Ecosystem monitoring in different management zones within the Jurien Bay Marine Park - results of 2004 surveys

Graham Edgar, Neville Barrett, Kevin Bancroft, James Brook and Kevin Crane

June 2005

Ecosystem monitoring in different management zones within the Jurien Bay Marine Park - results of 2004 surveys

Graham Edgar, Neville Barrett, Kevin Bancroft, James Brook and Kevin Crane

Summary

Densities of fishes, macroinvertebrates, corals and plants on subtidal rocky reefs within the Jurien Bay Marine Park (JBMP) were surveyed at 42 sites in October and November 2004. At the time of survey, JBMP had been created but legislation to implement the zoning scheme and hence enforce fishing restrictions was not in place. Survey data obtained in 2004 thus represent baseline conditions.

Monitoring surveys utilised the same underwater visual census techniques as used in monitoring programmes operating concurrently in Tasmania, New South Wales, South Australia and Victoria, forming part of a continental-scale study of the effectiveness of marine protected areas (MPAs). Twenty-five JBMP sites had been censused previously in 1999, 2000 and 2003, providing a detailed time series of baseline data. Following recommendations outlined in the 2003 report (Edgar et al. 2003), the monitoring program was considerably expanded in 2004 to encompass additional sites in the outer reef region and in inshore sanctuary zones, and data on rock lobsters were obtained from eight rather than four 50 m x 1 m transect blocks at each site.

The flora and fauna at different sites generally exhibited a low level of change between years compared to variation between sites. With a few exceptions, the biotic composition of sites was generally interspersed with respect to the three major MPA management zones – sanctuary, scientific reference and general use, with no zone possessing a predominance of one particular biotic assemblage type. The exceptions were a lack of deep reef sites located in sanctuary zones (none are included in the zoning plan), and somewhat anomalous sanctuary zone sites in the north near Fishermans Island and inshore opposite Boullanger Island (south of Island Point) that could not be paired in other zone types. Regardless, data collected encompassed most of the range of variability within zones, allowing unambiguous analysis of change through time. 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, other than ecosystem impacts caused by rock lobsters on deeper reefs.

The selection of 14 sites within each management zone provides sufficient replication to detect biologically meaningful change for common species and species richness indicators. Any future change in species richness per site of 2 taxa would be evident

as a significant effect, as would a doubling in rock lobster numbers within sanctuary zones relative to other fished zones.

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 management zones, but also information on indirect impacts of both rock lobster fishing and general recreational and commercial fishing on ecosystems, and regional effects associated with such factors as climate change.

We recommend:

- Baseline data on algal and sessile faunal assemblages be obtained from sites 31, 33, 34, 40 and 41 as a high priority in 2005
- Surveys of fishes and mobile invertebrates be repeated on an annual basis, and surveys of plant assemblages be conducted on a biennial basis, until biotic changes associated with MPA protection stabilise
- At least one sanctuary zone be extended to the outer reef region to fully protect the full range of biodiversity within JBMP. Additional sites within this new zone should then be monitored

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 and 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 field studies of 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 Jurien Bay Marine Park (JBMP) in October/November 2004. Coupled with data collected during the same season in 1999, 2000 and 2003, these surveys describe baseline conditions. Although JBMP was declared on 31 August 2003 and the different management zones marked by buoys, fishing restrictions had not been legally gazetted or enforced in 2004.

The JBMP 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), 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 JBMP area surveyed is centred around the towns of Jurien and Cervantes and extends along approximately 80 km of coastline to a distance of 5 km offshore (Fig. 1). The MPA is characterised by an extensive offshore development of limestone pavement, structured reef, seagrass beds, sand banks and islands that provide a protective barrier from the prevailing swells and seas. Wave height generally declines substantially eastward of a series of reefs running north-south at a distance of 5-7 km offshore. The inner three kilometres of coastal waters essentially form a protected lagoon with water depths <5 m. Isolated structured reefs outcrop in this area from sand and seagrass. The most highly protected management zones within the MPA comprise 7 sanctuary zones (4% of total area) and 3 scientific reference areas where commercial lobster fishing and shore-based line fishing are allowed (17% of total area).

Underwater visual censuses of fish, large mobile invertebrates and macroalgae were undertaken at a total of 14 sites within each of the major management zone types (general use, sanctuary and scientific reference area) in 2004. The survey methodology covers fish, invertebrate and plant assemblage types 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.

1. Methods

1.1 Sites

Methods used focus on reefs because these ecosystems are currently the most heavily exploited in the region and the most likely to show change following protection. Six categories of management zone afford different levels of protection in JBMP. We assess the three major zone types here:

1. Sanctuary zones provide the highest level of protection for vulnerable or specially-protected species and protect representative habitats from human disturbance. Passive activities are permitted and extractive activities are not.

2. Special Purpose (Scientific Reference) zones afford a high level of protection for marine flora and fauna. From vessels, rock lobster fishing is the only extractive activity permitted. From shore, line fishing, netting, rock lobster and abalone fishing are also permitted.

3. General Use zones are those areas of the marine park not included in sanctuary, special use or recreational zones. All activities are permitted in general use zones provided they do not compromise the ecological values of the marine park.

A total of 42 sites were surveyed during the three week period from 19 October to 5 November 2004. Sites examined extended from moderately sheltered reefs at 2 m depth to reefs exposed to oceanic swell at 12 m depth. Twenty-five sites were the same as previously censused in 1999, 2000 and 2003. The additional 17 sites were added to the monitoring program to encompass offshore reef habitats and also habitats in the large sanctuary zone south of the township of Jurien and small sanctuary zone at Wedge Island. Sites were selected to provide a balance between the different management zone types, including both inshore and offshore reefs, with the constraint that they needed to be of sufficient size for placement of a 200 m length transect. Fourteen sites were surveyed in each of the ‘General Use’, ‘Scientific Reference’ and ‘Sanctuary’ zone types.

1.2 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 JBMP monitoring method described below was specifically 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. Identical census protocols are concurrently being used for MPA monitoring in New South Wales, Victoria, Tasmania and South Australia.

Underwater visual census (UVC) is widely considered the most effective technique for monitoring reef communities at shallow-water sites in MPAs (Barrett & Buxton, 2002). UVC is non-destructive and allows the collection of large amounts of data on a broad range of plants and animals at defined spatial scales within a short dive period. Other techniques with widespread application, such as the use of baited underwater video to assess relative abundance of fished species or baited pots to assess rock lobster abundance, can provide important complementary information on population trends for key species but are limited to relatively few target species. In addition to heavily-exploited species that are predicted to recover in new MPAs, a comprehensive monitoring program should also encompass a range of unfished taxa to detect secondary effects of fishing.

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, which are 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 achieved 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 greatly 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.

1.3 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 reefs that were relatively flat with no obvious contour to follow, sketch maps were created to allow similar positions to be relocated on subsequent surveys.

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 in the middle 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 – transects 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. (2004). 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, 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). In order to increase precision of estimates for rock lobsters, a species of particular interest, counts for this species were recorded along both sides of the transect line (ie, a total of eight 1 m x 50 m transects per site).

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). Because of limited time, plants and sessile animals were not censused at five sites (numbered 31, 33, 34, 40 and 41 in Fig. 1 and Table 1).

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. Position was post processed in 1999 to overcome difficulties associated with selective availability of the GPS system. This was not necessary in subsequent years. Site positions and site details are listed in Table 1. All data were entered onto an Excel spreadsheet and checked for errors.

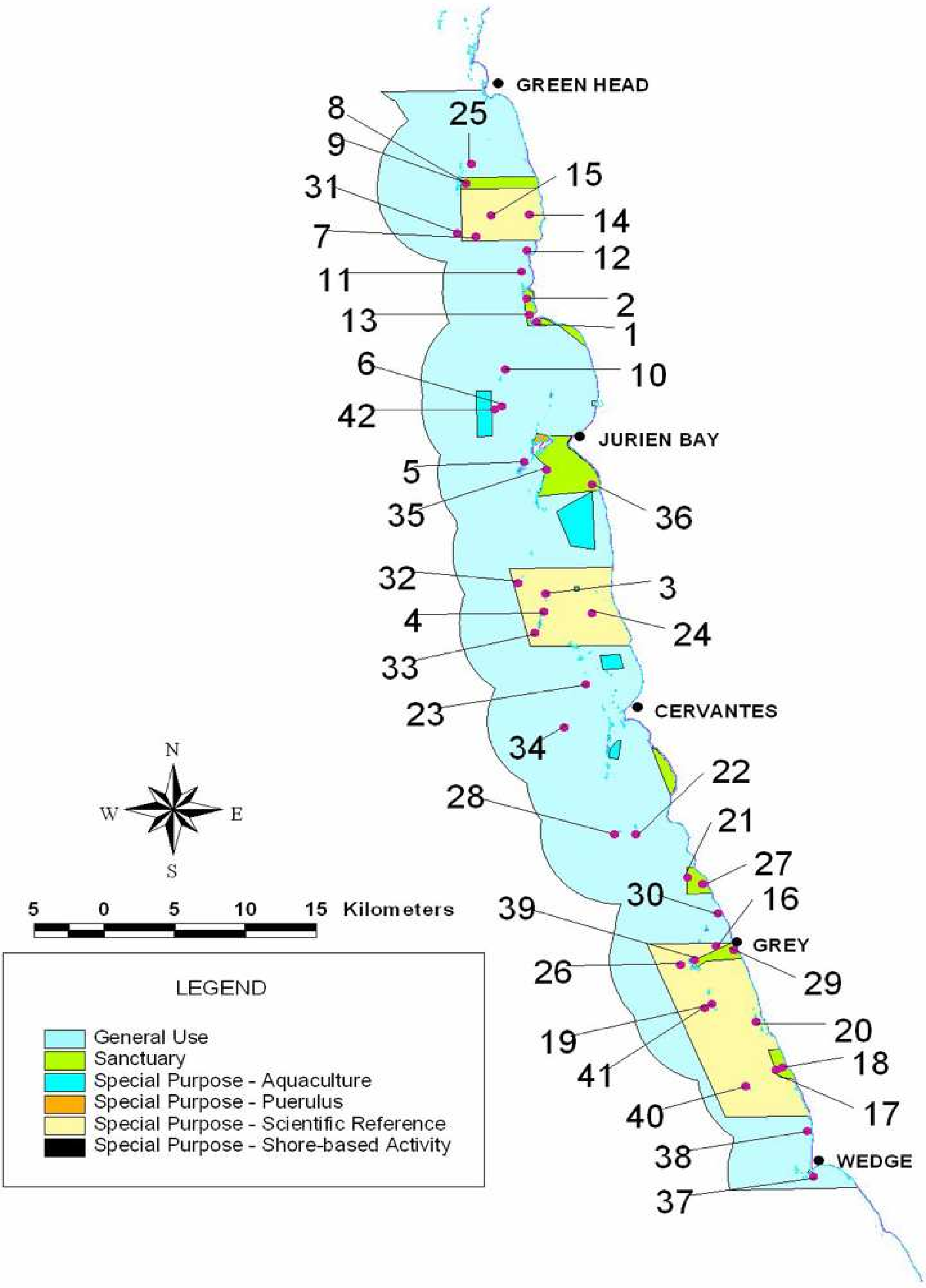

Fig. 1. Map showing the location of sites surveyed within the Jurien Bay MPA.

