Preliminary findings from the first baseline survey of the Magnetic Shoals

Project Progress Report

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Australian Government

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Australian Government

Department of the Environment and Water Resources

Funded through the Australian Government's
Marine and Tropical Sciences Research Facility
Project 4.8.2 Effects of the Great Barrier Reef Zoning Plan on inshore habitats
and biodiversity, of which fish and corals are indicators: Reefs and shoals

This report should be cited as:
Speare, P. and Stowar, M. (2007) *Preliminary findings from the first baseline survey of the Magnetic Shoals. Project Progress Report.* Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (22pp.).

Published online by the Reef and Rainforest Research Centre Limited for the Australian Government's Marine and Tropical Sciences Research Facility.

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March 2007

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Abstract

A baseline survey of green sites on Magnetic Shoal together with non-green sites in the adjacent blue zoned areas of the marine park was initialised in July 2006. On going monitoring was maintained in order to assess any seasonal effects on the fish and benthic communities. Magnetic Shoal is characterised by a mosaic of rich epibenthic filter feeding communities typically surrounded by low relief algae and seagrasses. These communities appear to be founded on loose sediments comprised of sand, rubble and foraminifera. Limited sub-bottom profiling identified a consolidated sub-seafloor acoustic reflector that may emerge and provide the foundation for these structurally complex communities.

A preliminary assessment of the fish communities enumerated with baited video sets (BRUVS) revealed a diverse assemblage across numerous taxonomic and trophic groups. Fish communities associated with patches of habitat were typically more diverse than those from the open, low relief areas and could be discriminated at the scale of 10s of metres. This result underlined the importance of very accurate deployment of sampling gear, especially in respect of on-going temporal monitoring.

The blue sites, nominally representing controls for the no-take green sites, included habitat features not present on Magnetic Shoal. These sites were selected on cross-shelf position/depth (the strongest biological gradient on the GBR) and location. They included artificial habitat (a wreck), calcareous reefal substrate and dense filter feeding communities. Many fish species were common to sites both on Magnetic Shoal and in these blue zones yet the concept of control-treatment contrasts cannot be readily applied in this study. Temporal monitoring should focus on the trajectories of each site as simple metrics of abundance and size may be confounded by the disparity between habitats and fish-habitat associations.

Thirty percent of all fishes recorded could be classified as targeted or otherwise taken by fishers. This relatively high percentage offers an excellent foundation for monitoring the impact of fishers who have access to a broad range of well represented species.

Introduction

The extensive inter-reefal habitats on the Great Barrier Reef (GBR) possess an enormous lack of information on fish communities and their associated habitats at scales suited to management. Biogeography, oceanographic processes, ontogenic movements, and fishing are some of the factors influencing the structure and biodiversity of these inter-reefal, relatively deep water fish communities (Brinkman et al. 2002, Longhurst and Pauly 1987). The associated benthic communities, often occuring on coarse sediments, include sponges, gorgonians, alcyonarians, corals and marine plants in great diversity (Birtles and Arnold 1988). They may possess a structural complexity which enhances protection and feeding opportunities for fish beyond that which less structurally complex habitats might sustain. These important but little understood reservoirs of fish biodiversity can be impacted by fishing directly (Sainsbury et al. 1997) or through habitat alteration (Pitcher et al. 2005). The Representative Areas Programme (RAP) has specifically addressed such issues by providing an extensive network of inter-reefal, no-take, green zones over the length of the GBR.

The objective of this task was to establish a baseline on which to build, via ongoing temporal survey, an understanding of the responses of biological communities (fish and benthos) to differential zoning of human use on inshore "shoals". Specifically, comparing areas closed to fishing (green zones) on Magnetic Shoal with adjacent areas open (non-green) to fishing. Marine Protected Areas (MPAs) are typically predicted to acquire measurable changes in the size, demographics and species composition of fishes (Russ 2002) and this study was designed to capture such changes which might be effected by the re-zoning. Additionally, document changes in the structure and complexity of the associated benthic communities. This report documents the initial surveys, which effectively established the monitoring sites, and additionally provides some insights to the relationships between the fish communities, habitats and time.

Fishers broadly use the term "shoal" to describe submerged bottom features that attract and hold significant numbers of fish in areas away from obvious emergent coral reef. These shoals, especially in the current study area, are generally identified by their GPS position, known as "marks".

A pilot study undertaken by Speare and Cappo (2006) identified several areas in the vicinity of Halifax Bay off Townsville with the potential for monitoring the effects of zoning on fish populations and habitats on inshore shoals. The current study was subsequently restricted to the "Magnetic Shoal" region of Halifax Bay, an area known by local anglers as highly productive "shoal country". The results of the wider pilot study were consistent with this reputation. Within this area, more diverse benthic assemblages were identified which, similarly, supported more diverse fish communities. Also, species of interest to fishers, in particular the "reds" (Lutjanus sebae, L. erythropterus and L. malabaricus), were only recorded above legal size in these deeper-water offshore habitats. This was consistent with ontogenic offshore movements indicated in other studies (Pitcher et al. 2005, Cappo and Kelley 2001) and the association of these fish with habitats of greater vertical structure (Sainsbury et al. 1997).

From the pilot study, Magnetic Shoal appeared to be entirely contained within a no-take (green) zone (MNP-18-1082) and without comparable adjacent control (blue) sites. Magnetic Shoal, as identified by fishers, was generally uncorrelated with any distinct features identified by conventional tools such as charts, acoustic seafloor imagery or single beam sounders. In this study, the relatively scarce fishers' GPS marks were used as a starting point and these were explored with towed video to search for areas supporting epibenthos that might support a more diverse fish fauna.

To accommodate a more extensive and robust comparison between protected and unprotected areas, additional sites were required within the green zone and areas with enhanced benthic structure were also sought in the adjacent blue zone(s). The coverage in the green zone was extended to the east and south east of the previously established site (Rap2 of the pilot study) and blue sites established off Cape Cleveland (RapMP) and east of Great Palm Island (Rap16) (Fig 1). RapMP, ~ 17nm SE, had previously been surveyed in December 2001 with BRUVS and in June 2003 with multibeam acoustics and towed video. Rap16, ~16nm NNW, was known as a "reds" fishing mark. Rap4, the control site carried over from the pilot study, had BRUVS data from 2001 and, consequently, some pre-zoning data has been incorporated into the current study.

