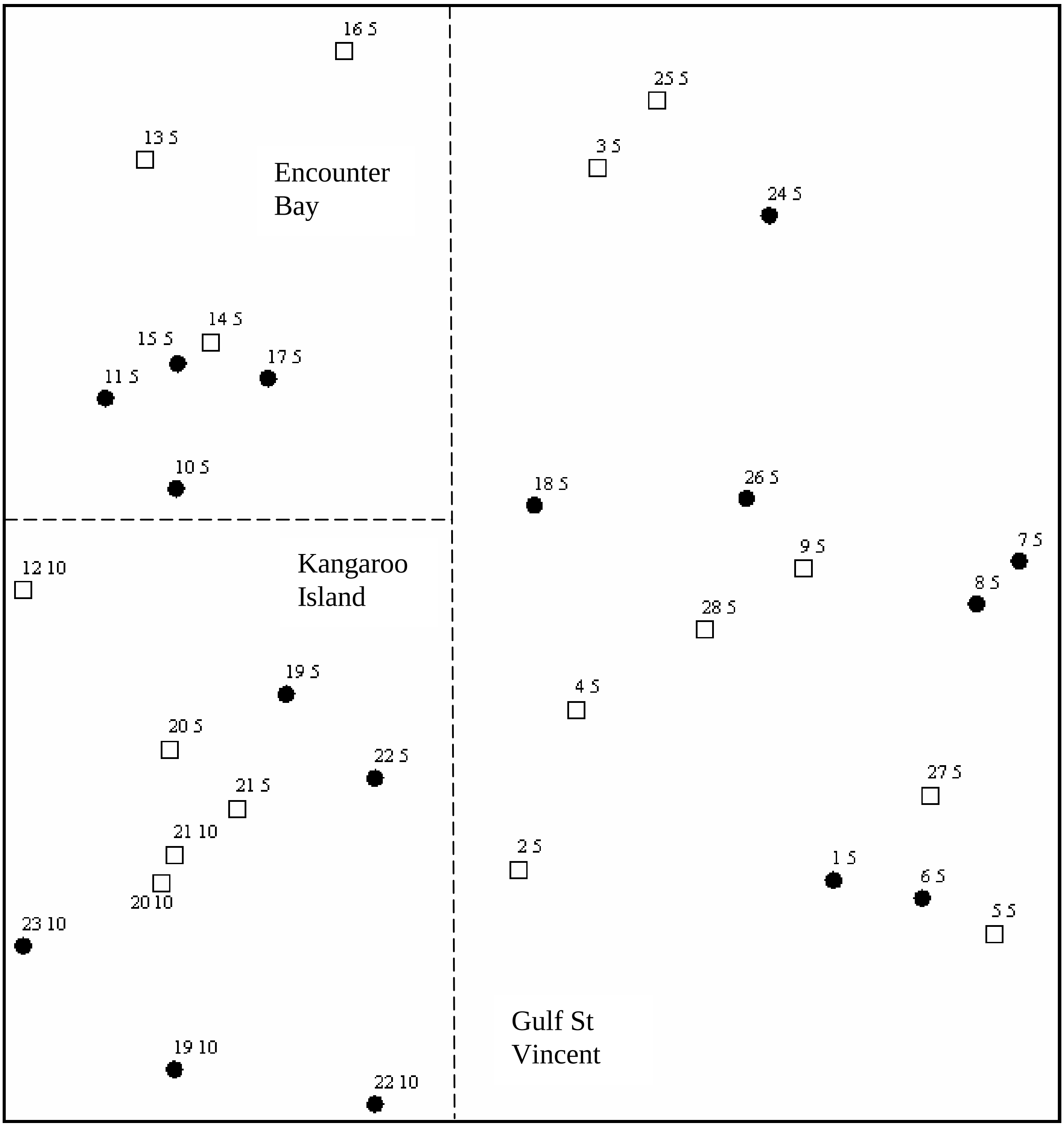

Fig. 3. Results of MDS showing relationships between sites for invertebrate assemblages in 2005. The stress statistic is 0.15. Sites are coded by numbers listed in Table 1 and the depth. In the figure, the filled circles represent “outside” control sites, and the squares represent sites “inside” Sanctuary Zones. The dashed lines partition the sites into the three general regions surveyed.

