

**Summary Field Report  
Saving Philippine Reefs**

**Coral Reef Monitoring Expedition to  
Tubbataha Reefs Natural Park,  
Sulu Sea, Philippines  
April 17-23, 2014**



**A Project of:**

**The Coastal Conservation and Education Foundation, Inc.**

**With the participation and support of the  
Expedition Volunteer Researchers**

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The Coastal Conservation and Education Foundation, Inc. (CCEF)

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Produced by the Coastal Conservation and Education Foundation, Inc. (CCEF)  
Cebu City, Philippines

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## EXECUTIVE SUMMARY

Covering 97,000 hectares in the epicenter of global marine biodiversity, the Tubbataha Reefs Natural Park and World Heritage Site is one of the greatest Philippine natural treasures. Its global ecological importance is recognized as studies show that it is a source of larvae for the fishing grounds and coral reefs in the Sulu Sea and in western Palawan Island. The atoll reefs are also home to thousands of marine species that attract scuba diving tourists and researchers from all over the world to enjoy the diversity of underwater life that Tubbataha offers.

This report is an analysis of the condition of the Tubbataha Reefs benthic and fish fauna, at seven selected and recognized dive sites within the protected area. Live hard coral ranged from fair to good. The highest percentage live hard coral (LHC) was recorded at SR-1 ( $53.63\% \pm 2.84$ ) for the shallow reef and NR-2 ( $58.56\% \pm 4.59$ ) for the deep reef. Despite a Crown-of-thorns breakout at NR-2 in 2009 and the major 1998 ENSO bleaching episode, overall the survey sites displayed stable or increasing trends in live hard coral cover.

For fish, the biomass per unit area increased in every site with the highest on Lighthouse Reef (SR1) at  $538.4 \text{ kg}/500\text{m}^2$ . In contrast, a general decline in fish densities (number per unit area) was observed in most sites. Factors that contributed to this decline are likely to be: 1) variation in spatial distribution of fish communities throughout the sites, and 2) an important newly apparent phenomena of an increasing biomass of larger predator type of fish that are feeding on smaller fish and thus reducing the total number of fish observed. Butterflyfish species seen totaled 31 which is comparable with past years. Although there was a slight rise in number of target fish/ $500\text{m}^2$  in all of the study sites of Tubbataha reefs since 2012, the general trend in the mean fish density for all reef fish species was declining. However, fish species richness for target fish species and all reef fish species have shown significant increases since 2012. For very large marine life, there have been increases in the number of turtles, sharks, and Humphead wrasse sightings over the past 10 years with 2014 being no exception.

With the 2007 addition of Jessie Beazley Reef to the marine park, and with its inclusion in regular patrolling, an improvement in this site is evident in 2014. Since 2012, Jessie Beazley had a small decrease of LHC ( $45.73\% \pm 4.12$ ) in the shallow reef. Fish density of target species ( $219 \text{ fish}/500\text{m}^2$ ) increased significantly in 2014 and there was a small increase in all reef species density of  $1,565 \text{ fish}/500\text{m}^2$  in 2014 compared to  $1,529 \text{ fish}/500\text{m}^2$  in 2012 (Table 22).

In conclusion, our research team agrees that Tubbataha Reefs Natural Park continues to be a proud legacy of the Tubbataha Management Office and its Park Rangers. As an important and rich marine resource, it continues to lend hope to the Philippines in sustaining food security and increasing eco-tourism. It is evident from the surveys in April 2014 that the reef and fish resources of Tubbataha continue to thrive as evidenced by increasing fish biomass in all survey sites which indicates that the Park protection and patrol team of rangers continue to do an excellent job despite the remote location of Tubbataha. Finally, it is important to maintain and improve efforts in patrolling, education, and research to maintain the already resilient protected area to overcome future challenges from increasing tourism, shipping in the Sulu Sea and other possible threats.



## **ACKNOWLEDGEMENTS**

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The Discovery Fleet dive boat staff are thanked for hosting our group with traditional Filipino hospitality and efficient operations in diving, chase boats and with excellent cuisine throughout the trip.

The Tubbataha Reefs Natural Park staff are thanked for an excellent briefing at the beginning our trip while in Puerto Princesa and also for the effective management and protection of the Park. Equally, the Park Rangers are thanked for hosting our visit to their station on the North Reef and for sharing their perspectives on their work in Tubbataha.

The final production of this report has been assisted by Sheryll Tesch, Dean Apistar, Danilo Delizo, and Vangie White.

Alan T. White  
Principal Investigator

## LIST OF ACRONYMS OF ABBREVIATIONS

ANOVA	Analysis of Variance
CA	coralline algae
CB	branching coral
CCEF	Coastal Conservation and Education Foundation, Inc.
CE	flat/encrusting coral
CF	foliose/cup coral
CM	massive coral
DC	white dead standing coral
DCA	dead coral with algae
ENSO	El Niño Southern Oscillation
FVC	fish visual census
JB	Jessie Beazley
LHC	live hard coral
M/V	marine vessel
MA	fleshy algae
MPA	marine protected area
NL	non-living
NR	North Reef
NS	not significant
OT	other animals
PAMB	Protected Area Management Board
PCSD	Palawan Council for Sustainable Development
R	coral rubble
RCK	rock and block
SC	soft coral
SD	standard deviation
SE	standard Error
SG	seagrass
SI	sand and silt
SP	sponge
SPP	species
SPR	Saving Philippine Reefs
SR	South Reef
TA	turf algae
TRNP	Tubbataha Reefs Natural Park
UVC	underwater visual census

## INTRODUCTION

Started in the 1980's by Dr. Alan White and his colleagues, the Saving Philippine Reefs (SPR) Expeditions have been vital in collecting essential information on underwater coral reef and fish health in important protected areas around the Philippines. Some of the sites that have been covered by the SPR project are in the provinces of Palawan, Batangas, Bohol, Siquijor, Negros Oriental, and Cebu. These monitoring expeditions have been continued through the years to gather crucial data that have been used to assist local managers of protected areas to create appropriate policies and make effective changes in management approaches to better protect precious reef resources.

Recognized and declared as a World Heritage Site by UNESCO in 1994, the Tubbataha Reefs Natural Park (TRNP) is a 97,000 hectare protected area that has been a regular SPR expedition focal site since A. White's first research trip there in 1984. Located in the Sulu Sea, and 150 kilometers southeast of Palawan Province's capital, Puerto Princesa City, this protected area has two prominent coral atolls which are uninhabited and teeming with marine life. Historically an ecologically important reef area, the TRNP draws tourists from around the world. It has been studied extensively and is known to house thousands of species of marine life. Notably, there are 13 cetaceans (TMO), 7 seagrass species, 79 algae species, and 372 coral species in these atolls alone (White and Arquiza, 1999), as well as a recorded 11 shark and 600 fish species (TMO). The islets on the atolls are also home to several turtle species and at least 27 identified resident bird species (Jensen, 2012), and up to 100 migrate birds. In 2012, the ray *Manta alfredi*, is a reef species that was identified by Dr. Terry Aquino and confirmed by Dr. Will White in Tubbataha and which is not found anywhere else in the Philippines.

The TRNP is located in the heart of the Coral Triangle--the global center of marine biodiversity--and plays a key role in keeping Sulu Sea a storehouse of Philippine marine biodiversity. As discovered by the University of the Philippines in Visayas in 2007, the Tubbataha Reefs serve as an important source of coral and fish larvae which supplies the fishery of Sulu Sea and adjacent fishing grounds. Protecting such an important source is vital in sustaining food security.

### Management History of Tubbataha Reefs Natural Park

Considering it is a large, isolated and uninhabited area, the Tubbataha Reefs Natural Park has always posed a challenge to managers that have worked tirelessly to protect the rich marine resources within it (White and Palaganas, 1991). Stakeholders and resource users have varied over the decades from local fisherfolk to commercial fishers from neighboring countries. Aptly described in detail by White et. al (2003) and the World Wide Fund for Nature (2006), the following table reflects the history of TRNP (modified and updated, CCEF):

1911	The first recorded/documented visit to Tubbataha by American colonial naturalist, Dean C. Worchester, who set foot on Bird Islet on the North Reef.
1938	The lighthouse on the South Reef atoll was built. In 1980, it was replaced by a more modern structure.
1970/80s	Tubbataha becomes a scuba diving destination. Cagayanon fishers start to fish at Tubbataha. The beginning of research studies. Mid-1980s Cagayanon fishers switch to motorized fishing boats. Visayan fishers introduce dynamite and

cyanide fishing into the area.

- 1988 Presidential Decree 306 is passed to declare the Tubbataha National Marine Park and is initially managed by the Tubbataha Foundation. It is also declared protected by Presidential Decree 705 under the Forestry Reform Code.
- 1989 First draft of park management plan is made based on limited information.
- 1990 Sporadic patrols start to stop illegal and destructive fishing practices in the protected area. A memorandum of agreement is signed by the Department of Environment and Natural Resources (DENR) and the Tubbataha Foundation. The park becomes part of the Palawan Biosphere Reserve which is recognized internationally under the UNESCO's Man and the Biosphere Programme.
- 1992 Several research expeditions collect baseline data on coral reef health.
- 1993 Park management plan is re-drafted while illegal fishing activities increase in area. UNESCO declares the Tubbataha National Marine Park a World Heritage Site.
- 1994 A Presidential Task Force is created to implement management in the park and to provide funds for operations. The Philippine Navy is assigned to guard the park.
- 1996 The Coastal Resource Management Project (CRMP) refines management plan with financial support from the Japan International Cooperation Agency (JICA), and in partnership with the Department of Environment and Natural Resources (DENR), the Palawan Council for Sustainable Development (PCSD), World Wide Fund for Nature (WWF), and stakeholders in Palawan Province and the Cagayancillo Islands. CRMP initiates study of legal basis for Protected Area Management Board (PAMB) to become functional together with DENR, PCSD, and WWF. JICA sponsors planning activities and supports an educational tour for the media to the park, in partnership with CRMP. Memorandum Circular 150 is issued to amend Memorandum Circular 128 turning over the chairmanship of the Task Force to the Secretary of National Defense with DENR and PCSD representatives as co-chairpersons.
- 1997 PAMB is formed, based on DENR/CRMP recommendations. The management plan is endorsed in a workshop with stakeholders present, supported by PCSD, DENR, WWF, and CRMP.
- 1998 PAMB becomes operational. A park manager is appointed and supported by WWF and guided by CRMP. The Tubbataha Protected Area Management Board (TPAMB) is created and is chaired by Palawan Provincial Governor, who is also the PCSD chairperson. The park management plan is approved by TPAMB. A coral bleaching event kills more than 18 percent of living coral cover in the park's atolls.
- 1999 Management plan is fully endorsed by the PAMB for implementation and a fee structure is designed based on willingness-to-pay study by WWF and CRMP.

	CRMP and Sulu Fund for Marine Conservation (now Coastal Conservation and Education Foundation or CCEF) jointly implement reef monitoring activities funded by volunteer divers (Saving Philippine Reefs Expeditions). Tubbataha is inscribed in the List of Wetlands of International Importance, also known as The Ramsar List. The Park Management Plan is approved by the PCSD and stakeholders of the park agree to adhere to the no-fishing policy.
2000	Financial contributions from the Marine Parks Centre of Japan, Sulu Fund for Marine Conservation Foundation, Inc. (now Coastal Conservation and Education Foundation or CCEF), Saguda Palawan, Inc., Philippine Navy and the Provincial Government of Palawan fund the construction of the ranger station on Tubbataha's North Atoll, as well as regular reef patrols.
2001	The Tubbataha Management Office (TMO) is established.
2002	The management plan is revised and considers entry permits, collection of conservation fees, and ecosystem research.
2004	The management plan is revised to consider the incorporation of park management effectiveness monitoring and evaluation program. There are amendments made in the delineation of the marine park to include Jessie Beazley reef as part of the protected area.
2007	Jessie Beazley is officially included as part of the Tubbataha Reefs Natural Park through an executive order issued by President Arroyo to increase the park size by 200 percent. This is also based on a study by the University of the Philippines in the Visayas that discovered that Tubbataha Reefs, Cagayancillo Islands, and Jessie Beazley reef are key sources of fish and coral larvae to the greater Sulu Seas and the fisheries within.
2009	Crown-of-Thorns ( <i>Acanthaster planci</i> ) sea star outbreak in Southeastern fringe of Tubbataha North Reef (Amos Rock).
2010 (April)	The Tubbataha Reefs Natural Park Act (Republic Act 10067) of 2009 (approved in 2009) is enacted that ensures the proper management of the Tubbataha Reefs Natural Park as a UNESCO World Heritage Site by strengthening the legislative mandate of the park's management bodies. Coral bleaching event happens at the atolls and destroys one percent of the live corals.
2012 (Sept.)	A silver award is announced to be given to the Philippines in the Future Policy Awards (FPA) of the World Future Council (WFC). (October) In Hyderabad two Best Oceans Policies Silver Awards is conferred by the United Nations during the Biodiversity Summit to the Philippines for its Tubbataha Reefs Natural Park Act of 2010.

## THIS EXPEDITION – 2014

This Saving Philippine Reefs Expedition is the ninth survey done by CCEF in Tubbataha Reefs from April 17 to April 23, 2014. It was implemented and participated in by 10 CCEF staff members and 19 international volunteers from the United States, Australia, and England. Two-thirds of the volunteers were already seasoned SPR expedition researchers and divers, who return often (if not annually) to join the research team. They are exceptional individuals who never fail to inspire and motivate the SPR team to accomplish expedition objectives and contribute to the overall vision of involved communities and sustainable coasts of CCEF.