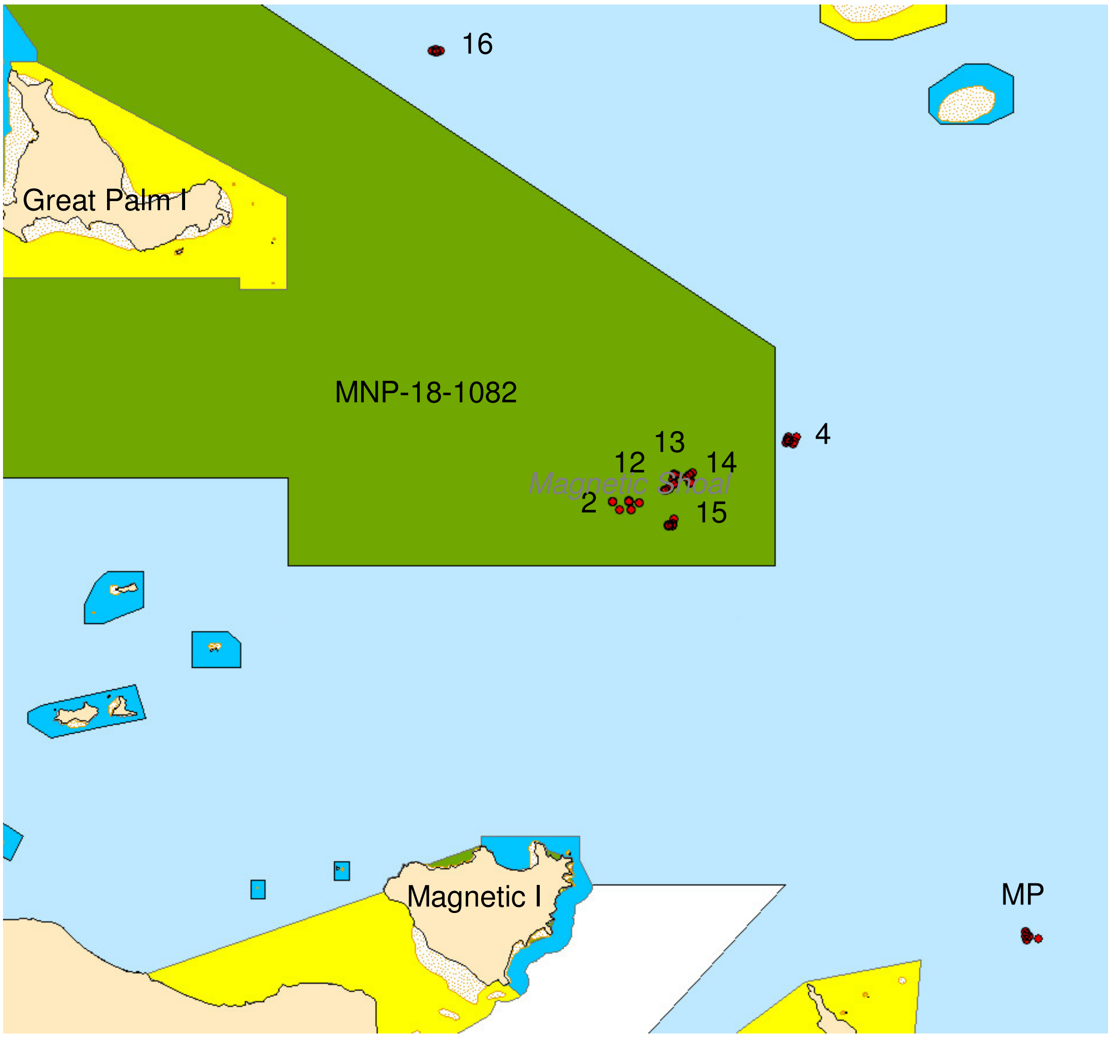

Figure 1. Location of study sites in the Marine National Park green zone on Magnetic Shoal and adjacent blue 'take' zones.

Materials and Methods

Earlier experience with acoustic surveys identified their limitations in discriminating bottom structure on which benthic communities, other than seagrass and algae, might be established. Rubble/boulder ground, outcrops, holes, etc with sufficient texture or relief are clearly identified with acoustics but unconsolidated substrates with low vertical relief do not provide clues for the existence of filter feeding benthos. Consequently, additional sites were initially identified with towed video, their extent determined from directional passes and acoustic mapping undertaken at a later date. Three small green areas were identified to the east of Rap2 (Rap12, 13, 14) and another to the SE (Rap15). Together this allowed a comparison of 3 blue sites (fished) and 5 green sites in the recently zoned MNP.

Habitat classification was undertaken as per Speare and Cappo (2006) with a low-voltage underwater video system towed behind an 8m vessel. The classification scheme included a schema for the abiotic substrate components and the overlying benthic organisms (Appendix I). A limited suite of individual organisms could also be recorded as point events. All data records were fixed in 4 dimensions, viz latitude, longitude, depth and time and geo-referenced to the World Geodetic System, WGS84, at a resolution typically less than 5m horizontally, 0.5m vertically and 3 seconds temporally (Fig 2).

Baited remote underwater video stations, known as BRUVS (Cappo et al. 2003), were deployed on-habitat and off-habitat to investigate the areal extent of fish communities associated with benthic structure. BRUVS have a clearly demonstrated advantage over alternative tools with respect to the breadth of species available to the respective gear types (eg. Cappo et al. 2004). Deployment sites were chosen from the geo-referenced video footage, and also with reference to acoustic maps, where available, to enable precise positioning with respect to habitat type (eg. Fig 3). The small size of habitat patches and the constraints associated with independent sampling, limiting sets to a minimum separation of 300m (Cappo et al. 2003), often restricted BRUVS sets to one on the habitat at any time. Sites were typically re-sampled over the same day to secure adequate representation (Table 1). These baited video camera sets were given a nominal 1 hour soak time and the fish fauna identified and enumerated over the full period of video capture. Metrics for each species included time from the gear settling on the bottom to the first sighting and the time elapsed to when the greatest number of each species (MaxN) occurred.

Stereo BRUVS (SBRUVS) were deployed after reviewing BRUVS for species of interest to fishers. SBRUVS offer the opportunity to accurately measure individual fish size (Harvey et al. 2003). As there is considerable processing time required to recover fish measurements from the SBRUVS, deployments preferably target sites where the fish of interest have already been encountered. The supporting software (Vision Metrology Services, Melbourne, Victoria) provides sub-millimetre accuracy in the measurement of fish from the recovered footage. Any trends in the size distribution of species, provided sufficient numbers are encountered, will be discernable with this gear and the associated measurement software.

Bathymetry was recorded with the James Cook University's multi-beam echo-sounder (RESON Seabat 8101) mounted to the survey vessel. This equipment generated 3-dimensional bathymetric data, after processing, with a spatial resolution of 1m.