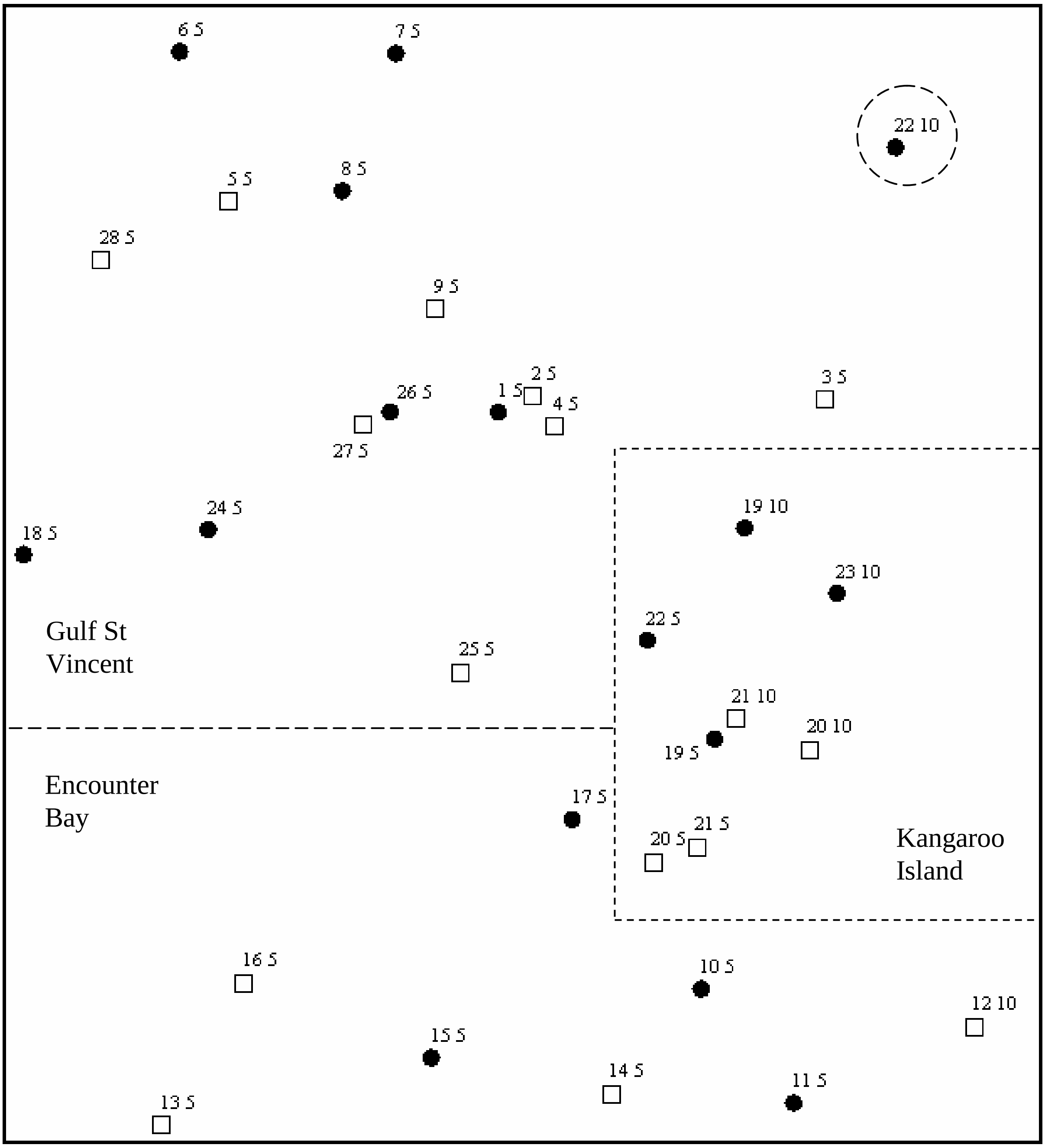

Fig. 4. Results of MDS showing relationships between sites for plant and sessile invertebrate assemblages in 2005. The stress statistic is 0.15. Sites are coded by numbers listed in Table 1 and the depth. In the figure, the filled circles represent "outside" control sites, and the squares represent sites "inside" Sanctuary Zones. The dashed lines partition the sites into the three general regions surveyed, apart from the 10 m survey at site 22, from Kangaroo Island (circled).

3.2 Patterns of species richness

Patterns of biodiversity at the site scale have been assessed using total number of species recorded in four 50 m transects. For fish, mobile macro-invertebrates and algae, results were highly consistent between management zones, with an average of ≈25 fish (Fig. 5), ≈15 macro-invertebrate (Fig. 6) and ≈27 plant species (Fig. 7) recorded at each site.

No significant differences in species richness between zones were evident when data were analysed using a single factor ANOVA (Table 2).

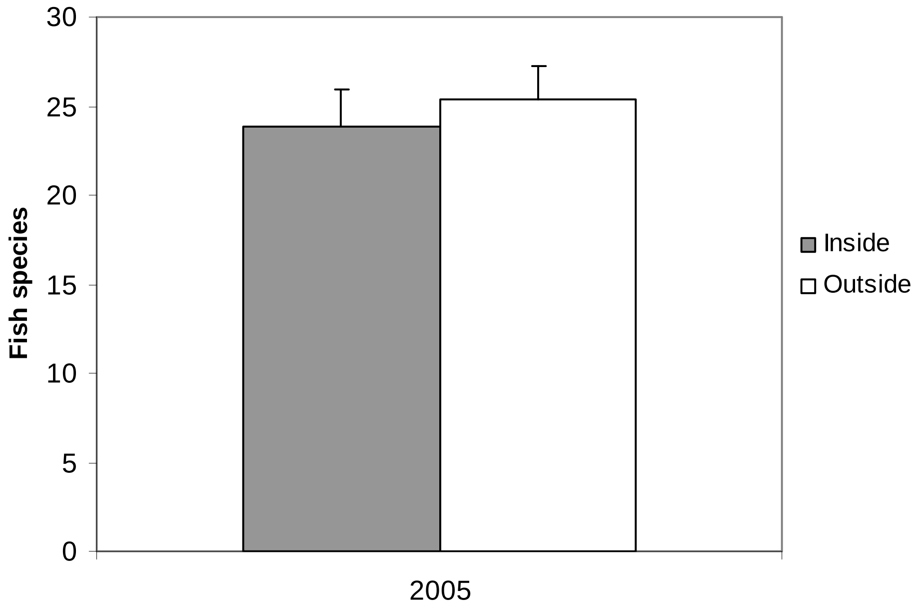

Fig. 5. Mean number of fish species per site (± SE) in different management zones.

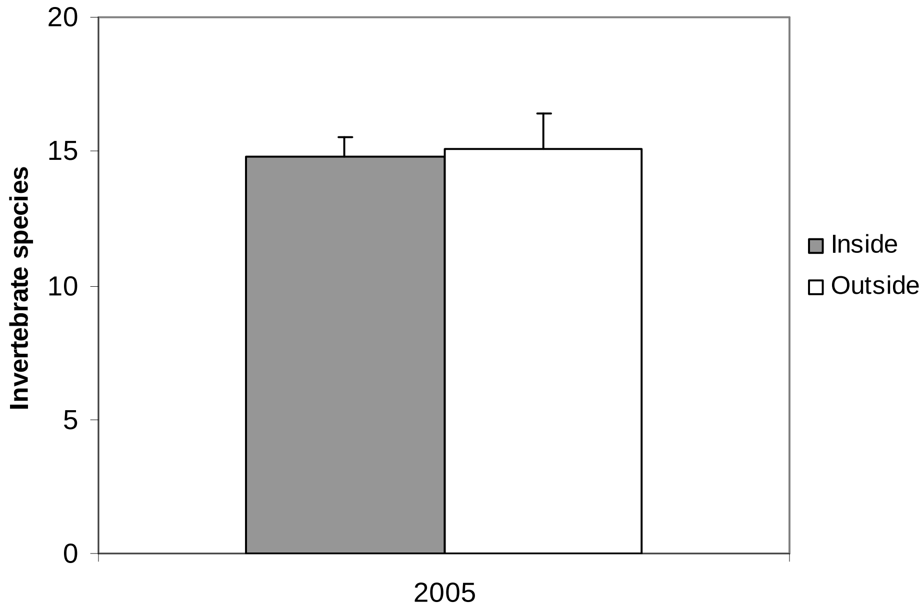

Fig. 6. Mean number of mobile invertebrate species per site (± SE) in different management zones.

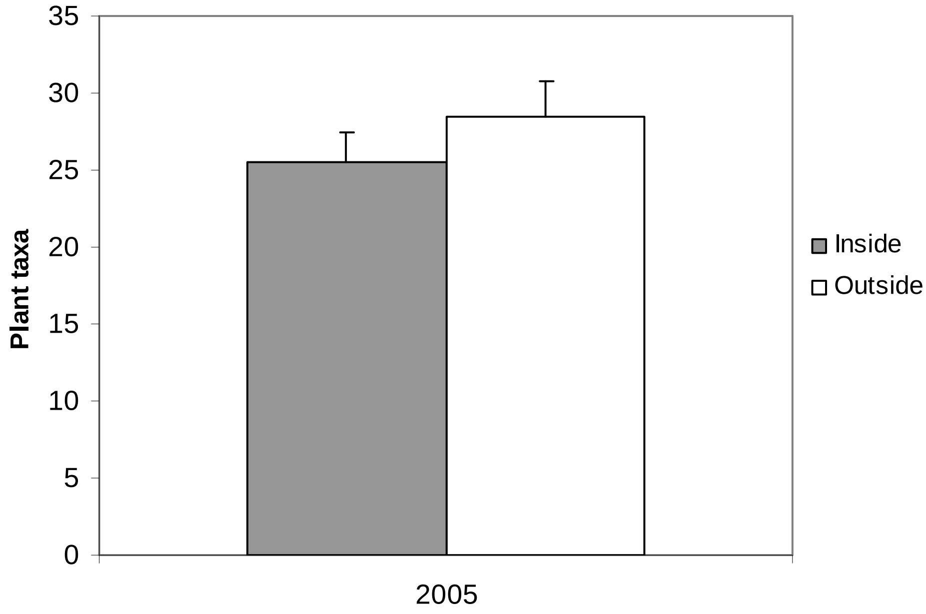

Fig. 7. Mean number (± SE) of plant and sessile invertebrate taxa per site in different management zones.