1.4 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 year and management zone fixed factors. 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.

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 changes over time in the plant and animal communities 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).

A power analysis was undertaken using the baseline data set to assess the minimum amount of change in species richness per site and density of lobsters in sanctuary zones that is necessary for any future change to be statistically significant (at $\alpha = 0.05$). This was done by boot-strapping, where the mean density of lobsters recorded at each site was firstly calculated, then the residual difference determined between this mean value and numbers censused for each year and each site, those residual difference measurements then randomised within sanctuary, scientific reference and general use zone groupings, and a constant added to all values within the sanctuary zone group only. This constant was then adjusted by iteration using the 'Solver' command in Excel until a one-way ANOVA (three levels: sanctuary, scientific reference and general use; df = 2/39) generated a probability value of 0.05 for the F-test. This procedure assumes that species richness and lobster numbers within sanctuary zones will increase in some future year relative to numbers in scientific reference and general use zones, and that the distribution of residuals in the future year will correspond with the distribution of residuals for baseline data. Rock lobster data but not species richness data were log (x+1) transformed.

Table 1. Site details for locations surveyed in Jurien Bay, with underwater visibility at time of survey. Positions given for sites 1-25 are those recorded by GPS in 2000 with selective availability off, for 26-42 are those recorded by GPS in 2004.

Site No.	Site name	Depth (m)	Latitude	Longitude	Zone	Date 99	Vis 99	Date 00	Vis 00	Date 03	Vis 03	Date 04	Vis 04
1	North Head 1	2	30º13.912'	114º59.924'	Sanctuary	26-Oct	7	23-Oct	12	7-Oct	5	19-Oct	6
2	Sandland Island	5	30º12.914'	114º59.524'	Sanctuary	26-Oct	7	23-Oct	9	15-Oct	6	19-Oct	6
3	Outer Rocks-Inner Coffins	5	30º25.285'	115º0.116'	Scientific	27-Oct	11	24-Oct	12	8-Oct	14	21-Oct	12
4	Outer Rocks (north) 2	5	30º26.026'	114º59.984'	Scientific	27-Oct	10	24-Oct	12	8-Oct	9	21-Oct	12
5	Escape Island	5	30º19.745'	114º59.263'	General	27-Oct	9	30-Oct	6	8-Oct	8	31-Oct	
6	Inner Seaward Ledge	5	30º17.404'	114º58.349'	General	28-Oct	10	30-Oct	10	14-Oct	12	24-Oct	9
7	Juddy Reef	5	30º10.275'	114º57.33'	Scientific	29-Oct	11	28-Oct	8	12-Oct	15	2-Nov	10
8	Fishermans Is 1	3	30º8.042'	114º56.935'	Sanctuary	29-Oct	10	25-Oct	15	13-Oct	15	20-Oct	10
9	Fishermans Is 2	3	30º8.042'	114º56.935'	Sanctuary	29-Oct	10	25-Oct	15	13-Oct	15	20-Oct	10
10	North Tail	6	30º15.87'	114º58.5'	General	30-Oct	14	28-Oct	15	11-Oct	18	30-Oct	
11	Australia Lump	4	30º11.788'	114º59.316'	General	30-Oct	10	28-Oct	6	15-Oct	8	22-Oct	6
12	Sandy Cape	2	30º10.882'	114º59.577'	General	30-Oct	10	26-Oct	9	15-Oct	10	29-Oct	9
13	North Head Island	4	30º13.61'	114º59.611'	Sanctuary	31-Oct	11	23-Oct	12	7-Oct	5	29-Oct	8
14	North Lumps	2	30º9.412'	114º59.73'	Scientific	31-Oct	15	26-Oct	9	11-Oct	16	22-Oct	7
15	Middle Lumps	5	30º9.407'	114º58.011'	Scientific	31-Oct	16	26-Oct	9	12-Oct	14	22-Oct	11
16	Longman Reef (off Grey)	3	30º40.131'	115º7.316'	Scientific	1-Nov	12	27-Oct	13	9-Oct	9	26-Oct	9
17	Flat Rock	3	30º45.343'	115º9.898'	Sanctuary	1-Nov	14	27-Oct	13	10-Oct	16	26-Oct	10
18	Flat Rock Reef	4	30º45.249'	115º10.174'	Sanctuary	1-Nov	9	27-Oct	8	10-Oct	13	26-Oct	6
19	Gazely Reef	4	30º42.557'	115º7.084'	Scientific	2-Nov	18	29-Oct	13	9-Oct	11	27-Oct	11
20	Kearn Reef	4	30º43.322'	115º9.042'	Scientific	2-Nov	16	28-Oct	13	10-Oct	13	27-Oct	11
21	Cavenaugh Reef	5	30º37.246'	115º6.143'	Sanctuary	2-Nov	15	31-Oct	6	9-Oct	11	26-Oct	6
22	Inner Seven Ft Reef	4	30º35.397'	115º3.889'	General	2-Nov	14	28-Oct	15	10-Oct	16	28-Oct	11
23	Sams Reef	5	30º29.108'	115º1.799'	General	3-Nov	18	31-Oct	6	11-Oct	17	1-Nov	
24	No Name Reef	3	30º26.111'	115º2.13'	Scientific	3-Nov	11	24-Oct	8	8-Oct	6	21-Oct	6
25	Fishermans Island	4	30º7.244'	114º57.219'	General	4-Nov	12	25-Oct	14	13-Oct	11	20-Oct	12

Table 1. (cont.)

Site No.	Site name	Depth (m)	Latitude	Longitude	Zone	Date 04	Vis 04
26	Outer Green Islands	12	30º40.886'	115º5.729'	Scientific	27-Oct	13
27	Cavanagh Reef	3	30º37.53'	115º6.802'	Sanctuary	27-Oct	8
28	Outer Seven Foot Rocks	10	30º35.391'	115º2.923'	General	28-Oct	16
29	Inshore Grey	5	30º40.3'	115º8.138'	Sanctuary	28-Oct	10
30	Inshore Grey North	2.5	30º38.772'	115º7.434'	General	28-Oct	11
31	Main Reef	10	30º10.15'	114º56.53'	General	2-Nov	
32	Offshore Hill River	10	30º24.8'	114º58.9'	Scientific	30-Oct	
33	Offshore Outer Rocks	10	30º26.908'	114º59.579'	Scientific	31-Oct	9
34	Big Wave Reef	10	30º30.87'	115º0.82'	General	1-Nov	18
35	Midshore Boullanger Is	2	30º20.08'	115º0.24'	Sanctuary	31-Oct	10
36	Inshore Boullanger Is	5	30º20.748'	115º2.2541'	Sanctuary	1-Nov	
37	Wedge Island	5	30º49.868'	115º11.463'	Sanctuary	4-Nov	8
38	North Wedge	5	30º47.951'	115º11.217'	General	4-Nov	8
39	SE Green Is	3	30º40.693'	115º6.36'	Sanctuary	5-Nov	7
40	Offshore Target Rocks	10	30º46.005'	115º8.518'	Scientific	5-Nov	12
41	Offshore Outer Gazaly Reef	10	30º42.716'	115º6.763'	Scientific	5-Nov	12
42	Outer Seaward Ledge	10			General	29-Oct	16

2. Results and discussion

2.1 Biotic similarities between sites

Given that the primary aim of the monitoring program was to identify differences in fished areas versus protected areas, the range of floral and faunal communities in sanctuary and scientific reference areas ideally should encompass the range of communities at general use sites. If not then trends through time may be confounded because the different community types in fished and unfished zones may track different environmental variates, and hence diverge into the future for reasons unrelated to effects of fishing. Excessive variation between years within sites will also complicate interpretation of future trends because patterns at sites are then affected by a high degree of between-year stochastic noise, and the power of tests will be low.

Overall biotic community changes between sites and years for fishes are depicted using MDS in Fig. 2, while densities of each fish species at different sites are shown in Appendix 1. Sites with high levels of biotic similarity lie adjacent to each other in Fig. 2, while sites with few similaries are positioned at distance. A high stress level is associated with this figure (0.19), indicating that care should be taken in interpretation as much of the variance between sites cannot be accommodated in a two-dimensional plot.

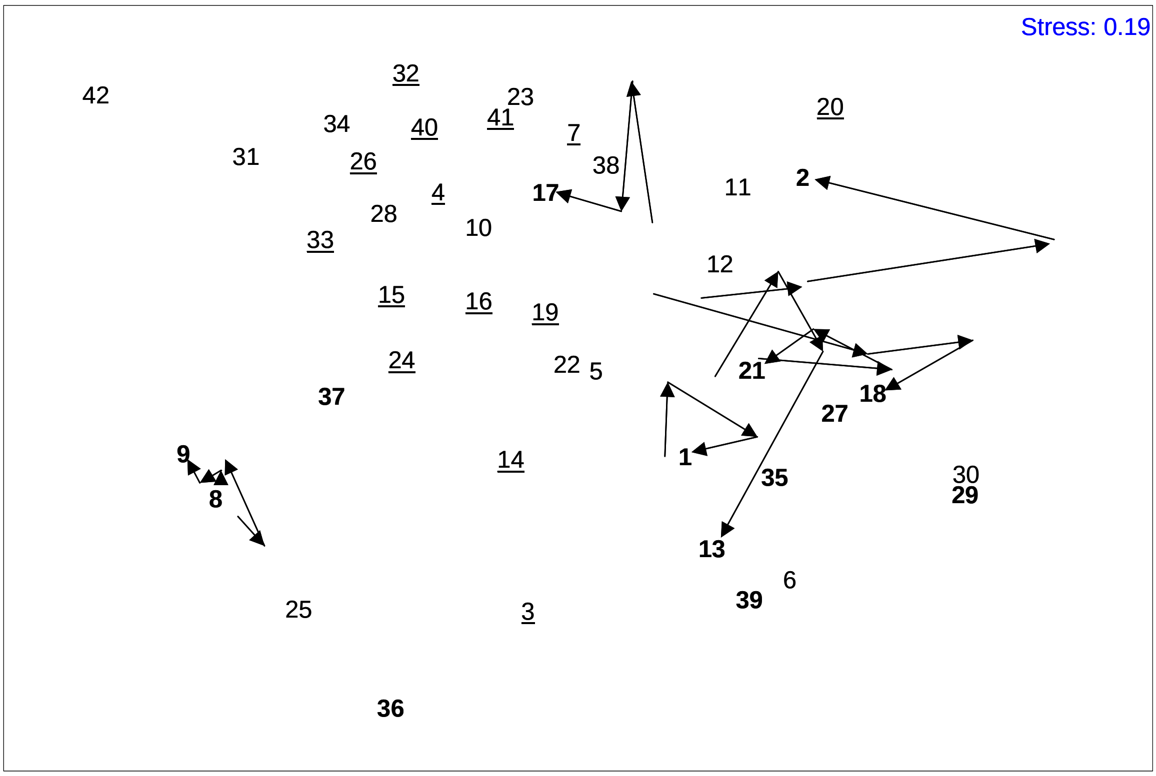

Fig. 2. Results of MDS showing relationships between sites for fish assemblages in 2004. Sites are coded by numbers listed in Table 1, with interannual change from 1999 to 2000 to 2003 to 2004 indicated by arrows for sanctuary zone sites. Site codes are underlined for scientific reference zones and shown in bold for sanctuary zones.