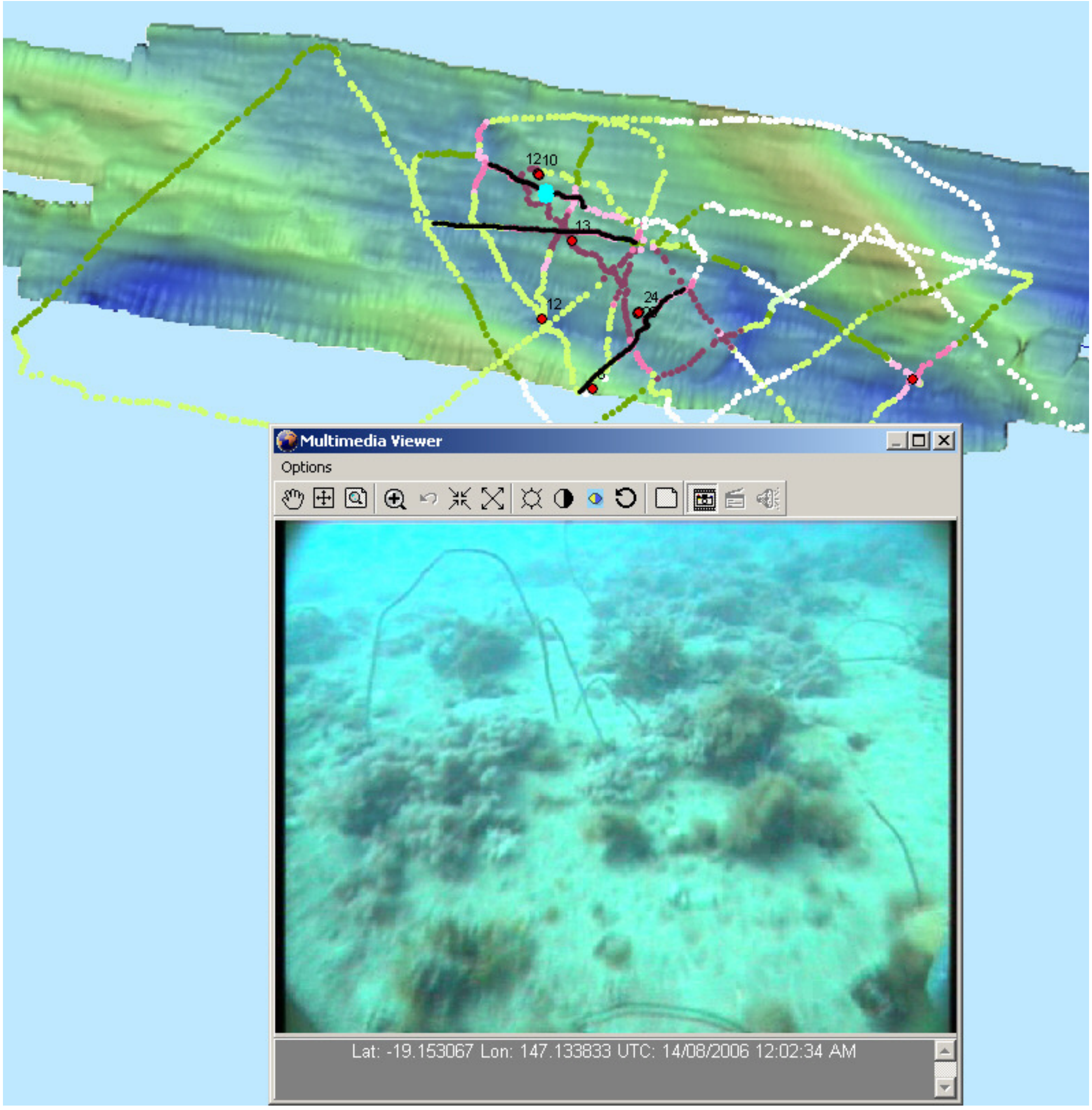

Figure 2. A frame grab from towed underwater video footage fully fixed in four-dimensional space (depth not displayed), geo-referenced (pale blue dot) and spatially displayed with respect to towed underwater video classification of the benthos, high-resolution acoustic imagery and BRUVS deployments (red dots with number of species displayed).

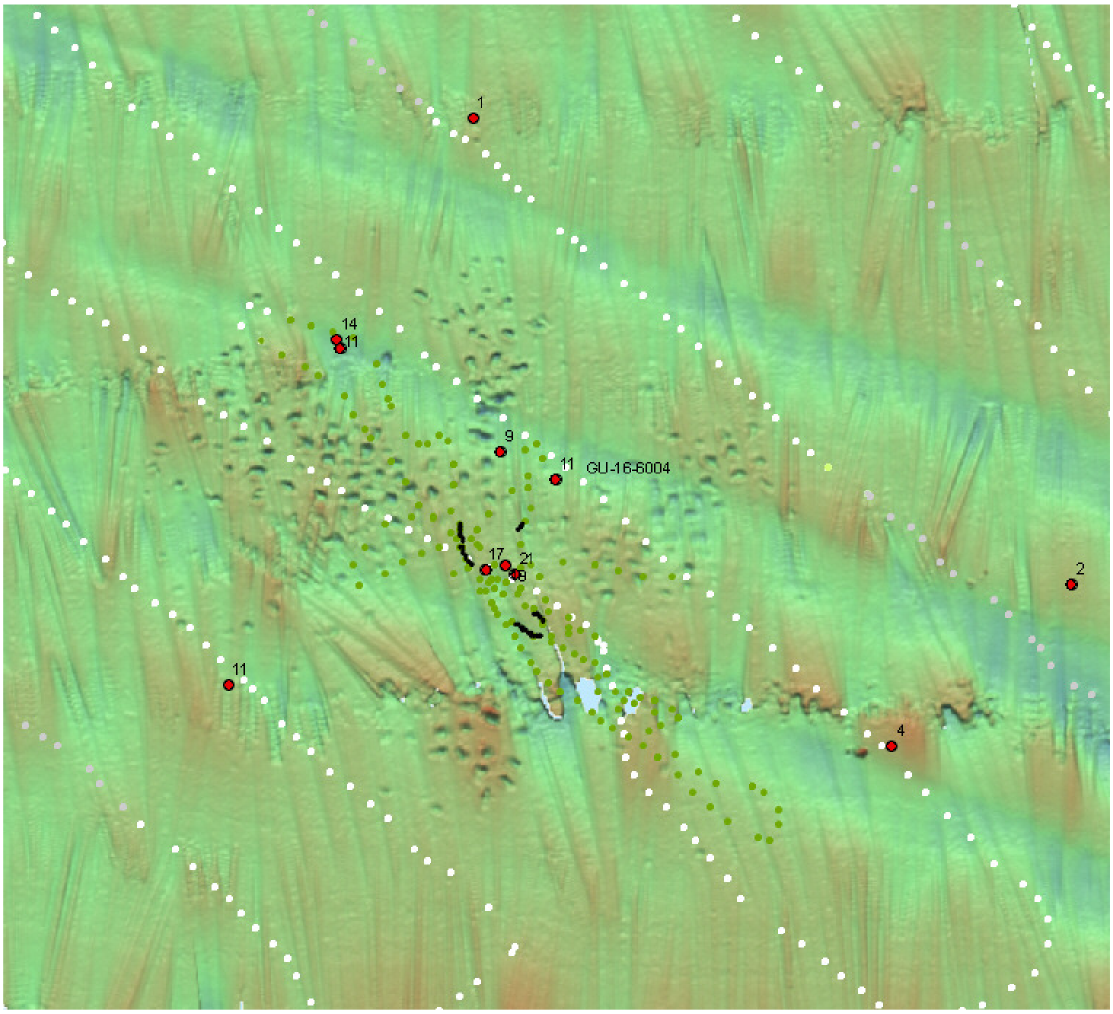

Figure 3. No-take blue site, Rap4, showing the 'intelligence' provided by high-resolution geo-referenced acoustic imagery and real-time classification of towed underwater video (dotted waypoints). The numbers represent the species count for each BRUVS set (red dots) and it is clearly evident that precise deployment is critical. Image width 600 metres.