Table 2. Results of one-way ANOVA (fixed factor zone) using data on number of species per 50 m transect for the 32 sites. The critical value of F for p<0.05 is 4.17.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
		Fish			
Between Groups	21.1	1	21.1	0.34	0.57
Within Groups	1884.4	30	62.8		
		Invertebrates			
Between Groups	0.78	1	0.78	0.05	0.83
Within Groups	508.19	30	16.94		
		Algae			
Between Groups	66.1	1	66.1	0.94	0.34
Within Groups	2105.9	30	70.2		

Given the low variance between sites and non-significant differences in species richness between zones for all three major taxonomic categories examined, future analyses should detect as significant relatively slight changes in "Inside" versus "Outside" zones.

3.3 Variation in faunal and floral density

In this baseline report, our primary aim has been to present basic data on species abundance within appendices; however, we here present baseline data relevant to some of the more interesting response variates in greater detail. Sanctuary zones are predicted to primarily enhance the number of large individuals of exploited species such as fish, rock lobster and abalone. Accordingly, one variate that should increase through time is the number of large individuals sighted along transects.

The mean total number of large (>325 mm) fish sighted at sites in different zones is shown in Fig. 8. Densities of silver drummer *Kyphosus sydneyanus* were excluded from this analysis because this species is avoided by fishers and it occurs in large schools that are haphazardly sighted, biasing results. Patterns of abundance of large fishes did not vary significantly between zones (one way ANOVA: df = 1/30, F = 0.022, P = 0.88).

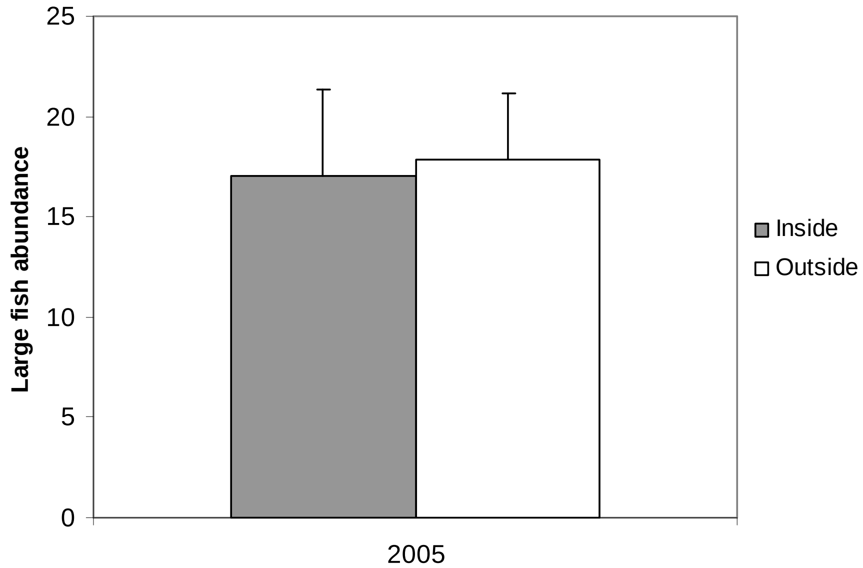

Fig. 8. Mean abundance of large fish (>325mm except Kyphosids) per site in different management zones.

The blue-throated wrasse (*Notolabrus tetricus*) is not extensively targeted but the mean size (and sex ratio) is considered to be an index of fishing pressure (Shepherd & Brook 2005). The mean size did not differ significantly between zones (Fig. 9; one way ANOVA: df = 1/30, F = 0.402, P = 0.53).

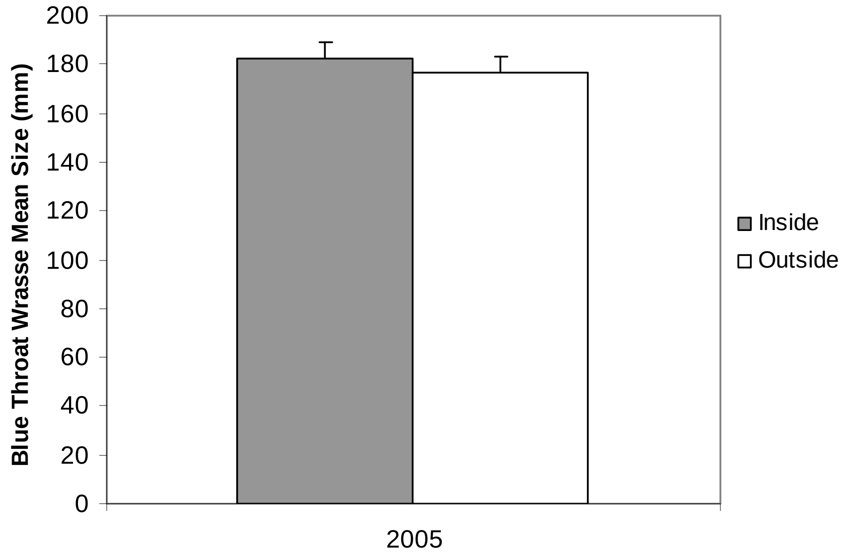

Fig. 9. Average mean length of blue-throated wrasse per site in different management zones.

One reef species often targeted is the sweep (genus *Scorpis*), for which there is a size limit of 240 mm. No significant difference was found between zones for the abundance of sweep in size classes 250 mm and above (Fig. 10; one way ANOVA: df = 1/30, F = 0.662, P = 0.42).