The SPR 2014 research team made the Discovery Fleet dive boat their home throughout the duration of the expedition. The boat and its crew offered good services and facilities that served to make the journey comfortable and the implementation of the research trip smooth and efficient. Further, the Hibiscus Lodge also offered the same excellent quality in services and logistics to help the team launch the expedition smoothly from the coast of Puerto Princesa City.

The SPR research team completed the underwater surveys of seven sites within the Tubbataha Reefs Natural Park that have been historically surveyed by the Saving Philippine Reefs project since 1984. These seven sites lie within the no-take area of the park and are completely protected from any form of extraction and fishing. Each day of the research journey consisted of two scuba dives to collect underwater data from the site scheduled for the day. Part of the methodology also included a snorkel survey between dives. At the end of each day, researchers encoded their data into a central locally-shared database. Evenings consisted of presentations from staff members and some volunteers about recent research and CCEF work that contribute to marine conservation.

Overall, the team collected information about the Tubbataha Reefs Natural Park, specifically coral reef biota and substrate conditions, fish diversity, fish abundance, fish biomass, indicator species, and human activities that directly affect the health of the reefs. This report documents the changes and trends in reef fish abundance and coral health over three decades of monitoring activities. Further, this report aims to report possible factors that contribute to changes in reef and fish conditions. The authors also provide recommendations for the improvement in the management of the TRNP.

### Study site

Tubbataha Reefs Natural Park lies in the middle of the Sulu Sea and its reef structure consists of both fringing and atoll reefs (White et. al. 2003). Continuous reef platforms, 200-250 m wide, completely enclose sandy and coral substrate lagoons that range from 1-24 meters in depth. At extreme low tide, portions of the atoll's shallow reef platforms are exposed. Data was gathered in seven sites, six were located in reefs that had long-term protection while Jessie Beazley was only included in the protected area in 2007 through an executive order issued by President Gloria Arroyo.

### Data collection

**Substrate cover.** Systematic snorkeling surveys were carried out in the shallow reef flat at 2-3 m depth covering a distance of 0.5 – 1 km parallel to the reef crest. The distance covered for sampling is limited by the reef extent and may be less than 0.5 km in some sites. The substrate was evaluated within an estimated area of 1m<sup>2</sup> quadrat at every 50-meter stop (or station). The following data was recorded:

1. Percent cover of living coral (hard and soft)
2. Percent cover of non-living substrate (e.g., rock, rubble, sand, dead coral)
3. Percent cover of living substrate (e.g., seagrass, algae, sponges)
4. Numbers of indicator species (e.g., butterflyfish, giant clams, lobsters, Triton shells, Crown of thorns sea-stars and other invertebrates)
5. Presence of large marine life (e.g., sharks, manta rays, Humphead wrasses, sea turtles, whales, dolphins and others)
6. Causes of reef damage

Distances between stations were estimated through kick cycles, wherein, volunteers calibrated their kicks along a transect tape prior to surveys. Each volunteer attempted to make at least ten or more stations on one snorkel survey which was limited by the extent of the reef. Scuba surveys were carried out in the deep area (6-8 m) parallel to the reef crest using a systematic point-intercept method. Transects were laid on sections of a reef flat, reef crest or slope. Substrate was evaluated at 25 cm intervals along a 50 m transect. Data gathered during scuba surveys were the same type as those collected during snorkel surveys. The distance between transects was approximately 5 m.

**Fish counts.** Fish abundance and diversity were estimated using a 50 x 10 m visual census (UVC; n = 4 - 10) technique done by five specialists (DP Delizo Jr, R Diaz, DP Dacal, AT White and TJ Mueller). Specified substrate transects were utilized as guides for the UVC. The abundance of target species, indicator species and numerically dominant and visually obvious species were all counted. Length of fish was also estimated (Uychiaoco et al. 2011; English et al. 1997). Biomass of target species was computed using length-weight constants ([www.fishbase.org](http://www.fishbase.org)).

## Data Analyses

**Coral and fish density, species abundance and biomass.** Substrate was categorized into total live hard coral (branching, massive, encrusting and foliose), soft coral, rubble, non-living substrate (white dead standing coral, dead coral, rock and block, sand and silt) and others (sponges, algae, and seagrass) for comparison and presented graphically. Each category was compared within site between years using a one factor analysis of variance (1-ANOVA) and Kruskal-Wallis whenever appropriate. Sites with surveys that have low replication (n>2) were excluded from statistical analyses. Only those years with available raw data were included in the analysis. Data plotted in graphs for years 1992 to 2012 are from White et al (2012). Data included in the statistical analyses were tested for normality (when necessary) and Levene's Test for homogeneity of variances; log or square root transformation was made whenever appropriate and Tukey's Test was used as post hoc. All statistical analyses used the software Minitab 14®.

In describing coral condition, the following terms may have the corresponding values:

Gomez et al. (1994) categories:

Live Coral Cover (%mean ±SE)			
Poor	Fair	Good	Excellent
0% – 24.9%	25% – 49.9%	50% - 74.5%	75% - 100%

Density and species abundance of fishes was presented and classified according to the 19 coral reef fish families/subfamily which include target fish families (Serranidae: Epinephelinae and Anthiinae, Lutjanidae Haemulidae, Lethrinidae, Carangidae, Caesionidae, Nemipteridae, Mullidae, Balistidae, Chaetodontidae, Pomacanthidae, Labridae, Scaridae, Acanthuridae, Siganidae, Kyphosidae, Pomacentridae and Zanclidae), used as indicators in Coral Reef Monitoring for Management (Uychiaoco et al. 2011).

When applicable, species richness was expressed as mean number of species per 500 m<sup>2</sup>. Target fish densities were compared between years where raw data is available, using 1-ANOVA or Kruskal-Wallis whenever appropriate. Tukey's Test was used for post hoc. All data were tested for variance equality and normality using Minitab 14®. A log or square root transformation was made whenever appropriate. In order to classify the year 2014 all reef fish densities to "high, mid or low" using the category of Hilomen et al. (2000), we extrapolated the 500 m<sup>2</sup> fish densities area to 1000 m<sup>2</sup>. However, what is reflected in this report are the 500 m<sup>2</sup> values to be consistent with the previous years.

Hilomen et al. (2000) categories:

<b>Fish Species Diversity (no. of species/1000 m<sup>2</sup>):</b>				
Very Poor	Poor	Moderate	High	Very High
0 – 26	27 – 47	48 - 74	75 - 100	>100
<b>Fish Density (no. of fish/1000 m<sup>2</sup>):</b>				
Very Poor	Poor	Moderate	High	Very High
0 – 201	202 – 676	677 – 2,267	2,268 – 7,592	>7,592
<b>Biomass (kgs/500m<sup>2</sup>)</b>				
Very Poor	Poor	Moderate	High	Very High
<10.0	10.1 – 40.0	40.1 – 70	70.1 – 149.0	>149

**Fish biomass.** Fish biomass was computed using the formula:  $a * L^b$  (Fishbase 2004), using the length-weight constants in FishBase ([www.fishbase.org](http://www.fishbase.org)). Biomass of target fish species were computed on the species level and summed per site, based on selected target fish/commercially important food fish: Epinephelinae (Serranidae), Lethrinidae, Lutjanidae, Acanthuridae, Caesionidae, Carangidae, Haemulidae, Nemipteridae, Mullidae, Scaridae, Siganidae, Labridae (larger species, i.e., *Cheorodon* spp., *Cheilinus* spp.), including a non-reef family, Scombridae and Sphyraenidae. Fish biomass data did not meet the assumptions of variance equality, thus, comparisons between families within sites used the Kruskal-Wallis multiple comparison test. For this report, biomass computations were based on consensus with species-specific lengths (n = 3-10).



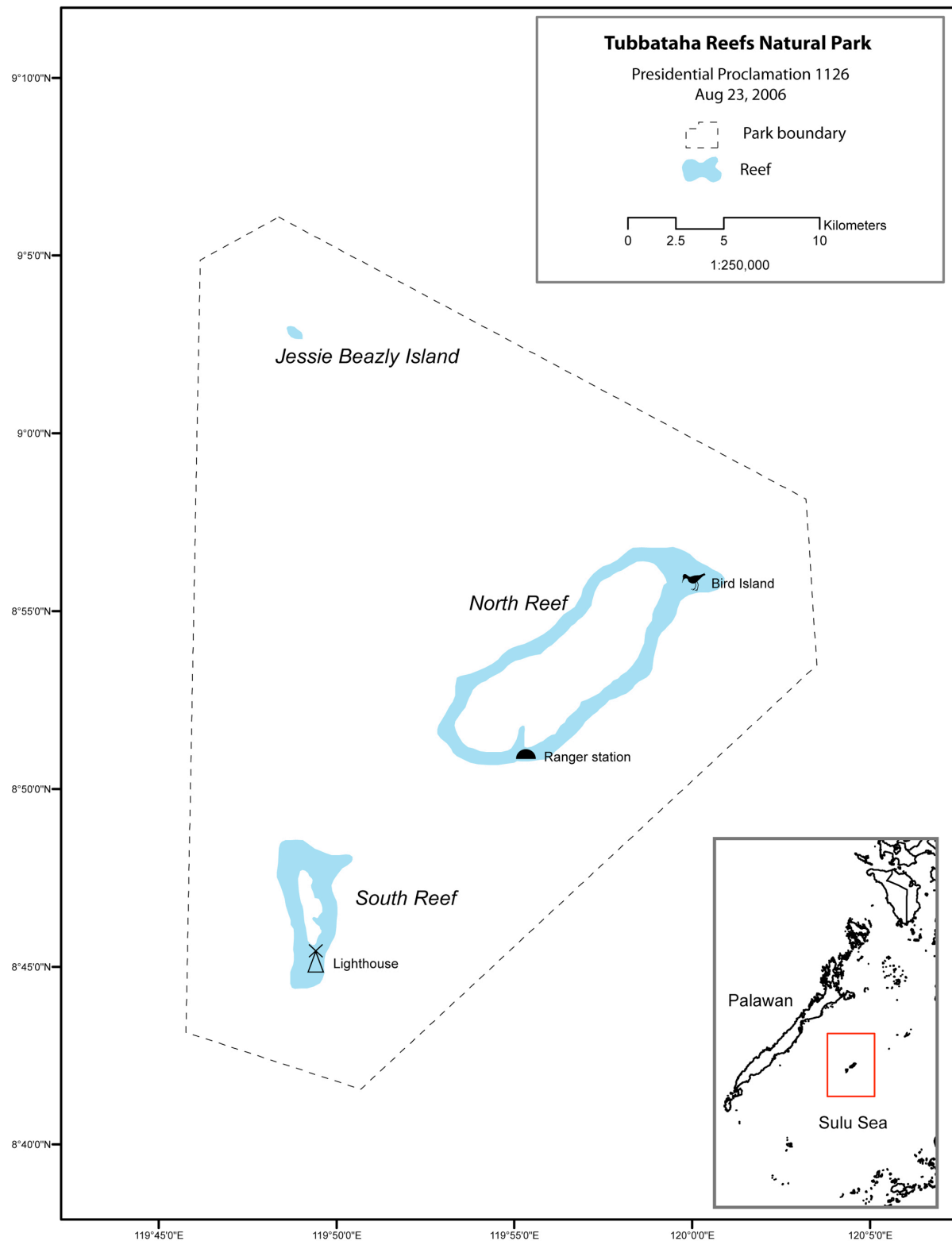


Figure 1. Location and delineation of Tubbataha Reefs Natural Park in Sulu Sea, Palawan.