Table 1. Counts of fish species of interest to fishers, recorded from BRUVS and SBRUVS at sites on Magnetic Shoal (green) and three sites open to fishing (blue). The numbers in brackets are fish recorded on SBRUVS and consequently available for measurement and size monitoring.

Zone	blue				green			
Species/Month	Jul	Sep	Oct	Nov	Jul	Sep	Oct	Nov
Carangoides chrysophrys	2	23	77(16)	2(2)			1	
Carangoides fulvoguttatus	7	14	8(2)		1	10	13	2(2)
Carangoides gymnostethus	35	40	29(20)			31	78(2)	2(2)
Gnathanodon speciosus	95	8	63(9)	3(3)	9	61		3(3)
Diagramma pictum		5	13(2)	3(3)		11	1	
Choerodon schoenleinii		2	3		3	6	3	1(1)
Choerodon venustus					1	8	5(1)	9(9)
Lethrinus laticaudis		3	5(1)			6	2	
Lutjanus erythropterus		6	25(10)		3	2		
Lutjanus malabaricus			26(3)		2	1	1	
Lutjanus sebae		2	23(12)	2(2)	2	45	4	12(12)
Rachycentron canadum		1	5(1)			2	4(1)	
Scomberomorus queenslandicus		1	10(1)		9	16	36(2)	4(4)
Epinephelus coioides		5	14(4)	2(2)	1	4	1	1(1)
Plectropomus leopardus			2			1		
Plectropomus maculatus		2	3(2)			2	2	
Argyrops spinifer			62(28)					

Results

Habitats

Approximately 41 kms of towed video was added to the existing database (the pilot study contributed 44kms), predominantly from surveying the new sites but with some limited additional tows of existing study sites. These tows generated 15,925 records at an average spacial resolution of 3.6m. All study sites were predominantly unconsolidated sediments ranging from sand to rubble or a mixture with foraminifera (Fig 4). The green zone sites of Magnetic Shoal included discreet patches of filter feeding communities visually dominated by gorgonians (Fig 5, 6). These patches were typically <50m (Rap12, 13, 14, 15) but up to 300m in linear extent (Rap2), sparsely covered (<30%) and standing up to ~2m off the bottom. Rap16 (blue) included a small area of reefal substrata which was established in the bottom of depressions ~ 30m wide and ~ 2m deep. Hard and soft coral, gorgonians and sponges were evident on the calcareous substratum as well as irregular small patches of gorgonians scattered on the unconsolidated bottom. Rap4 (blue) was the site of a timber trawler wreck circumscribed by a field of holes/depressions up to ~5m across. All wreckage, including the remains of the hull, A-frame, wire rope, etc lay on bare sand with other areas densely carpeted with algae (Fig 7).

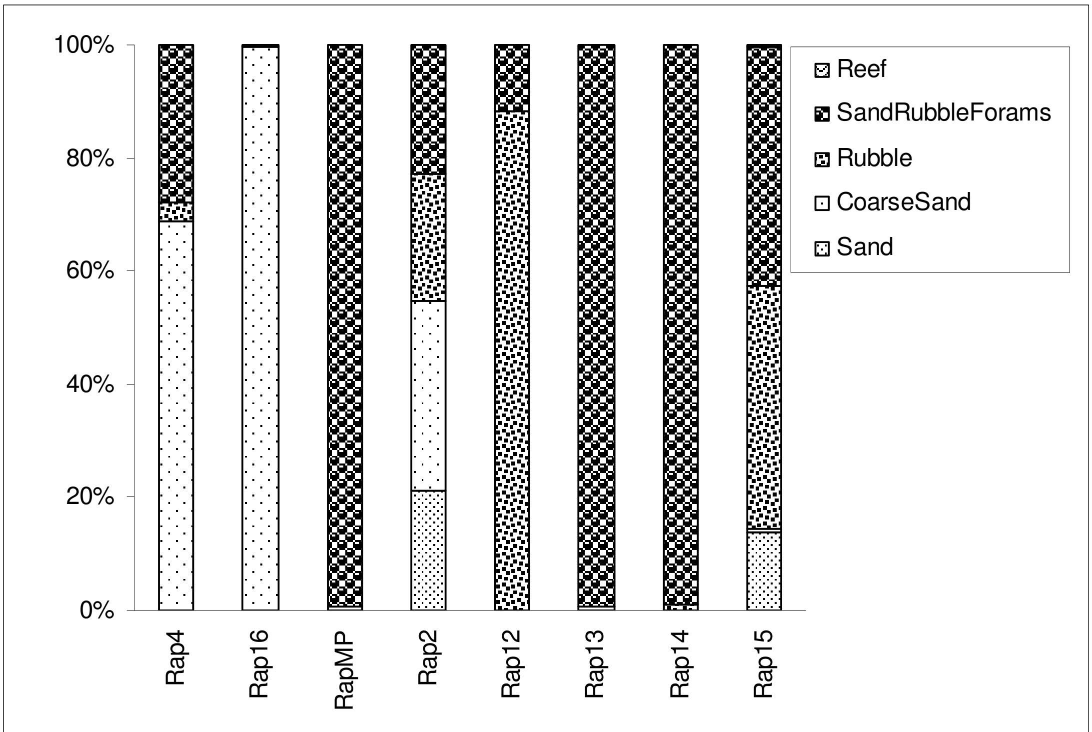

Figure 4. Proportional contributions of substrates at study sites based on visual classification from towed video surveys.

