Comparative marine biodiversity of the Rowley Shoals 2007: Benthic assemblages

Marine Science Program Data Report Series
MSPDR7 November 2008

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Department of
Environment and Conservation
Our environment, our future

This report can be cited as:
Long SC and Holmes TH (2009) Comparative marine biodiversity of the Rowley Shoals 2007: Benthic assemblages data report. Marine Science Program Data Report Series: MSPDR7. January 2009. Marine Science Program, Department of Environment and Conservation, Perth, Western Australia. 59p.

Cover images: (small images, left to right) Australian Institute of Marine Science (AIMS) research vessel the RV Solander; benthic biodiversity survey team at Cunningham Island, Imperieuse Reef, (L-R) Dr John Huisman, Steve Dutton, and Dr Katharina Fabricius; the RV Solander passing through Mermaid Channel; fish on reef flat in Clerke Reef lagoon; and (large image) bommie in Clerke Reef lagoon on calm day. Photos - Department of Environment and Conservation/ Marine Science Program

SUMMARY

A major marine biodiversity survey of the Rowley Shoals, led by the Australian Institute of Marine Science in collaboration with the Western Australian Department of Environment and Conservation, was undertaken from 1-17 December 2007. The multidisciplinary survey aimed to collect data that could directly inform management of the Rowley Shoals Marine Park and the Mermaid Reef National Marine Nature Reserve. This data report provides a record of the data collected, the sites sampled and the methods used by the DEC-led component of the expedition only; that being quantitative surveys of the benthic marine biodiversity. The full set of results and analysis of this work will be presented in a forthcoming Technical Report.

The coral reef communities of the Rowley Shoals are generally in excellent condition. Many key marine species – such as sharks, maori wrasse, and commercially important invertebrates - appear to be more abundant at the Rowley Shoals than most other coral reefs worldwide. Some coral communities show evidence of serious damage by recent cyclone activity, but encouraging signs of recovery are evident, with apparently high rates of coral recruitment. Loss of resilience of these reefs would mean that the capacity for recovery from such acute disturbance events would be limited. Compilation of the benthic assemblages monitoring data acquired during this survey with other data from previous years will enable long-term trends in benthic community condition to be detected over time.

Algal biodiversity of the Rowley Shoals was quantitatively surveyed, whilst the biodiversity of Western Australian soft corals was studied for the first time during this trip. These surveys will facilitate increased understanding of the important ecological role played by macroalgae (including Crustose Coraline Algae (CCA)) and soft corals on Western Australian reefs, via production of basic photo ID guides to the macroalgae and soft corals of the Rowley Shoals. The results of the other projects conducted during this survey are not covered in this data report and will be reported in detail elsewhere.

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1 INTRODUCTION

Coral reef communities are naturally highly dynamic ecosystems. This dynamism is expressed in terms of shifts over time in competitively dominant species and relative cover of some of the key components of these communities: hard corals, soft corals, and algae. Shifts occur in response to both acute and chronic disturbances. Shifts observed in coral reef communities elsewhere include domination of substrate by soft corals or algae following stress-related reductions in hard coral cover, or the loss of sensitive habitat-forming corals like branching acroporids due to acute disturbances such as bleaching. Both of these scenarios can cause significant detrimental flow-on effects to the ecosystem as a whole. Understanding the responses of coral reef communities to different kinds of disturbance is essential for effective conservation management, particularly as the nature of these responses signal the health of the ecosystem, which can also be thought of as its resilience to inevitably increasing levels of environmental stress.

Due to their isolation and protection from most human impacts, the Rowley Shoals are likely to be amongst the most pristine coral reef environments remaining in the world (Bellwood *et al.* 2003; Gilmour *et al.* 2007). As coral reefs continue to degrade worldwide, careful management of the Rowley Shoals will be required to establish and maintain them as regional and potentially global benchmarks for coral reef biodiversity conservation. However, successful management requires informed decision-making. Although all three shoals are managed by State or Commonwealth Departments as marine protected areas, information about trends in marine biodiversity over time is essential for comparison and assessment of the effectiveness of the different management regimes in effect (or shortly to be in effect) across the three shoals. We do not yet have a sufficiently quantitative understanding of the benthic assemblages of the Rowley Shoals that any such trends could be identified. This is a significant constraint to informed management.

The southern two shoals, Clerke and Imperieuse, are managed by the Department of Environment and Conservation (DEC). These two shoals were gazetted in 1990 and extended in 2005 under the Conservation and Land Management Act 1984 (CALM Act) as the Rowley Shoals Marine Park (RSMP). The management of the RSMP is outlined in the Rowley Shoals Marine Park Draft Management Plan and indicative management plan for extensions to the existing marine park 2004 (Department of Conservation and Land Management and the Marine Parks and Reserves Authority 2004). The RSMP is managed as a multiple-use marine park including general use, recreation and sanctuary (no-take) zones. The Department of Fisheries (DoF) is responsible for the management and regulation of recreational and commercial fishing, aquaculture and pearling within the RSMP under the Fish Resources Management Act 1994 (FRM Act).

Apart from the potential negative effects of climate change, the principal human impacts on the shoals derive from multi-day, charter-based recreational diving and fishing visits. Private vessel visitation also occurs, and pressures from illegal foreign fishing activity, although probably sporadic at present (Naomi Wolfe, Department of Water and Resources, pers. comm. 2006), may increase over time.

Qualitative and quantitative surveys of components of benthic marine biodiversity (hard corals, soft corals, algae) have been conducted at different times at various shoals by different agencies (DEC, AIMS, WA Museum) using diverse methods. Following the recent compilation and synthesis of these data by Gilmour et al. (2007), the stage was set for a collaborative, comprehensive survey to both build on previous work and enable informed assessment of the effectiveness of various management regimes for conserving benthic marine biodiversity over time.

Objectives:

We intended to collect quantitative information about the distribution and abundance of key components of benthic marine biodiversity (hard corals, soft corals, and algae). These data will:

- enable local spatial comparisons between the three Rowley Shoals, which although biologically and geologically similar have differing histories of pressures and management;

- in combination with comparable historical records from the Rowley Shoals, serve as a temporal baseline for longer-term monitoring of trends over time; and
- in combination with comparable datasets from other oceanic shoals off northwestern Australia, enable a timely overview of the regional and global conservation status of these coral reef communities to be undertaken.

Benthic communities at the Rowley Shoals have been surveyed sporadically using a variety of methods since 1994. Our survey in 2007 will construct a reasonably detailed temporal snapshot of benthic communities at all three Rowley Shoals, documenting algal and soft coral biodiversity quantitatively for the first time. A forthcoming technical report will view this snapshot in the context of the historical quantitative data, such that trends over time may be identified. The snapshot will also act as a unifying baseline upon which all future monitoring, and our understanding of benthic communities at the Rowley Shoals, can build.

2 METHODS

2.1 Study Location

The Rowley Shoals is comprised of three emergent reefs - Mermaid, Clerke and Imperieuse - located approximately 300 km west-northwest of Broome, Western Australia, along the edge of the continental shelf (Figure 1). The shoals are characterised by high diversity, with upwards of 530 fish, and 214 coral species currently recorded at the location (Gilmour *et al*. 2007). Due to their issolation, they also remain largely unaffected by commercial and traditional fishing practices, resulting in relatively high abundances of shark, trochus, holothuria and giant clam. The northern-most reef, Mermaid, falls within Commonwealth Waters and was gazetted in 1991 as a Marine National Nature Reserve under the National Parks and Wildlife Conservation Act 1975. The southern two shoals, Clerke and Imperieuse, were gazetted in 1990 and extended in 2005 under the Conservation and Land Management Act 1984 (CALM Act) as the Rowley Shoals Marine Park (RSMP).

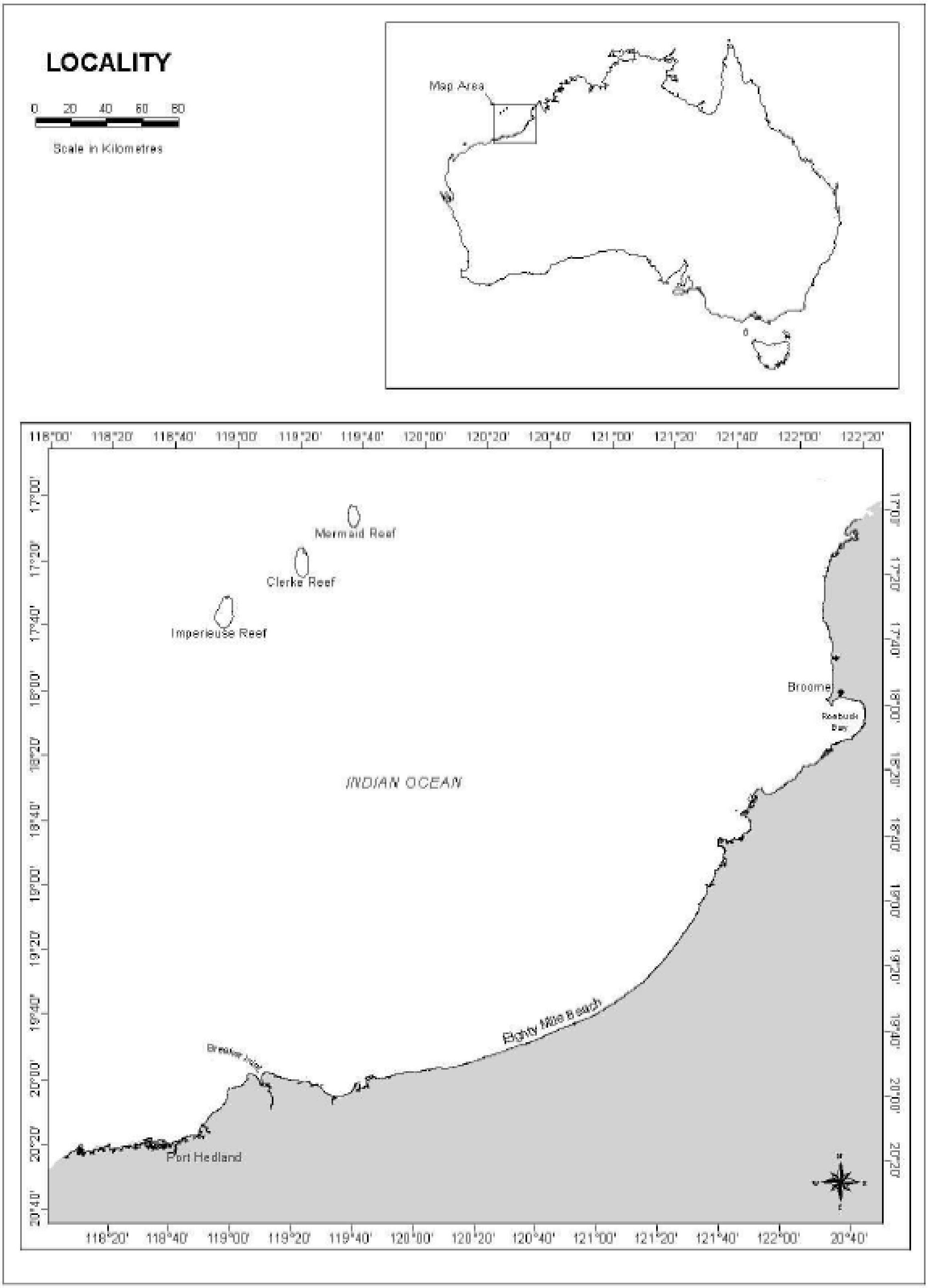

Figure 1. Location of the Rowley Shoals, north-western Australia.

2.2 Survey Locations

Benthic video transects and taxonomic biodiversity surveys were conducted at 10 sites on Clerke Reef, and 8 sites at both Imperiuese and Mermaind Reefs (total of 26 sites; Table 1, Figure 2a-c). Twenty-three of the sites were selected and identified from a historical list from previous DEC and WAM (2001 Rowley Shoals expedition), and AIMS (Long Term Monitoring sites) expeditions (see

Grubba *et al*. 2002 for description on how the original sites were selected and established). Due to the observed similarities between habitats across the three shoals, and the lack of known major disturbances, such as cyclones, since the last comprehensive survey, it was deemed unnecessary to revisit all of these historical sites. 2007 sites were selected on the basis of (a) the pre-existence of quantitative benthic cover data for that site, and/or (b) the need to balance study design in terms of the survey objectives. The remaining three sites, at Imperiuese (I23, I24) and Clerke (C25) reef's, were new sites established during this expedition. These were judged necessary to acquire baseline observations from different management zones, and to survey locations of particularly high human use, scientific interest or conservation value.

Table 1. GPS coordinates (WGS84) of sites at which video transects were recorded in December 2007. These sites are mapped in Figures Xa-c. A = algal samples; SC = soft coral samples.