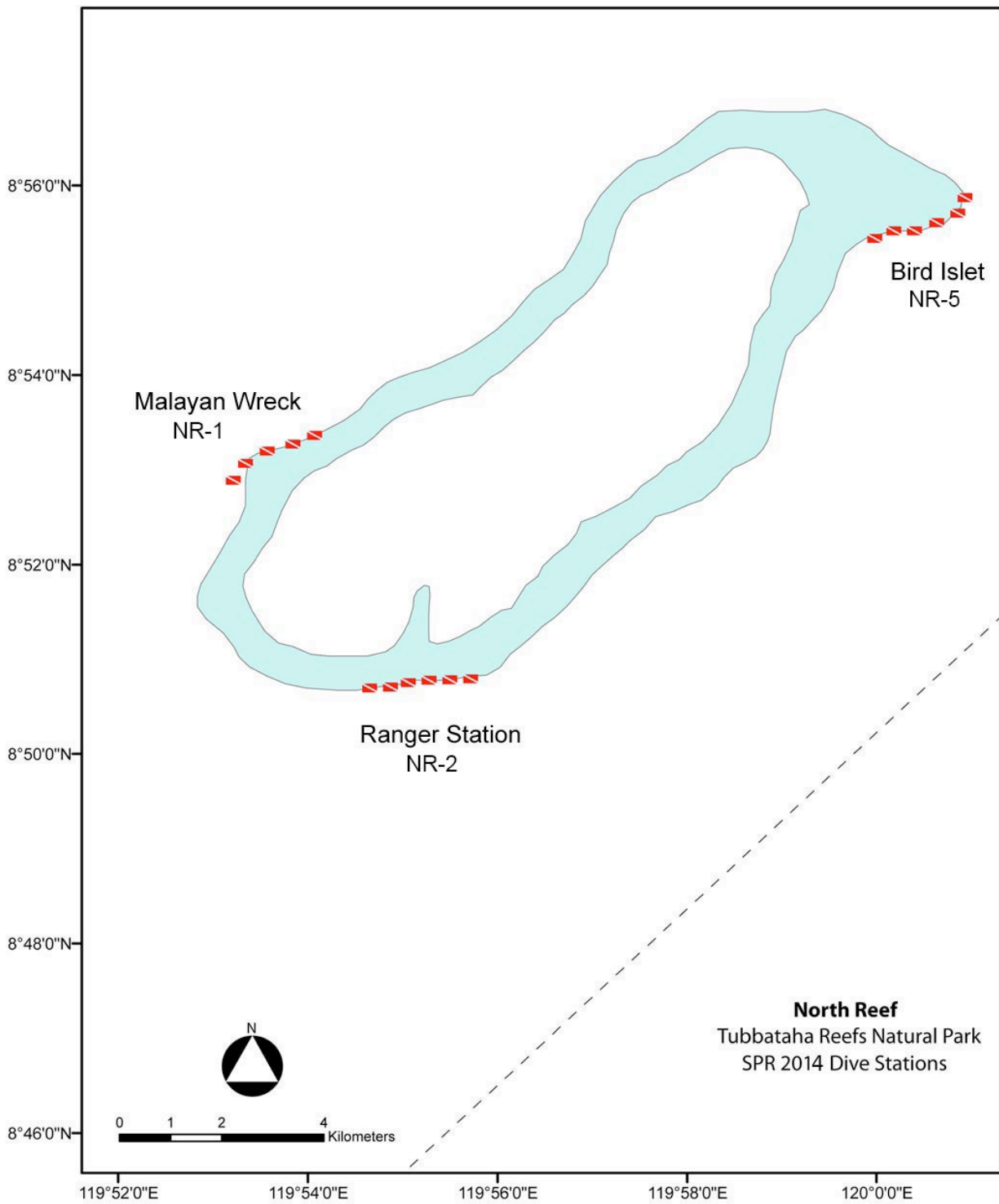


Figure 2. North Reef survey sites in Tubbataha Reef Natural Park (TRNP).

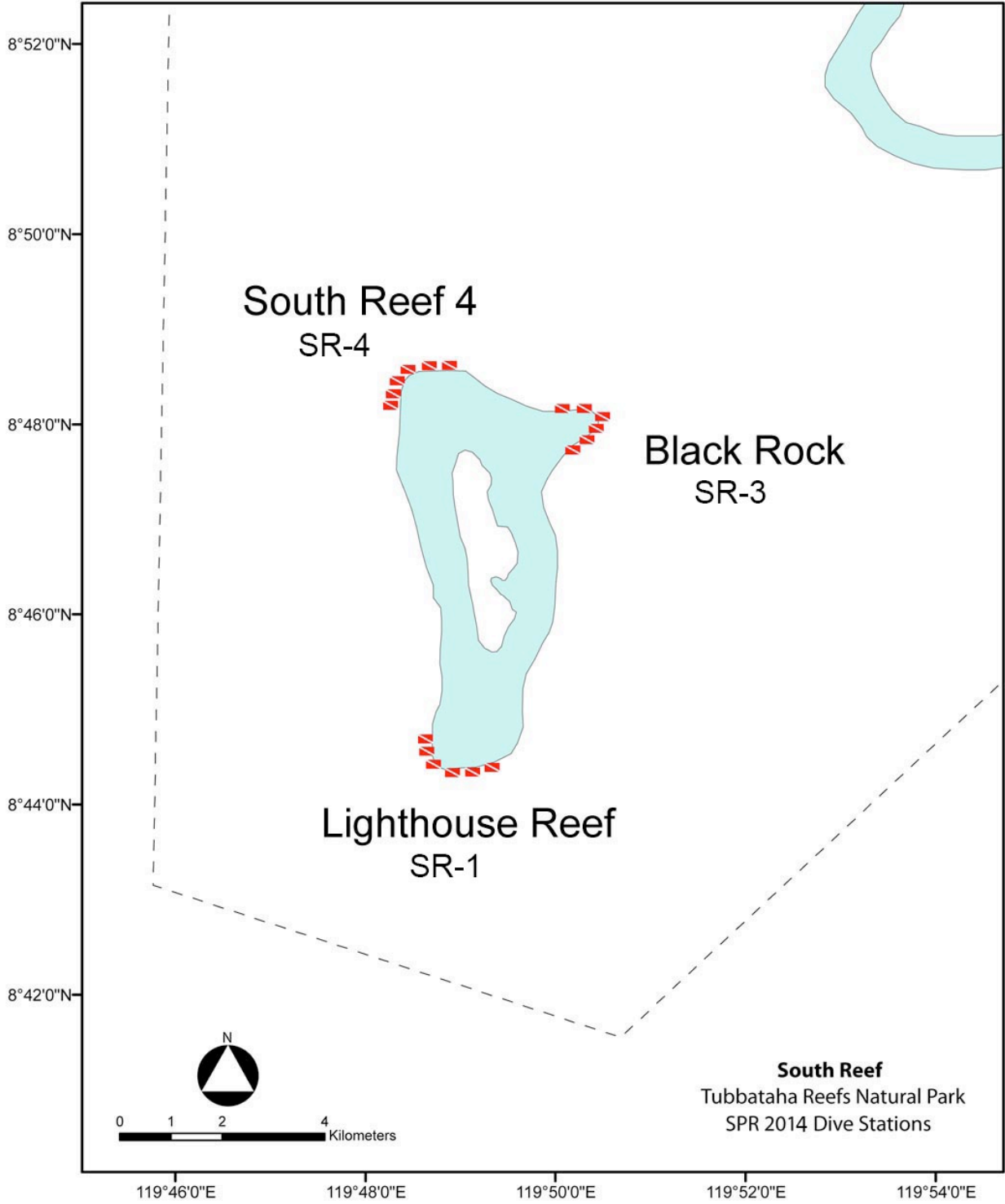


Figure 3. South Reef survey sites in Tubbataha Reef Natural Park (TRNP).

## OVERVIEWS OF SITE SURVEYS

### North Reef 5 (NR5: Bird Islet)

**Site Overview.** Bird Islet is located on the northeast side of the northern atoll. Being one of the few parts of Tubbataha that rise above sea level, this islet provides a resting place to over one hundred migratory bird species and a few permanent resident species. Underwater, the reef slope deepens to about 8 meters and plummets to the depths, forming a reef wall. On the sandy slope, sometimes referred to as “Shark Airport”, numerous white-tip reef sharks and even grey reef sharks can be seen resting. Also in the shallow region, many titan triggerfish were seen busy at work building their nests. Manta rays are also known to frequent the area, allowing the cleaner wrasses to work. This area is a great dive location because of the diversity of large organisms it offers, a generally healthy coral reef and diverse topography.

**Substrate.** NR5 was clearly affected by the 1998 ENSO (El Nino Southern Oscillation) event, when hard coral cover decreased significantly ( $p = 0.000$ ,  $F = 8.62$ ,  $DF = 5$ ), to the lowest LHC recorded during the 2000 assessment (deep:  $18.41 \pm 0.031\%$ ) (Maypa et al., 2004). The reef showed a noteworthy recovery from 2000 to 2012, doubling percent cover (shallow: 23.8% [2000] to 50.8% [2012] and deep: 18.4% [2000] to 42.5% [2008]). Unfortunately, cover dropped significantly in 2014 (ANOVA results) from good to fair reef condition (shallow:  $30.5 \pm 3.59\%$ ). The coral in the deeper areas stayed in fair condition, only slightly increasing in total LHC (deep:  $35.41 \pm 2.87\%$ ). Recovery since then has continued until 2012 (shallow) and 2008 (deep) but no longer follows a consistent trend (White et al. 2012).

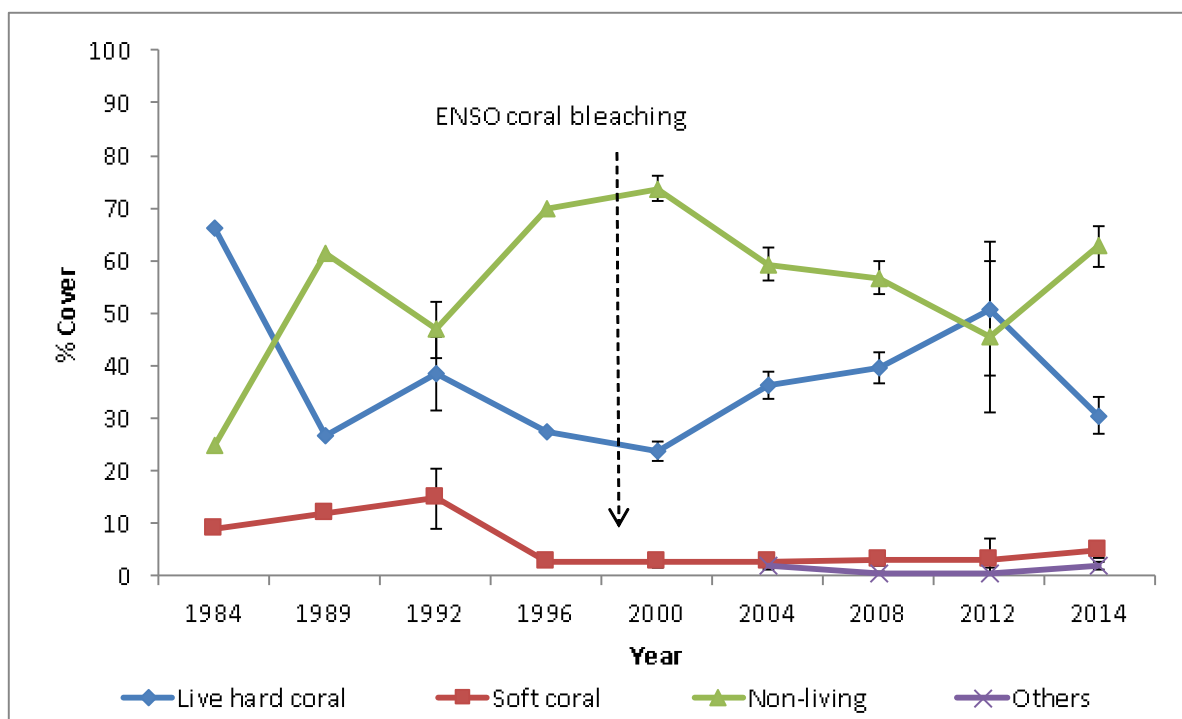


Figure 4. Changes in substrate composition (%mean  $\pm$ SE) in NR-5 (Bird Islet) from 1984 to 2014, 2-3m depth.

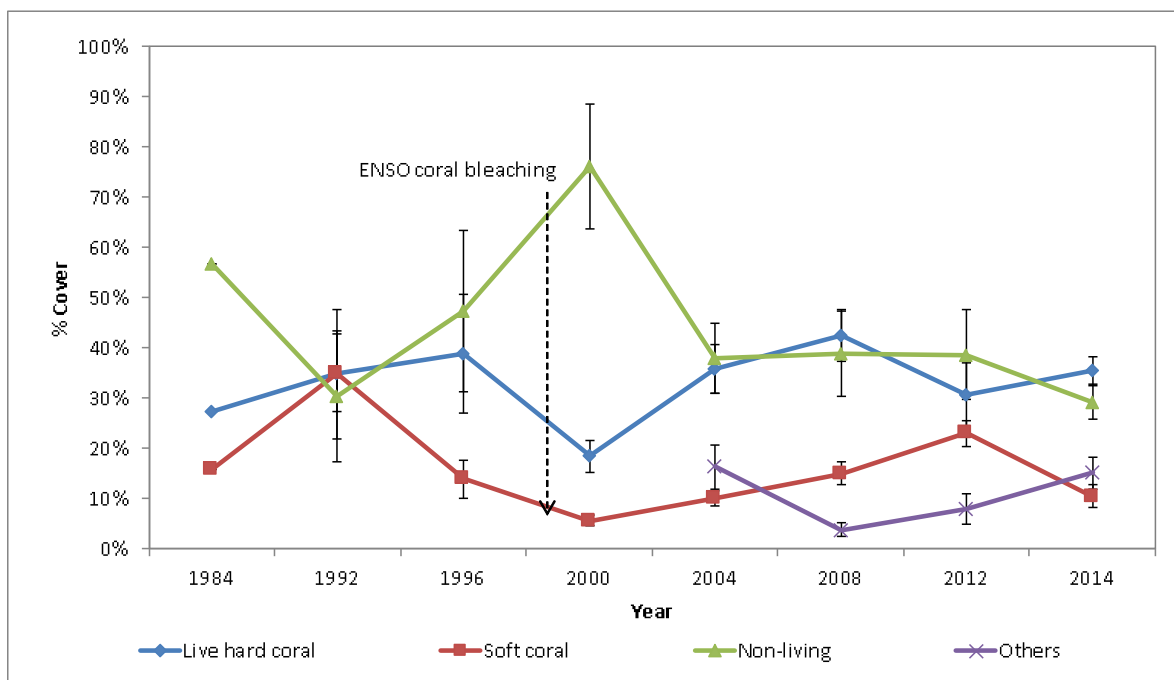


Figure 5. Changes in substrate composition (%mean  $\pm$ SE) in NR-5 (Bird Islet) from 1984 to 2014, 7-10m depth.