Variation between years within sites, as indicated in Fig. 2 for sanctuary zone sites only, was generally minor compared to total variation between sites. Thus, the fish fauna surveyed is reasonably stable. Nevertheless, a few sites exhibited substantial variation between years, most notably site 2, where the abundance of the fish species *Coris auricularis, Parma mccullochi* and *Scorpis georgiana* was anomalously low in 2003.

With some exceptions, fish species assemblages at sites in different management zones were overlapping. The two sanctuary sites at the Fishermans Islands (sites 8 and 9) were slight outliers in the plot, largely because subtropical species such as *Anampses geographicus, Pomacentrus milleri, Thalassoma lunare* and *T. lutescens* occur in disproportionately high abundance at these northern sites and nearby site 25. Site 36, a shallow site in the sanctuary zone inshore of Boullanger Island, was also anomalous. None of the sanctuary zone sites possessed a fish fauna comparable to the deep water offshore sites positioned in the upper left of Fig. 2, with site 17 (Flat Rock) most closely approaching this assemblage type.

Patterns of biotic similarity between sites and years for invertebrates were generally comparable to those for fishes (Fig. 3). Stress associated with this plot was again very high (0.22), indicating that considerable variation in biotic assemblages between sites has not been depicted. The deep offshore fauna at sites such as 33 and 34 was distinctly different to that found at inshore sites, including all sanctuary zones.

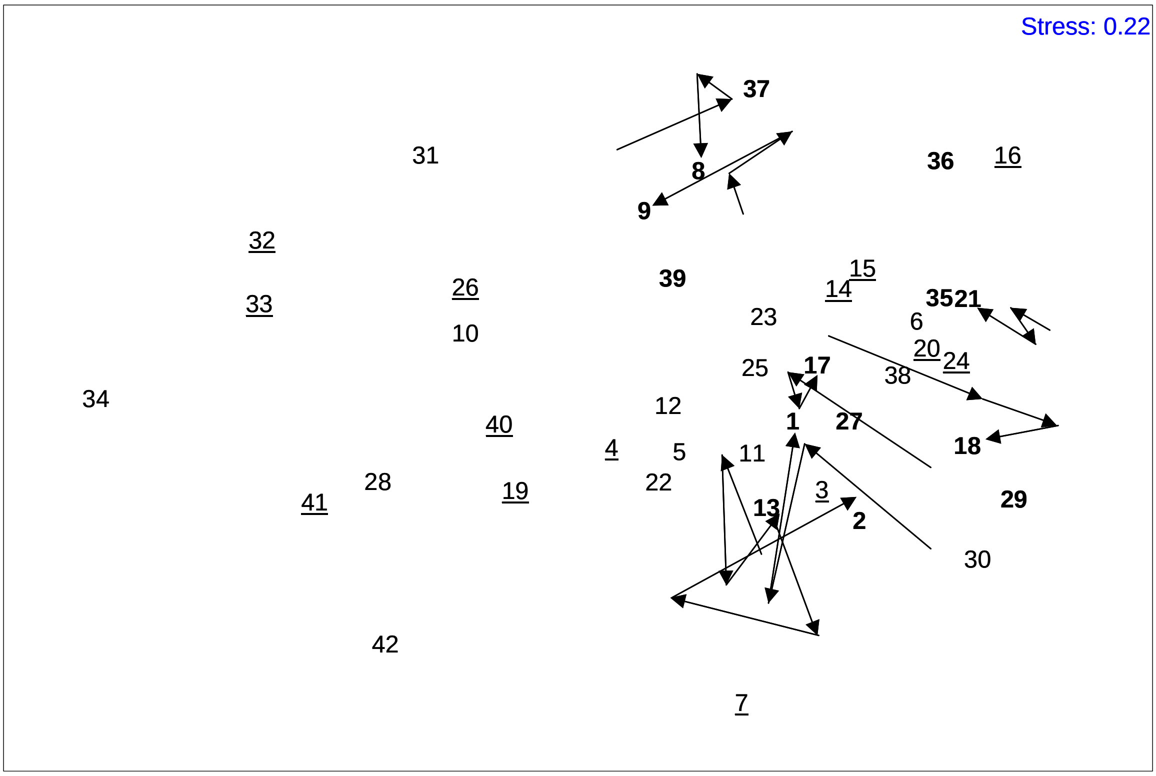

Fig. 3. Results of MDS showing relationships between sites for macroinvertebrate assemblages in 2004. Sites are coded by numbers listed in Table 1, with interannual change from 1999 to 2000 to 2003 to 2004 indicated by arrows for sanctuary zone sites. Site codes are underlined for scientific reference zones and shown in bold for sanctuary zones.

The anomalous nature of the Fishermans Island sites (8 and 9) was particularly reflected in the MDS for plants and sessile invertebrates (Fig. 4). Red algal species that were common at most sites such as *Callophycus oppositifolius* and *Pterocladia lucida* were largely absent, whereas corals such as *Pocillopora damicornis* were relatively common at these northern sites. Variation within sites between years tended to be lower than for fish or macro-invertebrates, with only data from the two Fisherman Island sites overlapping amongst sanctuary zones studied. Thus, sessile plants and animals apparently exhibited greater stability through time than for the mobile animals groups.

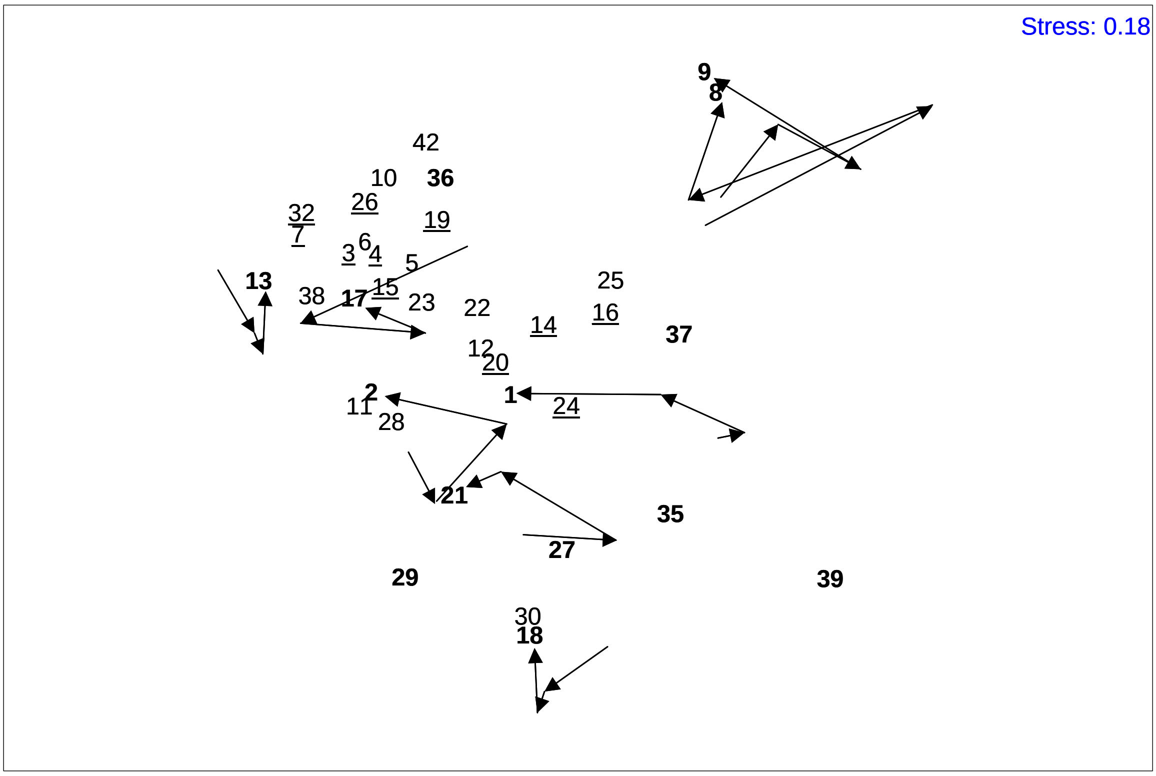

Fig. 4. Results of MDS showing relationships between sites for plant and sessile animal assemblages in 2004. Sites are coded by numbers listed in Table 1, with interannual change from 1999 to 2000 to 2003 to 2004 indicated by arrows for sanctuary zone sites. Site codes are underlined for scientific reference zones and shown in bold for sanctuary zones.

2.2 Patterns of species richness

Patterns of biodiversity at the scale of site have been assessed using total number of species recorded in four 50 m transects at a site. For both fish and mobile macro-invertebrate species, results were highly consistent between management zones and survey periods, with an average of ≈21 fish (Fig. 5) and ≈11 macro-invertebrate (Fig. 6) species sighted at each site. No significant differences in species richness between zones or between years were evident when data were analysed using a two-way ANOVA (Table 2).