Date	Reef	Site name	GPS coordinates start lat	GPS coordinates start long	GPS coordinates finish lat	GPS coordinates finish long	Habitat description	Depth (m)	Samples? A	Samples? SC	Remarks
2/12/2007	I	AIMS-1995-RS3-1	17.5484	118.9738	17.5507	118.9737	Slope NE	6 - 9	y	y	Acropora plates with white band syndrome
2/12/2007	I	DEC-2001-I14	17.54897	118.96654	17.55138	118.9651	Lagoon	10	y	y	none
3/12/2007	I	DEC-2007-I23	17.50957	118.93439	17.50681	118.93583	Slope NW	9	n	y	none
3/12/2007	I	DEC-2001-I19	17.57958	118.93665	17.58214	118.93602	Southern lagoon, shallow, dominated by powdery sand (huge infauna activity) with occasional sparse Acropora thickets	6	n	n	Poor visibility
3/12/2007	I	DEC-2001-I13	17.5599	118.94205	17.56247	118.94195	Middle of lagoon, fragile forms of Acropora, occasional bommies	6	n	n	Poor visibility
4/12/2007	I	DEC-2001-I9	17.61058	118.97475	17.61278	118.97434	Slope SE. Highly rugose	7 - 13	y	n	White band syndrome?
4/12/2007	I	DEC-2001-I12	17.5888	118.9637	17.5911	118.9640	Southern lagoon, undisturbed fragile Acropora forms interspersed with bommies	12	y	y	none
6/12/2007	I	DEC-2007-I24	17.6092	118.96384	17.61143	118.96307	Southern lagoon, undisturbed fragile Acropora forms interspersed with bommies	7 - 10	y	n	110 cm clam
7/12/2007	C	DEC-2007-C25	17.3155	119.3675	17.3144	119.3692	Southern edge of eastern lagoon. Murky shallow lagoon edge with very occasional bommies.	4 - 7	y	n	none
7/12/2007	C	DEC-2001-C5	17.34925	119.31541	17.35244	119.31586	Slope SW, reef crest at about 7 m then reef slope. Spur and groove structure, many large soft corals and sea whips below 12 m	9 - 12	y	n	Many juv maori wrasse
8/12/2007	C	AIMS-1995-RS2-1	17.2843	119.3769	17.2867	119.3771	Slope NE, low profile reef subject to strong wave action	6 - 10	n	n	Many long dead plates. Many deeper plates with white bands - coral disease? Temperature logger attached to stake at northern end
8/12/2007	C	DEC-2001-C3	17.27987	119.32131	17.28142	119.32047	Slope NW, steep slope, low rugosity, high wave action. Large areas of Acropora rubble. Many Acropora recruits.	7 - 9	y	y	none
9/12/2007	C	DEC-2001-C20	17.30749	119.3713	17.30974	119.37156	Eastern lagoon, shallow lagoon, patches of Acropora rubble on bommie shoulders - destroyed thickets?	5 - 7	y	y	none

Date	Ref	Site name	GPS coordinates				Habitat description	Depth (m)	Samples?		Remarks
			start		finish						
			lat	long	lat	long			A	SC	
9/12/2007	C	DEC-2001-C1	17.2477	119.3447	Not recorded due to strong currents; approx 300m west of start along depth contour		North slope, quite strong current, low profile, many Pocillopora and Sarcophyton-like softies, high energy environment	6 - 7	y	y	*Drupella* observed
10/12/2007	C	DEC-2001-C12	17.3032	119.3359	17.3051	119.3346	Lagoon, patches of rubble, many clams, occasional bommie.	12	y	n	none
10/12/2007	C	DEC-2001-C11	17.3448	119.3511	17.3473	119.3511	Southern lagoon, patches of rubble, occasional bommie, many juv maori wrasse	6	y	n	none
11/12/2007	C	DEC-2001-C21	17.3197	119.3607	17.3220	119.3606	Small inner lagoon. Shallow lagoonal habitat with occasional bommies.	8	y	n	T1 started twice
11/12/2007	C	DEC-2001-C9	17.3559	119.3842	Not recorded due to strong currents; transects ran in a southerly direction along depth contour		SE Slope. Steep slope/wall with strong spur and groove structure.	8	y	n	No evidence of white band disease amongst plate Acroporids. Filmed at 90 degrees to substrate.
12/12/2007	M	DEC-2001-M5	Not recorded due to strong currents. Transects ran in a southerly direction along 7 m contour adjacent to 17.1272° 119.5943° (old GPS mark for M5, further inshore)				SW slope. Surge and strong currents.	8	y	n	Vid will be challenging to analyse due to frequent changes of direction.
12/12/2007	M	DEC-2001-M1	17.02767	119.61792	17.02745	119.61633	Steep slope, not many fish. Shark listening station along T4, large porites bommie at finish	12	-	-	none
12/12/2007	M	AIMS-1994-RS1-1	17.0659	119.6497	-	-	Near vertical walls into blue water. Lots of soft corals and encrusting hard corals. Strong current off reef flat	8	-	-	none
13/12/2007	M	DEC-2001-M4	17.0762	119.5962	17.0774	119.5956	Almost completely destroyed reef, large areas of turf covered rubble, some acroporid recruits but most substrate still unstable	7-8	-	-	non
14/12/2007	M	DEC-2001-M7	17.1641	119.6277	17.16352	119.62491	Southern tip/slope of Mermaid. Rugose, every stable surface was covered in pocilloporid and acroporid recruits, few large coral colonies xpt encrusters and the odd Porites	10	y	n	none
14/12/2007	M	DEC-2001-M13	17.0891	119.63474	17.09034	119.62421	Northern lagoon. Patches of fragile Acropora with occasional small bommies sporting enormous plates. Some dead thickets covered in algae.	12	y	n	none
15/12/2007	M	DEC-2001-M11	17.13371	119.6339	17.13336	119.63336	Southern lagoon. Transects ran around "hillocks" of staghorn rubble, clams and fungiids. Deeper areas with sparse fine Acropora, fungiids, and rubble with turf.	8 - 12	n	n	none
15/12/2007	M	DEC-2001-M12	17.11469	119.63474	17.11421	119.63484	Middle lagoon. Transects ran around "hillocks" of staghorn rubble, clams and fungiids. Deeper areas with sparse fine Acropora, fungiids, and rubble with turf at 15 - 20 m.	8 - 12	n	n	none

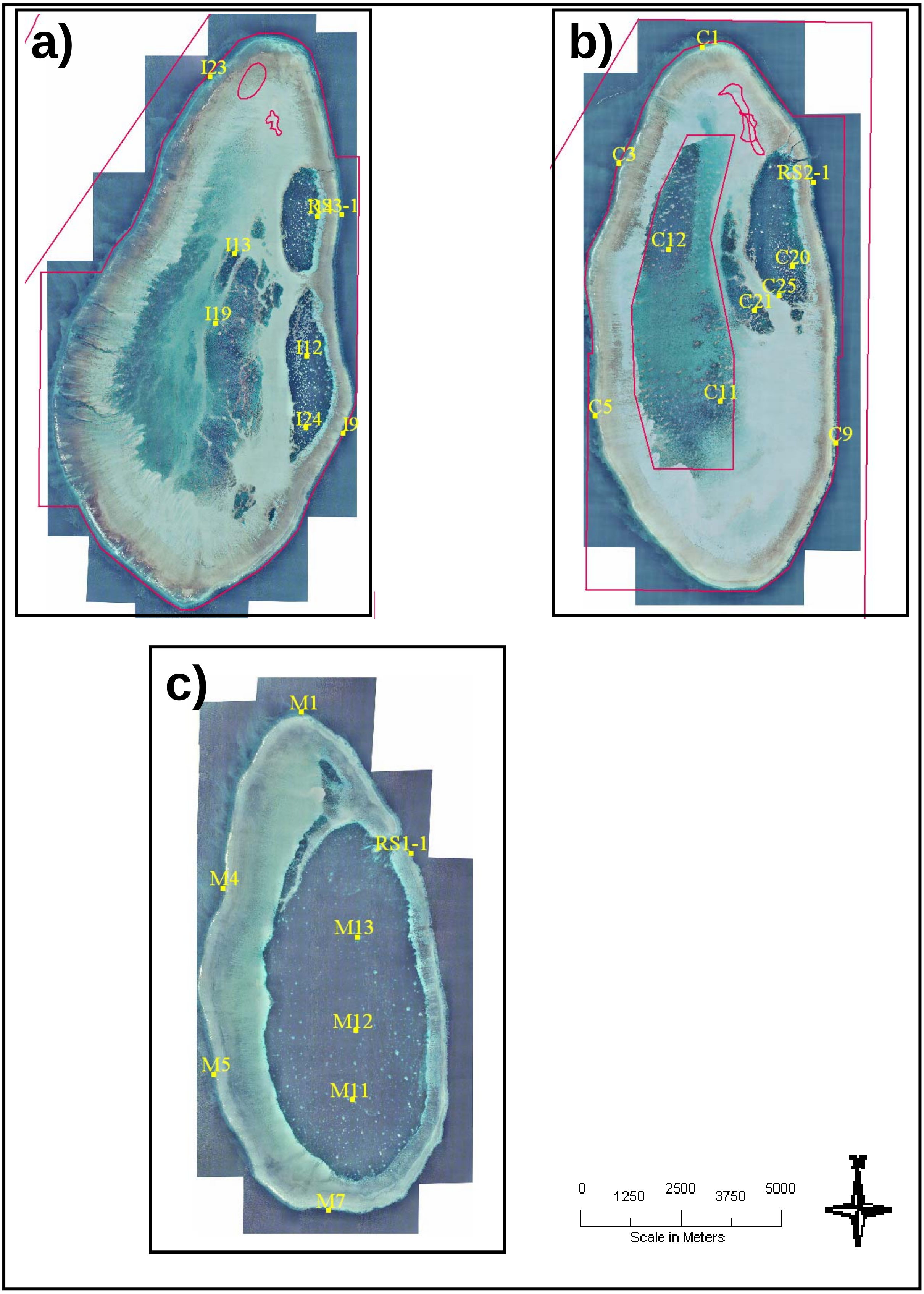

Figure 2a-c. Location of survey sites on (a) Imperiuese, (b) Clerke and (c) Mermaid reefs. Sites labelled 'RS' are AIMS long term monitoring sites.

In addition, a series of haphazard benthic photoquadrats were obtained from all three reefs. Two habitats were sampled using this method: shallow reef crests in the vicinity of the northernmost AIMS

LTM site at each reef, and sheltered lagoonal environments within Clerke and Mermaid (Table 2). For the lagoonal areas, images were made both inside and outside the anchoring zones (Table 2, Appendix 6 (anchoring zones)).

Table 2. Areas in which series of haphazard georeferenced benthic photoquadrats were made, Rowley Shoals, 1-17 Dec 2007.

Date	Reef	Site	Habitat	# quadrats
6/12/07	I	AIMS-1995-RS3-1	NE crest and slope, ranging from 1-13 m depth	70
8/12/07	C	Lagoon near anchoring zone	Sheltered lagoon with sand, rubble and Acropora thickets, 8-16 m depth; quadrats inside/outside anchoring zone	53
10/12/07	C	AIMS-1995-RS2-1	NE crest and slope, ranging from 1-16 m depth	84
16/12/07	M	NE reef crest and lagoon near anchoring zone	Shallow 2-4 m reef crest in vicinity of AIMS-1995-RS1-1; sheltered lagoon with sand, rubble and Acropora thickets, ~15 m depth, with quadrats both inside/outside anchoring zone	58

2.3 Survey Design

Five replicate 50 x 1 metre transects were conducted at each site (Figure 3). Transects were run linearly, starting from the site marker and following the depth contour of the site. Ten metre gaps were maintained between quadrats, for a total survey length of ~290 metres (i.e. 50+10+50+10+50+10+50+10+50 m). This is the standard adopted by the AIMS long-term monitoring program for benthic habitats on the GBR, and use of this method ensures comparability of results with historical data from the Rowley Shoals.

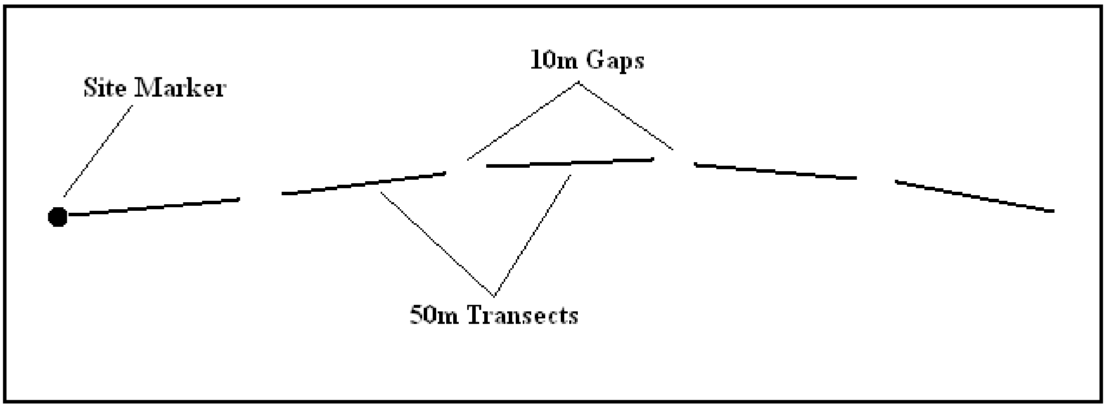

Figure 3. Outline of transect survey design conducted at each site

2.4 Sampling Methods

2.4.1 Benthic video transects

In most cases, sites were identified using historical coordinates, and the start of the first transect was marked by the deployment of a weighted buoy at those coordinates. At established AIMS sites, star pickets have been driven into the reef as permanent markers of the start and finish of each transect. For new sites, the start of the first transect was sited so as to permit all five transects to be laid within similar habitat.

As stated above, five 50 m transects were surveyed at each site. Use of a cotton spool rather than a tape measure to delineate each transect enabled each site to be completed easily within one dive. The first diver was responsible for laying the cotton, keeping to the depth contour and establishing the start and finish of each transect. Transects were laid linearly, with ~10 m between transects. The transects were videoed by the second diver, according to the established methods of AIMS and the Marine Science Program, swimming slowly (10 metres/min) with the camera ~50 cm above the substrate. A float was deployed at the completion of the final transect at each site. The GPS coordinates of the starting and finishing floats were recorded on the data sheet for each site, along with general habitat notes including depth. Notes were also made about the number of Acanthaster planci and feeding aggregations of the corallivorous gastropod Drupella observed along each transect. Photographs and notes were made of any observed incidences of coral disease.

2.4.2 Biodiversity survey

Although the replicate video transect method described above is relatively quick and enables repeatable quantification of benthic cover for a given area, identification of organisms to lower taxonomic levels can be problematic. To facilitate identification of the poorly-known algal and soft coral species from the video record, taxonomic experts Dr John Huisman and Dr Katharina Fabricius examined the vicinity of each transect in situ, making notes, photographs and collections where necessary. In the case of soft corals, transects commenced at ~20 m depth and ascended gradually, finishing at ~5 m depth over a horizontal distance of ~300 m. All octocorals encountered were identified (so far as possible in the field), most were photographed, and samples were taken of new observations for later taxonomic analysis. The resultant basic field guides to the algae and soft corals of the Rowley Shoals (Appendices 1 & 2) will enable non-specialists to tentatively identify taxa from the transect video (although obviously in many cases identification to lower taxonomic levels is impossible without microscopic examination). This should permit quantitative taxonomic discrimination within these key components of the benthic community to a degree that has not hitherto been possible in Western Australia.

2.4.3 Haphazard Photoquadrats

Using a digital camera, GPS and tripod system developed by Dr Andrew Heyward (AIMS), a series of highly detailed, haphazard, georeferenced benthic photoquadrats was obtained for several areas at the three reefs. This was a pilot study to investigate the method’s usefulness for assessing rates of coral recruitment, cover of various groups including crustose coralline algae, rates of recovery from anchor damage, and benthic habitat mapping. With the GPS running in track mode and the camera making high resolution images at 5 second intervals, the camera/tripod assembly was repeatedly lowered over the side of a small boat to the bottom, left for ~10 sec, and retrieved. GPS coordinates were later inserted into the EXIF data for each image using the software Downloader Pro.