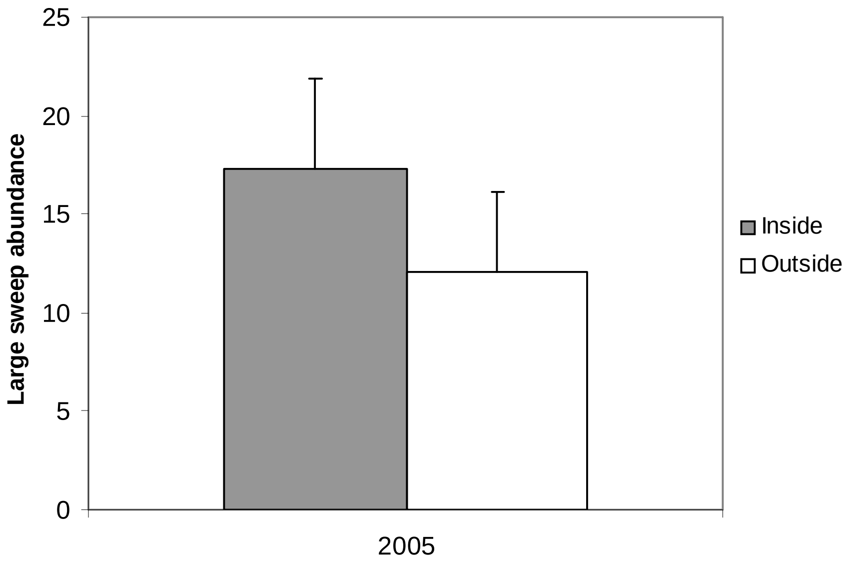

Fig. 10. Mean abundance of sweep above legal size per site in different management zones.

Blacklip abalone (*Haliotis rubra*) are fished by recreational divers and commercial abalone licence holders. No significant differences were found between the zones for this species (Fig. 11; one way ANOVA: data square root transformed, df = 1/30, F = 0.342, P = 0.56).

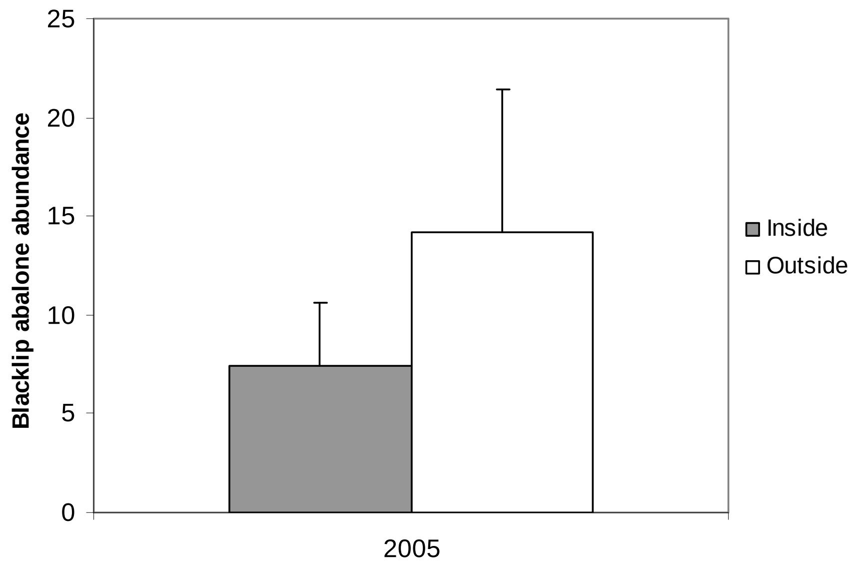

Fig. 11. Mean abundance of Blacklip abalone per site in different management zones.

Relative to other temperate water sites surveyed in Tasmania, Victoria and Western Australia, few (26) rock lobsters were recorded on transects during the entire study (Fig. 12). No statistical test was undertaken for this species because of the low numbers.

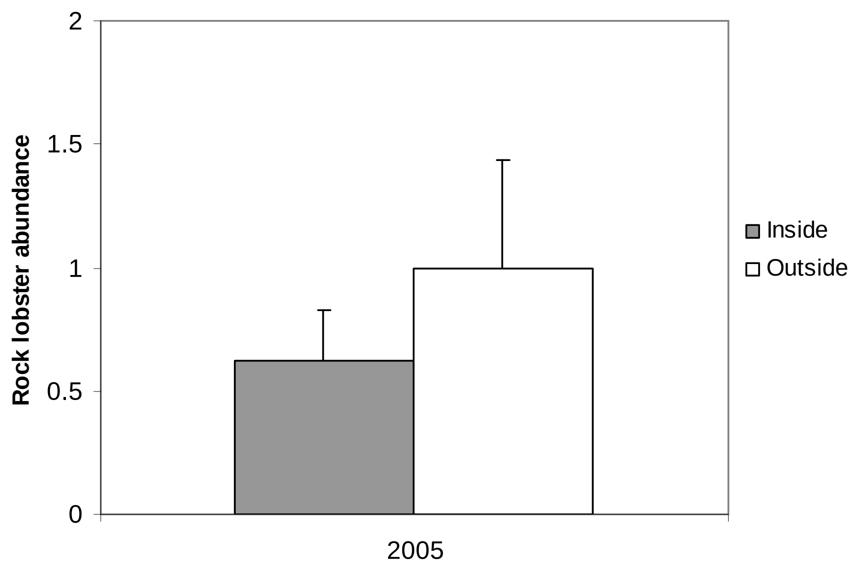

Fig.12. Mean abundance (± SE) of rock lobsters per site in different management zones.

Amongst the most important habitat variables at any site is cover of foliose algae, because differences in algal cover affect a variety of ecosystem processes and composition of associated fishes and invertebrates (Edgar *et al.*, 2004b). No variation between zones was found when total cover of foliose plants was examined (Fig. 13; one way ANOVA: df = 1/30, F = 1.62, P = 0.21).

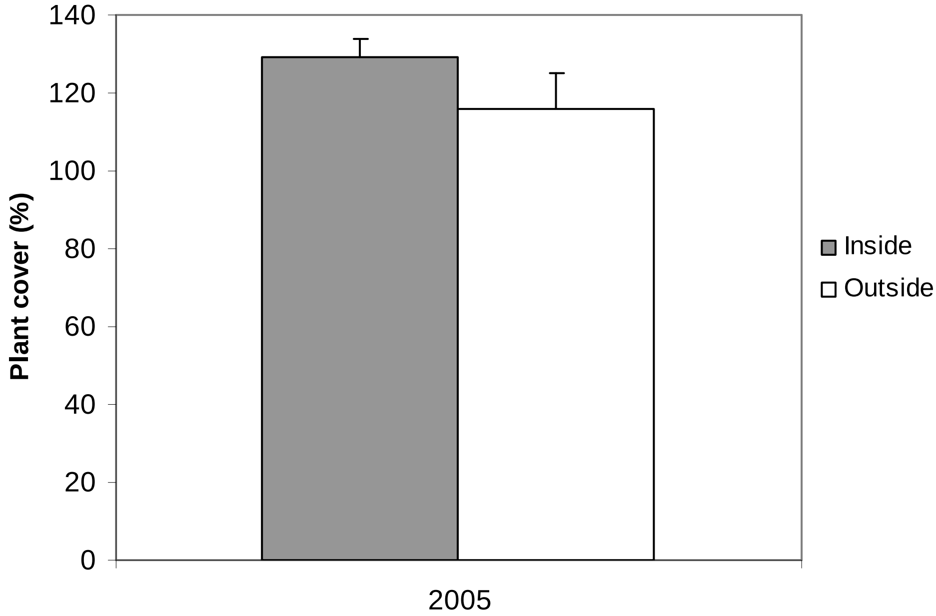

Fig. 13. Mean total cover (± SE) of foliose plants per site in different management zones.