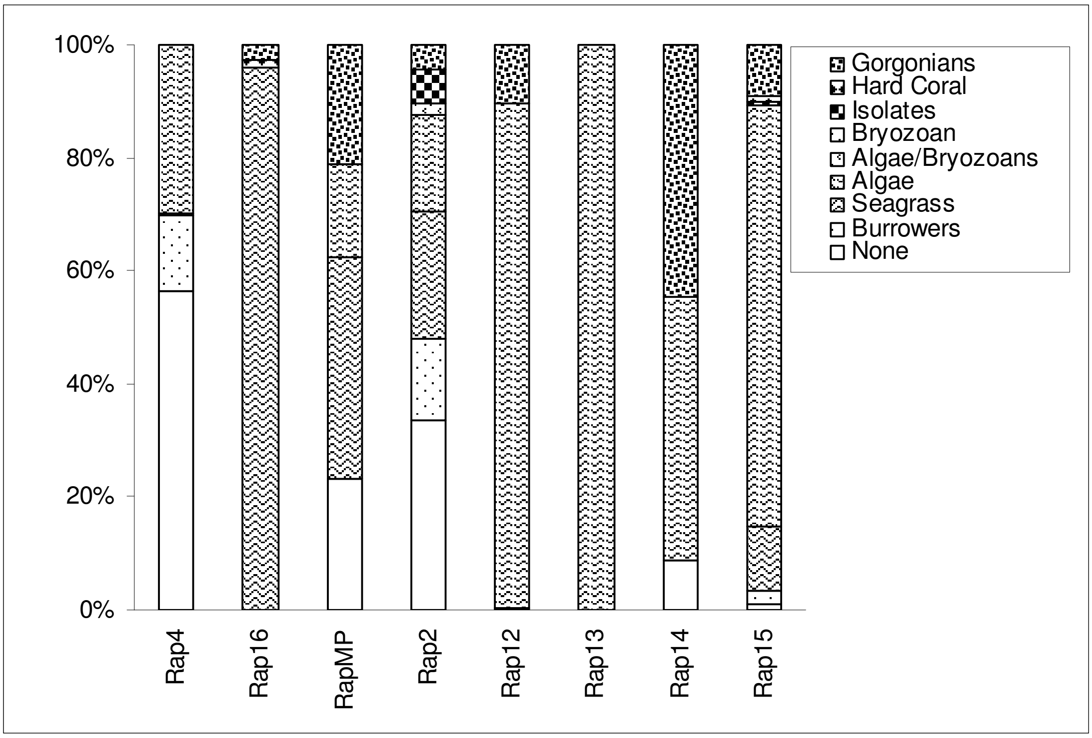

Figure 5. Proportional contributions of benthic categories at study sites from visual classification of towed video surveys.

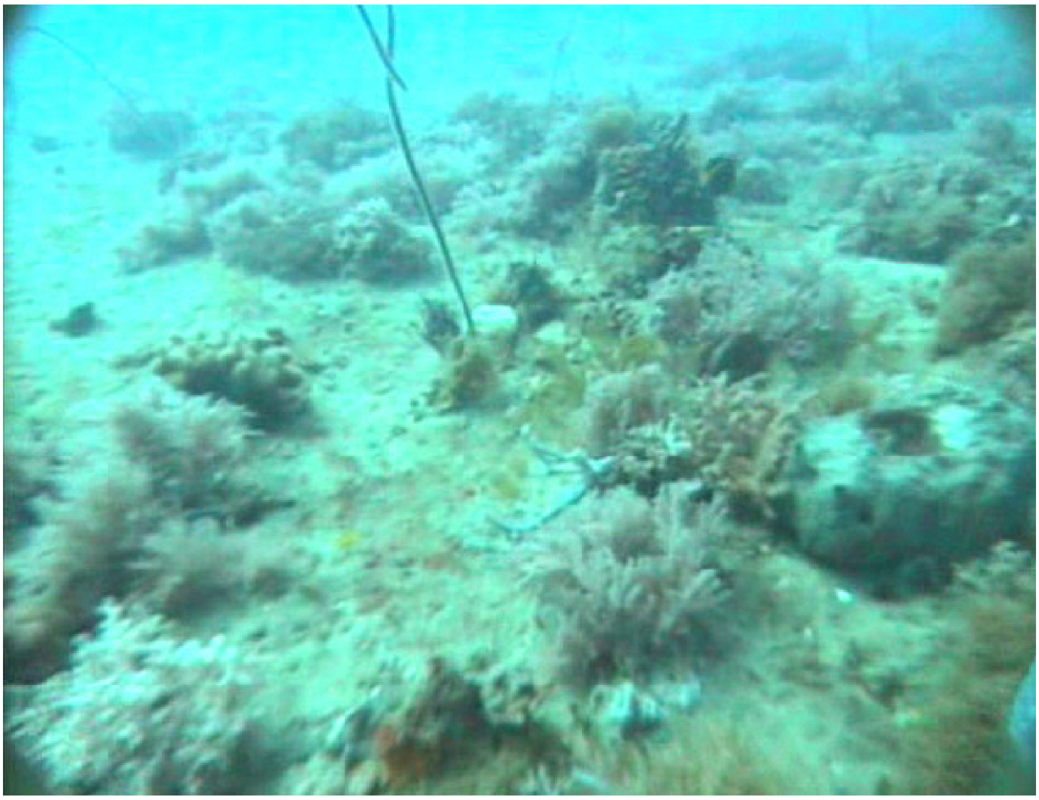

Figure 6. Image (frame grab) of a typical complex filter feeding community of soft coral, sponges, gorgonians and some hard corals.