2.5 Data Analysis

Transect videos were analysed using the standard AIMS point sampling method that is now used worldwide for coral reef monitoring programs, and which has been used historically at the Rowley Shoals by both AIMS and DEC. Two hundred points were sampled per transect, during which the organism or substrate occurring under each point were classified into the detailed benthic categories described in Page *et al.* (2001). The full list of benthic categories used in the analyses is given in Table 3.

Table 3. Full list of benthic categories used for analysis of the video transects.

Benthos Code	Benthos Description
AA	Algal assemblage
AB	Abiotic
AC	Acropora not ACR or ACB
ACB	Branching Acropora
ACC	Caespitose Acropora
ACD	Digitate Acropora
ACE	Encrusting Acropora
ACH	Staghorn Acropora
ACO	Corymbose Acropora
ACS	Submassive Acropora
ACT	Tabulate Acropora
ACX	Bottlebrush Acropora
AO	Algae Other
BG	Blue-Green Algae
CA	Coralline algae
CB	Branching non-Acropora
CE	Encrusting non-Acropora
CF	Foliose non-Acropora
CHL	Heliopora
CL	Solitary coral
CM	Massive non-Acropora
CME	Millepora
CMR	Mushroom coral
CS	Submassive non-Acropora
CST	Distichopora
CT	Tabulate non-Acropora
DC	Dead coral (recent)
DCA	Algae on Dead Coral
HA	Halimeda
MA	Macroalgae
OT	Other organisms
R	Rubble
RCK	Reefal substrate
S	Sand
SA	Arborescent Soft Coral
SAE	Arb & Enc Soft Coral
SB	Branching Soft Coral
SC	Soft coral
SCC	Capitate Soft Coral
SD	Digitate Soft Coral
SE	Encrusting Soft Coral
SER	Errect Soft Coral
SI	Silt
SL	Lobate Soft Coral
SM	Massive Soft Coral
SP	Sponge
SPB	Sponge Branching
SPE	Sponge Encrusting
SPF	Sponge Foliaceous
SPL	Sponge Blade
SPM	Sponge Massive
TA	Turf algae
UNK	Unknown
WA	Water
ZO	Zoanthid

3 DATA MANAGEMENT

3.1 Digital Video Records

All mini digital video (MDV) footage collected during the survey is held at two locations:

1. MDV masters have been archived in the Rowley Shoals Marine Park – Long Term Monitoring Program – Video Archive – Marine Science Program file (box) 2008/001941 held at the Information Management Branch, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0333.

2. MDV copies have been stored at the Marine Science Program, Science Division, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0333.

3.2 Benthic Video Database

The analysed benthic video database is contained within a Microsoft Access database file and stored in the following locations:

1. The Rowley Shoals Marine Park – Long Term Monitoring Program – Video Archive – Marine Science Program file (box) 2008/001941 held at the Information Management Branch, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0333.

2. The *Rowley Shoals* file on the MSP server at the Kensington offices. Ph. (08) 9334 0333.

3.3 Data Sheets

Copies of the data sheets collected during the 2008 survey are contained within the Rowley Shoals coporate data file, stored at the Marine Science Program offices, Kensington (File 2008/004448-1).

3.4 Digital Photoquadrats

All digital photoquadrats taken during the survey are archived on the MSP server at the Kensington offices. Ph. (08) 9334 0333.

3.5 Digital Still Photographs

All digital still photographs taken during the survey are archived in the image library on the MSP server at the Kensington offices. Ph. (08) 9334 0333.

3.6 Report Archivals

Hard copies of this report will be held at the following locations:

1. Marine Science Program, Science Division, Department of Environment and Conservation, 17 Dick Perry Avenue, Western Australia, 6152. Ph: (08) 9334 0333.

2. Woodvale Library, Science Division, Department of Environment and Conservation, Ocean Reef Road, Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641.

3. Archives, Woodvale Library, Science Division, Department of Environment and Conservation, Ocean Reef Road, Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641 (CD also attached).

4. Department of Environment and Conservation: Exmouth, 20 Nimitz St, Exmouth, Western Australia, 6007. Ph: (08) 99478000 Fax: (08) 99478050.

5. Department of Environment and Conservation: Regional Office - Karratha, Lot 3 Anderson Rd, Karratha Industrial Estate, Karratha, WA, 6714. Ph: (08) 91431488 Fax: (08) 91441118.

6. Serials Section, State Library of Western Australia. Alexander Library Building, Perth Cultural Centre, Perth, Western Australia, 6000.

A digital copy of this report is held on the MSP Server at the Kensington offices. Ph: (08) 9334 0229

4 DATA/RESULTS

4.1 Benthic Video Transects

Twenty-three long-term monitoring sites were resurveyed, and three new sites were established (Table 1). A summary of the video transect analyses is referred to in Appendix 3 in this report. Data has been processed and categorized into the percentage cover for each of the benthic categories, down to the replicate transect level. Although this version has been modified so that it can be placed into this report, the original version is stored within a Microsoft Access database.

4.2 Biodiversity Survey

Outcomes from the macroalgal and soft coral surveys can be found in Huisman (2009) and Fabricius (2008) respectively (refer to Appendices 1 and 2 for further detail). See Table 4 below for a summary of soft corals identified during the 2007 survey.

Table 4. Soft Coral families and genera identified during the biodiversity survey of the Rowley Shoals, December 2007 (from Fabricius 2008).

Leather corals and aborescent taxa	Phototroph/ Heterotroph	Gorgonians (sea fans, sea whips)	Phototroph/ Heterotroph	Blue coral, encrusting taxa and taxa with large polyps	Phototroph/ Heterotroph
Alcyoniidae		Subergorgiidae		Helioporidae	
Sinularia	p	*Annelia*	H	*Heliopora*	p
Dampia	p				
Cladiella	p	Melithaeidae		Clavulariidae	
Sarcophyton	p	*Melithaea*	H	*Clavularia*	p
Lobophytum	p				
		Acanthogorgiidae		Xeniidae	
Nephtheidae		*Acanthogorgia*	H	*Xenia*	p
Nephthea	p				
Litophyton	p	Plexauridae		Briareidae	
Stereonephthya	p + H	*Euplexaura*	H	*Briareum*	p
Scieronephthya	H	*Echinogorgia*	H		
Dendronephthya	H	*Menella*	H		
Lemnalia	p	*Astrogorgia*	H		
Paralemnalia	p				
		Gorgoniidae			
Nidaliidae		*Rumphella*	p		
Siphonogorgia	H	*Hicksonella*	p		
Chironeohthya	H				
		Ellisellidae			
		Ellisellia	H		
		Junceella	p + H		

4.3 Haphazard Photoquadrats

The full sets of high resolution images are available on the MSP server. An example is given in Figure 4. These sets include images which are unsuitable for quantitative analyses due to having been taken whilst the tripod was not settled on the substrate; such georeferenced images may however prove to be of use for benthic habitat mapping purposes. (For example, the lagoon of Mermaid Reef was frequently too deep (>16 m) for the tripod to reach the substratum. However, many of these georeferenced images provide good general overviews of the underwater landscape and thus have not been discarded). Of these sets, those images selected as being appropriate for further quantitative analyses are listed along with their depth class, habitat and GPS coordinates (WGS84) in Appendix 4.

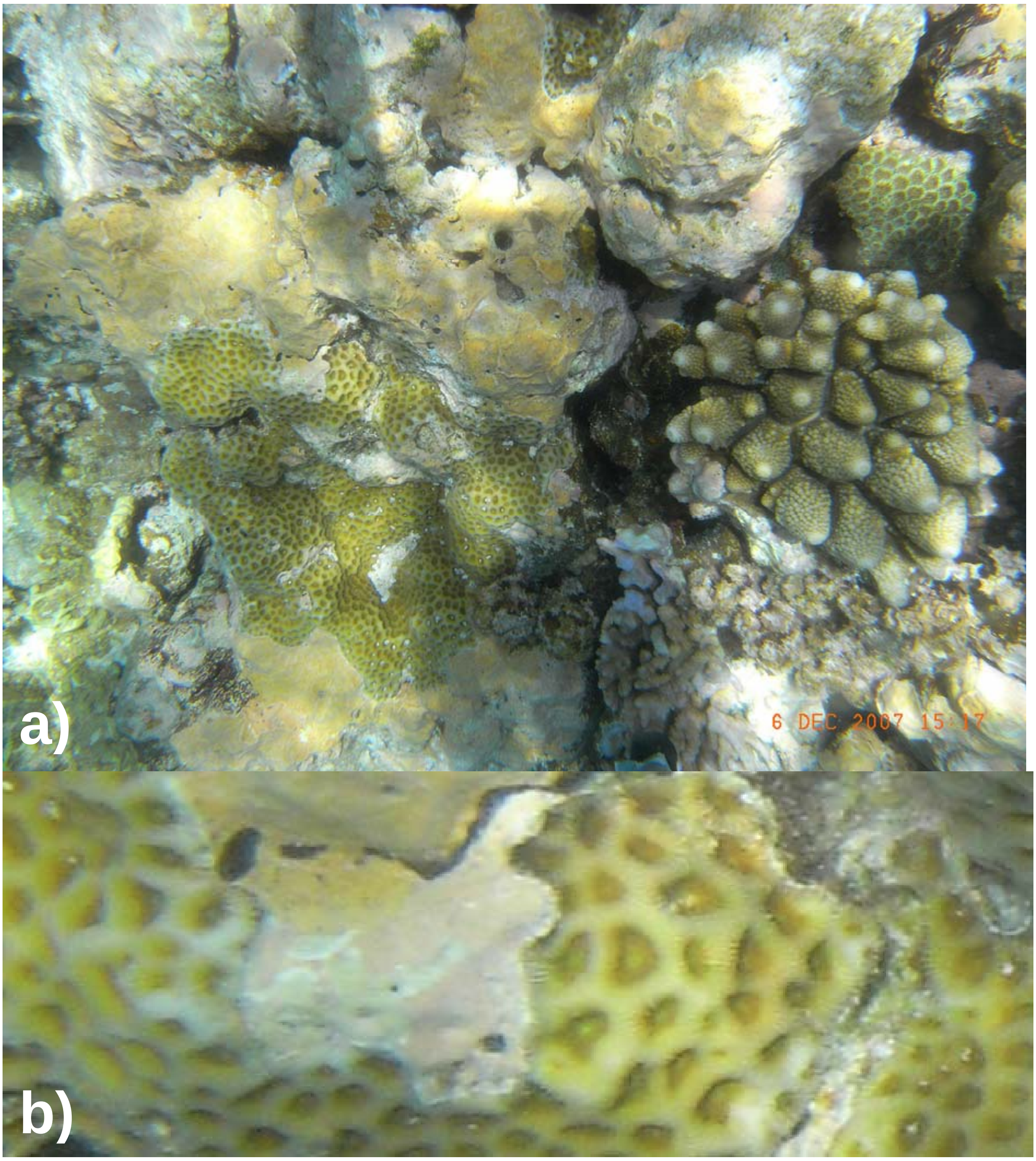

Figure 4. RS Imperieuse NE crest and slope 071206_550.jpg. Low resolution version showing wide angle (a); detail showing maximum resolution available (b).

This method works reasonably well in the field and can generate considerable amounts of data (images) in a relatively short period of time, without the risks and constraints associated with having scuba divers in the water. Consequently, although these images could not be analysed prior to the publication of this data report, the potential usefulness of this method for future Marine Science Program research should be investigated in the following ways:

- Using Coral Point Count software and the benthic categories given in Table 1 to generate percent cover of each category, enabling comparison of these results with those generated by the conventional video transect method at each northeastern crest/slope site.

- Using Coral Point Count software and the benthic categories given in Table 1 to generate percent cover of each category for lagoonal images, enabling statistical comparison of lagoonal benthic assemblages between reefs and inside/outside anchoring zones.
- Using image analysis software to measure the size/two-dimensional area of coral recruits identified in the northeastern crest/slope images, to compare rates of coral recruitment and the size and taxonomic composition of recruited corals in similar habitats across the three reefs.
- Assessment of whether a combination of these approaches could be used for statistically robust quantitative monitoring of condition and/or recovery of benthic assemblages in areas in which diving-based research is not feasible.

4.4 Record of any significant observations or problems encountered in the field

4.4.1 Coral disease observations

An unusually high number of dead plate *Acropora* colonies was observed along transects at long-term monitoring sites on the reef slope of eastern Imperieuse Reef (AIMS-1995-RS3-1 and DEC-2001-I9). Approximately 5-10% of live plate colonies in the vicinity of these sites showed features tentatively identified as symptomatic of white syndrome (Figure 5). These plates were in situ and not physically damaged, and there was no evidence of Crown of Thorns Starfish (COTS) predation. Qualitative observations suggested that the frequency of infection was highest at approximately 10 m and decreased with increasing depth.

Figure 5. Plate Acropora colony showing possible symptoms of white syndrome in the vicinity of long-term monitoring site AIMS-1995-RS3-1 at Imperieuse Reef in December 2007. Note completely dead, turf-covered plate and corymbose forms nearby.

Similar observations were made near the long-term monitoring site on the northeastern slope of Clerke Reef (AIMS-1995-RS2-1; Figure 6). To quantify the extent of infected colonies at this site, we filmed another parallel series of monitoring transects at a depth of 10 m, several metres deeper than AIMS-1995-RS2-1. This should enable future surveys to calculate the rate of colony death and infection at this site.

The northeastern slope of Mermaid Reef (AIMS-1994-RS1-1) was quite different in topography to Clerke and Imperieuse, being much steeper and with limited appropriate habitat for plate Acropora corals. Nonetheless several symptomatic colonies were also identified in this area.

Close inspection of symptomatic colonies along the deeper transect at AIMS-1995-RS2-1 showed that many hosted aggregations of *Drupella*. However, it is unclear whether these corallivores were responsible for the observed pathology or were secondarily opportunistically attacking the disease-weakened coral (*Drupella* are known to aggregate at areas where coral has been damaged).