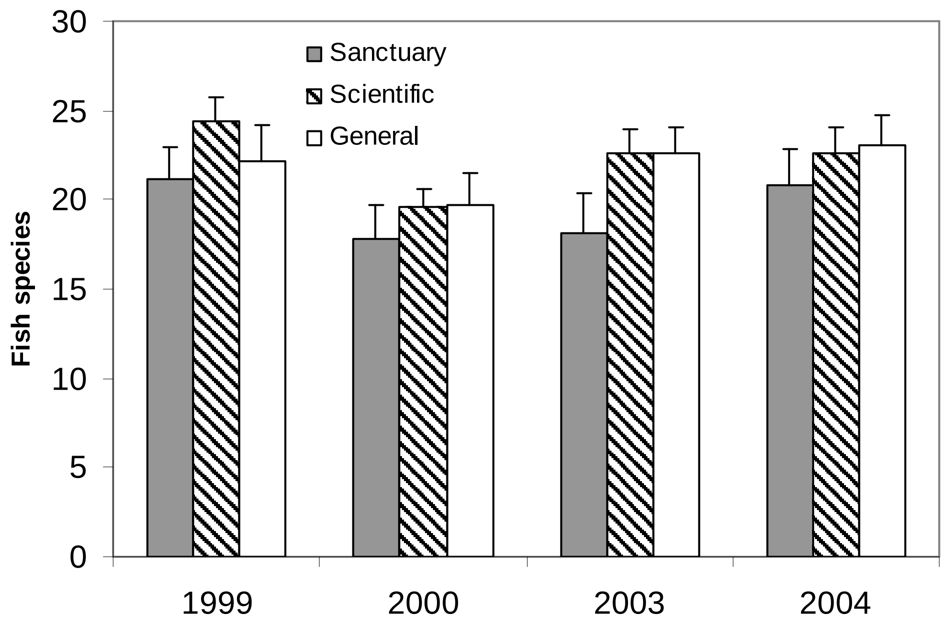

Fig. 5. Mean number of fish species per site (± SE) in different management zones.

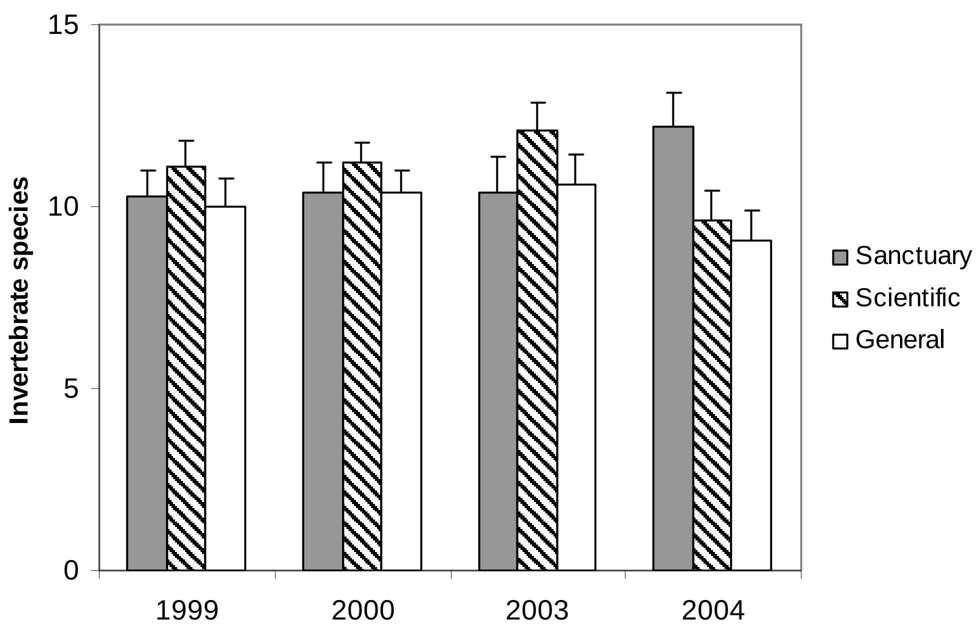

Fig. 6. Mean number of mobile invertebrate species per site (± SE) in different management zones.

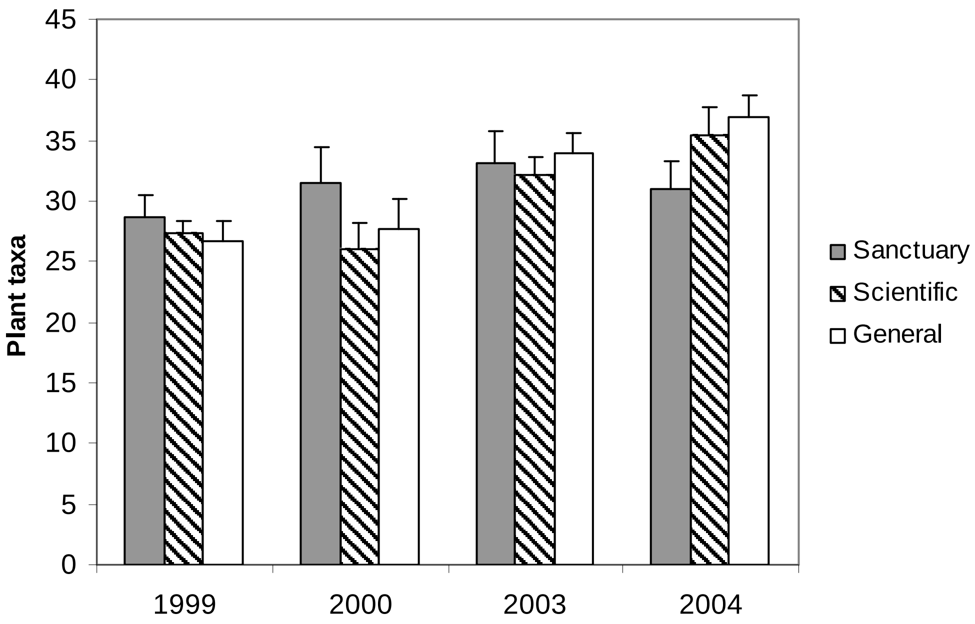

Fig. 7. Mean number (± SE) of plant and sessile invertebrate taxa per site in different management zones.

Table 2. Results of two-way ANOVAs (fixed factors year and zone) using data on number of species per 50 m transect for the 25 sites censused on four occasions.

Factor	DF	SS	MS	F	P
Fishes					
Year	3	166.0800	55.3600	2.1647	0.0979
Zone	2	134.8678	67.4339	2.6368	0.0772
Year * Zone	6	58.3922	9.7320	0.3805	0.8896
Error	88	2250.5000	25.5739		
Invertebrates					
Year	3	7.2800	2.4267	0.4807	0.6966
Zone	2	13.4574	6.7287	1.3328	0.2690
Year * Zone	6	18.4388	3.0731	0.6087	0.7227
Error	88	444.2639	5.0485		
Plants and sessile invertebrates					
Year	3	1191.8400	397.2800	10.3970	0.0001
Zone	2	70.1463	35.0731	0.9179	0.4032
Year * Zone	6	99.6843	16.6141	0.4348	0.8538
Error	88	3362.5694	38.2110		

The number of plant and sessile invertebrate taxa species recorded at sites was also evenly distributed at sites in different management zones (Fig. 7); however, significant change occurred between years (Table 2). Although this variation is probably due in part to changing environmental conditions, it also likely reflects the use of different observers in different surveys. In contrast to fish and macro-invertebrates where taxa other than hermit crabs are all categorised at the species level, algae were in some cases grouped at a higher taxonomic level. The number of algal species identified during dive transects increases with experience, as does the total number of taxa recorded. Regardless, any such diver bias should not affect tests of reserve effects where relative patterns between zones are of most interest, and effort of individual divers is not concentrated in particular zones.

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 sanctuary versus general use zones. Power analyses indicated that any future changes in species richness per site of 2.0, 1.4 and 2.1 taxa in sanctuary zones would generate a significant change ($\alpha = 0.05$) for fishes, invertebrates and plants, respectively.

2.3 Variation in faunal and floral density

Patterns of abundance for the more common animal and plant species were relatively stable at sites across the four year period of monitoring (Appendices cf. data presented in Edgar et al. 2003). This stability is not surprising given that most of the species observed are relatively long-lived and either sedentary or, for fishes, reside permanently on their home reef.

In this baseline report, our primary aim has been to present basic data on species abundance within appendices; however, we here discuss three of the more interesting response variates in greater detail. Sanctuary zones are predicted to primarily enhance numbers of large exploited species such as jewfish, baldchin groper and rock lobster. 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 the two kyphosid (buff bream) species *Kyphosus sydneyanus* and *K. cornelii* were excluded from this analysis because these species are avoided by fishers. Inclusion of data for kyphosids biases analyses because of high sporadic counts when schools of these fishes were sighted.

Patterns of abundance of large fishes did not vary greatly between zones, although counts were considerably lower in 2003 than in other surveys. Despite this, a two-way ANOVA using data on abundance of fishes >325 mm length other than kyphosids for the 25 sites surveyed on four occasions indicated no significant differences between years (df = 3/88, MS = 39.00, F = 2.65, $p = 0.054$), nor between management zones (df = 2/88, MS = 19.60, F = 1.33, $p = 0.27$) nor for year x zone interaction (df = 6/88, MS = 9.35, F = 0.63, $p = 0.70$).

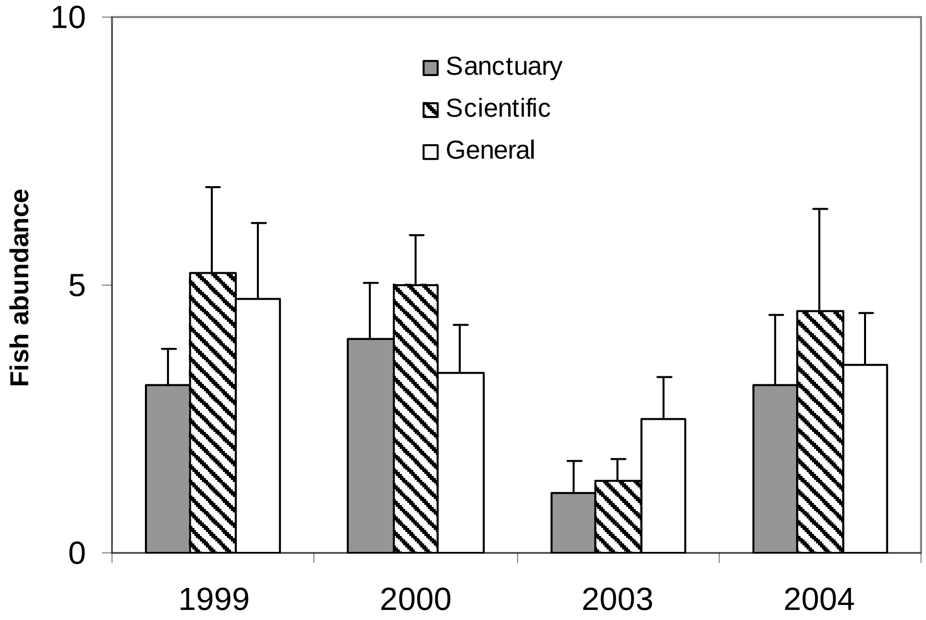

Fig. 8. Mean abundance (± SE) of fish >325 mm estimated length other than than kyphosids per site in different management zones.