4. Conclusion

Surveys of sites in the proposed Encounter Marine Park in 2005 provided a quantitative regional description of resident reef fishes, mobile and sessile invertebrates, and dominant plants on shallow inshore reefs. While examination of deeper outer reefs would have been desirable, these habitats were not included in the experimental design because of logistic inefficiencies involving diver bottom time, and because fishing impacts are most intense on the shallower reefs. Regardless, baseline surveys of deep reefs, seagrass beds and soft-sediment habitats inside and outside proposed sanctuary zones using non-destructive sampling techniques such as unbaited and baited video would prove very useful for assessing changes through the long term.

Examination of patterns of inter-site variation of the dominant species suggest that assemblages vary considerably between sites within the major protection categories, but that sites in sanctuary zones and fished zone types have broadly overlapping characteristics. Thus, future comparisons between categories should be valid using the current sites and experimental design.

Investigation of 14 different locations within each treatment, including two surveyed at two depths, should be sufficient to detect biologically meaningful change for common species. From the results of the Tasmanian MPA study (Edgar and Barrett 1999) and a workshop examining MPA monitoring techniques (Barrett & Buxton 2002), it appears that where the abundance of each species is adequately described at each site, six sites in each treatment would be an acceptable number of replicates per treatment for an effective monitoring program. The level of replication was almost three times greater than this, allowing differences between the three major regions to be tracked. By surveying a wide range of species the experimental design should also have sufficient power to detect ecosystem shifts as well as changes in the abundance of target species following MPA declaration.

Ideally the surveys should be repeated at least once prior to the gazettal of fishing regulations, then annually following the declaration of the MPA until patterns in sanctuary zones have stabilised relative to patterns in open fishing zones. The stabilisation process could take over 20 years. The time-series of data generated would then allow population trends in species affected by the MPA to be identified, and the efficacy of the MPA for biodiversity conservation to be appropriately assessed. Such a long-term multi-species data set would also prove invaluable for analysis of the impacts of introduced species and climate change on regional biota.

Nevertheless, we recognise that, despite the importance of MPA monitoring, funding is limited and trade-offs are generally required to maximise cost-effectiveness. If insufficient funding is available, then we recommend that surveys be repeated every two years rather than annually. Such a change in survey frequency should not greatly affect assessment of MPA efficacy, given that biological changes associated with protection from fishing typically take many years to manifest. The major loss would be associated with the use of MPA data to assess changes to reef communities in anomalously hot and cold years, important information when predicting impacts of climate change.

5. Acknowledgments

We would particularly like to thank staff of the Department for Environment and Heritage (Coast and Marine Conservation Branch) for logistical and technical assistance, Hugh Kirkman for help and advice in the field, and the Australian Research Council for partial funding.

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Appendix 1. Total abundance of fishes recorded in four 50 m x 10 m transects surveyed at different sites in 2005.

	Site/Depth																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Acanthaluteres brownii	22	34	2	17	1	37	13																	8	3			4	21	31	39	77
Acanthaluteres vittiger	12	4						1	1	48		1	1	2	1		1	1							1	2		31	2	1	3	2
Achoerodus gouldii			1								4	2		5	3		1		10	17	4	8	8	4	16	4	5					1
Aetapcus maculatus	1																															
Anoplocapros amygdaloides												1					1															
Anoplocapros lenticularis																				1												
Aplodactylus arctidens														3			1					2			1		1					
Aracana aurita																	1															
Arripis spp.							20																									
Austrolabrus maculatus	6	19	12		9	44	34	24	21											3	1	3		9		48	14	16	13	4	3	4
Brachaluteres jacksonianus																												2				
Caesioperca rasor																				47		12		9			48			1		
Cheilodactylus nigripes	6	10	16	12	13	6	25	17	13	10	1	26		10	21	3	9	4	27	32	11	26	15	9	29	5	21	25	16	9	5	10
Cheilodactylus spectabilis												1		2													1					
Chelmonops curiosus	12	3	7	1	2	4	11	2	9	2		1							1	5	1	8	9	3	3		5	15	6	15	2	
Dactylophora nigricans				7		3		5	1	1								6	8	3		3	6	1	2		1	1	2	1		8
Dinolestes lewini	9		3	30		1	2			115	100									9				15	94		2		24	2		
Dotalabrus aurantiacus	3	3	2	3	5	3	6	11	13	1			2				1	2	9	8			2	4	5	6	7	3	1	3	3	4
Enoplosus armatus	6	31	13	69			16	1	11		1	2					30		8	99		2	5	32	38		22	52	49	13		
Eubalichthys gunnii																						2				1					1	
Eubalichthys mosaicus				2					1																							
Eupetrichthys angustipes																			4				2		2	3	2		1	1	1	3
Girella tricuspidata														1							1											
Girella zebra			47	14	3		12	60		1	3	1	1	3	8	1		8	46	87	8	12	11	6	42	7	16		16	35		
Helcogramma decurrens																													3			
Hypoplectrodes nigrorubrum									1											2		3		1			1					
Kyphosus sydneyanus	48		104	18			14				6	1		5	6		13			2	7	11	9	13	5		8	3	5	8	25	2
Meuschenia flavolineata	14	1	10	9		4	1		1	1		7			2		1		9	12	18	18		6	16		3	4	20	3	1	4
Meuschenia freycineti	1																														1	
Meuschenia galii	10	2	5	10	1	1	1		1									1	1									5	10	7	2	1
Meuschenia hippocrepis	30	31	8	85	15	11	22	11	20		9				12		5	12	16	9	7	3	4	5	43		2	44	37	27	9	18
Muraenichthys australis													1																			
Myliobatis australis						1																										
Neatypus obliquus	2	8	4																													
Nemadactylus valenciennesi																				3		3					1					
Neoodax balteatus						4																			7	2						
Neosebastes scorpaenoides																									1							
Notolabrus parilus			4	4	4	1	4	6	9		2							1								1		5	6	2	1	1