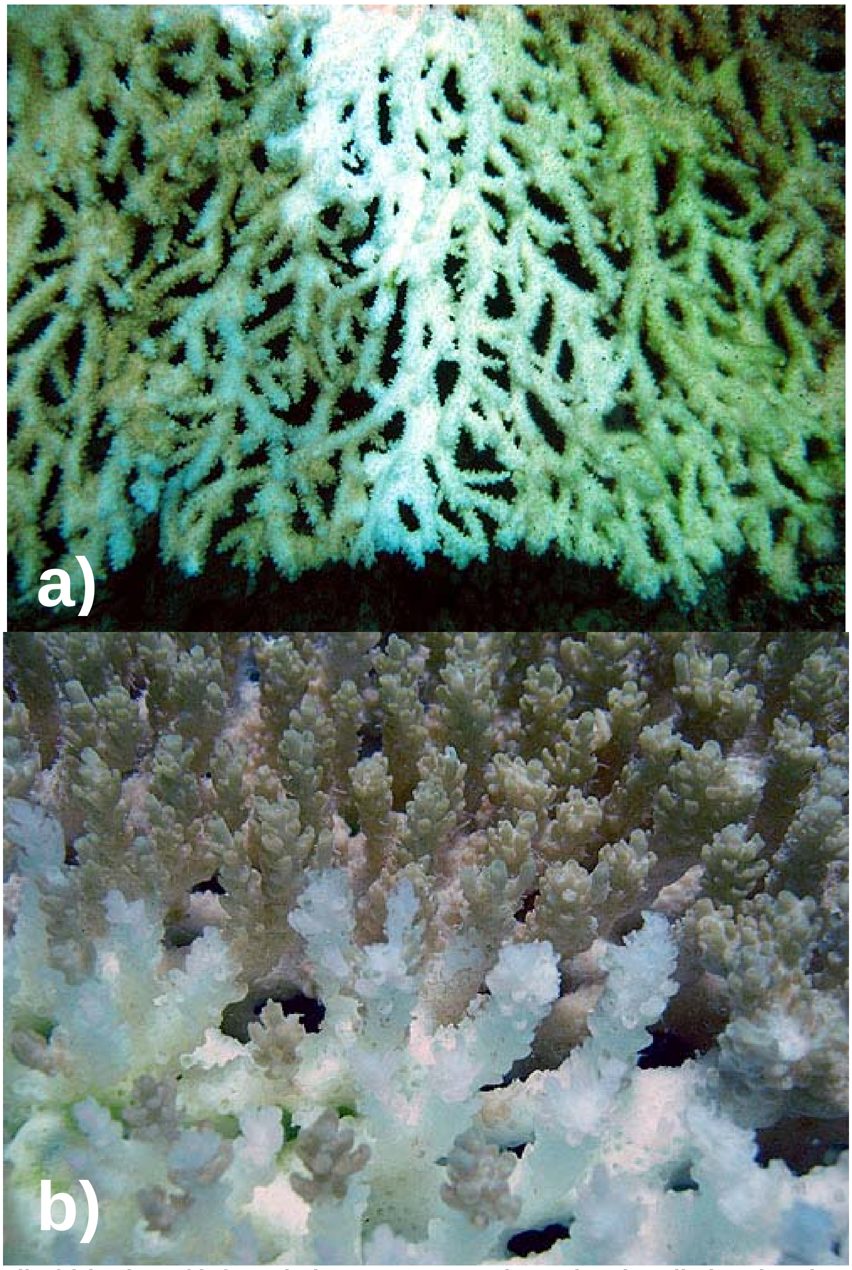

Figure 6. Detail of (a) edge of infected plate Acropora colony showing distinct bands of living (left), recently dead (white, middle) and algae-covered (right) tissue, in the vicinity of AIMS-1995-RS3-1 at Imperieuse Reef in December 2007; and (b) disease front on another colony at the same site (photo courtesy of John Huisman).

Samples from two symptomatic colonies were inspected microscopically shortly after collection. The white-brown front on the first sample showed many cases in which the front passed directly through polyps, such that half the polyp was white and the other brown. Zooxanthellae were observed escaping from damaged tissues at the front. White areas appeared to be bare skeleton, with little or no tissue attached. The second sample, however, from the Cod Hole at Mermaid Reef, had quite a different microscopic appearance. In this case shreds of live tissue remained in the vicinity of the front, and entire rather than partial polyps tended to be affected. No *Drupella* were observed in the vicinity of either of these sampled colonies.

Another apparently pathological condition affecting plate *Acropora* colonies was observed patchily across Imperieuse and Clerke reefs (Figure 7). The apparent loss of coral skeleton as well as living tissue in affected areas means that these dead patches are unlikely to be COTS feeding scars. Further scientific opinion will be sought regarding these observations.

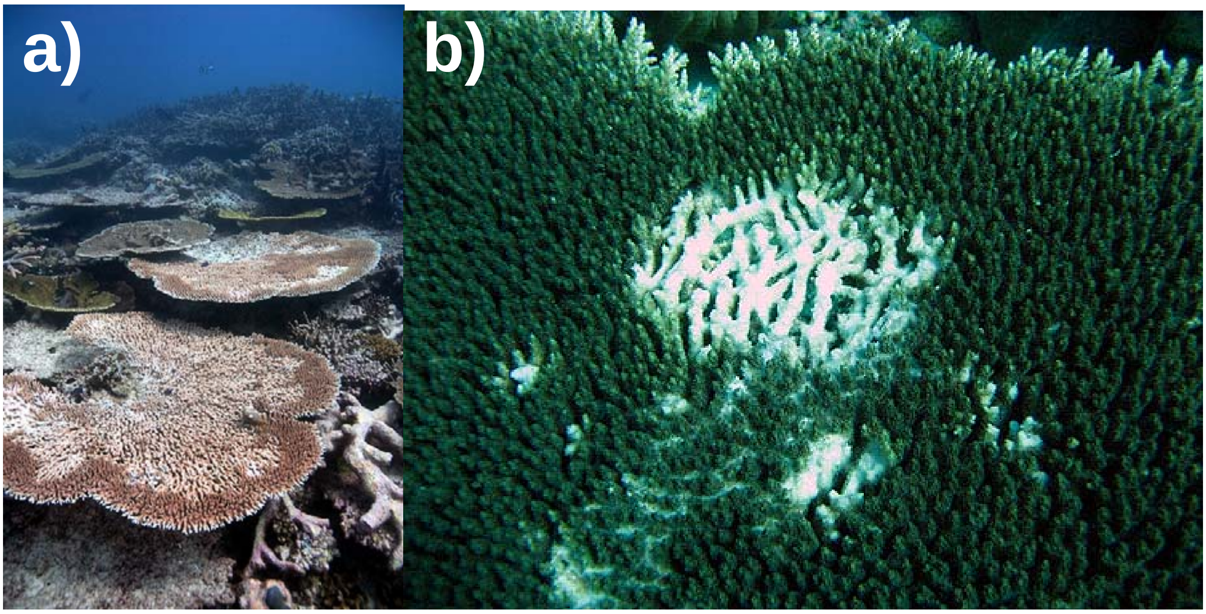

Figure 7. (a) Apparently pathological condition affecting plate Acropora colonies near the finish mark of DEC-2007-I23 at Imperieuse Reef in December 2007, (b) Detailed view of same.

4.4.2 Corallivores

Only two *Acanthaster planci* were observed during the entire period of field operations, indicating that crown-of-thorns starfish are currently not in sufficient numbers to pose a threat to Rowley Shoals coral communities (at least at depths <30 m).

However, *Drupella* feeding aggregations were observed on all three reefs (Figure 8). Aggregations were always in association with *Acropora* or *Pocillopora* colonies, which have been reported to be preferred prey species for *Drupella* elsewhere in the Indo-Pacific, including Ningaloo Reef. Qualitative observations indicated that Rowley Shoals aggregations were generally less common and composed of fewer, larger individuals relative to aggregations at Ningaloo Reef. As previously mentioned, aggregations were also observed in association with some plate Acropora colonies appearing to show symptoms of white syndrome (see above). It is possible that *Drupella* feeding aggregations could be the causative agent of the relatively high incidence of plate acroporid colony death observed at these sites.

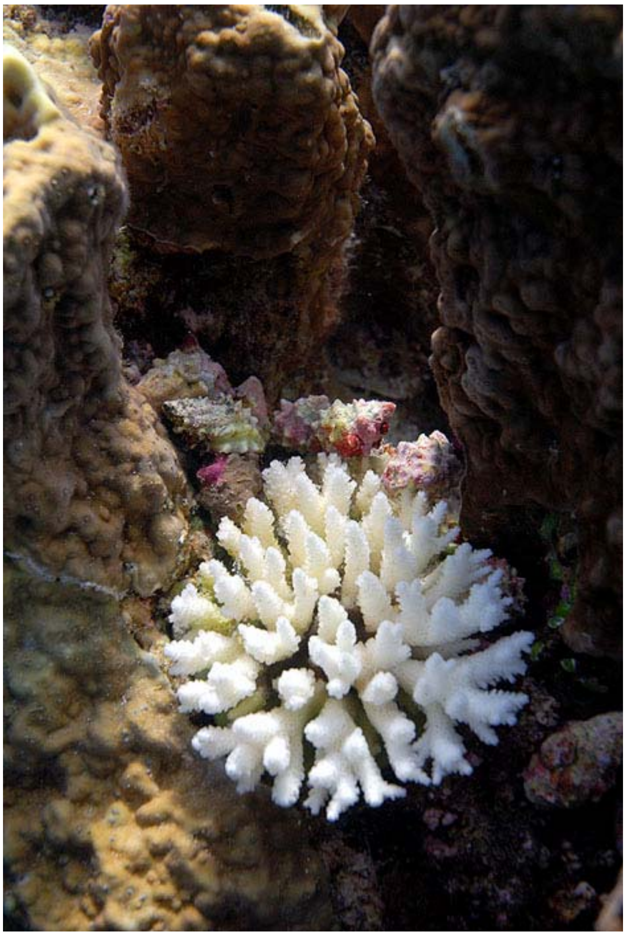

Figure 8. Feeding aggregation of corallivorous Drupella cornus (~10 individuals) that has consumed a small acroporid colony. The lack of macroalgal settlement to the white coral skeleton indicates that this colony was eaten very rapidly and recently, probably within a few days.

It is recommended that a microscopic study be made of tissue consumption patterns associated with *Drupella* predation of plate *Acropora* corals. Sufficient understanding of these patterns might in future enable symptoms of *Drupella* predation to be relatively easily distinguished from disease-caused pathologies in the field.

4.4.3 Sharks

As reported by Meekan & Cappo (2004), Rowley Shoals shark populations appear to be healthy. Although no quantitative observations were made, the Rowleys benthic team saw around three sharks per dive, compared to around one shark every five days by research teams on the Great Barrier Reef (Katharina Fabricius, pers comm.). Grey reef sharks, whitetip and blacktip reef sharks appeared to dominate shark assemblages, and rarely appeared concerned by the presence of divers. Grey reef sharks seemed the most aggressive of these species, with threatening behaviour towards divers observed on a couple of occasions (Mermaid lagoon). Care should be taken when diving in the vicinity of this species in all future activities at the Rowley Shoals. Whitetips regularly closely approached divers working in lagoons. The largest shark seen was a great hammerhead (*Sphyrna mokarran*) approximately 2.5-3 m in length, which very closely approached the benthic team at site DEC-2001-C3.

4.4.4 Turtles

Relatively few turtles were observed during field operations at the Rowley Shoals compared to reefs in more coastal regions of Western Australia (such as the Montebellos/Barrow Island or Ningaloo Reef). It is unknown whether the Rowley Shoals normally supports few turtles, or whether at this time of year Rowley Shoals turtles have migrated towards coastal nesting beaches for the reproductive season. Anecdotal reports of an individual turtle that regularly approaches divers in the vicinity of AIMS-1995-RS2-1 (the northernmost transect) at Clerke Reef were confirmed by the benthic team (Figure 9).

Figure 9. Dr Katharina Fabricius fending off an unusually inquisitive turtle in the vicinity of AIMS-1995-RS2-1 at Clerke Reef, 10 December 2007.

No turtle tracks were observed on 2 December 2007 at Cunningham Island (Imperieuse Reef). Fourteen green turtle tracks were observed on Bedwell Island (Clerke Reef) on 10 December 2007, although it is unknown over what time period these tracks had been made. At least one of these appeared to have resulted in a nest successfully being dug, although no attempt was made to verify whether eggs had been laid. However, given the limited area available and in line with previous reports, it seems unlikely that significant turtle nesting occurs at the Rowley Shoals.

4.4.5 Spawning sea cucumbers

Individual spawning sea cucumbers *(Bohadaschia graffei)* were observed on several occasions during the survey, usually in the late afternoon/early evening.

4.4.6 Nocturnal fauna observations

Night-time shark-fishing activities off the back deck of the RV Solander afforded many opportunities to make natural history observations of the marine organisms attracted to the lights and berley trail. The assemblage of organisms attracted to the vessel each night was highly variable and unpredictable. On a couple of nights very large numbers of crab megalopae clustered around the vessel (visible as bright spots in Figure 10), crawling out onto any available surface, including up fishing lines. On several separate occasions, numerous small (~20 cm long) banded eels (possibly *Myrichthys colubrinus*) were observed swimming on the surface for long periods, possibly feeding on small organisms attracted to the lights. These may have been juveniles, as adults of this species group are diurnal and benthic in shallow reef flat habitats. Notably, none of the larger predatory fish present were observed to attack these eels, the banded pattern and swimming style of which is thought to mimic the banded sea krait, *Laticauda colubrina*. (It's interesting that this form of protection apparently works despite the fact that no sea snakes have ever been reported from the Rowley Shoals.) Other observations of note included the brief presence of a pair of unidentified extraordinary fish (Figure 10), which were seen on a couple of occasions on a single night. These small fish (~10 cm SL, and apparently quite deep-bodied) had extremely elaborated streamers on their fins which, along with their closely paired, smooth swimming style, made them appear superficially similar to a cubozoan jellyfish. No attacks were observed on these slow-moving, fragile-looking fish.