**Fish Diversity, Abundance, and Biomass.** All reef fish density (1,782.5 fish/500m<sup>2</sup>) and reef species richness (57.7 species/500m<sup>2</sup>) were both moderate in 2014, based on the Hilomen et al. (2000). The overall trend of all reef fish density from 1992 to 2014 is just slightly decreasing due to the low numbers in 2012 and 2014, especially compared to the high counts in 2008 while the target fish stayed steady. That decline was attributed to the spatial and temporal variation of the population of fusiliers (*Caesionidae*) and their highly mobile, schooling behavior. The further drop in target species numbers is probably due to increasing sizes of fish as reflected in the biomass increase. Species richness has stayed fairly consistent throughout the years.

Fish biomass showed a significant increase in 2014, as compared to years before which recorded decreasing fish biomass at 148.6 kg/500m<sup>2</sup> in 2004 to 102.7 kg/500m<sup>2</sup> in 2012. The increase from 2012 to 2014 pushed to 235.5 kg/500m<sup>2</sup>.

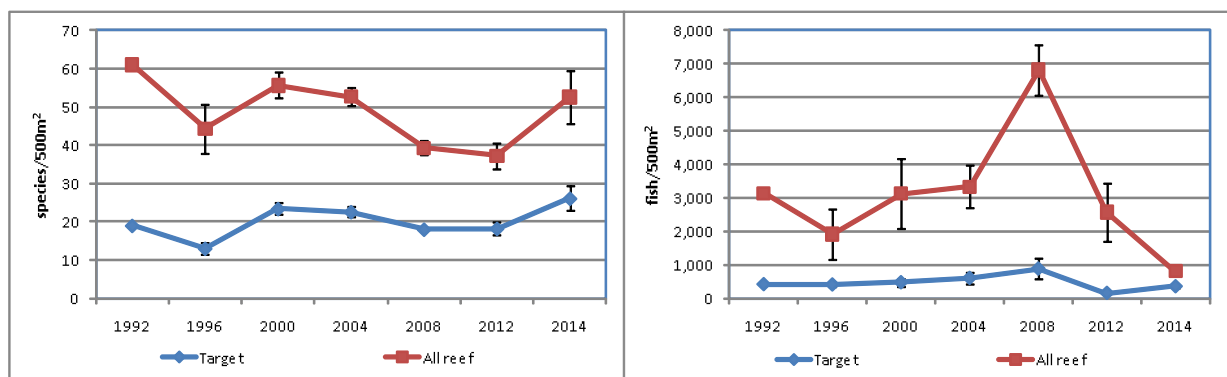


Figure 6A. Fish species richness (mean  $\pm$ SE) and fish density (mean  $\pm$ SE) at NR-5 (Bird Islet) from 1992 to 2014.

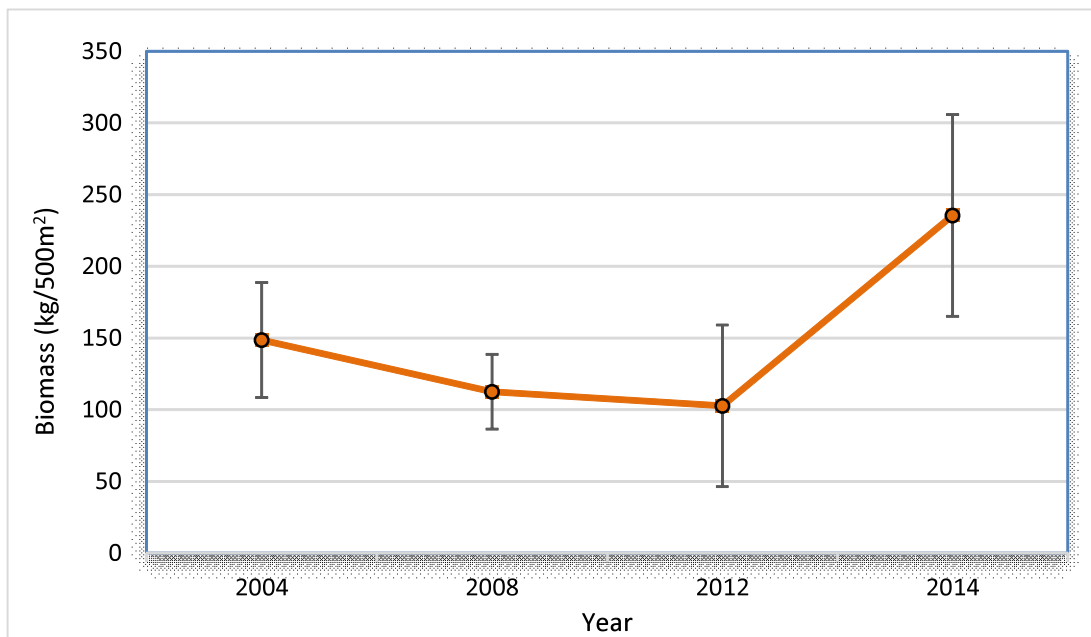


Figure 6B. Target fish biomass (mean  $\pm$  SE) at NR5 (Bird Islet) in Tubbataha Reef Natural Park from 2004 to 2014.

### North Reef 1 (NR1: Amos Rock or Malayan Wreck)

**Site Overview.** The dive site North Reef 1 is more commonly known as Amos Rock or Malayan Wreck because of the wreck that lies in the shallows of this south eastern side of the atoll. As usual in Tubbataha reefs, the slope gradually deepens and then drops into a wall. The wall area here is called “Wall Street” by regular dive operators due to the strong currents streaming along the wall and diversity of marine life, including the whale shark seen on this year’s expedition. This area is unique to the other areas due to the high density of Bumphead parrotfish near the edge of the slope as well as other large animals seen. White-tip sharks will also exploit the shallow sandy patches here for recharging. Because of this distinct occurrence of fish, Malayan Wreck is a popular site for recreational divers. Amos Rock was the area most affected by the Crown-of-Thorns sea-star (*Acanthaster planci*) outbreak in 2009, affecting many hard corals here.

**Substrate.** North Reef 1 remains in fair condition in both the deep ( $34.90 \pm 3.05\%$ ) and shallow ( $28.98 \pm 4.06\%$ ) reef in 2014. Similar to NR5, North Reef 1 was heavily affected in 1998 by the mass bleaching event where LHC declined significantly to 14% (shallow) and 18% (deep). Indications of slow recovery in the deep, but not in the shallow, were observed in 2004, through a significant increase in LHC. (Maypa et al. 2004, White et al. 2004). There was an outbreak of Crown-of-Thorns, in 2009 in the area but there was no significant difference between 2008 and 2012.

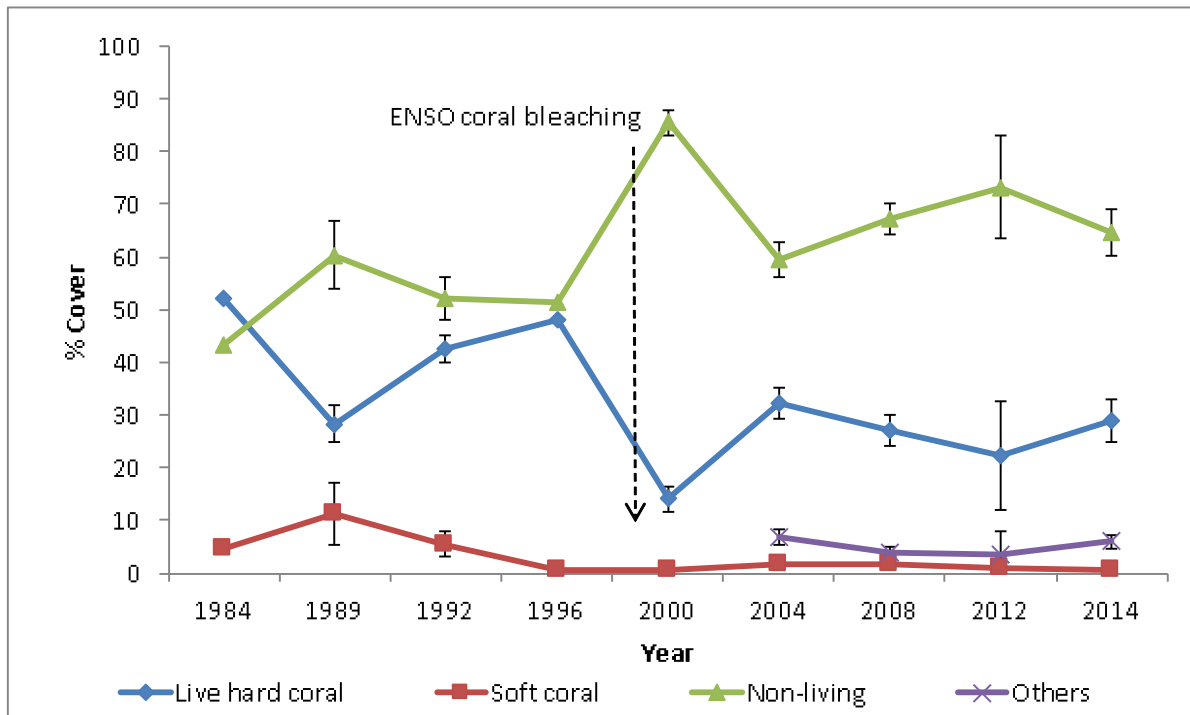


Figure 7. Changes in substrate composition (%mean  $\pm$ SE) in NR-1 (Amos Rock/Malayan Wreck) from 1984 to 2014, 2-3m depth.

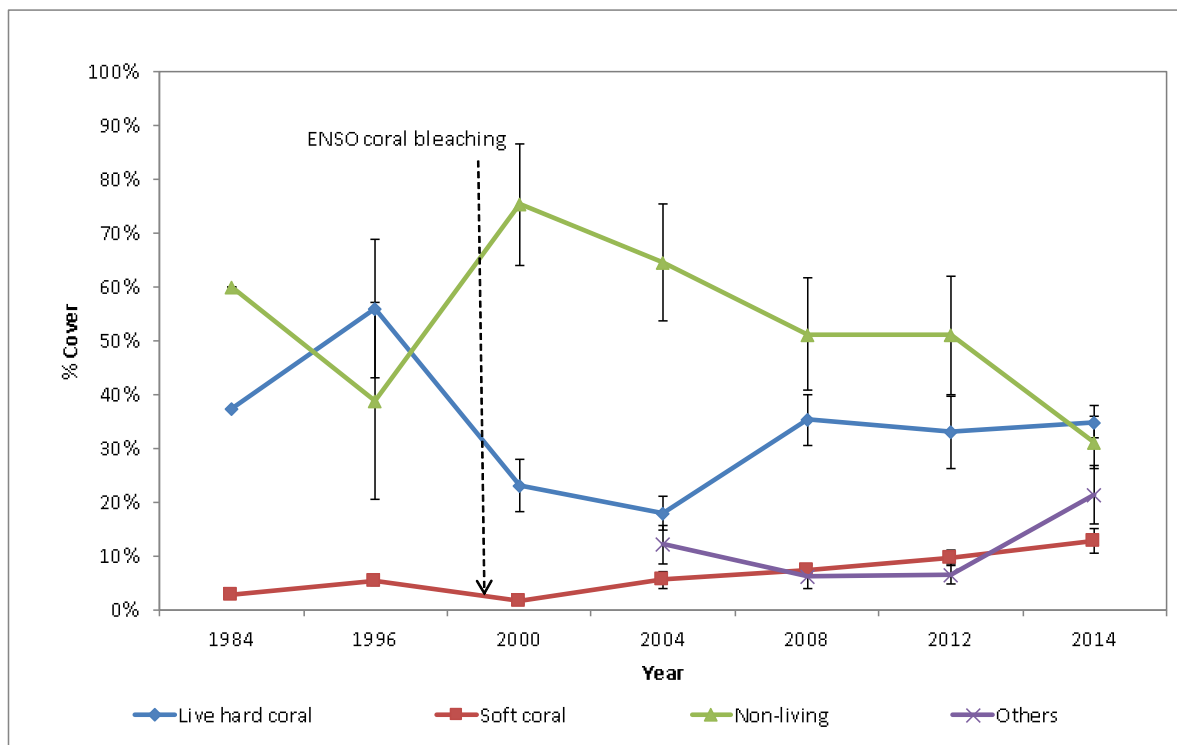


Figure 8. Changes in substrate composition (%mean  $\pm$ SE) in NR-1 (Amos Rock/Malayan Wreck) from 1984 to 2014, 7-10m depth.

**Fish Diversity, Abundance, and Biomass.** All reef fish density (938.6 fish/500m<sup>2</sup>) and reef species richness (59.8 species/500m<sup>2</sup>) were both moderate in 2014 at North Reef 1. Declining trends were observed in all aforementioned parameters over time, as well as target species density and richness. A significant drop in both density and species richness occurred between 2008 and 2012, and in each case, the data collected in 2014 showed an improvement from those lows (Figures 9 and 10).

There has been an increasing trend in the fish biomass for Malayan Wreck (NR1) survey site. Since 2004 (51.7 kg/500m<sup>2</sup>) when data was initially collected for biomass in fish. There was a big increase from 2012, at 138.6 kg/500m<sup>2</sup>, to 2014 with 182.2 kg/500m<sup>2</sup>.