Mean rock lobster abundance in sanctuary zone sites surveyed increased greatly in 2004 (Fig. 9) due to the anomalous nature of a single new site (36, inshore Boullanger Island), where 206 animals were observed in the eight 50 m blocks. Nevertheless, when data for the 25 sites investigated on all four sampling occasions were analysed by two-way ANOVA, no significant change between years (df = 3/88, MS = 1.72, F = 2.46, p = 0.07) nor reserve x year interaction (df = 6/88, MS = 1.14, F = 1.63, p = 0.15) was evident. A marginally significant difference between management zone types was found (df = 2/88, MS = 2.19, F = 3.13, p = 0.049). For this ANOVA, data were ln (x+1) transformed and abundance data from the eight transects at each site in 2004 divided by two to maintain consistency in area sampled with the four transects surveyed per site in other years.

Power analysis indicated that a future 94% increase in mean density of rock lobsters in sanctuary zones relative to the general use and scientific reference zones (equivalent to a mean rise of 0.8 animals per 50 m transect block) will be detectable as significant change.

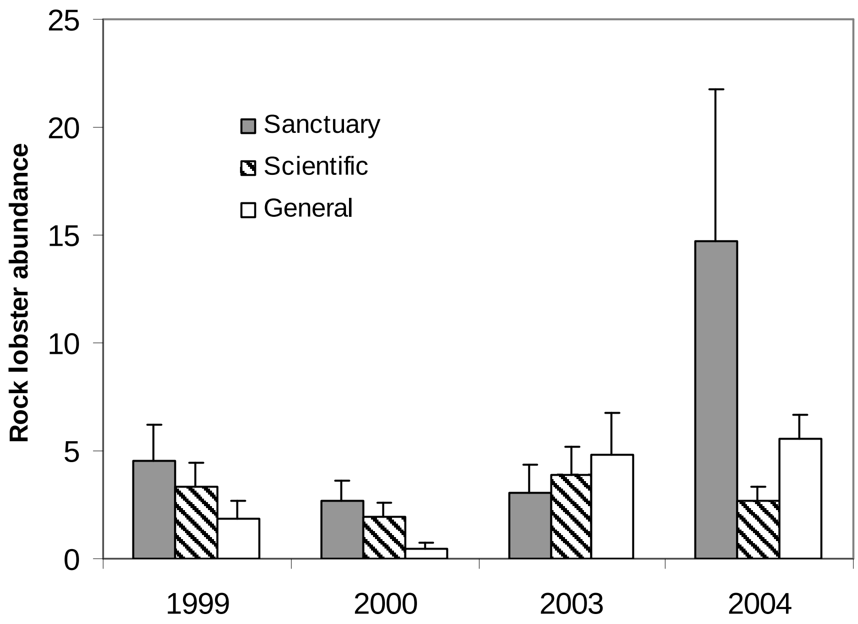

Fig. 9. Mean abundance (± SE) of rock lobsters per site in different management zones.

A different pattern of variation was evident when total cover of foliose plants was plotted (Fig. 10). Variation between sites in plant cover is very low, resulting in small error bars and high power to detect differences. Within each year of survey, plant cover was lowest in sanctuary zones. This was indicated by a significant ‘zone’ effect in the two-way ANOVA (df = 2/88, MS = 3371.16, F = 3.54, p = 0.033). Zonal differences in plant cover were probably caused by sanctuary zones being disproportionately located within 1 km of the coast, and having a relatively high proportion of bare sand patches overlaying the reef.

Plant cover also varied significantly between years (df = 3/88, MS = 5015.44, F = 5.27, p = 0.0022), possibly as a consequence of diver bias. No significant interaction between zones and years was detected (df = 6/88, MS = 212.58, F = 0.2234, p = 0.97).

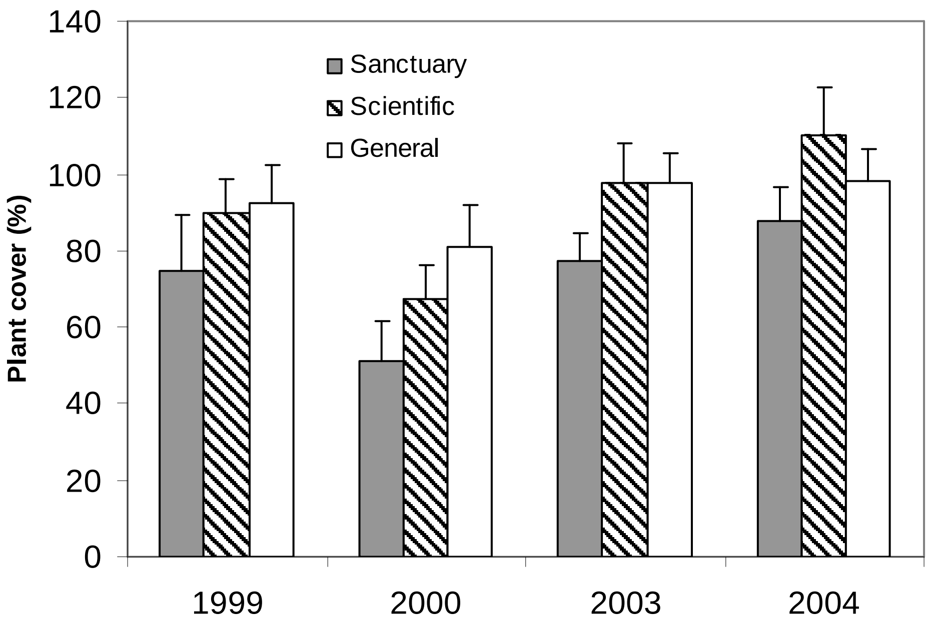

Fig. 10. Mean total cover (± SE) of foliose plants per site in different management zones.

3. Conclusion and recommendations

The JBMP reef monitoring program was greatly expanded in 2004 through the addition of sites on the outer reef and sanctuary zones. The immediate priority in surveying these extra sites was the collection of density information for fishes and large invertebrates. Because of time constraints, baseline data on densities of plants and sessile invertebrates were not obtained at five sites. Collection of this missing baseline information should be afforded higher priority during 2005 surveys than repeated surveys of plant cover at other sites. Any future changes in plant assemblages associated with protection from fishing in sanctuary and scientific zones are likely to take many years to manifest themselves compared to changes in fished species. Consequently, little loss of important information should occur if plant surveys are undertaken at two-yearly rather an annual intervals.

Interpretation of change at outer reef sites will be complicated by the lack of any sanctuary zone with deep reef habitat. Ecosystem effects involving rock lobsters at outer reef sites cannot be detected because comparisons are only possible between general use and scientific reference zones, in both of which rock lobster fishing is permitted. Clearly, the lack of water depths >8 m in sanctuary zones is a major deficiency in the JBMP zoning system, not only because the full range of ecosystem types remains to be adequately protected, but also because an adequate scientific evaluation of effects of rock lobster harvesting cannot be undertaken. Given the importance of such an evaluation, including relevance to export permits granted under the Environmental Protection and Biodiversity Conservation Act, we recommend that extension of sanctuary zones to the outer reef area is afforded highest priority when management zone boundaries are reviewed, and that such extension is accommodated by the addition of extra sites to the monitoring program.

Two sites in the largest sanctuary zone, located inshore of Boullanger Island, were also added to the JMBP reef monitoring program during 2004. Appropriate sites were difficult to locate in this zone because seagrass and sand predominated throughout. The most inshore monitoring site within this zone (site 36) is somewhat anomalous, with a distinctive fauna including over an order of magnitude more rock lobsters than other sites. This site is also utilised by CSIRO in their regional monitoring study.

As a result of baseline surveys conducted in the JBMP from 1999 to 2004, we now have a quantitative broad-scale description of inter-site and inter-annual variation in communities of reef fishes, large mobile invertebrates and cover-forming plants and animals. The census of organisms at 14 sites within each management zone type provides a powerful basis for detecting biotic change associated with fishery restrictions.

4. Acknowledgments

We would like to acknowledge the Australian Research Council and the Strategic Research Fund for the Marine Environment for funding surveys in 2004. We would particularly like to thank the logistical and technical assistance provided by the Department of Conservation and Land Management (Moora District Office and the Marine Conservation Branch).

5. References

ANZECC, 1999. Strategic plan of action for the national representative system of marine protected areas. A guide for action by Australian Governments. Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas, Environment Australia, Canberra, 80 pp.

Barrett, N.S., Buxton, C., 2002. Examining underwater visual census techniques for the assessment of population structure and biodiversity in temperate coastal marine protected areas. Tasmanian Aquaculture and Fisheries Technical Report Series 11, 1-114.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol. 18, 117-143.

Davis, G.E., 1981. On the role of underwater parks and sanctuaries in the management of coastal resources in the southeastern United States. Env. Conserv. 8, 67-70.

DeMartini E.E., Roberts D., 1982. An empirical test of biases in the rapid visual technique for species-time censuses of reef fish assemblages. Mar. Biology 70: 129-134.

Dugan, J.E., Davis, G.E., 1993. Introduction to the International Symposium on Marine Harvest Refugia. Can. J. Fish. Aquat. Sci. 50, 1991-1992.

Edgar, G.J., Barrett, N.S., 1999. Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. J. Exp. Mar. Biol. Ecol. 242, 107-144.

Edgar, G., Barrett, N., Bancroft, K. 2003. Baseline surveys for ecosystem monitoring within the Jurien Bay Marine Park, 1999-2003. TAFI Internal Report, University of Tasmania.

Edgar G.J., Barrett N.S., Morton A.J., 2004. Biases associated with the use of underwater visual census techniques to quantify fish density and size-structure. Journal of Experimental Mar. Biology and Ecology 308: 269-290.