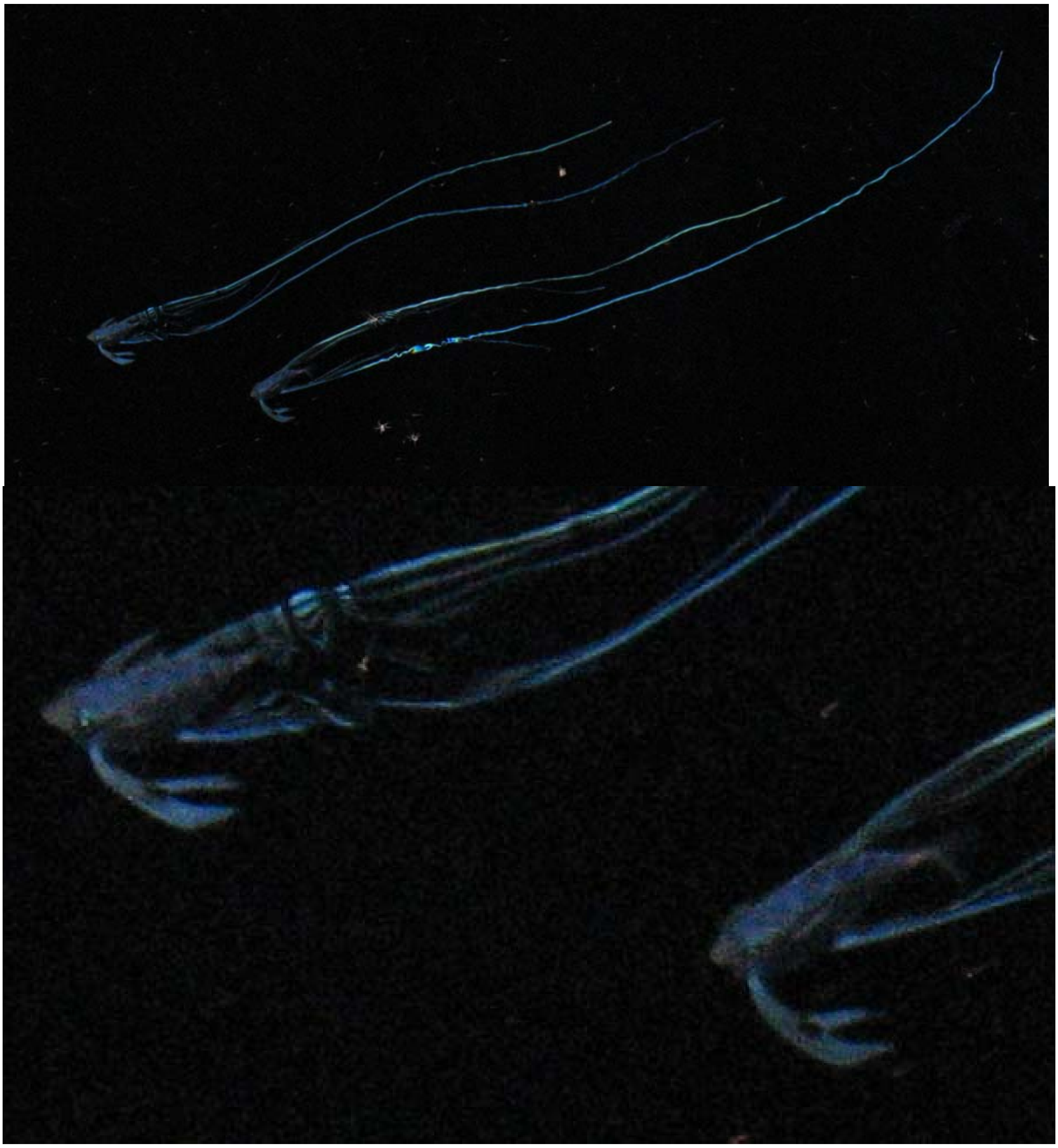

Figure 10. Unidentified pair of extraordinary-looking fish with extremely long fins that appeared to be mimicking a cubozoan jellyfish. Lower image is a detailed version of the upper image. Image courtesy of Iain Field.

4.4.7 Whale shark at Clerke Reef

On 9 Dec 2007, a whale shark (*Rhincodon typus*) twice approached the RV Solander while the vessel was anchored in the vicinity of AIMS-1995-RS2-1 at Clerke Reef. The shark was relatively small (~ 4 m long) and thin (Figure 11) and on both occasions – once at around midday, and once just after sunset - came within metres of the Solander's hull for at least 15 minutes, before slowly swimming away. Figure x has been entered into the global whale shark ID database by Dr Iain Field, and no matches for this individual have been found (although the image is borderline in quality for identification purposes).

Figure 11. Small (~4 m long) whale shark (Rhincodon typus) alongside the RV Solander at Clerke Reef on the evening of 9 Dec 2007 (Image courtesy of Iain Field).

Whale sharks have been anecdotally reported from the Rowley Shoals[1] but it is unknown whether the Shoals constitute important habitat for a resident or transient population of these globally threatened sharks.

5 ACKNOWLEDGEMENTS

This survey was led by the Australian Institute of Marine Science (AIMS) in collaboration with the Western Australian Department of Environment and Conservation (DEC). The project was funded by the AIMS, DEC, the Western Australian Museum and the Commonwealth Department of Environment Heritage and the Arts. In-kind support was provided by Charles Darwin University (Ian Field). The time and effort of volunteers who provided field support was greatly appreciated. In particular we would like to thank the master and crew of the AIMS research vessel the Solander.

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[1] For example http://www.escuba.com/articles/index.asp?WCI=Article1&WCE=79

Marine Conservation Branch, Department of Conservation and Land Management, Fremantle, Western Australia (unpublished report). 265p.

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Long SC, Armstrong S, Fabricius K, Field I, Cook K, Coquhoun J, Huisman J (2008) Comparative marine biodiversity survey of the Rowley Shoals (1-17 Dec 2007): metadata report. In: (ed. MSP-2008-01 MSP). DEC, Perth. 14p.

Meekan MG, Cappo M (2004) Non-destructive techniques for rapid assessment of shark abundance in northern Australia. In. AIMS report for the Department of Agriculture, Fisheries and Forestry, Townsville. 36p.

7 APPENDICES

Appendix 1: Photo ID guide to the macroalgae of the Rowley Shoals

A brief photo ID guide to the plants of the Rowley Shoals

These images and identifications were made **by Dr John Huisman** during a marine biodiversity survey of the Rowley Shoals (1-17 December 2007). While this guide does not represent a complete inventory of the plants of the Rowley Shoals, the most common shallow forms are likely to be included. This basic photo-based guide is intended to be used to assist non-specialists in further study of this ecologically important but relatively little-known group in Western Australia's tropical coral reef environments.

Further information:
Huisman J. (2000) Marine plants of Australia. University of Western Australia Press, Perth.

Contents

Department of Environment and Conservation

Huisman J (2009) A brief photo ID guide to the macroalgae of the Rowley Shoals. DEC, Perth.

This guide is in its final stages of production and is not yet available online.

Appendix 2: Photo ID guide to the soft corals of the Rowley Shoals

A brief photo guide
to the shallow-water octocorals
of the Rowley Shoals,
Western Australia

Katharina Fabricius

Australian Institute of Marine Science
PMB 3, Townsville Q4810
Email: k.fabricius@aims.gov.au

Report to the Department of Environment and Conservation,
Government of Western Australia.
January 2008

Australian Government

Australian Institute of Marine Science

Department of Environment and Conservation

Fabricius K (2008) A brief photo guide to the shallow-water octocorals of the Rowley Shoals, Western Australia. AIMS and DEC. 39p.

Available online from DEC at
http://www.naturebase.net/component/option,com_hotproperty/task,view/id,161/Itemid,755/

Appendix 3: Benthic video transect raw data

The analysed benthic video database are contained within a Microsoft Access database file and stored in the following locations:

3. The Rowley Shoals Marine Park – Long Term Monitoring Program – Video Archive – Marine Science Program file (box) 2008/001941 held at the Information Management Branch, Department of Environment and Conservation, 17 Dick Perry Avenue, Kensington, Western Australia. Ph: (08) 9334 0333.

4. The *Rowley Shoals* file on the MSP server at the Kensington offices. Ph. (08) 9334 0333.

The data has been analysed down to replicate transect level and summaries to percent cover for each of the benthic categories.

Appendix 4: Haphazard photoquadrats raw data

These images described in the following tables are the set selected for usefulness from the full range available on the MSP server at the Kensington offices. Ph. (08) 9334 0333.

Table Ap4a: Haphazard photoquadrats made on the northeastern crest and slope of Imperieuse Reef on 6 December 2007, in the vicinity of the northernmost AIMS LTM site (AIMS-1995-RS3-1). Depth class: s = 1-4 m (regularly emersed); m = 5-10 m; d = >10 m. Habitat = spur or groove. GPS coordinates in WGS84 datum.

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Imperieuse NE crest and slope 071206_8	17° 32' 08.0" S	118° 58' 21.5" E	d	groove
RS Imperieuse NE crest and slope 071206_17	17° 32' 07.7" S	118° 58' 21.6" E	m	groove
RS Imperieuse NE crest and slope 071206_35	17° 32' 08.5" S	118° 58' 20.9" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_45	17° 32' 08.4" S	118° 58' 21.4" E	m	groove
RS Imperieuse NE crest and slope 071206_74	17° 32' 09.8" S	118° 58' 20.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_77	17° 32' 09.7" S	118° 58' 20.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_83	17° 32' 09.5" S	118° 58' 20.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_87	17° 32' 09.4" S	118° 58' 20.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_93	17° 32' 09.2" S	118° 58' 20.9" E	m	groove
RS Imperieuse NE crest and slope 071206_120	17° 32' 11.2" S	118° 58' 20.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_126	17° 32' 11.2" S	118° 58' 20.7" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_131	17° 32' 11.1" S	118° 58' 20.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_136	17° 32' 11.0" S	118° 58' 21.0" E	m	groove
RS Imperieuse NE crest and slope 071206_144	17° 32' 10.8" S	118° 58' 21.4" E	m	groove
RS Imperieuse NE crest and slope 071206_165	17° 32' 13.1" S	118° 58' 20.3" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_168	17° 32' 13.0" S	118° 58' 20.3" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_174	17° 32' 12.9" S	118° 58' 20.4" E	m	groove
RS Imperieuse NE crest and slope 071206_181	17° 32' 12.8" S	118° 58' 20.6" E	s	groove
RS Imperieuse NE crest and slope 071206_183	17° 32' 12.7" S	118° 58' 20.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_185	17° 32' 12.7" S	118° 58' 20.6" E	m	groove
RS Imperieuse NE crest and slope 071206_190	17° 32' 12.6" S	118° 58' 20.8" E	m	crest of spur
RS Imperieuse NE crest and slope 071206_192	17° 32' 12.5" S	118° 58' 20.8" E	m	crest of spur
RS Imperieuse NE crest and slope 071206_199	17° 32' 12.4" S	118° 58' 21.0" E	m	groove
RS Imperieuse NE crest and slope 071206_205	17° 32' 12.3" S	118° 58' 21.1" E	m	groove
RS Imperieuse NE crest and slope 071206_208	17° 32' 12.2" S	118° 58' 21.2" E	s	groove
RS Imperieuse NE crest and slope 071206_211	17° 32' 12.1" S	118° 58' 21.3" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_216	17° 32' 12.0" S	118° 58' 21.4" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_223	17° 32' 11.9" S	118° 58' 21.7" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_249	17° 32' 08.8" S	118° 58' 19.9" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_268	17° 32' 08.7" S	118° 58' 20.2" E	m	crest of spur
RS Imperieuse NE crest and slope 071206_272	17° 32' 08.7" S	118° 58' 20.3" E	m	groove
RS Imperieuse NE crest and slope 071206_276	17° 32' 08.6" S	118° 58' 20.4" E	m	groove
RS Imperieuse NE crest and slope 071206_280	17° 32' 08.6" S	118° 58' 20.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_283	17° 32' 08.5" S	118° 58' 20.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_287	17° 32' 08.5" S	118° 58' 20.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_291	17° 32' 08.4" S	118° 58' 20.9" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_296	17° 32' 08.4" S	118° 58' 21.0" E	m	groove
RS Imperieuse NE crest and slope 071206_301	17° 32' 08.3" S	118° 58' 21.2" E	m	groove
RS Imperieuse NE crest and slope 071206_305	17° 32' 08.2" S	118° 58' 21.3" E	m	groove
RS Imperieuse NE crest and slope 071206_330	17° 32' 07.6" S	118° 58' 19.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_334	17° 32' 07.6" S	118° 58' 19.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_337	17° 32' 07.5" S	118° 58' 19.6" E	s	crest of spur

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Imperieuse NE crest and slope 071206_346	17° 32' 07.4" S	118° 58' 19.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_357	17° 32' 07.2" S	118° 58' 20.0" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_359	17° 32' 07.2" S	118° 58' 20.0" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_367	17° 32' 07.1" S	118° 58' 20.4" E	m	groove
RS Imperieuse NE crest and slope 071206_372	17° 32' 07.0" S	118° 58' 20.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_390	17° 32' 06.7" S	118° 58' 19.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_393	17° 32' 06.6" S	118° 58' 19.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_397	17° 32' 06.5" S	118° 58' 19.3" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_400	17° 32' 06.5" S	118° 58' 19.4" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_408	17° 32' 06.4" S	118° 58' 19.7" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_412	17° 32' 06.3" S	118° 58' 19.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_418	17° 32' 06.2" S	118° 58' 20.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_435	17° 32' 06.0" S	118° 58' 18.9" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_440	17° 32' 05.9" S	118° 58' 18.9" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_441	17° 32' 05.8" S	118° 58' 18.9" E	m	groove
RS Imperieuse NE crest and slope 071206_450	17° 32' 05.7" S	118° 58' 19.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_455	17° 32' 05.7" S	118° 58' 19.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_458	17° 32' 05.6" S	118° 58' 19.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_460	17° 32' 05.6" S	118° 58' 19.1" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_469	17° 32' 05.5" S	118° 58' 19.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_479	17° 32' 05.3" S	118° 58' 19.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_483	17° 32' 05.2" S	118° 58' 19.5" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_486	17° 32' 05.2" S	118° 58' 19.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_491	17° 32' 05.1" S	118° 58' 19.7" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_498	17° 32' 04.9" S	118° 58' 19.9" E	m	groove
RS Imperieuse NE crest and slope 071206_517	17° 32' 04.3" S	118° 58' 17.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_519	17° 32' 04.3" S	118° 58' 17.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_534	17° 32' 03.9" S	118° 58' 18.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_538	17° 32' 03.8" S	118° 58' 18.3" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_540	17° 32' 03.7" S	118° 58' 18.4" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_543	17° 32' 03.7" S	118° 58' 18.4" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_548	17° 32' 03.5" S	118° 58' 18.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_550	17° 32' 03.5" S	118° 58' 18.6" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_555	17° 32' 03.4" S	118° 58' 18.8" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_562	17° 32' 03.3" S	118° 58' 19.0" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_571	17° 32' 03.3" S	118° 58' 19.0" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_579	17° 32' 03.3" S	118° 58' 19.2" E	s	crest of spur
RS Imperieuse NE crest and slope 071206_586	17° 32' 03.2" S	118° 58' 19.6" E	d	groove

Table Ap4b: Haphazard photoquadrats made on the eastern crest and slope of Imperieuse Reef on 6 December 2007. Depth class: s = 1-4 m (regularly emersed); m = 5-10 m; d = >10 m. Habitat = spur or groove. GPS coordinates in WGS84 datum.