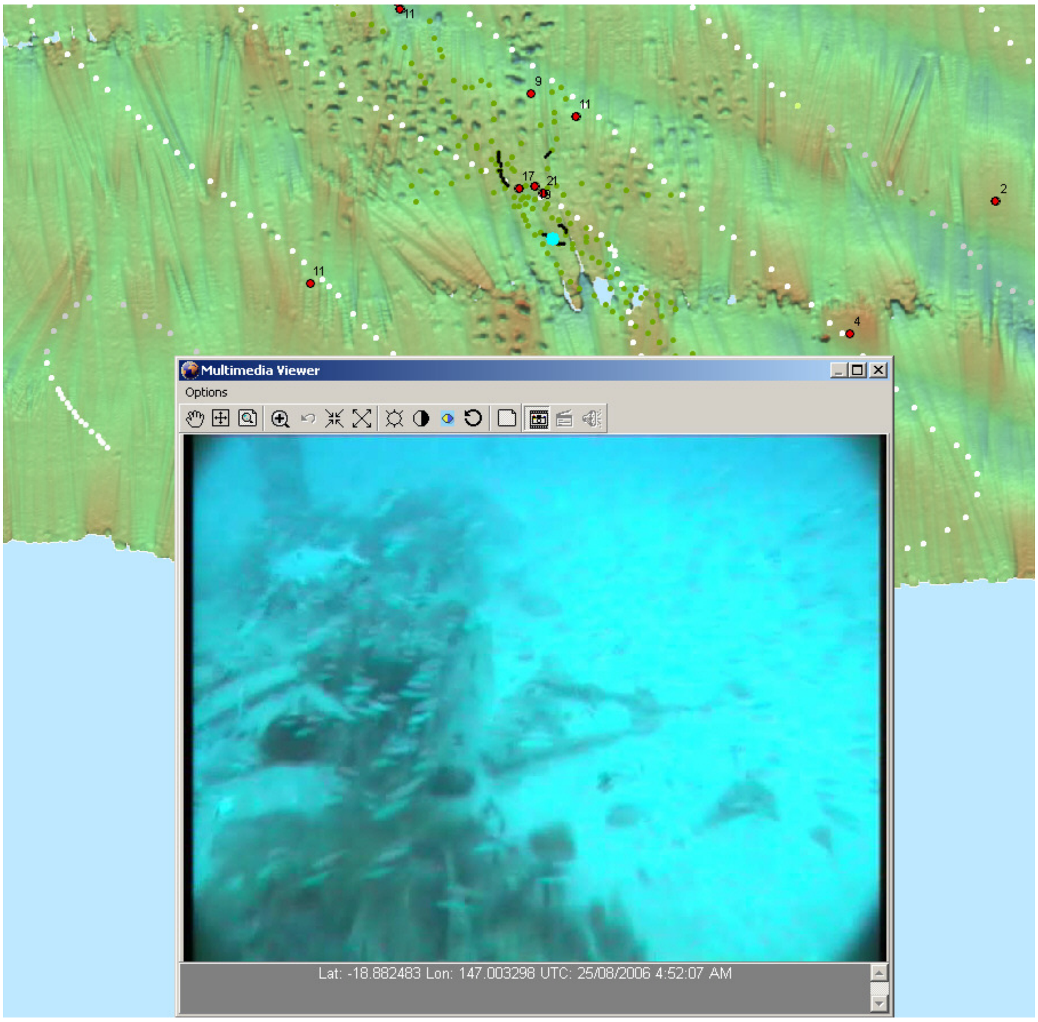

Figure 7. The hull of an old wooden trawler as fish habitat on Rap4. The screen grab precisely positions the wreck (pale blue dot) which is partly obscured by fish. Seagrass and/or algae were widespread and common to all sites. These plant communities had very low relief and little complexity but where they were replaced by the visually dominant filter feeding gorgonians and corals, there was a substantial increase in the complexity and vertical structure of the benthos (Fig 2). These more complex habitats comprised ~ 13% of the surveyed bottom. Site RapMP (refer Fig 1) had the most extensive and complex communities visually dominated by whip gorgonians to a height of ~ 2m off the bottom. In limited areas, together with hard and soft corals and sponges, they contributed close to 100% coverage of the bottom.

Fish

Fifty-six BRUVS sets were deployed between July and October 2006 and 11 SBRUVS in October and November. Data from 2 additional deployments of 6 BRUVS each on Rap4 and RapMP were available from December 2001 (Table 2). 3517 individuals representing 139 taxa from 35 fish and 4 elasmobranch families were recorded (Appendix II). Sets made on and off habitat in green and blue zones highlighted the more diverse fauna associated with patches of more complex habitat represented by filter feeding communities, hard calcareous rock or wreckage (Fig 8, Appendix III). There was typically twice the number of species recorded on habitat patches compared to areas 100 to 500m distant from these patches. Marked changes in the fauna were often recorded at no more than 100m from the habitat patches.

Table 2. Numbers of BRUVS and SBRUVS sets on study sites in green and blue zones.

Operations/Site	**Zone**	**Pre 2001 Dec**	**Post-zoning 2006**			
			Jul	**Sep**	**Oct**	**Nov**
BRUVS						
Rap4	blue	6	4	4	2	
Rap16	blue				6	
RapMP	blue	6		3	4	
Rap 2	green		4	4	2	
Rap12	green			3	2	
Rap13	green			4	2	
Rap14	green			4	2	
Rap15	green			4	2	
SBRUVS						
Rap4	blue				1	1
Rap16	blue				2	
RapMP	blue				1	
Rap13	green					1
Rap2	green				1	1
Rap14	green					1
Rap15	green				1	1

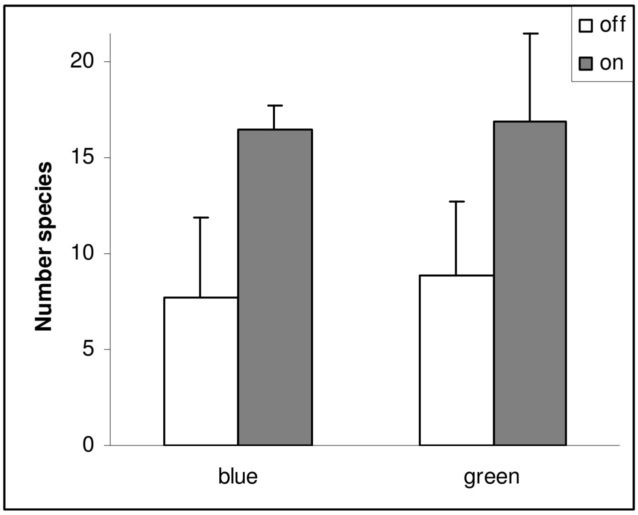

Figure 8. Mean number of species recorded on and off habitat patches in blue and green zone sites (error bars – 1StDev).

The total number of species recorded both on and off habitat patches did not appear to differ significantly between green and blue zone sites (Fig 8).

A total of 1053 fish or approximately 30% of all taxa recorded were considered to be of interest to fishers. These 17 species included the 3 “reds” (large and small mouth nannygai and red emperor), trout, cod, tuskfish, trevally, cobia and doggie or school mackerel. A number of these fish were captured on stereo video thereby facilitating accurate (<1mm) size measurement (Table 2).

The mean abundance of a species with regard to zone showed marked differences for several species (Fig 9), however these differences in abundance of some species between green and blue zone sites are accompanied by high standard error values (Fig 9). This reflects the limited number of samples collected to date, and as such is strongly influenced by factors such as variation in habitat size and type within different zones, and the schooling nature of many species. At this stage of the study statistical analyses and drawing conclusions from the differences in fish abundance between green and blue zones would be premature.