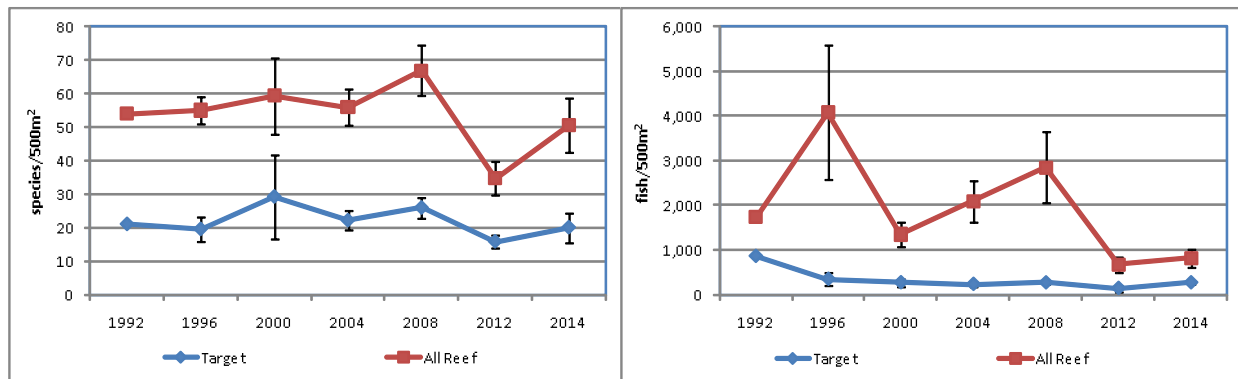


Figure 9A. Fish species richness (mean  $\pm$  SE) and fish density (mean  $\pm$  SE) at NR-1 (Amos Rock/Malayan Wreck) from 1992 to 2014.

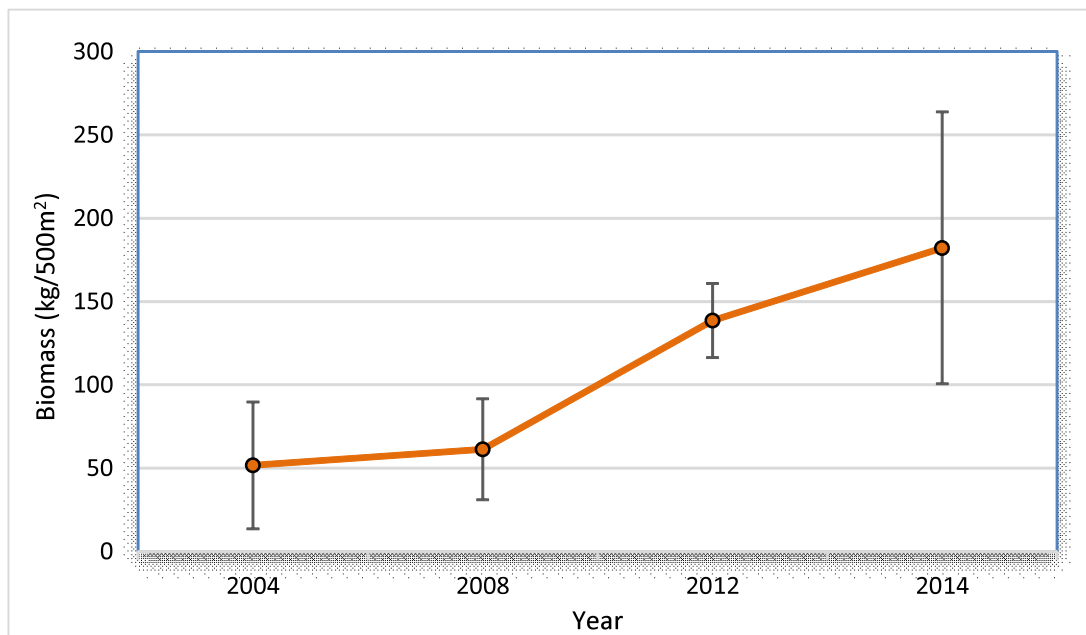


Figure 9B. Target fish biomass (mean  $\pm$  SE) at NR-1 (Amos Rock/Malayan Wreck) in Tubbataha Reef Natural Park from 2004 to 2014.



## North Reef 2 (NR2: Ranger Station)

**Site overview.** Located at the southern end of the North Reef atoll, the Ranger Station was strategically built to give the park rangers a good view of most of Tubbataha's reefs. The Ranger station is surrounded by large areas of sand that are frequented by large sea cucumbers, seastars, triggerfish, rays, turtles, and young sharks. During some months, divers may have to be cautious of the nesting triggerfish that become territorial and protective over their sand-buried eggs. The reef is characterized by a gradual slope that drops off to a coral-rich crest and steep wall. Overall, it is a sheltered area that is positioned in a reef channel and where scuba divers can enjoy a relatively calm and current-free dive.

**Substrate.** LHC remains in good condition in NR2 (deep:  $58.56 \pm 4.59\%$ ) and also increased slightly more in 2014. Although the LHC cover improvements are not significant from one year to the next, the coral cover has risen 25% since 1992. Six years ago, there was a crown-of-thorns infestation observed that did not affect the LHC cover overall. The deeper portion of NR2 was one of the sites that recovered quite well after being affected by the 1998 ENSO event. Although the shallow reef was not surveyed in 2014 coral cover has stayed consistently around 40% since 2000.

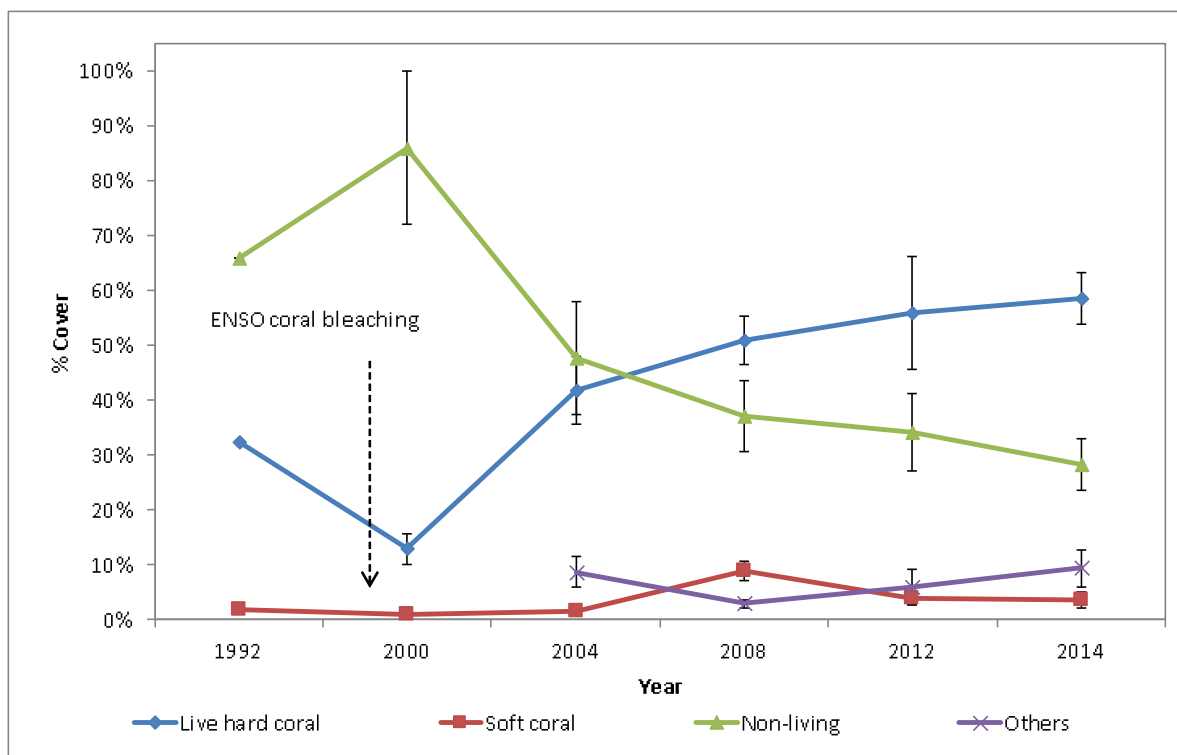


Figure 10. Changes in substrate composition (%mean  $\pm$ SE) in NR-2 (Ranger Station) from 1984 to 2014, 7-10m depth.

**Fish Diversity, Abundance, and Biomass.** All reef fish density is moderate ( $2,028.6$  fish/ $500\text{m}^2$ ) in 2014, 23% ( $278.6$  fish/ $500\text{m}^2$ ) of which was comprised of the target species and reef species richness ( $55.8$  species/ $500\text{m}^2$ ), also moderate in 2014, is made up of 48% target species ( $24.6$  species/ $500\text{m}^2$ ). As in

North Reef 5, there was a significant decrease in both fish density and species richness from 2008 to 2012, but with increasing trends noted in 2014.

An increasing trend was recorded in fish biomass at the Ranger Station (NR2) since 2008 (64.3 kg/500m<sup>2</sup>). In 2012, fish biomass was at 92.3 kg/500m<sup>2</sup> and it increased to 127.1 kg/500m<sup>2</sup> in 2014. This may be attributed to improved protection in the site in the last six years.

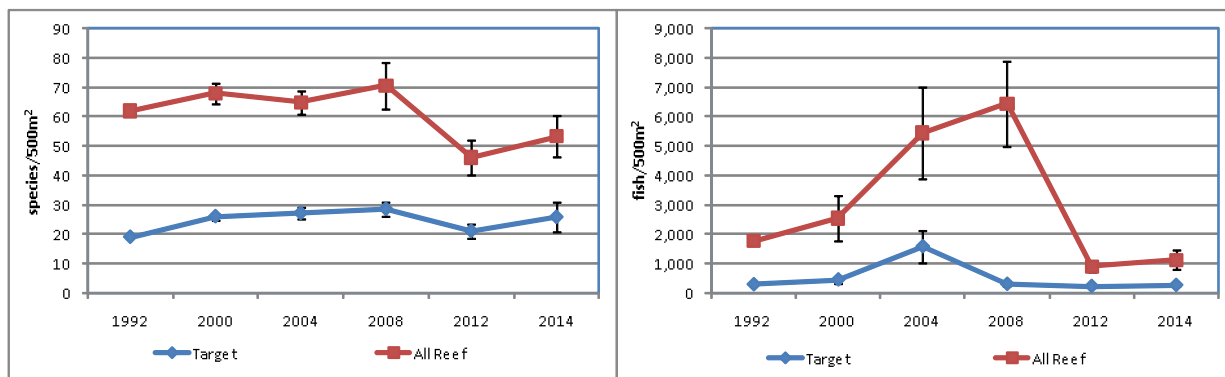


Figure 11A. Fish species richness (mean  $\pm$  SE) and fish density (mean  $\pm$  SE) at NR-2 (Ranger Station) from 1996 to 2014.

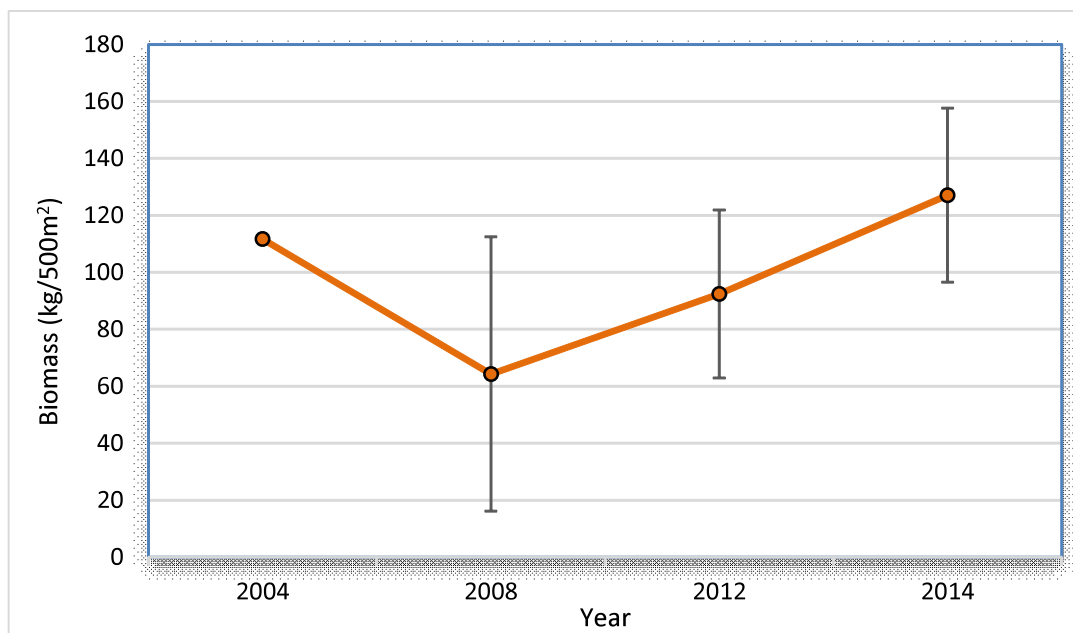


Figure 11B. Target fish biomass (mean  $\pm$  SE) at NR-2 (Ranger Station) in Tubbataha Reef Natural Park from 2004 to 2014.

### South Reef 3 (SR3: Black Rock)

**Site Overview.** Excitement on the southern atoll picks up when the unpredictable currents escort a variety of large marine life to this dive site. Included in sightings this year were a number of green sea turtles, various sharks and the ever-present triggerfishes. With a diverse array of living substrate, many small critters can be found as well. Coral are crawling with brittle stars, nudibranchs, and other interesting invertebrates like the occasional octopus. All of these and the large and spectacular soft coral colonies really bring the reef to life. Along the top of the wall, there are valleys, between healthy reef crests, covered in branching coral rubble but provide a secluded hiding place for the larger fish, and even sea turtles.