Fairweather, P.G., McNeill, S.E., 1993. Ecological and other scientific imperatives for marine and estuarine conservation. In: Ivanovici, A.M., Tarte, D., Olsen, M. (Eds.), Protection of marine and estuarine areas: a challenge for Australians. Occasional Paper No. 4, Australian Committee for IUCN, Sydney, pp. 39-48.

Green, R. H., 1979. Sampling design and statistical methods for environmental biologists. Wiley, Chichester, UK.

Jennings, S., Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. Adv. Mar. Biol. 34, 201-352.

Kulbicki M. & Sarramega S., 1999. Comparison of density estimates derived from strip transect and distance sampling for underwater visual censuses: a case study of Chaetodontidae and Pomacanthidae. Aquatic Living Resources 12: 315-325.

Roberts, C.M., Polunin, N.V.C., 1991. Are marine reserves effective in management of reef fisheries? Rev. Fish Biol. Fish. 1, 65-91.

Roberts, C.M., Polunin, N.V.C., 1993. Marine reserves: Simple solutions to managing complex fisheries? Ambio 22, 363-368.

Roberts, C.M., Hawkins, J.P., 2000. Fully-protected marine reserves: a guide. WWF, Washington.

Sobel, J., 1993. Conserving marine diversity through marine protected areas. Oceanus 36, 19-26.

Thompson A.A., Mapstone B.D., 1997. Observer effects and training in underwater visual surveys of reef fishes. Mar. Ecology Progress Series 154: 53-63.

Underwood A.J., 2000. Importance of experimental design in detecting and measuring stresses in Mar. populations. Journal of Aquatic Ecosystem Stress and Recovery 7: 3-24.

Walters C.J. & Holling C.S., 1990. Large-scale management experiments and learning by doing. Ecology 71: 2060-2068.

Zann, L.P., 1995. Our sea, our future. Major findings of the state of the marine environment report for Australia. Great Barrier Reef Marine Park Authority, Townsville, Queensland.

Appendix 1. Total abundance of fishes recorded in four 50 m x 10 m transects surveyed at different sites in 2004.

Species	Site																																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Acanthaluteres vittiger			1																																							
Achoerodus gouldii																										1														2		1
Anampses caeruleopunctatus																																										
Anampses geographicus								11	2							1									14	1		1			1			1			1					
Anoplocapros amygdaloides												0		1		1					1									1							3					2
Anoplocapros lenticularis	1															1		1				1															1					1
Apogon cyanosoma																																										
Apogon victoriae	6	1	1									5	3	1							1						2		3	1					1	25	2	2	11			
Arripis georgiana																																										
Austrolabrus maculatus	3		3	4			10	21	21	2					16	20	1	4	4		14		1	6	6	26		17	2		19	14	9	34	6	20	6	3	13	13	15	72
Bodianus frenchi							1									5	1							7	1			3			8	2	3	2		5		1			1	4
Callanthius australis																															3											
Caranx dentex			40																														1			60						
Chaetodon assarius															1										5		2			2	1		1		1	16						
Cheilodactylus gibbosus	2																																				3					
Cheilodactylus rubrolabiatus									1			1				1	3	6							1		2	1			1		1				6	2		2		1
Chelmonops curiosus	3		1	1	1		1	4	3		1	2	1	2	7	7	4	2		3	2	3		8		4		6		4	5	2	1	12		11	12	9				8
Choerodon rubescens								3							2										7	2		2			18	1	2	5		13				2		
Chromis klunzingeri																																				16			2			
Chromis westaustralis																															71	155	40	145								615
Cirripectes sp.								4	3																1																	3
Coris auricularis	170	68	135	227	125	159	92	333	279	193	74	46	53	116	243	115	47	54	121	26	80	176	97	197	374	196	79	212	54	34	406	104	212	194	93	309	174	55	101	79	113	333
Dactylophora nigricans				1																										1						1						
Dotalabrus alleni	1		1		3		4			3					1		3		10	4	3	22	2	1		3	2	8	2		1	7	4	1	4	1						1
Dotalabrus aurantiacus			3								1					1																										
Enoplosus armatus						4		1	1					2	2	1					3		2	2	10					1						3		16	3			
Epinephelides armatus			1	1			2	2	2	2					3	5	3	3	1		2	1	2	1		2		1			3	2	3	3			7	2			4	3
Girella tephraeops																																										
Girella zebra																																										
Glaucosoma hebraicum										1							1									1					2			3								1
Halichoeres brownfeldi	60	13	16	2	39	47	1	38			18	19	67	11	12	13	34	11	12		96	62	5	4	43		52		80	54		1	1		73	21	3	18	73		1	
Helcogramma decurrens								1																																		
Hypoplectrodes maccullochi																																										
Hypoplectrodes nigrorubrum					1																																					
Hypoplectrodes wilsoni																																					1					
Kyphosus cornelii	1		10	37	7		9	384	298	57	2	32	4	89	5		39		95			49		57	677			35			2	24	138	10			208	2		4	4	7
Kyphosus sydneyanus	5		9	2	10					10		2	6	75	7		55		1			12		96		6	8				2	20				7	26			11		103
Labracinus lineata	2	4	1					5		1	1	5	4	2		18	2			1	1	2	3	2	1				2	3						10		1				
Labroides dimidiatus																																										
Meuschenia flavolineata			2																						1											1						
Meuschenia freycineti																										1																
Meuschenia galii			3	1										1		2						1	1			1		2						1						5		1
Meuschenia hippocrepis		1																				1			1	1								2						1		6
Microcanthus strigatus																																					1					
Neatypus obliquus				80											80		27				11		53	2		1		10		10	71	61	2	21		23		112		9		135
Notolabrus parilus	72	80	25	42	51	15	26	38	54	37	51	50	72	52	64	66	34	141	56	122	50	90	26	59	51	54	148	55	254	205	65	33	40	60	111	24	57	31	42	35	27	23
Octopus sp.																																										
Odax acroptilus						1	1								2		1		1		1					1		1		1			1	1				2	2			
Odax cyanomelas			21	67	12	9	13	1	1	4	2	5	14	1	5	9	26		30		1	3	2		7	2	2	2	2	2	1	4	1	10	13	56		5	1	2	1	4
Ophthalmolepis lineolata			1	24	3	9	19			37	5		1		4	3			9	1	2	4	38			13		50			26	55	28	43	1			4		29	43	9
Orectolobus ornatus																																				1						
Othos dentex			1												2	1																										

Appendix 1 (cont.). Total abundance of fishes recorded in four 50 m x 10 m transects surveyed at different sites in 2004.

Species	Site																																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Parapercis haakei																					1				1				2													
Paraplesiops meleagris										1	1						3			2					1			7			5							1				
Parma mccullochi	10	61	12	79	23	2	25	238	122	32	15	26	22	44	91	113	63	3	40	46	17	97	87	83	55	83	6	32			47	26	38	50	3	45	70	32	16	107	33	106
Parma occidentalis	30	1	2			2		2	21	1	1	8	10	4				36	1	10	16	8			31		15		11	17			1		13	22	3	14	8			
Parma victoriae																		1																								
Parupeneus chrysopleuron								1	3																											9						
Parupeneus signatus					2			16	10						1										15	1		2			2	1	1		8	2	1					
Pelates sexlineatus																								3																		
Pelsartia humeralis																																				1			73			
Pempheris affinis																																										
Pempheris klunzingeri		132	177					61	28		155	1	534		13	11	70						31		3						75		5			86	45	17		1	1	60
Pempheris multiradiata										1			3			4			1	4						1					3		1	3		5	2	11		1		7
Pentapodus vitta	1				1			1									3							1											2	8		5				
Phyllopteryx taeniolatus			1																																							
Pictilabrus laticlavius	1		9	5	6	9	6	2		2	2				9	8	5	2	5						2	4	2	4	5	3		2	2		2	4		3	1	2	1	1
Pictilabrus viridis	1	1	210	37	5	5	13	1		13	14	33	4		2	18	31	2	40	28		43	54	1			8	1				1		1	5	3	13			10		
Plagiotremus rhinorhynchos																									1																	
Plagiotremus tapeinosoma																																										
Plectorhinchus flavomaculatus	3		2					2	2					5	3	5		5						6	4			1		2	1			2	1	13	2	2	4			2
Pomacentrus coelestis																																										
Pomacentrus milleri	9	2						41	22		5	18	6	19	6			1						5	23			1							1	208	1					
Psammoperca waigensis								1	2							1									1													3				
Pseudolabrus biserialis	1		8	8	6		3	43	41	11				1	20	22	1			1			8	6	1	70		38			31	36	38	34		6	14	2		17	23	100
Pterois volitans																																										
Rhabdosargus sarba																																										
Scarus ghobban																																										
Schuettea woodwardi					4						2				2	1										8																
Scobinichthys granulatus																							1																			
Scorpis aequipinnis																																								2	1	
Scorpis georgiana	4	13	1	5						5	4	7	15	4	9	6	13	4	6	10	1	4	2			10	5	4		1	6	8	6	12			10	12		4	4	
Sepia apama																																										
Seriola hippos																										2																1
Seriola lalandi																																										1
Siphonognathus beddomei																												2														
Siphonognathus caninus					4																					1						3										
Siphonognathus radiatus					1																												3									
Sphyraena obtusata																																										
Stegastes obreptus								34	13			1		2											6						1					1	12					
Stethojulius bandanensis																									5																	
Suezichthys cyanolaemus								1						1																						3						
Thalassoma lunare								29	44										3			1			21												6		6			
Thalassoma lutescens			3	2	2	2		64	34	3				1	10				3			2		2	14						2		1	1	4		20		3	10		3
Thalassoma septemfasciata							1		1					2											12																	
Tilodon sexfasciatus																																					1					
Torquigener pleurogramma	1	14	39				1			5	2	5	2												1										2							
Trachinops noarlungae															123											8					10		26									11
Trachurus novaezelandiae																																										
Unidentified fish				1						2																																
Upeneichthys vlaminghii																												1								1						
Urolophus sp.					1																																					
Urolophus sp. (striped stingaree)																																										

Appendix 2. Total abundance of mobile macro-invertebrates recorded in four 50 m x 1 m transects surveyed at different sites in 2004.