Appendix 1 (cont.). Total abundance of fishes recorded in four 50 m x 10 m transects surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Odax acroptilus	4	1	6	1		1					1				1			1	2	1	1	2					2	2	4	4	5	2
Odax cyanomelas	14		10	18		1		1		14	27	31	23	65	10	24	15	7	11		18	4	24	4	2		2		7	12		1
Omegophora armilla	1								1																							
Othos dentex																			2	2		4	1	3	1		1			1		
Paraplesiops meleagris							1		1										1	2		17		8			1			2		2
Parapriacanthus elongatus	17	297	200				900		335										35	1060		210		900	4700		258	272	22	8717	810	530
Parequula melbournensis	1		2			6	8	7	4											32							1	4	2	1		
Parma victoriae	4	4	12	7	8	4	2		12	7	13			18	21		3	5	11	16	5	13	8	17	16		7	2	8	11	2	7
Pempheris klunzingeri	80		2	12			2		20			5					6					115			5			76	27	165		
Pempheris multiradiata	124	1	13	14		3	2		5	4		36		1			69		138	29	127	161	44	178	231		111	99	181	124	25	
Pempheris sp. (Orange-lined)							8										1												59	9		
Pentaceropsis recurvirostris											1	3					1			4		17		2								
Pictilabrus laticlavius	4	15	5	28	37	29	6	14	15	2		4	1	10	12	12	5	15	33	69	7	22	7	12	32	55	14	14	8	4	21	35
Platycephalus speculator																													1			
Pseudocaranx dentex																				1												
Scobinichthys granulatus	1																	3												3	1	
Scorpis aequipinnis	5		62	37	22		39	17	19	36	87	79		135	117	5	35	20	41	66	24	45	59	65	43		33	33	95	10	31	27
Scorpis georgiana																								1								
Sepia apama	1	2	28				2																					1	1		3	
Sepioteuthis australis				1		9																							42	14	4	
Siphamia cephalotes	1349	144	13	263	26	20			121	159	2	8					31	14			8			4		9		39	377	112	1	61
Siphonognathus attenuatus									1									6						1	1				1	1		
Siphonognathus beddomei	8	12	10	58	4	5		22	11	3	5		4		9	4	8	4	180		386	97	167	77		3	68		13	26	24	8
Siphonognathus caninus																						3					1					
Siphonognathus radiatus			2		1																											
Siphonognathus tanyourus						5															1	2		3								
Sphyraena novaehollandiae		1																												13	1	
Tilodon sexfasciatus	12	8	7	12	25	32	31	11	17	9	2	3		4	2		3	4	9	27		29	3	13	55	7	15	10	22	21	11	25
Trachichthys australis										2		1																				
Trachinops noarlungae	2978	2095	865	603	70	2276	1390	6	960										62	899		3		76	3895	3	35	190	2435	5945	1980	190
Unidentified fish									500																							
Upeneichthys vlaminghii	2	1	5	28	16	9	24	17	11	4				1	1	1		15	5	4		5			7	28	5	10	3	7	8	10
Urolophus gigas	1																															

Appendix 2. Total abundance of mobile macro-invertebrates recorded in four 50 m x 1 m transects surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Echinoderms																																
Amblypneustes ovum				1				1					2		2				3		1				2							
Anthaster valvulatus																															1	
Astroboa ernae																					1						2					
Cenolia tasmaniae										1	2		5																			
Cenolia trichoptera	1	126	2				2	4	1	100	29	144	27	27	33	2	130	2	22	52	110	50	76	60	13	3	15	4			1	4
Centrostephanus tenuispinus																								1								
Conocladus australis																						3					3					
Echinaster arcystatus										1		1			1																	1
Echinaster glomeratus										1																						
Fromia polypora																															1	
Goniocidaris tubaria						2																			1							
Heliocidaris erythrogramma	1	1		1						4	29	2	21	1	3	3	3		3		42	2	7	6	2					9		2
Holopneustes porosissimus	1		1								1		22	3	2	1													2			
*Holopneustes sp_*																	1															
Nectria macrobranchia												6		2	6			1														
Nectria multispina														1	3		1															
Nectria ocellata				1				1	1					1	2		2	2										5				
Nectria saoria										2	4	10		9	15	1																
Nepanthia troughtoni											7	12	1	1	2			1														1
Patiriella brevispina										2		2	1							3				1	3	2	37					
Patiriella calcar													103			197																
Pentagonaster dubeni	7	3	3	2	8	2	1		1	2								1	2		2	3		2				1	4	3	7	3
Petricia vernicina	1	12	2	2	1	2			3	3	5	10		2	10	1		2	2	3	6	3	5	5	4	4	4			4	1	4
Phyllacanthus irregularis		4			1	5			1									1			1	1	1	2	3							7
Plectaster decanus					1																										1	
Stichopus ludwigi																								1								
Stichopus mollis				2		1		2	2										1	10	2	3		2	12	2	7	1	1	1	1	
Tosia australis	1	5	4	4	1	1	2	1		1	4	2	17	10	3	4	4	1	11		1				2	10	1	2	1	3	5	
Uniophora granifera			2																			2								1		

Appendix 2 (cont). Total abundance of mobile macro-invertebrates recorded in four 50 m x 1 m transects surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Molluscs																																
Austrocochlea odontis																71																
Cabestana tabulata											1																	1				
Ceratosoma brevicaudatum																		1					1									
Conus anemone				1	1									1																		1
Dicathais orbita			11							5	1	6	29	10	9	64	3		1		1							1	21	2		14
Fusinus australis																									1				1			
Haliotis cyclobates													7																			
Haliotis laevigata		1								1	2				1	2									2	2						
Haliotis roei													3																			
Haliotis rubra				10					4	38	28	8	45	13	114	30	11	14	5		2	3	1	1	7	1	6		1	3		1
Mitra glabra																									1							
Neodoris chrysoderma																						2										
Penion mandarinus										1			1					1														
Phasianella australis								5	12							3												1		72	15	3
Phasianella ventricosa	40	40	1	6	6	29	11	8									2	3					1		2			11	1	1	45	24
Phasianotrochus eximius																												1		2		
Pleuroploca australasia	2	2	27	5	1	3	17	4	11						1	11		3	1	2			2		4			8	29	4	1	4
Pterynotus triformis									1									2				1						1	1			
Scutus antipodes												2															1					
Sepia apama																									2		2	2		2		
Turbo torquatus											2		4	8	2				4		1											
Turbo undulatus			401							24	45		99	58	35	181	69	8										493	701			
Crustaceans																																
Jasus edwardsii				1						5	2	1		1			5		2		3	1	1		2				1			1
Leptomithrax gaimardii																				1					12							
Nectocarcinus integrifrons									1																							
Nectocarcinus tuberculatus											2		1	1			3										1					1
Pagurid u/i		1	17				4	1	3	1			2		1		2				4				1			4	3	4	3	1
Paguristes frontalis																			1								1			8		1
Petrocheles australiensis																								1								
Plagusia chabrus	1		1	2					2	4	9	3	9	2	2	3	13	1	3				1	2	2				1	2		
Trizopagurus strigimanus																												1				

Appendix 3. Total abundance of cryptic fish recorded in four 50 m x 1 m transects surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Aetapcus maculatus		1		1													1		1											1	1	
Blennidae sp.																	1															
Brachaluteres jacksonianus						2																										
Chelmonops curiosus		1																														
Cochleoceps bicolor																				9												
Diodon nichthemerus		1																														
Foetorepus calauropomus									1																							
Gnathanacanthus goetzii																			1	1												
Heteroclinus johnstoni																			1													
Heteroclinus tristis																				2												
Neosebastes scorpaenoides																					1				1							
Othos dentex																			1	1	3	5	1		1		1					
Paraplesiops meleagris				1															4	2	4	9	1	11	2		1					
Parascyllium variolatum												1																				
Pempheris sp. (Orange-lined)		1																														
Scorpaena papillosa														1																1		
Sepia apama																									2		2	2		2		
Thysanophrys cirronasus			1												1																	
Tilodon sexfasciatus	1																															
Trachichthys australis																					1											
Tripterygiid spp.					1	4	55	47	17					1						1					1	1		24	4	30		23