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Imperieuse E crest and slope 071206_2	17° 36' 32.7" S	118° 58' 31.2" E	s	crest of spur
RS Imperieuse E crest and slope 071206_21	17° 36' 32.7" S	118° 58' 31.6" E	m	groove
RS Imperieuse E crest and slope 071206_31	17° 36' 35.0" S	118° 58' 30.6" E	s	crest of spur
RS Imperieuse E crest and slope 071206_41	17° 36' 35.2" S	118° 58' 31.0" E	m	groove
RS Imperieuse E crest and slope 071206_51	17° 36' 36.3" S	118° 58' 28.6" E	s	crest of spur
RS Imperieuse E crest and slope 071206_72	17° 36' 36.2" S	118° 58' 28.8" E	m	groove

Table Ap4c: Haphazard photoquadrats made on the northeastern crest and slope of Clerke Reef on 10 December 2007, in the vicinity of the northernmost AIMS LTM site (AIMS-1995-RS2-1). Depth class: s = 1-4 m (regularly emersed); m = 5-10 m; d = >10 m. Habitat = spur or groove. GPS coordinates in WGS84 datum.

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Clerke NE crest and slope 071210_2	17° 17' 02.4" S	119° 22' 34.4" E	m	groove
RS Clerke NE crest and slope 071210_6	17° 17' 02.2" S	119° 22' 34.4" E	m	groove
RS Clerke NE crest and slope 071210_12	17° 17' 02.0" S	119° 22' 34.3" E	m	groove
RS Clerke NE crest and slope 071210_18	17° 17' 01.8" S	119° 22' 34.3" E	m	groove
RS Clerke NE crest and slope 071210_22	17° 17' 01.7" S	119° 22' 34.3" E	m	groove
RS Clerke NE crest and slope 071210_26	17° 17' 01.5" S	119° 22' 34.2" E	m	groove
RS Clerke NE crest and slope 071210_30	17° 17' 01.4" S	119° 22' 34.2" E	m	groove
RS Clerke NE crest and slope 071210_35	17° 17' 01.2" S	119° 22' 34.2" E	m	groove
RS Clerke NE crest and slope 071210_40	17° 17' 01.0" S	119° 22' 34.2" E	m	groove
RS Clerke NE crest and slope 071210_54	17° 17' 00.8" S	119° 22' 34.0" E	s	crest of spur
RS Clerke NE crest and slope 071210_58	17° 17' 00.6" S	119° 22' 33.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_60	17° 17' 00.6" S	119° 22' 33.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_65	17° 17' 00.4" S	119° 22' 33.8" E	s	crest of spur
RS Clerke NE crest and slope 071210_67	17° 17' 00.3" S	119° 22' 33.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_69	17° 17' 00.2" S	119° 22' 33.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_73	17° 17' 00.1" S	119° 22' 33.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_75	17° 16' 60.0" S	119° 22' 33.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_78	17° 16' 59.9" S	119° 22' 33.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_82	17° 16' 59.7" S	119° 22' 33.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_87	17° 16' 59.5" S	119° 22' 33.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_90	17° 16' 59.4" S	119° 22' 33.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_92	17° 16' 59.3" S	119° 22' 33.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_94	17° 16' 59.2" S	119° 22' 33.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_96	17° 16' 59.1" S	119° 22' 33.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_99	17° 16' 59.0" S	119° 22' 33.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_103	17° 16' 58.8" S	119° 22' 33.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_106	17° 16' 58.8" S	119° 22' 33.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_114	17° 16' 58.5" S	119° 22' 33.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_121	17° 16' 58.2" S	119° 22' 33.1" E	m	groove
RS Clerke NE crest and slope 071210_126	17° 16' 57.9" S	119° 22' 33.0" E	m	groove
RS Clerke NE crest and slope 071210_129	17° 16' 57.8" S	119° 22' 33.0" E	m	groove
RS Clerke NE crest and slope 071210_134	17° 16' 57.5" S	119° 22' 32.9" E	m	groove
RS Clerke NE crest and slope 071210_138	17° 16' 57.4" S	119° 22' 32.8" E	m	groove
RS Clerke NE crest and slope 071210_142	17° 16' 57.2" S	119° 22' 32.8" E	m	groove
RS Clerke NE crest and slope 071210_146	17° 16' 57.0" S	119° 22' 32.7" E	m	groove
RS Clerke NE crest and slope 071210_151	17° 16' 56.8" S	119° 22' 32.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_152	17° 16' 56.7" S	119° 22' 32.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_155	17° 16' 56.6" S	119° 22' 32.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_158	17° 16' 56.5" S	119° 22' 32.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_163	17° 16' 56.2" S	119° 22' 32.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_166	17° 16' 56.1" S	119° 22' 32.2" E	s	crest of spur
RS Clerke NE crest and slope 071210_171	17° 16' 55.9" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_174	17° 16' 55.9" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_185	17° 16' 55.6" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_187	17° 16' 55.5" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_190	17° 16' 55.4" S	119° 22' 32.0" E	s	crest of spur

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Clerke NE crest and slope 071210_192	17° 16' 55.3" S	119° 22' 31.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_193	17° 16' 55.3" S	119° 22' 31.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_195	17° 16' 55.2" S	119° 22' 31.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_198	17° 16' 55.1" S	119° 22' 31.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_213	17° 16' 54.9" S	119° 22' 31.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_215	17° 16' 54.8" S	119° 22' 31.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_217	17° 16' 54.7" S	119° 22' 31.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_219	17° 16' 54.6" S	119° 22' 31.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_224	17° 16' 54.4" S	119° 22' 31.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_226	17° 16' 54.4" S	119° 22' 31.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_244	17° 16' 53.6" S	119° 22' 32.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_246	17° 16' 53.5" S	119° 22' 32.6" E	m	groove
RS Clerke NE crest and slope 071210_249	17° 16' 53.4" S	119° 22' 32.6" E	m	groove
RS Clerke NE crest and slope 071210_251	17° 16' 53.3" S	119° 22' 32.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_253	17° 16' 53.2" S	119° 22' 32.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_258	17° 16' 53.1" S	119° 22' 32.4" E	m	crest of spur
RS Clerke NE crest and slope 071210_260	17° 16' 53.0" S	119° 22' 32.4" E	m	groove
RS Clerke NE crest and slope 071210_279	17° 16' 53.0" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_283	17° 16' 52.9" S	119° 22' 31.9" E	s	crest of spur
RS Clerke NE crest and slope 071210_296	17° 16' 53.0" S	119° 22' 32.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_301	17° 16' 52.8" S	119° 22' 32.6" E	m	groove
RS Clerke NE crest and slope 071210_304	17° 16' 52.9" S	119° 22' 32.6" E	m	groove
RS Clerke NE crest and slope 071210_308	17° 16' 52.8" S	119° 22' 32.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_311	17° 16' 52.8" S	119° 22' 32.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_312	17° 16' 52.7" S	119° 22' 32.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_314	17° 16' 52.7" S	119° 22' 32.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_316	17° 16' 52.7" S	119° 22' 32.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_319	17° 16' 52.6" S	119° 22' 32.2" E	s	crest of spur
RS Clerke NE crest and slope 071210_321	17° 16' 52.6" S	119° 22' 32.2" E	s	crest of spur
RS Clerke NE crest and slope 071210_322	17° 16' 52.6" S	119° 22' 32.1" E	s	crest of spur
RS Clerke NE crest and slope 071210_332	17° 16' 52.4" S	119° 22' 31.8" E	s	crest of spur
RS Clerke NE crest and slope 071210_335	17° 16' 52.3" S	119° 22' 31.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_337	17° 16' 52.3" S	119° 22' 31.7" E	s	crest of spur
RS Clerke NE crest and slope 071210_339	17° 16' 52.2" S	119° 22' 31.6" E	s	crest of spur
RS Clerke NE crest and slope 071210_343	17° 16' 52.1" S	119° 22' 31.5" E	s	crest of spur
RS Clerke NE crest and slope 071210_345	17° 16' 52.0" S	119° 22' 31.4" E	s	crest of spur
RS Clerke NE crest and slope 071210_347	17° 16' 52.0" S	119° 22' 31.3" E	s	crest of spur
RS Clerke NE crest and slope 071210_350	17° 16' 51.9" S	119° 22' 31.2" E	s	crest of spur

Table Ap4d. Haphazard photoquadrats made in the lagoon of Clerke Reef on 8 December 2007, in the vicinity of anchoring zone. Depth class: s = 1-4 m (regularly emersed); m = 5-10 m; d = >10 m. Habitat = inside or outside anchoring zone. GPS coordinates in WGS84 datum.

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Clerke lagoon 071208_1	17° 16' 59.5" S	119° 21' 40.6" E	d	lagoon
RS Clerke lagoon 071208_4	17° 16' 59.4" S	119° 21' 40.7" E	d	lagoon
RS Clerke lagoon 071208_6	17° 16' 59.5" S	119° 21' 42.1" E	d	lagoon
RS Clerke lagoon 071208_9	17° 17' 00.4" S	119° 21' 44.7" E	d	lagoon
RS Clerke lagoon 071208_14	17° 16' 58.5" S	119° 21' 46.0" E	d	lagoon
RS Clerke lagoon 071208_16	17° 16' 58.4" S	119° 21' 46.1" E	d	lagoon

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Clerke lagoon 071208_22	17° 16' 57.6" S	119° 21' 46.5" E	d	lagoon
RS Clerke lagoon 071208_24	17° 16' 57.4" S	119° 21' 46.6" E	d	lagoon
RS Clerke lagoon 071208_28	17° 16' 56.9" S	119° 21' 46.8" E	d	lagoon
RS Clerke lagoon 071208_30	17° 16' 56.6" S	119° 21' 46.9" E	d	lagoon
RS Clerke lagoon 071208_31	17° 16' 56.4" S	119° 21' 46.9" E	d	lagoon
RS Clerke lagoon 071208_33	17° 16' 56.2" S	119° 21' 47.0" E	d	lagoon
RS Clerke lagoon 071208_36	17° 16' 55.9" S	119° 21' 47.0" E	d	lagoon
RS Clerke lagoon 071208_39	17° 16' 55.6" S	119° 21' 47.1" E	d	lagoon
RS Clerke lagoon 071208_43	17° 16' 55.1" S	119° 21' 47.2" E	d	lagoon
RS Clerke lagoon 071208_46	17° 16' 54.8" S	119° 21' 47.2" E	d	lagoon
RS Clerke lagoon 071208_50	17° 16' 54.3" S	119° 21' 47.4" E	d	lagoon
RS Clerke lagoon 071208_51	17° 16' 53.8" S	119° 21' 47.5" E	d	lagoon
RS Clerke lagoon 071208_54	17° 16' 53.2" S	119° 21' 47.7" E	d	lagoon
RS Clerke lagoon 071208_57	17° 16' 53.0" S	119° 21' 47.9" E	d	lagoon
RS Clerke lagoon 071208_60	17° 16' 51.7" S	119° 21' 48.8" E	d	lagoon
RS Clerke lagoon 071208_61	17° 16' 46.7" S	119° 21' 50.0" E	d	lagoon
RS Clerke lagoon 071208_66	17° 16' 45.6" S	119° 21' 50.4" E	d	lagoon
RS Clerke lagoon 071208_74	17° 16' 44.0" S	119° 21' 51.2" E	d	lagoon
RS Clerke lagoon 071208_80	17° 16' 43.0" S	119° 21' 51.6" E	d	lagoon
RS Clerke lagoon 071208_82	17° 16' 42.7" S	119° 21' 51.8" E	d	lagoon
RS Clerke lagoon 071208_85	17° 16' 42.2" S	119° 21' 52.0" E	d	lagoon
RS Clerke lagoon 071208_86	17° 16' 42.2" S	119° 21' 52.0" E	d	lagoon
RS Clerke lagoon 071208_89	17° 17' 11.8" S	119° 21' 52.6" E	d	lagoon
RS Clerke lagoon 071208_91	17° 17' 05.7" S	119° 21' 36.4" E	d	lagoon
RS Clerke lagoon 071208_93	17° 17' 04.8" S	119° 21' 38.7" E	d	lagoon
RS Clerke lagoon 071208_95	17° 17' 04.6" S	119° 21' 39.0" E	d	lagoon
RS Clerke lagoon 071208_98	17° 17' 04.5" S	119° 21' 39.2" E	d	lagoon
RS Clerke lagoon 071208_99	17° 17' 04.4" S	119° 21' 39.3" E	d	lagoon
RS Clerke lagoon 071208_100	17° 17' 04.2" S	119° 21' 39.4" E	d	lagoon
RS Clerke lagoon 071208_101	17° 17' 04.1" S	119° 21' 39.4" E	d	lagoon
RS Clerke lagoon 071208_102	17° 17' 04.0" S	119° 21' 39.5" E	d	lagoon
RS Clerke lagoon 071208_103	17° 17' 03.9" S	119° 21' 39.5" E	d	lagoon
RS Clerke lagoon 071208_104	17° 17' 03.7" S	119° 21' 39.7" E	d	lagoon
RS Clerke lagoon 071208_105	17° 17' 03.5" S	119° 21' 39.8" E	d	lagoon
RS Clerke lagoon 071208_106	17° 17' 03.6" S	119° 21' 57.2" E	d	lagoon

Table Ap4e: Haphazard photoquadrats made at Mermaid Reef on 8 December 2007, on the reef crest in the vicinity of AIMS-1995-RS1-1 and in the lagoon in the vicinity of anchoring zone. Depth class: s = 1-4 m (regularly emersed); m = 5-10 m; d = >10 m. Habitat = crest, groove or for lagoon sites inside/outside anchoring zone. GPS coordinates in WGS84 datum.