Species	Site																																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Echinoderms																																										
Allostichaster polyplax		1																																								
Amblypneustes leucoglobus																		5						1			1		15	3			1									
Amblypneustes pachistus																																										
Amblypneustes sp.																																										
Anthaster valvulatus																																										
Cenolia trichoptera	3											1				42	9	14		60	40		1	25			1		61	9					20	21		3				
Centrostephanus tenuispinus								5	3	3									3																	2				10		
Clarkoma sp.																																				2						
Comatula purpurea																																										
Coscinasterias muricata																				2															2	1						
Echinaster varicolor																																										
Fromia polypora															3	6	1						2			18		1			3	12	8	9						10	6	45
Heliocidaris erythrogramma	15	49	31	10	13	150	32	10	2		15	6	24	36	254	219	40	12	2	168	279	3	70	42	6		16		13	22					136	85	1	255	11	11		
Holopneustes porossimus		6	3	4	1		3			3	12	19	7		1		2	1	2	4		7	1															2		1		6
Holopneustes sp. (red)		5	3				33					1				1	6			1						1	1										1	1				8
Holopneustes sp. (WA flattened test)																						1																				
Pentagonaster dubeni		2			1								1	4			4							2	1				1							10		2				
Petricia vernicina	1	2	1		3					1			1	2	2		10			2			3	4	1	1			2						1	5		2	2			
Phyllacanthus irregularis	1	7	1	3				10	13	2	3	3	3	6	12	59	11	15	3	7	6	5	11	44	6	1	1	2	2	2		1			12	93	5	2		4		
Stichopus ludwigi									2								1	1							1				1						2							
Stichopus mollis		1	2		1	2							1	4	5		1	3						7	3		1		7						18	7	2		4			
Tosia australis																																										
Tripneustes gratilla						1																				1																
Unidentified starfish																								1											9							
Molluscs																																										
?Dendrodoris tuberculosa																																										
Aplysia dactylomela																									1																	
Aplysia sp.																																			2		1					
Astraea tentorum					4	1		2				3		70	1					1	1			2	1	1					3		1		1	2						
Campanile symbolicum	30	38	8		1	6	1				20	4	2	43	7		4	18		14	7	2		4	10		21		17	16					31	2	1					
Charonia lampas rubicunda										1									1																							
Charonia powelli																																										
Cypraea venusta																																		1								
Dicathais orbita	2	3	1	2			6	28	22	2	2		1	9	10	5	16		2	3	4		3		1	2	1				9	3	6		4	1	1	1	2	1		1
Haliotis elegans		1																																								
Haliotis rubra																																						2				
Haliotis scalaris		2				1										2	2						12																			
Melo miltonis										1								1			1			1					1													
Octopus sp.	1							1					1					1			1														1	1	1					
Ranella australasia																																										
Sepia apama																		1																							1	
Turbo jourdani															1	1	1						1			2			1					1		1					1	
Turbo pulchra (intercostalis)	1			3	1	4	8	8	2	13		5	1	6		16				31	10	2	6	1		1	6	1				2			1	1		5				
Turbo torquatus	1	3	4	30	38	11	21		1	17	2	65		3	1		14		33	3			1			5		1				3	15	1	28	2		14		2	1	
Crustaceans																																										
Unidentified hermit crab	9		3		10	4		16	17	1	5	13		27	17	9	6	7		13	4	3	4	6	8	5	12		4		4			1	16	13	5	1	6		2	1
Naxia aurita																																										
Paguristes purpureantennatus																																										
Panulirus cygnus	10	5	2	11	9	4		3	15	1	11	5	46	5	5	0	21	39	10	10	20	20	20	14	8	5	13	13	28	20	7	0	1	0	2	207	1	12	2	2	10	26
Plagusia chabrus																1											1															
Trizopagurus strigimanus																																										
Unidentified crab											1												1																			

Appendix 4. Mean cover (%) of brown algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2004.

Species	Site 1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0
Caulocystis uvifera	0.3																				
Chlanidophora microphylla			0.2													0.1		0.1			
Colpomenia peregrina																1.1				0.5	0.3
Colpomenia sinuosa								0.2							0.1	0.2					
Cystophora brownii												1.7									
Cystophora spp.																					
Cystoseira trinodis																					
Dictyopteris spp.																0.2			1.1		
Dictyota spp.			0.2	0.8			0.2			0.2	0.7	0.3	0.4		0.9			0.5	0.2		1.7
Dilophus sp.																					
Ecklonia radiata	3.5	5.3	61.9	53.5	60.9	72.5	63.4	3.4	3.8	23.4	15.1	8.1	52.5	0.2	47.1	6.4	42.4		31.6	3.8	
Encyothalia cliftoni																				0.6	
Filamentous browns															0.3						
Glossophora nigricans																					0.5
Hormophysa cuneiformis	0.2											0.3									
Hydroclathrus clathratus								0.9	1.4			0.1		0.1							
Lobophora variegata	2.4				1.4		0.3	1.4	0.4	0.3	0.4	2.8		0.5	0.1	0.5	1.9			0.5	0.1
Lobospira bicuspidata					0.2	0.2				0.2					0.8	0.2	1.7	0.7		2.0	0.2
Myriodesma serrulatum	3.0	4.5					1.5				2.8	0.1	0.7					3.1	0.9		2.1
Myriodesma sp.	0.9	1.6									0.6							0.4	3.2	1.4	2.3
Pachydictyon paniculatum		0.5																			
Padina sp.								0.1	0.5									0.2			
Platythalia angustifolia		3.3		1.0						0.0									2.9	1.6	
Sargassum decurrens	0.1											0.9					0.5				
Sargassum spp.	11.1	5.7	11.4	7.2	20.3	15.0	4.6	2.8	0.6	1.6	4.4	17.8	2.3	33.2	7.7	6.4	2.6	23.7	17.4	18.8	14.7
Scaberia agardhii																					
Scytothalia dorycarpa			11.7	19.0	5.5	0.5	26.5			2.7					0.8		6.1		13.5		
Zonaria angustata	0.5												0.2				1.0				
Zonaria spiralis												0.6									0.4
Zonaria turneriana	0.2																			0.5	

Species	Site 22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0
Caulocystis uvifera																					
Chlanidophora microphylla							0.1														
Colpomenia peregrina			0.4												0.2	1.0					
Colpomenia sinuosa	0.1		0.1	0.1																	0.1
Cystophora brownii																					
Cystophora spp.						2.9															
Cystoseira trinodis														0.8							
Dictyopteris spp.			0.2			0.3			0.2												
Dictyota spp.					0.3	1.3	0.6		0.5		0.9				1.2						
Dilophus sp.						0.4															
Ecklonia radiata	15.3	23.2		3.8	36.7		9.3				56.3				69.9	5.3	56.1				38.4
Encyothalia cliftoni																					
Filamentous browns	2.4															1.8					
Glossophora nigricans																					
Hormophysa cuneiformis				0.4																	
Hydroclathrus clathratus			0.4				0.1														
Lobophora variegata	2.2	1.7	0.3	1.3	0.3	0.2	0.1		0.1					1.8	0.5	1.5					0.3
Lobospira bicuspidata		0.9		1.7	0.1	0.2	0.7		0.6		0.2										
Myriodesma serrulatum	0.5					0.4		0.8	1.2												
Myriodesma sp.																					
Pachydictyon paniculatum																					
Padina sp.			2.0	0.3		0.1			0.3						0.1						
Platythalia angustifolia							1.4				4.9										
Sargassum decurrens																					
Sargassum spp.	21.3	21.7	15.5	54.3	0.3	5.3	7.2	1.0	5.2		3.6			54.9	13.1	1.6	5.1				0.7
Scaberia agardhii						0.5															
Scytothalia dorycarpa					1.9		1.2				19.0						1.4				
Zonaria angustata		0.4									1.4						0.1				0.9
Zonaria spiralis							0.4														1.6
Zonaria turneriana																					0.1

Appendix 5. Mean cover (%) of green algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2004.

Species	Site																																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Abjohnia laetevirens													1.4																													
Bryopsis spp.					0.1	0.1	0.5			0.0									0.1									0.4														
Caulerpa cactoides	0.4	1.7									0.2	1.1		0.6	0.3	0.1				3.1	0.8		1.1	6.8	0.2										0.4	0.4						
Caulerpa distichophylla																0.2						0.1		0.1													0.3					
Caulerpa flexilis											1.2		10.0			0.2		0.3				1.6	0.3							0.4									3.9			
Caulerpa flexilis var. *muelleri*		0.2									1.0		0.4		0.1	0.1						0.4		0.1		0.3																
Caulerpa geminata	0.1	0.2			0.2				0.1		0.1	1.4		0.5	0.1			0.2		0.5		0.3	0.8	0.6			0.4		0.7	0.3					0.4	0.6	5.2					0.3
Caulerpa longifolia		1.4											0.2			0.3	2.8			0.8			0.2						0.3								1.8					0.9
Caulerpa longifolia crispata	0.1	0.2														0.9				0.1			0.8	0.9		0.1													1.4			
Caulerpa obscura									0.4							0.7				0.6				2.6	0.7												0.3					
Caulerpa racemosa														0.1		0.6							0.9		0.4																	
Caulerpa scalpelliformis																0.2				0.3	0.3		0.3	0.1			0.5		0.6	0.1												0.2
Caulerpa simplisciuscula																							0.3	0.5																		
Codium fragile																	1.0			1.2			0.8																			
Codium laminarioides?														0.1												0.1																
Codium spongiosum														0.1																												
Codium spp.							0.8		0.3					0.2							0.4				0.5														0.5			
Filamentous greens	0.1				0.2	0.8		0.5	0.5								0.1	0.1	0.4			0.2				0.2		0.4							26.7		0.2	7.4				
Halimeda cuneata		0.1							0.1					0.1		0.4				0.5	0.1	0.1	1.5	0.1				0.6							0.3							
Rhipilopsis peltata		0.1																						0.5	0.4				0.2	0.1												
Ulva spp.	0.7	0.1	0.3	0.1	0.8	1.1		0.4	0.1	0.7		0.2	0.6	0.2	0.4				0.3	0.3	0.1	2.5			0.7														0.4			0.2

Appendix 6. Mean cover (%) of red algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2004.