Appendix 4. Mean cover (%) of brown algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Acrocarpia paniculata				0.3						15.5	27.0		53.8	43.9	34.6	18.0	11.2		0.9		7.7	0.9	7.5	2.0	3.1							
Carpomitra costata																						1.5										
Caulocystis cephalornithos	7.3				2.6	15.7												3.0												0.9	2.0	7.7
Caulocystis uvifera					4.4																											
Chlanidophora microphylla															1.2													4.2				10.2
Cladosiphon filum																										0.7						
Cladostephus spongiosus																							0.2									
Colpomenia spp.						0.4		0.2	0.3																							
Cystophora ?siliquosa																			0.8													
Cystophora brownii	0.2	0.2				0.5	5.9	7.7										3.2										6.1		0.4		
Cystophora expansa	14.4	24.0		2.6	14.5	15.6	10.8	10.9	19.0									27.2		0.3								2.5		30.0	3.0	33.0
Cystophora intermedia																					0.7											
Cystophora monilifera	3.2	5.2		1.0	4.0		0.8	0.8	0.9					4.8	13.3		3.5	15.0	8.5	3.1	3.3	3.4	13.1	9.6	16.4	0.8	3.1			1.4	22.9	2.4
Cystophora moniliformis	3.3	1.7		4.8			4.2	6.9	10.0	0.6			21.0			4.2	2.0	4.7	4.7	1.9	2.3		2.5	0.9	1.6		0.4	4.5	2.4	5.0		
Cystophora racemosa			17.8						8.6																				3.3			
Cystophora retroflexa	1.8		12.5	0.2	0.6		17.0	0.3	1.8				0.1																			
Cystophora spp.																					0.3											
Cystophora subfarcinata								18.2	13.5	3.9			1.4		5.0	22.0	3.7	9.3			0.4		0.7					17.4	16.1			
Dictyopteris muelleri						0.1																					0.2					
Dictyota spp.					0.5	1.1		0.2							0.1	0.7		0.3		0.3							0.2	0.2				
Distromium flabellatum																														4.2	1.1	
Distromium multifidum																					0.3	0.9										
Ecklonia radiata	44.6	33.6	40.2	27.2	0.6		0.4	0.7	12.6	63.1	52.4	68.0		12.4	0.9		41.9		36.0	17.2	48.3	50.5	32.6	41.5	18.9	1.1	17.3	8.0	46.9	24.6	19.5	2.3
Encrusting brown algae																												4.6				0.4
Filamentous browns																				31.1		7.8	8.0	10.7			7.7					
Halopteris spp.										0.2				0.5	0.3		0.4	5.2		0.6		1.1	4.4	0.6						0.1		
Homeostrichus olsenii																												0.3		0.6	3.3	3.0
Homeostrichus sinclairii																															1.0	3.5
Lobophora variegata	7.2	3.0		0.8	0.9	6.8	19.6	7.9	10.5	2.0					0.9											0.2	7.7	12.7	0.7	11.3	5.6	1.8
Lobospira bicuspidata			1.9							1.2	2.9				0.7		2.9	1.0	5.7				2.1	0.9	6.9		1.1					
Pachydictyon paniculatum																		2.8					0.3									
Perithalia cordata						0.1							1.9	2.5	0.2	0.6																

Appendix 4 (cont.). Mean cover (%) of brown algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Sargassum ?lacerifolium																														4.2		
Sargassum decipiens				4.9	3.7	14.9												9.0			0.6	0.6	0.6	1.1						3.1	15.3	11.2
Sargassum fallax																		0.4				1.0						2.3			4.1	
Sargassum heteromorphum				0.2	2.1													0.1		0.1												0.9
Sargassum linearifolium	0.4																														16.2	
Sargassum sonderi																		1.2				0.6										
Sargassum spinuligerum																												9.9		12.8		15.3
Sargassum spp.	22.2	37.3	15.8	35.7	45.7	50.2	22.7	51.1	14.2	0.2			0.4			1.0	4.5	1.1	7.9	17.3	1.5	5.4	1.7	7.5	16.0	21.5	7.6	5.7	8.9	21.6	23.6	28.5
Sargassum varians	0.9			17.0	7.4	3.6												4.5		0.4								8.8		11.9	15.9	16.3
Sargassum verruculosum															0.2			17.5	4.0	5.6	1.0	2.6	2.0	2.5	0.5		0.4	0.2		1.0	0.5	
Sargassum vestitum											0.2	0.6		0.2	0.6																	
Scaberia agardhii	0.2				10.4	0.4			1.9									4.6													0.1	1.5
Scytothalia dorycarpa				0.3						0.3	12.9	1.2	57.6	23.9	14.5	46.0	45.2				16.2	9.6	17.3	10.1			8.1					
Seirococcus axillaris				10.0											6.3		1.9		45.2	4.9	23.8	4.4	22.2	5.7	17.6		1.3					
Sporochnus sp.																				0.2			1.0				3.6					
Xiphophora chondrophylla															0.4	0.8																
Zonaria angustata	1.5	1.1	1.7	2.2	18.7	11.2	23.7	10.6	7.5		0.4		3.2		5.4	7.2	1.1	2.4		1.9		0.2			1.6			0.5	1.4	2.3	1.2	
Zonaria sp.											0.2				0.3	2.7	3.3	1.3	0.1	0.1	0.2		0.1		0.2			1.2	0.6			
Zonaria spiralis													1.7	0.1	1.6	2.1	0.7	0.4					0.1					1.3	4.2			
Zonaria turneriana																															0.4	

Appendix 5. Mean cover (%) of green algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Caulerpa brownii					0.2					0.2					0.9	0.2		2.1	0.1									0.8				0.4
Caulerpa cactoides						0.1																										0.1
Caulerpa flexilis															0.1			0.5	0.2	4.6					0.3			4.8	0.2			
Caulerpa flexilis var. *muelleri*																												2.9				
Caulerpa geminata											0.4																					
Caulerpa hodgkinsoniae											0.2				0.1																	
Caulerpa papillosa																										0.2						
Caulerpa scalpelliformis																		0.1														
Caulerpa trifaria																				0.4					0.2	0.6	0.4					
Caulerpa vesiculifera					0.2								0.1																			
Codium spp.			0.1																							0.6	0.1					
Dictyosphaeria sericea	0.4						0.7	0.7																						0.2		0.1
Ulva spp.											0.1																					