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Mermaid NE crest and lagoon 071213_600	17° 03' 49.1" S	119° 38' 54.6" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_605	17° 03' 49.1" S	119° 38' 54.6" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_609	17° 03' 49.1" S	119° 38' 54.6" E	m	groove
RS Mermaid NE crest and lagoon 071213_613	17° 03' 49.1" S	119° 38' 54.5" E	m	groove
RS Mermaid NE crest and lagoon 071213_624	17° 03' 48.9" S	119° 38' 54.4" E	m	groove
RS Mermaid NE crest and lagoon 071213_627	17° 03' 48.8" S	119° 38' 54.3" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_631	17° 03' 48.8" S	119° 38' 54.2" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_633	17° 03' 48.7" S	119° 38' 54.2" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_636	17° 03' 48.7" S	119° 38' 54.1" E	s	crest of spur

Image filename.jpg	Latitude	Longitude	Depth class	Habitat
RS Mermaid NE crest and lagoon 071213_640	17° 03' 48.7" S	119° 38' 54.0" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_641	17° 03' 48.6" S	119° 38' 54.0" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_642	17° 03' 48.6" S	119° 38' 54.0" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_643	17° 03' 48.6" S	119° 38' 54.0" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_646	17° 03' 48.6" S	119° 38' 53.9" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_648	17° 03' 48.6" S	119° 38' 53.8" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_652	17° 03' 48.6" S	119° 38' 53.7" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_653	17° 03' 48.6" S	119° 38' 53.7" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_656	17° 03' 48.6" S	119° 38' 53.6" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_685	17° 03' 54.1" S	119° 38' 55.8" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_687	17° 03' 54.2" S	119° 38' 55.8" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_701	17° 03' 54.4" S	119° 38' 55.2" E	m	crest of spur
RS Mermaid NE crest and lagoon 071213_703	17° 03' 54.4" S	119° 38' 55.2" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_708	17° 03' 54.6" S	119° 38' 55.1" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_709	17° 03' 54.7" S	119° 38' 55.1" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_753	17° 03' 59.4" S	119° 38' 57.6" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_756	17° 03' 59.7" S	119° 38' 57.5" E	s	crest of spur
RS Mermaid NE crest and lagoon 071213_776	17° 04' 44.2" S	119° 38' 37.5" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_779	17° 04' 44.3" S	119° 38' 37.4" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_783	17° 04' 44.3" S	119° 38' 37.3" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_787	17° 04' 44.2" S	119° 38' 37.3" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_791	17° 04' 44.2" S	119° 38' 37.3" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_795	17° 04' 44.1" S	119° 38' 37.2" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_799	17° 04' 44.0" S	119° 38' 37.2" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_805	17° 04' 44.0" S	119° 38' 37.2" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_809	17° 04' 43.9" S	119° 38' 37.1" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_814	17° 04' 43.8" S	119° 38' 37.1" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_817	17° 04' 43.8" S	119° 38' 37.1" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_823	17° 04' 43.7" S	119° 38' 37.0" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_828	17° 04' 43.6" S	119° 38' 37.0" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_833	17° 04' 43.5" S	119° 38' 36.9" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_838	17° 04' 43.4" S	119° 38' 36.9" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_846	17° 04' 43.3" S	119° 38' 36.8" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_852	17° 04' 43.2" S	119° 38' 36.8" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_856	17° 04' 43.2" S	119° 38' 36.7" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_897	17° 04' 46.3" S	119° 38' 22.7" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_900	17° 04' 46.3" S	119° 38' 22.5" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_905	17° 04' 46.2" S	119° 38' 22.3" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_910	17° 04' 46.2" S	119° 38' 22.0" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_914	17° 04' 46.1" S	119° 38' 21.9" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_920	17° 04' 46.0" S	119° 38' 21.9" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_925	17° 04' 46.0" S	119° 38' 21.8" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_932	17° 04' 45.9" S	119° 38' 21.8" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_939	17° 04' 45.7" S	119° 38' 21.7" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_944	17° 04' 45.7" S	119° 38' 21.6" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_995	17° 04' 44.6" S	119° 38' 20.8" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_999	17° 04' 44.5" S	119° 38' 20.7" E	d	lagoon
RS Mermaid NE crest and lagoon 071213_1005	17° 04' 44.3" S	119° 38' 20.6" E	d	lagoon

Appendix 5: Maps of anchoring zones at Clerke and Mermaid

Extensive anchor damage has been reported within the designated anchor areas at Clerke and Mermaid reefs. Although visual inspection of the areas was not possible during this field survey, series of haphazard photoquadrats were made in the vicinity at each reef (Appendix 4). Analysis of these may permit some assessment to be made of the extent of the damage and potential for recovery. Note that the installation of moorings within Clerke and Mermaid lagoons in 2007 should result in substantial reduction in potential for anchor damage in future in these areas.

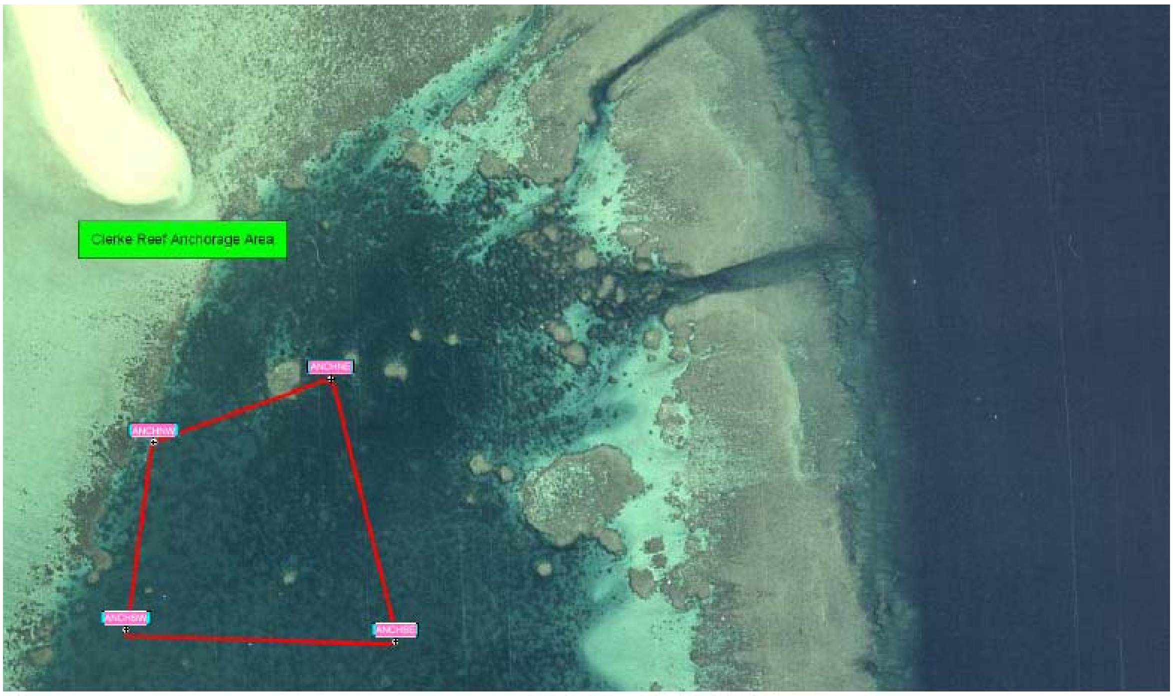

Figure Ap5a: The anchoring area at Clerke Reef is within a box described by the following coordinates: 17º 16.884’S 119º 21.722’E; 17º 16.810’S 119º 21.930’E; 17º 17.107’S 119º 22.011’E; 17º 17.098’S 119º 21.693’E. GPS coordinates in WGS84 datum.

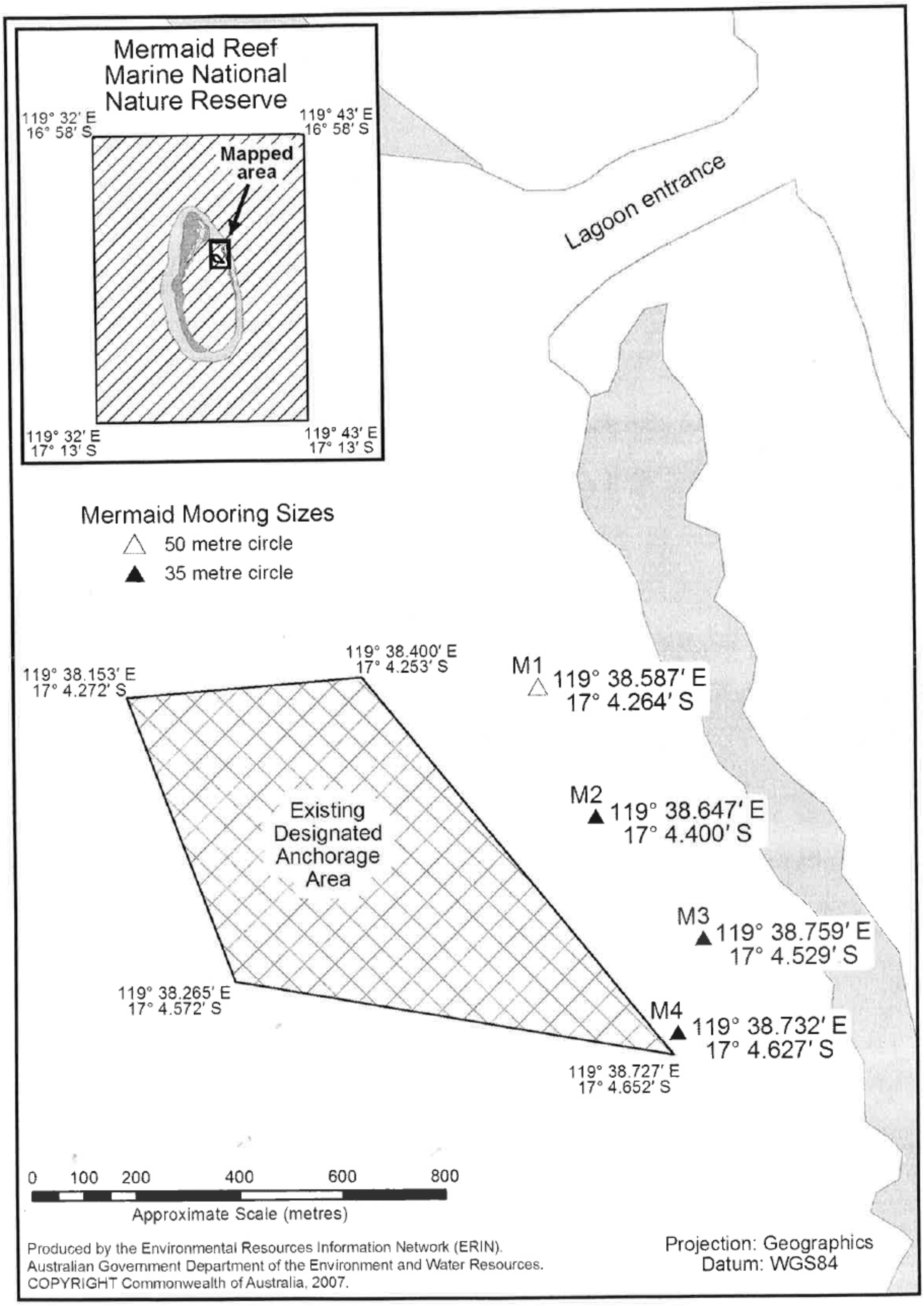

Figure Ap5b: Mermaid Reef anchoring zone. GPS coordinates in WGS84 datum.

Appendix 6: Disturbance history of the Rowley Shoals

Interpretation of long-term datasets of coral community condition will require information about the disturbance history of the Rowley Shoals. The major disturbance events for this region are cyclones. The following series of historical cyclone track maps (Figure Ap7a-d) are from the Australian Bureau of Meteorology's cyclone tracking site (http://www.bom.gov.au/cgi-bin/silo/cyclones.cgi; most recent data available from 2004/05). Cyclones were selected on the basis of year and whether they tracked within 100 km of the approximate location of Clerke Reef (17.3 S, 119.3 E).

While cyclones obviously vary considerably in intensity, size and speed of travel, these maps do provide some indication of the cyclone-related disturbance history of the Rowley Shoals. These historical data indicate that there is ~80% chance of a cyclone impact somewhere in the Rowley Shoals in any given year (an average of ~4 cyclones per five-year period; Figure Ap7e). This high probability of disturbance may mean that coral communities at the Rowley Shoals – especially shallow slope communities - will be temporally and spatially dynamic relative to coral reefs elsewhere, rarely having the opportunity to reach a mature state. The summers of 1999/2000 and 2000/01 appear to have been notably disturbing ones for the Rowley Shoals, with three cyclones in the vicinity during each season (Table Ap6; Figure Ap7e). Since then (up to 2005/06) the frequency of disturbance has decreased, although the intensity may have increased (especially noteworthy here is the potential impact of category 5 Cyclone Glenda in March 2006; Table Ap6; Figures Ap7e-f).

Each of the three shoals is likely to be impacted differently by each cyclone, according to proximity and wind/wave direction. Several long-term monitoring sites visited in December 2007 showed clear signs of relatively recent cyclone-related disturbance (for example DEC-2001-M4 on the northwest slope of Mermaid Reef, at which coral communities had been reduced to rubble from the surface to well below 20 m depth), while others appeared relatively undisturbed.

Table Ap6: Details of cyclone activity in the vicinity of the Rowley Shoals 1999-2006 (compiled from the Bureau of Meteorology and www.australiasevereweather.com). Time = hours that the cyclone was within ~100 km of Clerke Reef; wind speed = average wind speed during this period; central pressure = average central pressure during this period; category = cyclone category during this period according to the international scale of severity, based on wind speed and central pressure. See Figure Ap6e for graphical representation of recent cyclone impacts at the Rowley Shoals.