**Substrate.** Live hard coral (LHC) in South Reef 3 remained in good condition (shallow:  $52.2 \pm 4.14\%$ , deep:  $52.64 \pm 7.21\%$ ), showing no significant changes from 2012 for hard coral or other living substrate (Figures 12 and 13). The deep survey of South Reef 3 showed the highest total hard coral cover of all sites in 2014.

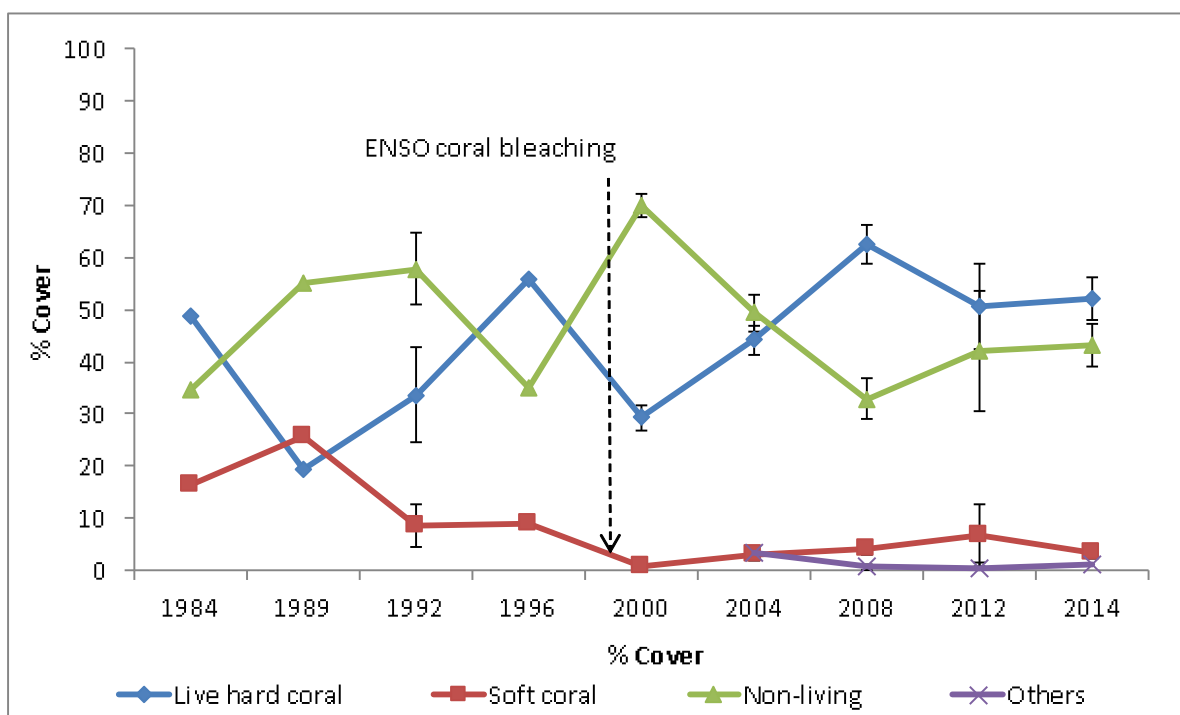


Figure 12. Changes in substrate composition (%mean  $\pm$ SE) in SR-3 (Black Rock) from 1984 to 2014, 2-3m depth.

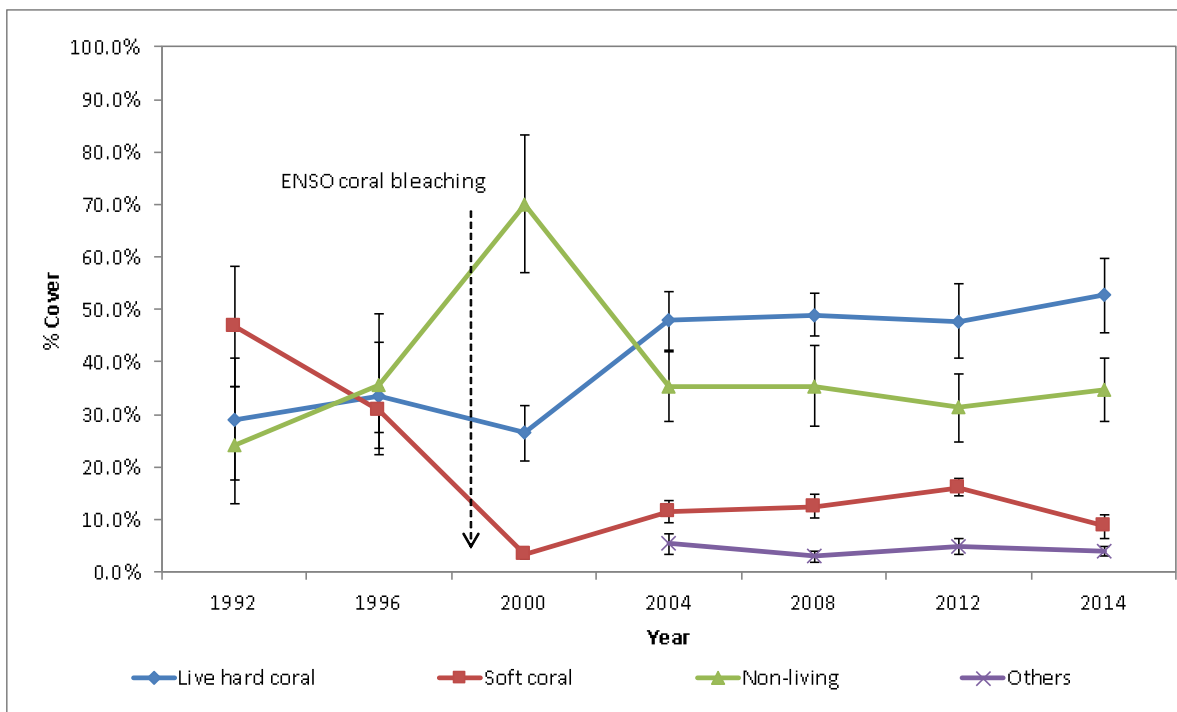


Figure 13. Changes in substrate composition (%mean  $\pm$ SE) in SR-3 (Black Rock) from 1984 to 2014, 7-10m depth.

### Fish Diversity, Abundance, and Biomass.

All reef and target fish species increased from 2012 to 2014. For all reef species, in 2012, species richness was recorded at 28.1 species/500m<sup>2</sup>. In 2014 this went to 61.4 species/500m<sup>2</sup>. In terms of target fish species, there was also an increase from 2012 (12.6 species/500m<sup>2</sup>) to 2014 (26.4 species/500m<sup>2</sup>). Fish density increased for target species of fish from 151 fish/500m<sup>2</sup> in 2012 to 222.4 fish/500m<sup>2</sup>. There was a decrease in all reef fish density from 2,034 fish/500m<sup>2</sup> in 2012 to 1,856.4 fish/500m<sup>2</sup> in 2014.

The biomass of fish in Black Rock (SR3) increased significantly from 2012 at 68.6 kg/500m<sup>2</sup> to 160 kg/500m<sup>2</sup> in 2014. Biomass has been steadily increasing over the years when data was initially collected in 2004 (31.9 kg/500m<sup>2</sup>).

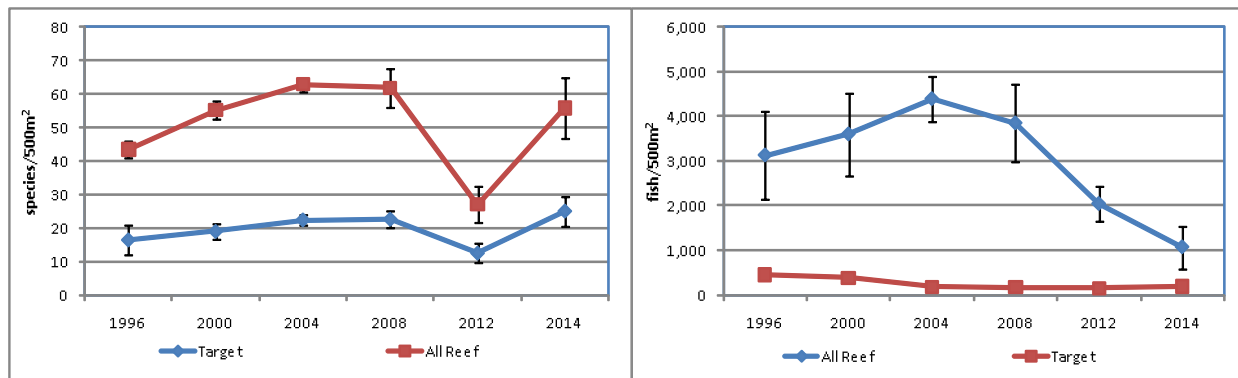


Figure 14A. Fish species richness (mean  $\pm$  SE) and fish density (mean  $\pm$  SE) at SR-3 (Black Rock) from 1996 to 2014.

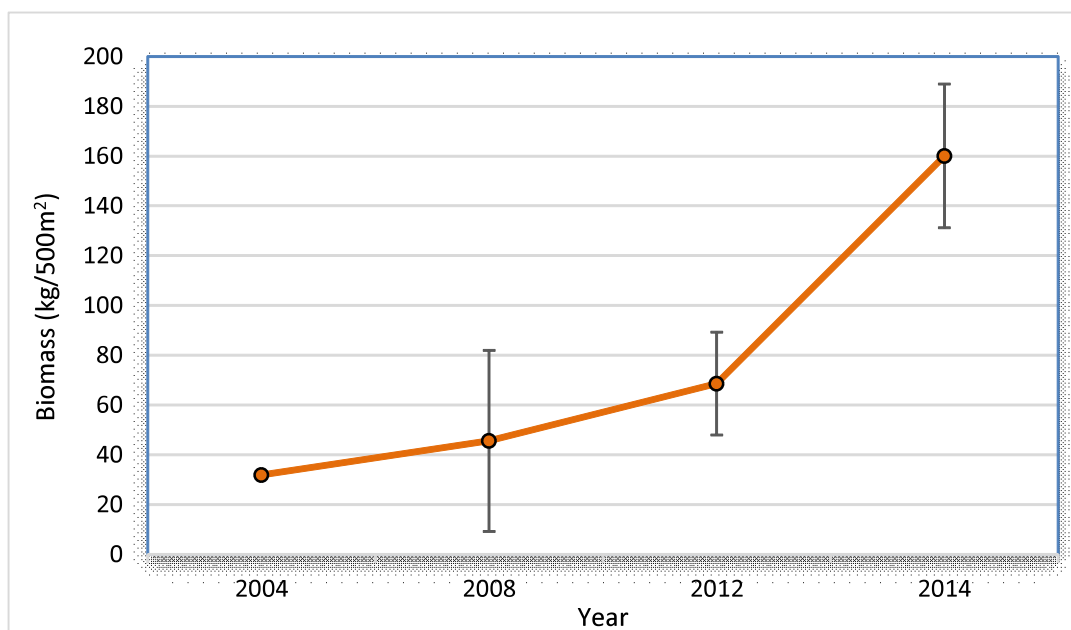


Figure 14B. Target fish biomass (mean  $\pm$  SE) at SR-3 (Black Rock) in Tubbataha Reef Natural Park from 2004 to 2014.

#### South Reef 4 (SR4: Northwest corner of the south atoll)

**Site Overview.** At the northwest corner of the southern atoll, this site is susceptible to strong currents but is rich with all sorts of marine life. The reef wall reaches up from the depths, teeming with beautiful sea fans and soft corals reaching for the light above. Fishes hover off the wall, including the typical reef dwellers; an innumerable count of fairy basslets, surgeons, damsels and butterflyfishes, but also attracts the occasional barracuda, large schools of Rainbow runners, mackerel and jacks. The unique topography also provides protective crevices where sea turtles and sharks can find a place to rest undisturbed. This is the site, where in 2012, the survey team watched a shark feeding frenzy that contained 30- 40 sharks.

**Substrate.** The LHC cover at 6-8 m depth reached its lowest this year, with a significant decrease from 2012, shifting the reef from good to fair condition (deep [2012]:  $51.28 \pm 10.66\%$ , deep [2014]:  $32.64 \pm 2.91\%$ ), and breaking the trend of increasing percent cover since first being surveyed in 1992. In the shallow reef, the coral cover remains in fair condition (shallow:  $42.28 \pm 8.24\%$ ) Although the shallow area, in general, has been on a slight decline since 1992, the branching coral cover is the highest it's been since 1992, with opposite results of the deep survey area.