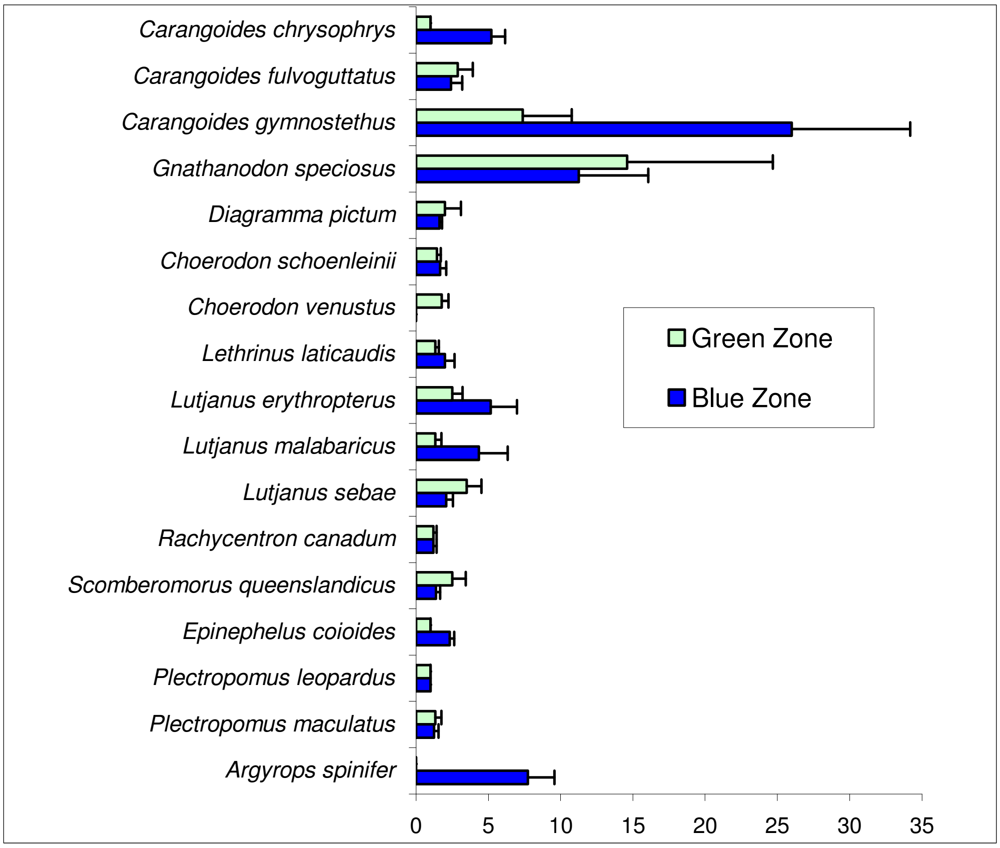

Figure 9. Mean abundances (+/-1SE) of seventeen species of interest to fishers from study sites in the green and blue zones.

Discussion

The structurally complex habitats found on Magnetic Shoal are generally small with sparse (<30%) to medium (<60%) cover of epibenthic communities of filter feeders. Similar types of communities, but also including dense cover, were found on RapMP, off Cape Cleveland, but the other sites were structurally different. The topography, especially on Magnetic Shoal, is subtle and while this can be revealed and visualised through acoustic survey data these have not, to date, provided clues as to the location of the epibenthic communities. This has required the deployment of more time consuming towed video with little preliminary "intelligence". Also, we have little idea of the areal extent of this mosaic of habitats and it may well be far more extensive and logistically problematic to fully comprehend.

Some efforts have been made to address this issue through the limited tandem deployment of a sub-bottom profiler (Datasonics Chirp) when multibeam acoustic surveys were being undertaken. The dominant filter feeding organisms require a solid foundation to attach and proliferate and such geological control over habitat formation may present an opportunity for more rapid, widespread and predictive survey. The available data have not been comprehensively compiled and analysed but it is evident that a subsurface reflector, likely a Pleistocene sediment surface (Stieglitz 2006) which may be buried a few metres below the seafloor, will emerge coincident with the location of habitat patches. The deployment of such a tool could support a more rapid survey of Magnetic Shoal as a precursor to targeted video tows.

The 17 species of fish most likely to be taken by fishers contributed a substantial portion of the fish fauna. In particular, the "reds" were recorded on all sites, both on and off habitat patches. Pitcher et al. 2005 found no specific association between these fishes and megabenthos but, fishers invariably target these fish at night on habitat (Higgs 1993). It is likely that these fish roam widely over the open bottom while retaining a relationship with the habitat patches which is evident among the juveniles (Sainsbury et al. 1997). Speare and Cappo (2006) identified the need for rapid assessment techniques over much larger spatial scales on Magnetic Shoal in order to capture the extent of the habitat mosaic. This is also necessary to ensure representative and robust sampling of the mobile components of the fish communities as well as ensuring adequate coverage by stereo video for monitoring the sizes of fish.

There was a diverse assemblage of fish representative of most trophic groups but, counts will be variable due to the movements and schooling behaviour of some species including several which are targeted by fishers. The error bars associated with the abundance figures for many of the fished species tend to underline the schooling behaviour and relative school sizes for these fishes. This was evident for the trevallies, especially *Gnathodon speciosus* and *Carangoides gymnostethus*, the nannygai (*Lutjanus erythropterus* and *L. malabaricus*) and school mackerel (*Scomberomorus queenslandicus*) and this mobile schooling behaviour, at times, effectively diminished the expected coverage by SBRUVS which were deployed only following confirmation of suitable sites for fish measurement using BRUVS. Size monitoring, provided adequate samples can be obtained, may provide discrimination between take and no-take zones in the marine park. It was evident that the deployment of SBRUVS only following evaluation of BRUVS did not guarantee maximum return (refer to Table 2) for this more labour intensive equipment. Size monitoring requires substantial processing of the captured imagery and a greater investment in this technology is required to realise efficiency dividends. This is necessary before this equipment can be routinely deployed as the tool of choice for the dual role of securing abundance indices and size monitoring. The present approach of stationary deployments is also limited in such a patchy habitat owing to the fact that the relatively small number of fish from localised habitat patches continually re-enter the field of view. Development of a mobile tool for survey of fishes may have advantages in gaining greater breadth of coverage for a given sampling effort.

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Appendix 1

Classification schedule employed for habitat mapping using towed underwater video. O – individual organism/point event, S – substrate class, B – benthic class.

Category	KeyType
Solitary Hard Coral	O
Solitary Soft Coral	O
Hydroid	O
Crinoid	O
Urchin	O
Starfish	O
Bryozoan	O
Holothurian	O
Gastropod	O
Ascidian	O
Anemone	O
Icelet	O
No Sediment	S
Soft Mud	S
Silt (Sandy-Mud)	S
Sand	S
Coarse Sand	S
Sand Rubble Forams	S
Rubble(5-50 mm)	S
Stones(50-250 mm)	S
Rocks(> 250 mm)	S
Reef	S
Seagrass - Sparse	B
Seagrass - Medium	B
Seagrass - Dense	B
Algae - Sparse	B
Algae - Medium	B
Algae - Dense	B
Whip Garden- Sparse	B
Whip Garden- Medium	B
Whip Garden- Dense	B
Gorgonian Garden- Sparse	B
Gorgonian Garden- Medium	B
Gorgonian Garden- Dense	B
Porifera (Sponge) Garden- Sparse	B
Porifera (Sponge) Garden- Medium	B
Porifera (Sponge) Garden- Dense	B
Hard Coral Garden (Flowerpots)- Sparse	B
Hard Coral Garden (Flowerpots)- Medium	B
Hard Coral Garden (Flowerpots)- Dense	B
Live Reef Corals	B
Caulerpa	B
Halimeda	B
Bivalve Shell Beds	B
Tube Polychaete Beds	B
Burrowing Animals (Bioturbated Mud)	B
Flora	B
null	B

Appendix 2

Mean of MaxN for each species recorded from initial baseline surveys of green (Rap2, 12, 13, 14 and 15) and blue (Rap4, 16 and MP) sites. The species of interest to fishers are highlighted.