Date	Cyclone Name	Time (h)	Wind speed (knots)	Central pressure (hPa)	Category
1999 Dec 13	John	6	71	963	3
1999 Dec 16	Ilsa	8	35	994	1
2000 Apr 19	Rosita	18	68	966	3
2001 Jan 30	Terri	12	56.8	978	2
2001 Feb 14	Vincent	15	40.8	990	1
2001 Apr 19	Alistair	6	54.4	980	2
2003 Feb 26	Graham	24	32.1	996	1
2004 Mar 26	Fay	<24	?	?	3
2006 Jan 8	Clare	<24	?	?	3
2006 Mar 28	Glenda	<24	? (>108)	? (<920)	5

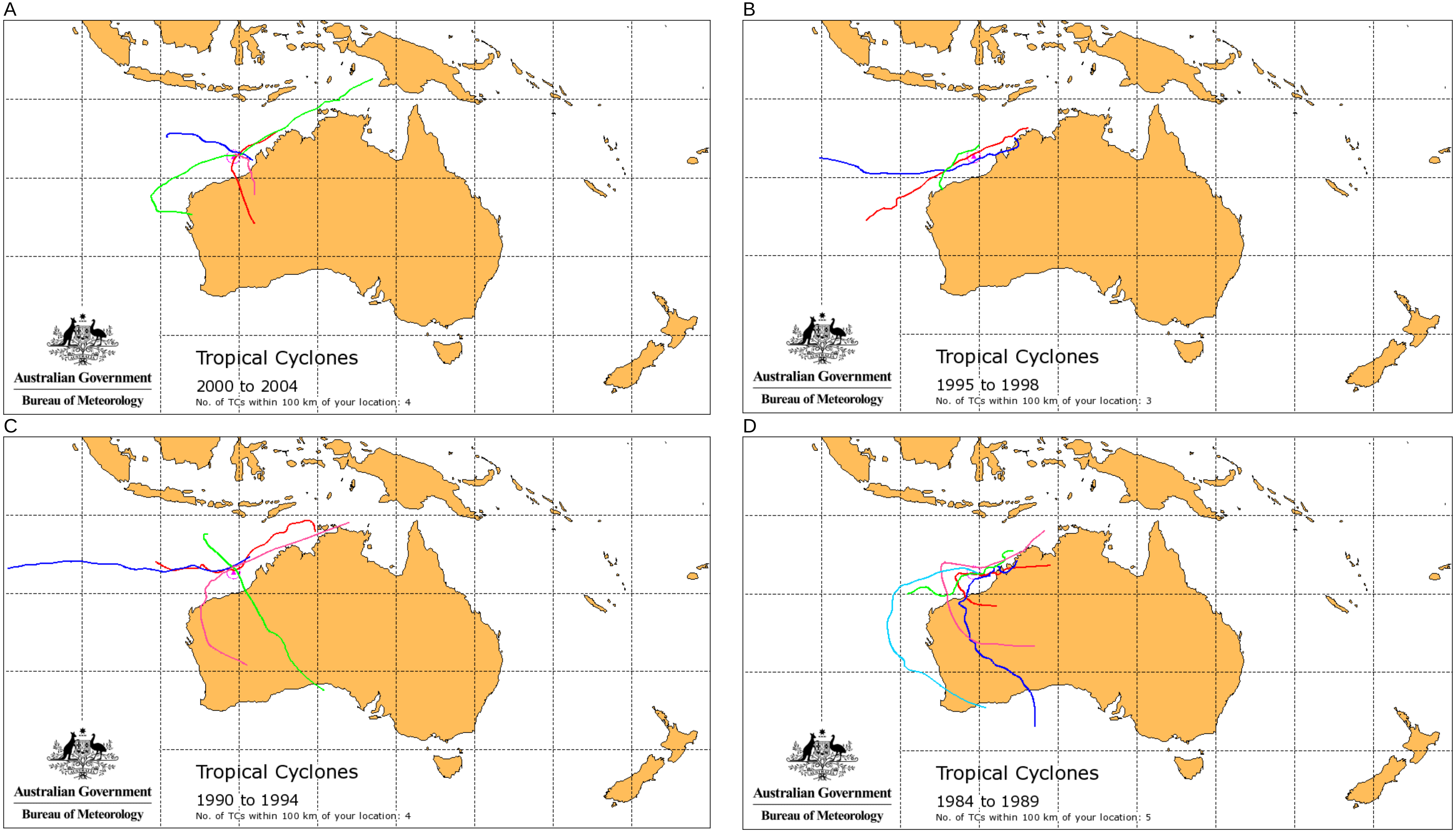

Figure Ap6a-d: Historical cyclone tracks within ~100 km radius of Clerke Reef, Rowley Shoals (red circle). (A) 2000 – 2005. (B) 1995 – 1999. (C) 1990 – 1994. (D) 1985 – 1989.

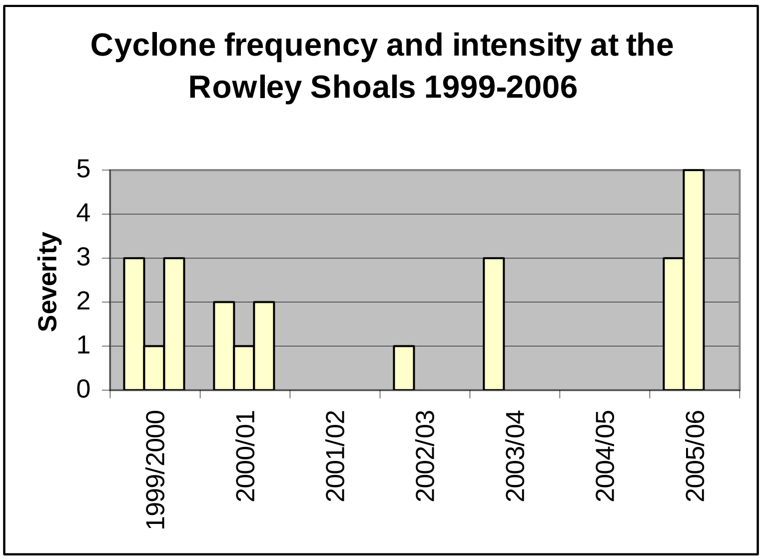

Figure Ap6e. Cyclone frequency and severity at the Rowley Shoals, 1999-2006. See Table Ap6 for details of each cyclone.

Figure Ap6f. Category 5 Cyclone Glenda in the vicinity of the Rowley Shoals, from the International Space Station, ~29 Mar 2006. Picture courtesy of the Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center (image ID ISS012-E-22054).

Appendix 7: Draft media statement

DRAFT MEDIA STATEMENT
MINISTER FOR THE ENVIRONMENT

TBA
EMBARGOED 17 DECEMBER 2007

The Rowley Shoals: a marine wilderness worth saving

Data generated from a major collaborative marine biological survey conducted off the Kimberley coast will be used to help protect one of the world's most pristine coral reef environments, Environment and Climate Change Minister David Templeman said today.

"The team of scientists that returned to Broome today has identified the Rowley Shoals as a global benchmark for coral reef conservation," Mr Templeman said.

"The data collected during the 17-day survey will be vital to the successful future management of the Rowley Shoals Marine Park and the Commonwealth-managed Mermaid Reef National Marine Nature Reserve.

"The Rowley Shoals are among the most unspoiled coral reef ecosystems remaining on the planet, and the importance of their successful conservation cannot be overstated," said Mr Templeman.

"It is imperative that we protect these reefs for future generations."

The Rowley Shoals survey was the maiden scientific voyage of the RV Solander, the latest addition to the research fleet of the Australian Institute of Marine Science (AIMS). The 35 m high-tech vessel was built in Fremantle by WA company Tenix Defence Pty Ltd. The RV Solander will enable large multidisciplinary teams of scientists to conduct urgent marine research in WA.

Team members included cruise leader Jamie Colquhoun (AIMS), Dr Katharina Fabricius (AIMS), Eric Matson (AIMS), Kylie Cook (AIMS), Dr Iain Field (AIMS/Charles Darwin University), Warren White (Wildlife Resources), Dr Suzanne Long (DEC Marine Science Program), Dr John Huisman (DEC/WA Herbarium), Shannon Armstrong (DEC Marine Science Program), Steve Dutton (DEC), Huw Dilley (DEC) and Phil van Dyk (volunteer).

MAJOR FINDINGS OF THE SURVEY:

The research team, led by AIMS in collaboration with WA's Department of Environment and Conservation (DEC), found that the coral reef communities of the Rowley Shoals are generally in excellent condition.

Many key marine species – such as sharks, maori wrasse, and commercially important invertebrates such as trochus shell, trepang/bêche de mer) and giant clams and other clam species appear to be more abundant at the Rowley Shoals than most other coral reefs worldwide. Rowley Shoals populations of trochus, holothuria and tridacnid clams seem more abundant, are larger in size and inhabit a more diverse habitat range than populations to the north at Scott, Ashmore, and Cartier Reefs, which are heavily fished. More detailed analysis of the data collected at the Rowley Shoals will give us a clearer picture of the differences between the populations inhabiting these reefs.

Some coral communities that were seriously damaged on one of the reefs by a recent cyclone are showing good recovery, with high abundances of newly settled corals. Proximity to undamaged reefs within the Rowley Shoals is fundamental to recovery. This highlights the importance of replication within marine reserve networks, and underlines the need for effective conservation of all three Rowley Shoals.

Amidst growing concern for global reef shark populations, a project has commenced to determine movement and migration patterns for the main shark species at the Rowley Shoals. Although sharks are large charismatic marine predators relatively little is known about their ecology, especially their movement patterns. This is vital information for their conservation. This innovative pilot study aims to determine the sharks' reef attendance, movement and local migration patterns. To do this a small number of sharks will carry acoustic transmitters, known as pingers, which transmit an individual code to a series of listening stations placed at key locations around the three reefs. As the sharks swim past one of the listening stations their presence will be logged building up a picture of when and where the sharks spend their time. Each shark's pinger will transmit for approximately 12 months and the receivers will be recovered shortly after. The project is a collaboration between researchers at AIMS and Charles Darwin University and has been partially funded by the Commonwealth Dept of Environment and Water Resources.

The biodiversity of Western Australian soft corals was studied for the first time during this survey. Quite spectacular sea fan gardens comprised of both Pacific and Indian ocean species are found in the deeper waters of the Rowley Shoals. This survey was the first step towards understanding the importance of the ecological role played by soft corals on Western Australian reefs.

Crustose coralline algae, which consolidate reefs and are an important substratum for coral larvae to settle upon, form a major component of the flora of the Rowley Shoals. Several algal species were collected that have never been recorded from the Rowley Shoals before. Specimens collected during this survey will be the subject of future international research collaborations aimed at increasing our understanding of this ecologically important but little-known group.

ACTIVELY MANAGING WA'S MARINE ENVIRONMENT:

Climate change threatens coral reefs by increasing the likelihood of coral bleaching and disease, and making the seas more acidic. This means that passive conservation is not going to be sufficient to ensure that coral reefs such as the Rowley Shoals have a future.

Active management as well as ongoing research and monitoring programs will be necessary to preserve coral reefs despite the challenges posed by climate change. These problems are real and are happening now: a Bleaching Watch alert (calculated by US NOAA from sea surface temperatures) was issued on 13 December 2007 and is current for Scott Reef, to the north of the Rowley Shoals.

As a step towards addressing these urgent research needs, in January 2008 AIMS scientists will take the RV Solander to coral reefs in the Montebello and Barrow Islands Marine Protected Areas, as well as Ningaloo Marine Park. There they will commence a project investigating how WA's coral reefs responded to past changes in climate.

Mr Templeman said that DEC had allocated $150,000 to scientific research at the Rowley Shoals over the next three years, while AIMS had contributed around $300,000 to the December 2007 survey.

"There are twelve marine parks and reserves in WA, and the State Government is committed to further improving WA's world-class marine conservation reserve system," he said.

"In the next few months the State Government also plans to establish new marine parks and reserves for the Walpole and Nornalup inlets, the Dampier Archipelago/Regnard area, and around the southwest Capes."

LIST OF EXSISITNG MARINE SCIENCE PROGRAM REPORTS

Data Report Series

MSPDR 1. Preliminary assessment of coral communities at selected sites in the proposed Dampier Archipelago Marine Park. Armstrong SJ (2008).

MSPDR 2. Anoxic impacts at Bill's Bay, Ningaloo Marine Park associated with the 2008 coral spawning event. Armstrong SJ, Syme R (2009).

MSPDR 3. Mapping the coral reef communities of the Shark Bay marine protected areas: Data collected during the February 2008 field survey. Bancroft KP (2009).

MSPDR 4. Establishing long-term coral community monitoring sites in the Montebello/Barrow Islands marine protected areas: data collected in December 2006. Bancroft, K.P. (2009).

MSPDR 5. Ningaloo Marine Park *Drupella* long-term monitoring program: Data collected during the 2008 survey. Armstrong SJ (2009).

MSPDR 6. Assessing the effectiveness of sanctuary zones in the proposed Dampier Archipelago Marine Park: Data collected during the 2007 survey. SJ Armstrong (2009)

Other Marine Science Program Reports

MSP 2006/01 Long-term monitoring program in the Montebello/Barrow Islands marine protected areas. Scoping field trip: 8-11 August 2006. Field Program Report. Bancroft KP, Simpson CJ, Long S (2006).

MSP 2006/02 Establishment of additional long-term monitoring sites for *Drupella cornus* populations in the southern section of the Ningaloo Marine Park and the Muiron and Sunday Islands Marine Management Areas. Field Program Report. Armstrong SJ (2006).

MSP 2006/03 Long-term monitoring program in the Montebello/Barrow Islands marine protected areas. Scoping field trip: 8-11 August 2006. Data Report. Bancroft KP (2006).

MSP 2006/04 Disturbance and recovery of coral communities in Bill's Bay, Ningaloo Marine Park: 2006 survey. Field Program Report. Long S (2006).

MSP 2006/05 Establishing baseline benthic community monitoring sites in the Montebello/Barrow Islands marine protected areas: 7-22 December 2006. Field Program Report. Bancroft KP, Armstrong SJ (2006).

MSP 2007/01 Bibliography of marine scientific research relevant to the Rowley Shoals Marine Park and the Mermaid Reef Marine National Nature Reserve. Data Report. Edwards A, Bancroft KP (2007).

MSP 2007/02 Current and proposed marine research projects relevant to the Rowley Shoals Marine Park and the Mermaid Reef Marine National Nature Reserve. Data Report. Edwards A, Bancroft KP (2007).

MSP 2007/03 Ningaloo Marine Park Drupella Long-term Monitoring Program: Results of the 2006 survey. Technical Report. Armstrong SJ (2007).

MSP 2007/04 Summary of the winter coral bleaching event at Ningaloo Marine Park, July 2006. Data Report. Armstrong S, Webster F, Kendrick A, Mau R, Onton K (2007).

MSP 2007/05 Disturbance and recovery of coral communities in Bill's Bay, Ningaloo Marine Park: Field survey 16-23 October 2006. Technical and Data Report. Long S (2007).

MSP 2007/06 Bibliography of marine scientific research relevant to Perth's metropolitan marine protected areas and adjacent waters. Data Report. Lierich D, Bancroft KP (2007).

MSP 2007/07 Current and proposed marine research projects relevant to Perth's metropolitan marine protected areas and adjacent waters. Data Report. Lierich D, Bancroft KP (2007).

MSP2007/08 Disturbance history of coral communities in Bill's Bay, Ningaloo Marine Park, 1975-2007. Data Report. van Schoubroeck P, Long S (2007).

MSP 2008/01 Comparative marine biodiversity survey of the Rowley Shoals 1-17 December 2007. Metadata Report. Long S, Armstrong SJ, Fabricius K, Field I, Cook K, Colquhoun J, Huisman J (2008).