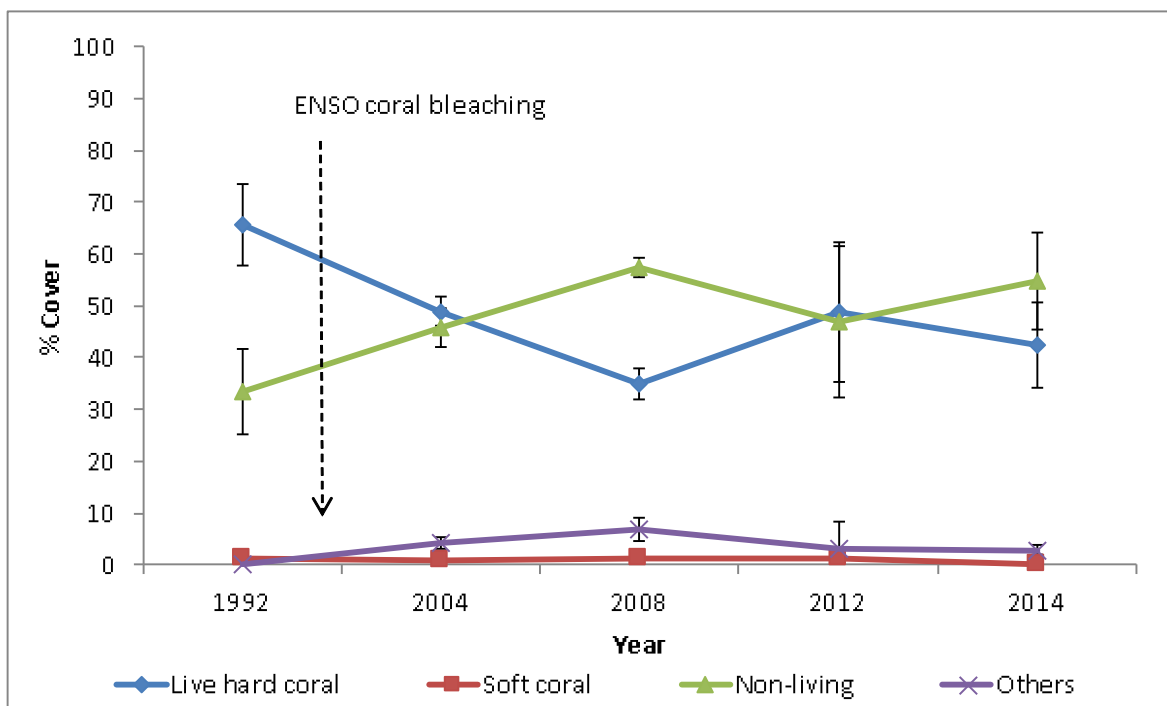


Figure 15. Changes in substrate composition (%mean  $\pm$  SE) in SR-4 (Northwest corner of the south atoll) from 1984 to 2014, 2-3m depth.

### Fish Diversity, Abundance, and Biomass.

In terms of fish species richness for both target and all reef species for SR4, there were significant increases. There was an increase in fish species richness from 2012 (12.8 species/500m<sup>2</sup>) to 2014 (23 species/500m<sup>2</sup>) for target species of fish. Another increase in fish species was in all the reef species from 2012 (27 species/500m<sup>2</sup>) to 2014 (45 species/500m<sup>2</sup>). For fish density, a decrease happened in all reef species from 1,459.2 fish/500m<sup>2</sup> in 2012 to 838.5 fish/500m<sup>2</sup> in 2014. Target fish species showed an increase from 172.2 fish/500m<sup>2</sup> in 2012 to 261.5 fish/500m<sup>2</sup> in 2014. Overall, this survey site showed some of the lowest fish densities recorded.

Biomass, however, increased despite the low fish densities, from 2012 at 83.2 kg/500m<sup>2</sup> to 213.1 kg/500m<sup>2</sup> in 2014. This area is susceptible to strong currents and historically there has been a decreasing trend in fish density. Overall, this survey site has a varied record of species richness and density showing that this area attracts many fish that pass through and feed but not always seen on a given day or time. Biomass continues to increase indicating the fish are larger on average than in the past.

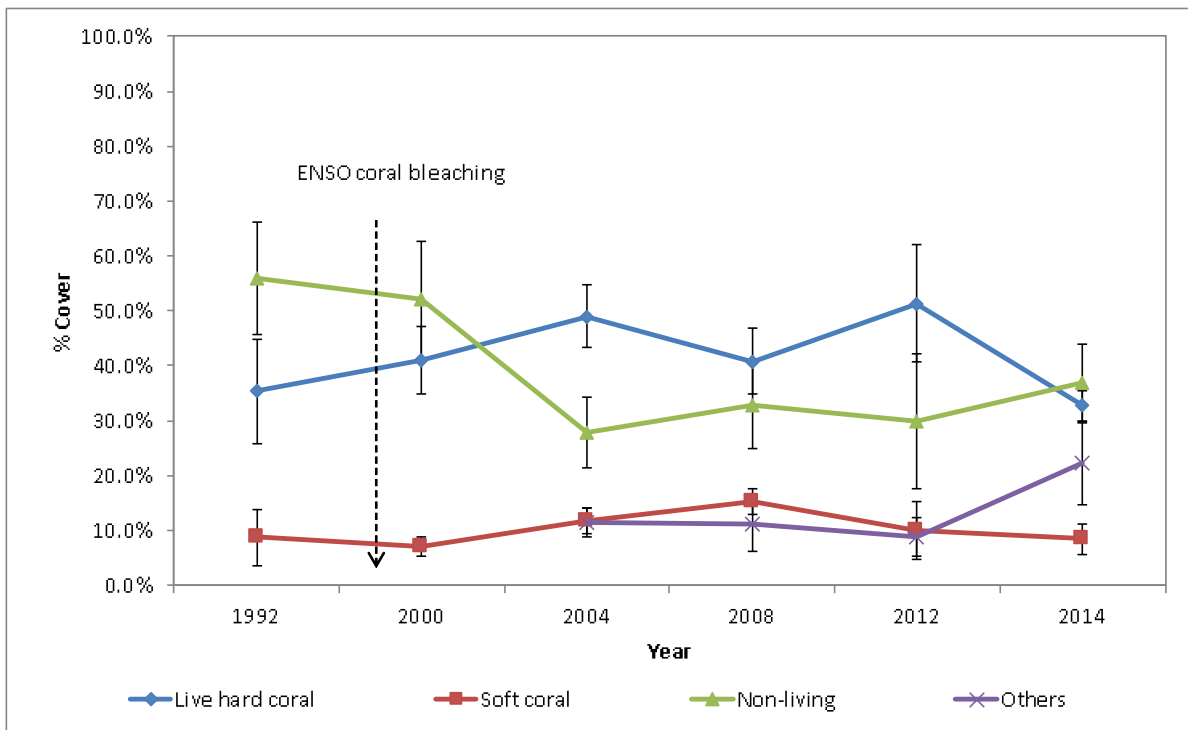


Figure 16. Changes in substrate composition (mean  $\pm$ SE) in SR-4 (Northwest corner of the south atoll) from 1984 to 2014, 7-10m depth.

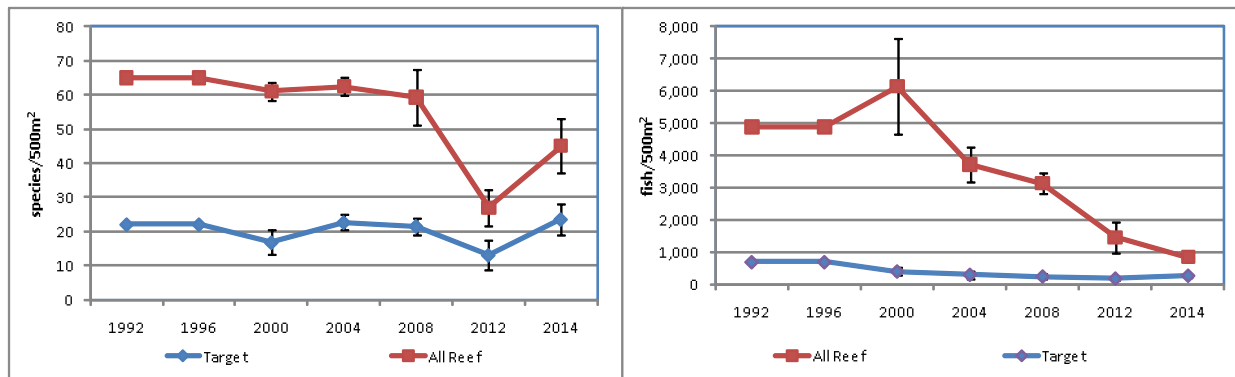


Figure 17A. Fish species richness (mean  $\pm$ SE) and fish density (mean  $\pm$ SE) at SR-4 (Northwest corner of the south atoll) from 1992 to 2014.

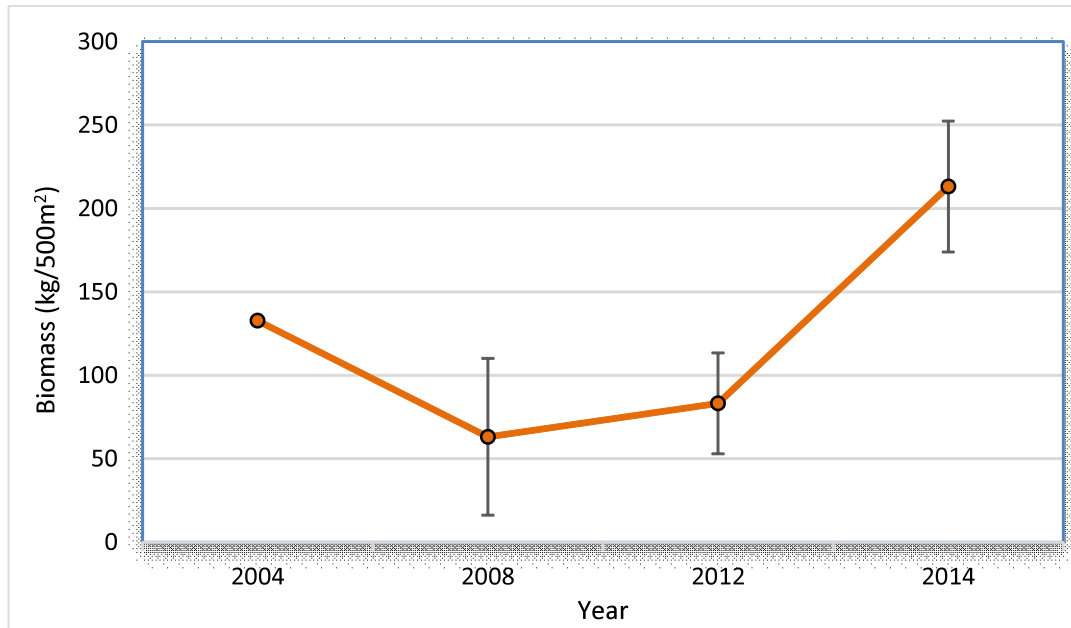


Figure 17B. Target fish biomass (mean  $\pm$  SE) at SR-4 (Northwest corner of the south atoll) in Tubbataha Reef Natural Park from 2004 to 2014.

### South Reef 1 (SR1: Lighthouse Islet)

**Site Overview.** The southernmost dive site in Tubbataha, Lighthouse Reef is a popular destination because it provides a site above the surface where the lighthouse rests and a variety of nesting and migratory birds even though visiting the lighthouse and inner lagoon reefs is now off limits to visitors. A beautiful display of surgeonfish and schooling bannerfish speckled the deep blue abyss mirroring the steep wall. The large cover of branching *Acropora* coral provides refuge for many fairy basslets and damselfishes. The crest, beautifully decorated with all morphologies of coral, sea fans, giant barrel sponges, and crinoids. Lighthouse reef has a history of attracting hammerhead sharks, although none were seen in 2014. However, we were lucky enough to experience a very large school of jack fishes and the second whale shark sighting. Napoleon wrasses were also cruising along the edge of the crest where the wall drops, where many sweetlips speckled the reef.

**Substrate.** The 2014 survey shows that overall, the reef is in its best recorded condition (shallow:  $53.63 \pm 2.84\%$ , deep:  $51.28 \pm 6.71\%$ ). Both of these conditions are a significant improvement from 2012 when conditions were only rated as fair (shallow:  $38.88 \pm 9.40\%$ , deep:  $37.85 \pm 0.08\%$ ). Coral cover in South Reef 1 has had a fluctuating trend since the first survey in 1984 that may be attributed to the 1998 ENSO and the pulses of coral bleaching thereafter (Maypa et al. 2004), although the LHC, along with the deep site of SR4, were not measurably affected by the 1998 event, the only sites in Tubbataha not affected.



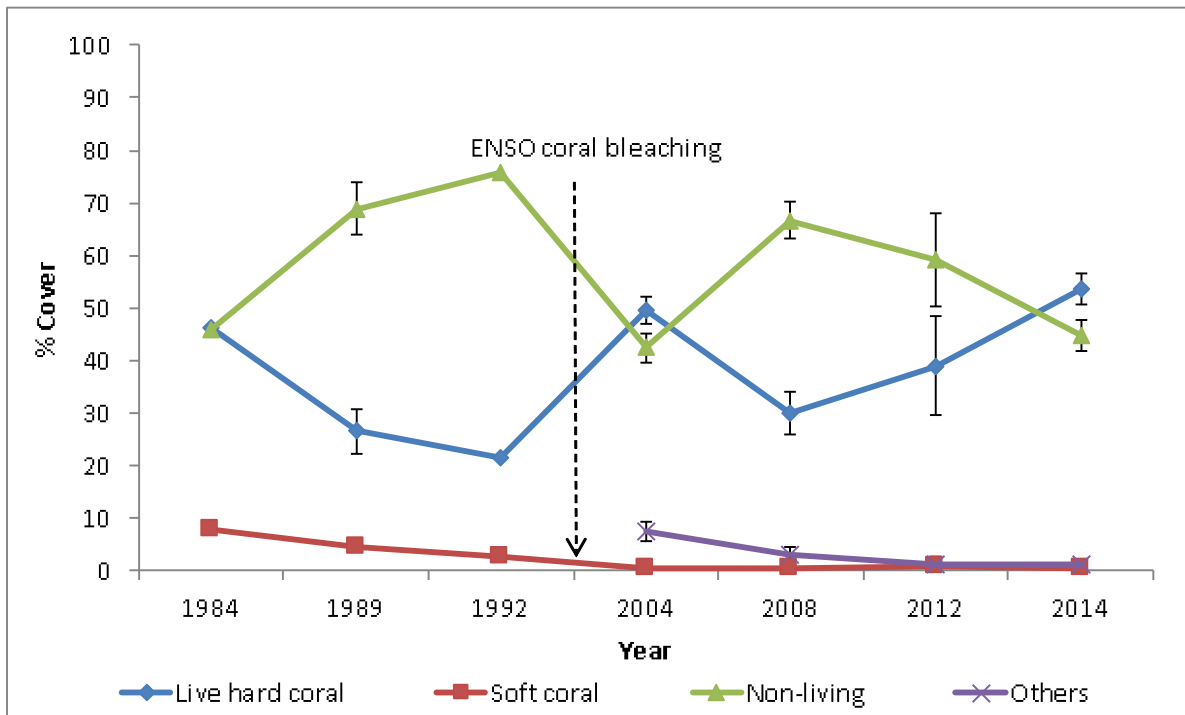


Figure 18. Changes in substrate composition (%mean  $\pm$  SE) in SR-1 (Lighthouse Islet) from 1984 to 2014, 2-3m depth.