Species	Site																																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Acanthophora dendroides							0.3									1.2							0.2	0.2																		
Amphiroa anceps	1.9	2.0	1.3	1.7	3.4	0.6	1.5	2.4	2.7	1.4	2.8	2.5	0.2	3.0	5.7	2.2	2.2	1.5	0.2	4.7	1.9	3.7	2.7	1.5	4.4	8.5	0.6	0.7	1.8			1.4			0.4	0.5	0.7	1.5	2.4			10.1
Amphiroa gracilis		1.4			0.9			2.0	0.7			1.1		0.9		0.2	0.3	0.6	0.8	4.3	0.2	0.6	0.5	1.0	0.6	2.2	0.4	2.1				0.5			1.2				0.5			6.4
Asparagopsis armata		0.4			0.9	0.8					1.6	0.1	0.6		2.0		1.3			0.2		1.0	0.6	1.0		1.0		0.8	0.7							1.5						
Betaphycus speciosum	0.3				0.3		1.8	1.0		3.2		2.4		0.7		1.4		0.5		0.9			2.8					0.1										2.5				2.3
Botryocladia leptopoda																										0.1		0.8	0.9	0.8		1.1										
Botryocladia sonderi	0.2	1.3		0.3							2.0	0.3		0.6				0.1		0.3	1.3	0.1		0.3			2.7	0.9	1.7	2.0					1.7							
Callophycus dorsiferus	1.7	1.7									0.5				0.8		0.3			0.1					0.3			0.3														
Callophycus oppositifolius	2.3	2.0	0.5	3.7	6.1	0.3	11.8			3.1	0.4	1.8	3.7		0.9		2.1		2.3	0.1			3.3	2.1		3.3	0.5	2.8	3.3			7.7						0.4				0.8
Callophyllis rangiferinus																			0.1							0.2		0.4														
Callophyllis sp.														0.2	0.2																											
Carpopeltis elata							0.7																			0.2																0.2
Champia sp.	0.6	0.1							0.1					0.2							0.5		0.2			0.3													0.4			
Chondria spp							0.2			0.0					0.6					4.6		1.3								0.3		0.3						1.5				
Claviclonium ovatum	0.5	2.3	0.1				0.2			0.2	0.7	0.6	0.5	1.0	0.3		0.5	2.1	0.3	0.2	2.2		0.2	1.1		0.5	3.4	0.8	0.7	1.9					0.4		1.5	0.7	0.4			
Cliftonaea pectinata					0.9					0.0										0.4								0.5	0.4													
Cryptonemia kallymenioides					0.5																																0.2					
Curdiea spp.	2.1	10.2	7.5	2.9	10.3	2.1	4.6			2.5	9.7	5.4	7.3	4.5	8.0	2.3	3.8	0.5	3.6	7.9	9.7	7.2	2.1	3.6	2.9	1.4	2.3	0.8	0.6	1.2		0.8			0.9	2.6	1.5	1.4	1.7			4.9
Dasya sp.		3.3					1.2				3.3							1.0		0.6								0.6	0.6							0.5		0.7				
Delisea spp			0.1								0.1		2.3		0.4		0.1		0.1									0.3														
Dictyomenia sonderi	2.2	4.6	4.2	0.4	3.1	5.0	4.4			0.0	21.5	4.8	8.9	1.6	3.3		10.8	1.5		3.4	28.6	5.4	2.2	1.0		0.2		19.9	26.0	3.5		1.5			0.5			1.8				
Dictyomenia tridens		2.9									2.2			1.2		1.4										0.4																
Erythroclonium spp.																														0.8												
Euptilota articulata			0.8		0.3		2.9			0.5	0.3	0.4	1.8				0.2				0.4																	1.3				
Filamentous red algae	5.8	4.8	2.3	1.1	7.9	2.6	0.7	0.6		0.3	18.1	16.4	4.7	29.2	11.1	6.1	4.5	16.6	9.4	8.7	22.8	16.1	13.9	16.0	6.3	1.6	17.4	5.8	12.3	14.2		0.0			13.6	3.6		2.9	44.0			0.3
Foliose red alga	6.2	11.6	5.2	5.7	5.4	9.2	10.5		1.6	4.5	16.0	3.4	10.0	5.3	5.1	11.7	7.6	3.7	4.4	10.7	5.8	9.9	5.8	12.6	3.3	9.3	8.6	14.7	10.6	5.9		8.7			1.7	6.2	1.6	4.9	1.1			4.2
Galaxaura marginata	0.3	5.2	0.3		0.3																	0.4	0.3																			
Galaxaura obtusata	0.2	0.1				0.7	0.3								0.1		0.6																									
Gelinaria ulvoidea											0.5						0.3						1.0																			
Gigartina disticha										0.0	1.2				0.7			0.2					0.4						0.1													
Gloiosaccion brownii	1.8					0.2	0.4			0.0	0.3			0.1	0.1		0.2		0.1	0.5						0.2		0.4	0.4													
Gracilaria cliftoni					0.2																	0.1																				
Gracilaria flagelliformis																		0.1																								
Gracilaria preissiana							3.1			0.3													0.4			0.5		0.3				0.4										
Gracilaria sp.																									0.5																	
Grateloupia filicina	0.8																																									

Appendix 6 (cont.). Mean cover (%) of red algae recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2004.

Species	Site																																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Haliptilon roseum	0.2			0.2					2.2			2				0.2			1.9	0.9		3				0.1	1.9	1.6		1.8												1.7
Haloplegma preissii	0.3				0.3	0.3	1.7			0	0.4	0.2	0.3	0.2			0.1	0.2		0.3	0.1		1.2			0.2		0.8										0.2	0.4			
Halymenia floresia																				0.2																						
Hennedya crispa	1.1	7.5	5.7	4.7	0.8	4.2	13.2			3.3	2.8	1.5	14.8	0.9	5.8		6.4		1.8		0.7	1.5	1.2	1	0.6	6.6	0.6	2.6	0.5			16.3						12.7	0.7			2.9
Holotrichia comosa																		2.9																								1.7
Hymenocladia sp.		0.2																																								
Jania spp.	0.4	0.4						1.7	0.8			6.5					0.2										2.2	1.4		2		2.5										0.2
Kallymenia cribrosa																	0.2			0.1						0.2												24.3				
Kuetzingia canaliculata										0.5																																
Laurencia brongniartii			0.2		0.2					0						0.1						0.3	0.4									0.3						1.3				1.3
Laurencia elata													0.3		0.3											0.4				0.9												
Laurencia filiformis														5.1								0.6																				
Laurencia spp.	8	15.4		0.4	3.2	0.9	2.1	0.8	1	2.4	11.8	5.1	2.1	8.3	3.7	7	2.2	10.3	1.1	4.2	8.4	3.2	10.9	4.7	1	0.3	12	1	12.6	16		0.6			4.6	0.2	0.9	2	5			0.1
Lenormandia spp			0.2																																							
Lithophyllum spp.																																			2.7							
Melanthalia abscissa								8.9	11.7	1																																
Metagoniolithon radiatum	2.4			0.3							4	1.4		0.8		0.3				0.3	0.2				0.3	1.4	0.6			0.2						0.3						0.1
Metagoniolithon stelliferum	3.7											2.9													2		6.5			7.9												
Metamastophora flabellata		4.7	9.5	3.2	0.8	3.5	0.8	1.1	1.9	0.4	4.8	5	11.8	2.5	19.1	0.6	3.7			6.7	4.9	6.8	8.1	0.8	1.7	2.2	1.5		3.1	0.4		0.4			0.4		1.6	0.3	1.5			1.1
Neurymenia fraxinifolia	0.6	1.9									0.7					39.8	3.4	55.3		6	1.5	0.7		1.3			22.6		43.3	21.8						0.6	17.1	3.6	9.5			
Nizymenia conferta					0.3		0.6					0.5																1										0.5				0.3
Nizymenia furcata					0.5								0.6																			1.2										
Osmundaria prolifera																		0.9									4.7		3	12.7												
Peyssonelia novaehollandiae		0.8		0.5		2.9							0.7			0.8	1.9								0.2			0.8														0.2
Peyssonnelia sp. (flat)	3.8		2.9	4.3	4.1	0.5	0.2			1.5		0.2	2		6.1	1.1	4.3		3.3	0.7	0.3		0.4			3.2	0.3	0.3				0.9				8.6		1.7				2.3
Phacelocarpus alatus							0.6						1.4										0.3																			
Phacelocarpus apodus			0.3				0.2																					0.6														
Phacelocarpus sp.		0.4		0.3							1.3		0.7							0.3						0.2				0.1												
Plocamium cartilagineum					0.2					0												0.1	1			0.1																
Plocamium preissianum		0.5	0.2	1	0.5	0.2	4.3			0.9	1	0.4	3.1	0.3	2.8		0.9			0.1		0.3	4.2			0.6		0.5				3.8										0.6
Pterocladia lucida	3.3	1.7	6	3	6.3	9.5	6.2			8.5	0.8	0.4	2.5		3.8	0.6	7.5	0.4	1.1	0.4	0.7	3.5	0.7		1.7	5		1.3		0.4		6.2				14.8			0.6			7.1
Rhodopeltis australis			0.1	0.8	0.2	0.4	2.2				0.7	0.2	0.3	0.1	0.2	0.2	0.7					0.1	0.8		0.1	0.3						0.8										
Rhodymenia spp.	0.2			0.5	0.5	2.4			0.6	0.2	0.3		1.5	1.5	2.3		0.4	0.2				0.2				0.2			0.2	0.2		1.2				0.4		0				
Scinaia sp.																														0.4												
Sonderopelta coriacea			0.3																																							
Thuretia quercifolia		3.5					1.5				2.7		0.2					0.2			0.3								1.6	2		0.3						0.3				
Vidalia spiralis	2.3										0.5	2.7	0.4	0.2			0.9	1.6		0.1	1	0.3	0.2				2.8	1.8	4.9	1.1					1.9			0.5				

Appendix 7. Mean cover (%) of seagrass and sessile invertebrates recorded in 20 0.25 m^2 quadrats surveyed at different sites in 2004.

Species	Site																																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Seagrasses																																										
Amphibolis antarctica	4.0			0.8	0.8						6.9	2.6			2.1			4.7	7.3		0.3			0.2	4.0		31.7	1.1	0.4	18.5					6.5		0.2					
Amphibolis griffithi	14.3	0.1																			6.2				4.5					9.7									4.3			
Halophila australis	1.2							1.2	1.6								0.5		1.5																							
Halophila ovata																																			5.8				0.6			
Posidonia australis															0.3										1.7			7.3							6.5				42.3			
Posidonia sinuosa																					2.1																					
Syringodium isoetifolium	0.5							0.1																	0.8														9.4			
Thalassodendron pachyrhizum																					2.9																					
Invertebrates																																										
Coral (other than Montipora)									2.5			1.0		0.2		2.3									2.8												1.5					0.2
Herdmania momus		0.4	0.1					0.2						0.2	0.5	1.4	0.4			0.6				9.9				0.8							0.3		0.4	0.8				0.8
*Montipora sp_*									0.6																	0.6																2.9
Palythoa ?densa								1.0	8.1																																	
Plesiastraea versipora									0.1						0.1	0.1									0.1	0.1																
Pocillopora damicornis								0.1	0.3					0.3																												
Zoanthus praelongus								0.4	0.7		0.8	0.3								0.1				0.1					0.1													