Appendix 6. Mean cover (%) of red algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Amphiroa anceps	0.3		0.7	0.9			1.1			0.3			4.3							1.1		0.2					0.3		0.3			
Areschougia congesta										0.4	0.5					0.3																
Areschougia spp.										1.0	1.5	1.3																				
Asparagopsis armata															1.2																	
Ballia callitricha										0.7		3.4		2.3					0.1		1.2											
Botryocladia obovata					1.0																				0.2	0.2					0.4	0.5
Botryocladia sonderi																				0.5												0.3
Callophyllis lambertii																								0.1								
Callophyllis rangiferinus				0.4															0.5	0.3		1.7										
Carpopeltis phyllophora													29.8																			
Cheilosporum sagittatum										1.2			2.9	11.7	8.2																	
Corallina officinalis													0.5		0.3	3.1			0.4						1.3	1.6						
Crustose coralline algae	30.6	5.3	30.4	4.7	0.9	0.2	0.2	0.3	3.9	43.8	38.1	16.5		13.8	6.8	21.9	32.0	0.6	22.3	5.1	41.9	11.8	16.0	13.8	6.5	0.1	3.0	7.2	58.7	10.2	8.5	1.9
Delisea spp.										0.7	0.2						0.1															
Dictyomenia tridens																							0.1									
Echinothamnion hystrix															2.5							0.3					2.1					
Euptilota articulata										1.6		2.5																				
Filamentous red algae	2.5																	0.3	2.8	5.5	0.5	1.3		4.1	9.0	26.9	10.5					
Gelidium australe																					0.2											
Gelidium glandulaefolium										0.3		0.8		1.2													0.8					
Gelidium sp.																			5.5						5.7							
Geniculate corraline turf																												2.1				
Geniculate corralines	0.6			0.5			8.6	5.8	1.5											0.2					2.0							
Gigartina crassicaulis																				0.1												
Gloiosaccion brownii					1.4																									0.4		0.3
Gracilaria sp.																				0.1												
Haliptilon roseum					0.8					2.3			21.9	16.8	2.6	3.0		11.5	0.7		4.0	0.7	2.2	0.3	2.5	0.7	0.2	0.8	0.2			2.0
Haloplegma preissii																							0.4				0.7					
Halymenia plana												0.2																				
Hildenbrandia sp.														0.2																0.4		
Hypnea sp.											0.2				0.4						0.3											
Jania pulchella																0.2																
Jania spp.																							0.1									

Appendix 6 (cont.). Mean cover (%) of red algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Laurencia spp.				0.2							0.6							0.2					0.4		0.4							
Lenormandia smithiae																						0.5		0.3			3.4					
Lophurella periclados											0.8																					
Melanthalia abscissa										0.4	2.0	1.0									0.2											
Melanthalia concinna											0.2								0.1													
Melanthalia obtusata												0.7																				
Melanthalia sp.										0.5		1.5		1.1	1.0							0.3										
Metagoniolithon radiatum				0.6	0.2								4.6		0.2	3.1		2.4	0.4		0.1				1.0							0.9
Metagoniolithon stelliferum																		1.1														
Metamastophora flabellata											0.1				2.1																	
Osmundaria prolifera															0.1																	
Osmundaria spiralis				5.4							0.5																					
Peltasta australis											1.3	0.3																				
Peyssonnelia novaehollandiae											4.0																			0.8	0.5	
Peyssonnelia sp.	0.7	0.1		1.1						0.7					0.5						0.5											
Peyssonnelia spp. (encrusting)	1.1	0.4	0.2	0.4				0.5		10.7	28.6	18.6	4.9	5.8	3.1	0.8	15.9		4.5	0.1	4.8		1.8	0.5	1.3		0.3		0.4	2.4	1.5	
Phacelocarpus alatus										0.9	1.2				0.4																	
Phacelocarpus apodus											2.2	2.6		0.3	0.5																	
Phacelocarpus peperocarpus										5.1	3.4	6.3	1.2	3.6	7.0																	
Plocamium angustum				3.5							0.3	0.9		0.3	3.6				0.9	0.4	0.4	0.7	0.6		0.5							
Plocamium cartilagineum														0.2	0.3				0.2													
Plocamium costatum																						0.2										
Plocamium dilatatum										0.2		0.7		7.4	1.2																	
Plocamium mertensii											1.1	6.1		1.8	1.7							2.2	1.5									
Plocamium patagiatum												0.8																				
Plocamium preissianum												1.8		0.3	0.8								1.7									
Pterocladia capillacea										0.3				0.2	1.5						0.5											
Pterocladia lucida										4.4	0.8	13.1		3.1			0.4		1.2	1.2	0.3	0.3		0.6	0.8		1.2					
Rhodopeltis australis															0.1		0.2															
Rhodymenia spp.										1.1	0.6	6.9		0.9	0.2				0.2		1.9		0.2	0.7								
Sonderopelta coriacea											0.4																					
Thamnoclonium dichotomum										0.3											0.5											
Turfing red		0.9	7.3	1.2	0.4				0.5	5.2	0.6	2.0					3.8								4.7				5.0	0.5	0.3	
Unidentified Foliose reds					0.7					2.5	5.5	5.3		1.2	10.6	0.5	0.1		2.6	4.2		0.9	1.0	1.9	11.2	0.7	3.8					

Appendix 7. Mean cover (%) of seagrass and sessile invertebrates recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2005.

	Site/Depth																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	20	21	21	22	22	23	24	25	26	27	28
Species	5	5	5	5	5	5	5	5	5	5	5	10	5	5	5	5	5	5	5	10	5	10	5	10	5	10	10	5	5	5	5	5
Seagrasses																																
Amphibolis antarctica						2.4																										
Amphibolis griffithi					5																											
Heterozostera tasmanica																							0.5									
Invertebrates																																
Ascidians		0.9	0.2		0.4	1		0.1	0.2					1.9	0.2		0.5		0.1	0.3	0.7	0.4	3.1	1.4	0.3	0.3	0.4	0.3		1	1.1	0.2
Botrylloides magnicoecum																										0.4						
Bryozoans		0.1								1.9		2.3		0.5	0.1		2.2	0.1	6.4	2.7	7.1	17.6	8.1	9.2	0.7	0.2	3.4					
*Capnella sp_*																								0.7			1.2					
Cnemidocarpa pedata												1																				
Erythropodium hicksoni																								0.3		1.2						
Herdmania momus										0.3		2.9		0.5	0.2	0.2	0.2				1.6	1.4	3.1	0.5				0.4				
Hydroids												1.5		0.6																		
*Mopsea sp_*																						0.1										
Other sponges																												2.7	1.1	1.4	1.1	1.8
Phallusia obesa																				0.2												
Pyura gibbosa														0.1																		
Sponge (encrusting)											5	4.9		2	0.4	0.1	3.4	1.5	1.2	1.1	0.7	1.1	5.4	1.2	2.6		0.9	2.7	1.4	2.5	1.9	0.1
Sponges (erect)	2.2	4.6	2.6	3.7	3.5	1.7	0.7	1.8	2	4.5	1.5	9	1.9	8.5	1	0.7	2.7	3.1	5.4	9	3.4	4.1	7.7	6.9	3.6	7.7	11.8	4.9	1.7	1	2.1	1.1
*Zoanthid sp_*				0.5																												