Family	Species	2	12	13	14	15	4	16	MP
Acanthuridae	Acanthurus grammoptilus	7.0					1.0		
	Acanthurus xanthopterus	5.0			2.0				
Balistidae	Abalistes stellatus	7.0		3.0	5.0	1.5	1.0	4.7	2.5
Bathysauridae	Saurida sp	1.0							
Blenniidae	Meiacanthus luteus								1.0
Caesionidae	Pterocaesio marri					20.0			
Carangidae	Atule mate	1.0							
	Carangoides chrysophrys						6.0	4.7	16.0
	Carangoides coeruleopinnatus		2.0					2.0	
	Carangoides dinema						2.0		
	Carangoides ferdau							9.0	
	Carangoides fulvoguttatus	1.0			8.0		2.5		1.0
	Carangoides gymnostethus			15.0		6.0	35.0		9.0
	Caranx ignobilis						1.0		
	Caranx papuensis							1.0	
	Caranx sp2							1.0	
	Decapterus russelli					100.0			
	Gnathanodon speciosus	9.5		50.0			36.5	3.0	
	Megalaspis cordyla							30.5	
	Scomberoides commersonnianus						1.0		
	Selaroides leptolepis					1.0			
	Seriolina nigrofasciata				1.0			1.0	1.0
	Trachinotus blochii						2.5		
Carcharhinidae	Galeocerdo cuvier						1.0		
Chaetodontidae	Chaetodon aureofasciatus	1.0							1.0
	Chelmon rostratus	2.0							2.0
	Coradion altivelis	1.0			1.0				3.0
	Coradion chrysozonus	1.0		1.0	1.0				
	Heniochus acuminatus	2.0			1.0		1.0		
	Heniochus diphreutes	1.0							
	Parachaetodon ocellatus	1.0		3.0	1.5	1.0			1.0
Dasyatidae	Dasyatis kuhlii						3.0		
Echeneidae	Echeneis naucrates	2.0					2.0	2.3	1.0
Ephippididae	Platax batavianus						1.0		
	Zabidius novemaculeatus							21.0	
Ginglymostomatidae	Nebrius ferrugineus							1.0	
Grammistidae	Diploprion bifasciatum	1.0							1.5
Haemulidae	Diagramma pictum		1.0	7.0		1.0	2.0	1.7	
Labridae	Anampses caeruleopunctatus							1.0	
	Cheilinus trilobatus				1.0				
	Choerodon cephalotes	1.0		1.0					
	Choerodon gomoni					1.0			
	Choerodon schoenleinii	2.0	1.0			2.0		1.0	2.0
	Choerodon sp			1.0					
	Choerodon venustus	1.0		2.0	1.5	1.0			

Family	Species	2	12	13	14	15	4	16	MP
	Choerodon vitta				1.0	4.0			1.0
	Coris pictoides								2.0
	Halichoeres sp								2.0
	Labroides dimidiatus						3.0		1.0
	Labroides sp					4.0			
	Thalassoma amblycephalum			2.0					
Lethrinidae	Gymnocranius audleyi	2.0						1.5	
	Lethrinus genivittatus	5.0		1.0	1.0				
	Lethrinus laticaudis	1.0	2.0			2.0			3.0
	Lethrinus lentjan	14.0						1.0	
Lutjanidae	Lutjanus carponotatus		1.0		2.0				1.0
	Lutjanus erythropterus	2.5			1.0		1.0	10.0	
	Lutjanus malabaricus	2.0				1.0		7.0	
	Lutjanus sebae	9.5	1.5	3.3	5.0	1.0	1.0	2.5	1.0
	Lutjanus vitta	8.0	1.0	80.0	27.0	6.0			2.0
	Symphorus nematophorus					1.0	2.0	1.0	1.0
Monacanthidae	Aluterus monoceros							2.0	
	Monacanthus chinensis	1.0							
Mullidae	Parupeneus barberinoides					1.0			
	Parupeneus heptacanthus			3.5	4.5	8.0			
	Parupeneus indicus	1.0							1.5
	Upeneus tragula			2.0					
Muraenidae	Gymnothorax sp			1.0					
Myliobatididae	Aetobatus narinari						1.0		
Nemipteridae	Nemipterus furcosus	10.5		2.0	2.0				
	Nemipterus theodorei	1.0							
	Pentapodus paradiseus	7.0		16.0	8.0	6.5			
	Scolopsis monogramma	2.0		1.0	1.0				1.5
	Scolopsis sp					1.0			
Pomacanthidae	Chaetodontoplus duboulayi	2.0		1.0	1.0				2.0
	Chaetodontoplus meredithi	1.0		2.0	1.5				1.0
	Pomacanthus imperator	1.0							
Pomacentridae	Amphiprion clarkii	2.0		3.0		1.0			
	Dascyllus trimaculatus	2.0		3.0					
	Neopomacentrus bankieri								7.0
	Pomacentrus nagasakiensis	1.0				3.0			
	Pomacentrus wardi	1.0							
	Pristotis jerdoni			50.0		7.0			
Rachycentridae	Rachycentron canadum			1.0				1.5	
Rhynchobatidae	Rhina ancylostoma							1.0	
Scaridae	Scarus ghobban	2.0				1.0		1.0	
Scombridae	Scomberomorus queenslandicus	2.0	1.0	2.0				1.0	1.0
Serranidae	Cephalopholis boenak	1.0							
	Cephalopholis sp				2.5				
	Cromileptes altivelis	1.0							
	Epinephelus areolatus	1.5		4.0	1.5				
	Epinephelus coioides	1.0	1.0	1.0		1.0	3.0		1.0
	Epinephelus lanceolatus			1.0					
	Epinephelus malabaricus							1.0	
	Epinephelus quoyanus	2.0							1.0
	Epinephelus sexfasciatus							1.0	

Family	Species	2	12	13	14	15	4	16	MP
	Epinephelus sp	1.0							
	Plectropomus leopardus					1.0		1.0	
	Plectropomus maculatus	1.0	1.0				1.0		1.0
Siganidae	Siganus fuscescens	4.0		5.0	10.0				2.0
Sparidae	Argyrops spinifer							4.7	
Sphyraenidae	Sphyraena forsteri					40.0			
	Sphyraena jello						3.5	1.5	
Tetraodontidae	Arothron sp	1.0							
	Arothron stellatus							2.0	
	Canthigaster coronata	1.0							
	Feroxodon multistriatus						1.0		

Appendix 3

Mean numbers (+1StDev) of species of fish and elasmobranchs recorded from BRUVS sets through July to November 2006 on and off patches of habitat on Magnetic Shoal (green – Rap2, 12, 13, 15) and sites outside the green zone (Rap4, 16, MP).