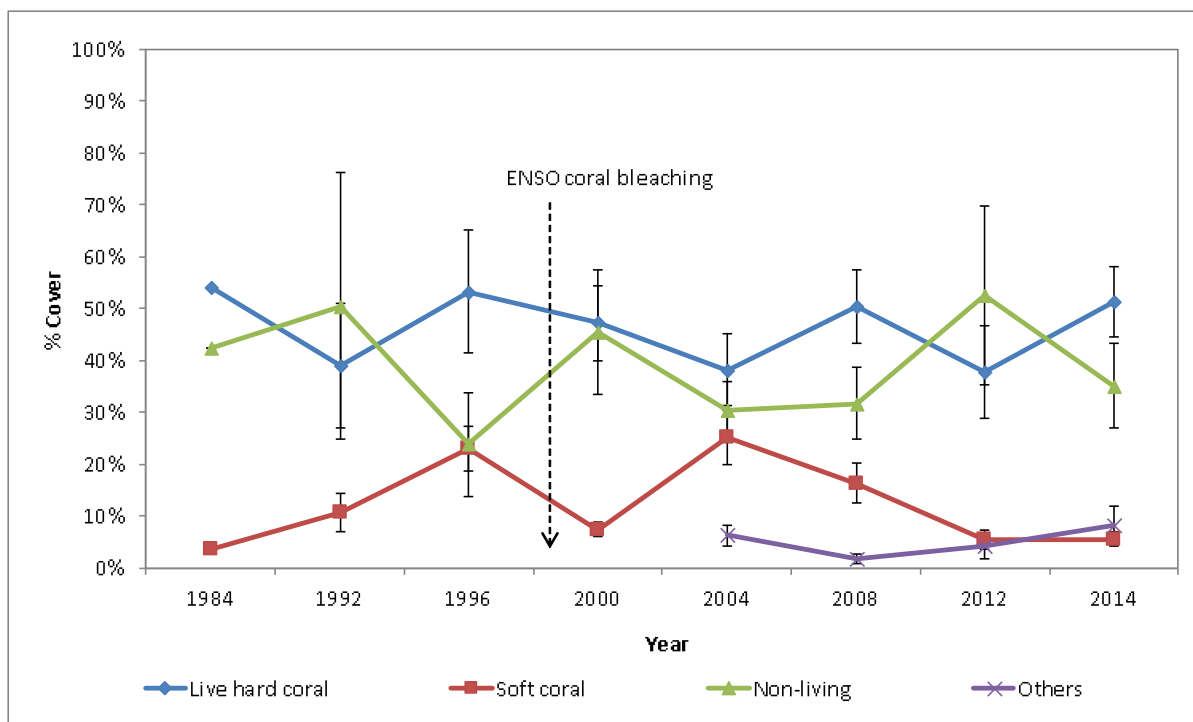


Figure 19. Changes in substrate composition (%mean  $\pm$  SE) in SR-1 (Lighthouse Islet) from 1984 to 2014, 7-10m depth.

**Fish Diversity, Abundance, and Biomass.** All reef fish density is moderate (1,942.9 fish/500m<sup>2</sup>) in 2014, and reef species richness is poor (48.6 species/500m<sup>2</sup>) according to the Hilomen et al. ratings.

Since 2004 (42.7 kg/500m<sup>2</sup>), biomass has been increasing in the Lighthouse Islet until 2014 (538.4 kg/500m<sup>2</sup>). Increases from 2012 (504.1 kg/500m<sup>2</sup>) were slight. However, biomass has been recorded to be the highest among all of the survey sites, and maintenance of the same has been excellent since the last survey in 2012.

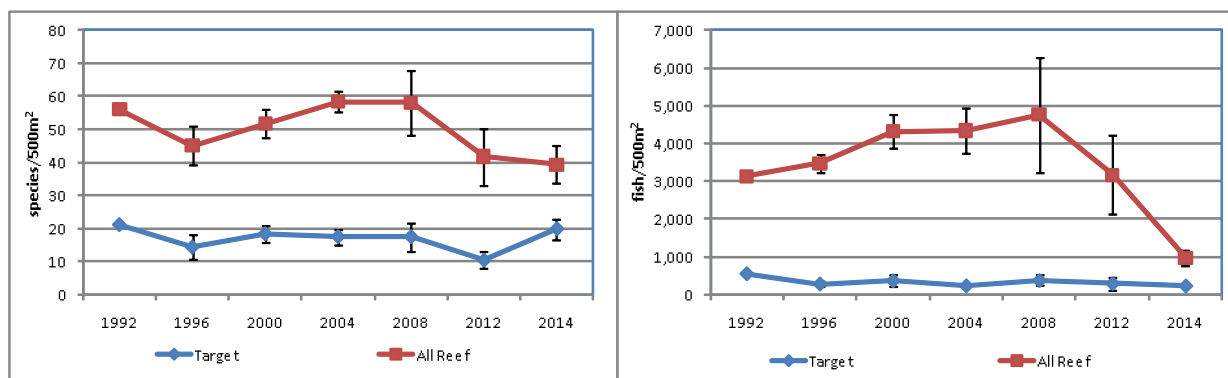


Figure 20A. Fish species richness (mean  $\pm$ SE) and fish density (mean  $\pm$ SE) at SR-1 (Lighthouse Islet) from 1992 to 2014.

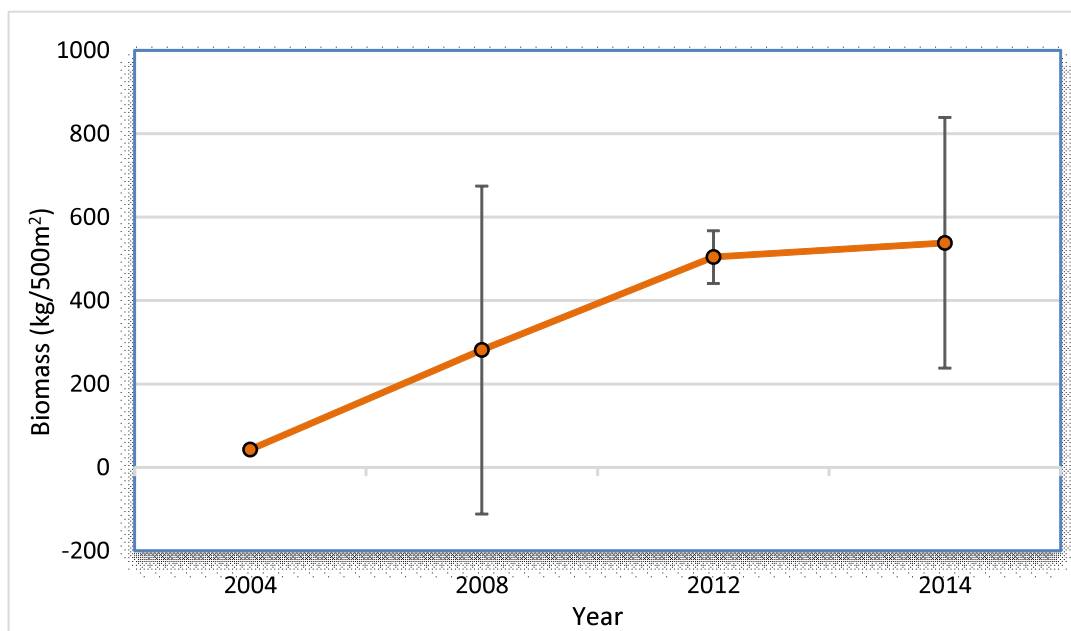


Figure 20B. Target fish biomass (mean  $\pm$ SE) at SR-1 (Lighthouse Islet) in Tubbataha Reef Natural Park from 2004 to 2014.

## Jessie Beazley Reef

**Site Overview.** Jessie Beazley is an isolated pinnacle reef that rises from the deep surrounding waters about 20 kilometers from Tubbataha's north reef atoll. The inclusion of Jessie Beazley reef in the Park in 2007, by Presidential Executive Order, increased Tubbataha's area by 200% because of its remote location in relation to the main atolls. Jessie Beazley was exposed to commercial and destructive fishing practices until it was officially protected. In 2008, there was still clear evidence of dynamite fishing, abandoned nets, longlines and large fish traps around the reef. In 2012, however, there were indications of reef recovery with the increased number of gray reef sharks and white-tip sharks sighted in the area. Past expeditions have seen whalesharks at Jessie Beazley, but none in 2014. The shallow reef is small with a tiny coral rubble beach exposed during low tide. Varieties of butterfly fish are attracted to the shallow reef, with its richness of branching corals, rocks and giant clams. The shallow reef slopes to a crest or drops to a wall to the deep blue in some areas. Some areas have crevices that hook under sections of the reef and meet a sandy patch on the wall as well as deep and large cave-like formations covered in coralline algae and sponges. Hawkfish, angelfish, unicornfish, triggerfish, mackerel, barracuda and snappers are attracted to the area by the rich biodiversity of coral and presence of sea fans on the crest and wall.

**Substrate.** The LHC at Jessie Beazley is fair in the shallow 2-3m area:  $45.73 \pm 4.12\%$ ) and good in the deeper 7-8m area:  $56.85 \pm 4.77\%$ ) in 2014, a slight decrease for the shallow reef, but a significant improvement for the deep reef (ANOVA). Since SCUBA surveys began at Jessie Beazley in 2004, the LHC has continued to improve, now with 20% more cover. Although Jessie Beazley has been protected the shortest time (6 years), the total coral cover, including both hard and soft coral, is the highest of all surveyed sites in Tubbataha at about 78.6% cover, at 7-8 meter depth, which reflects a small but healthy and growing reef in mid-seas, not connected to the main atolls reefs in Tubbataha.

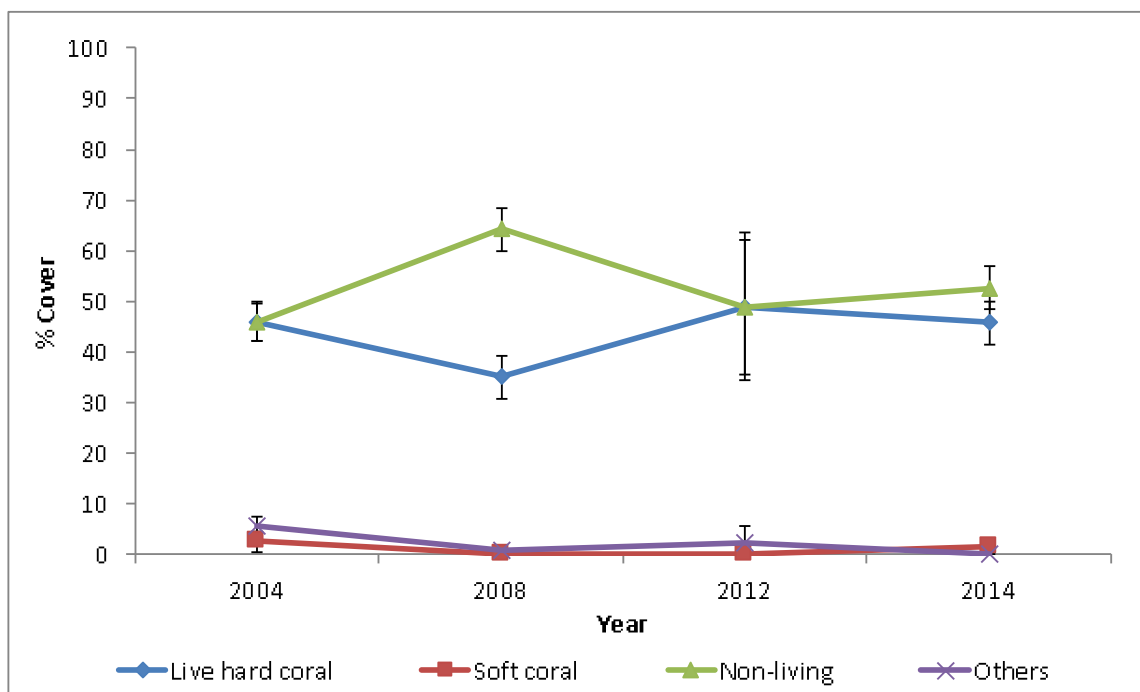


Figure 21. Changes in substrate composition (%mean  $\pm$  SE) in Jessie Beazley from 1984 to 2014, 2-3m depth.

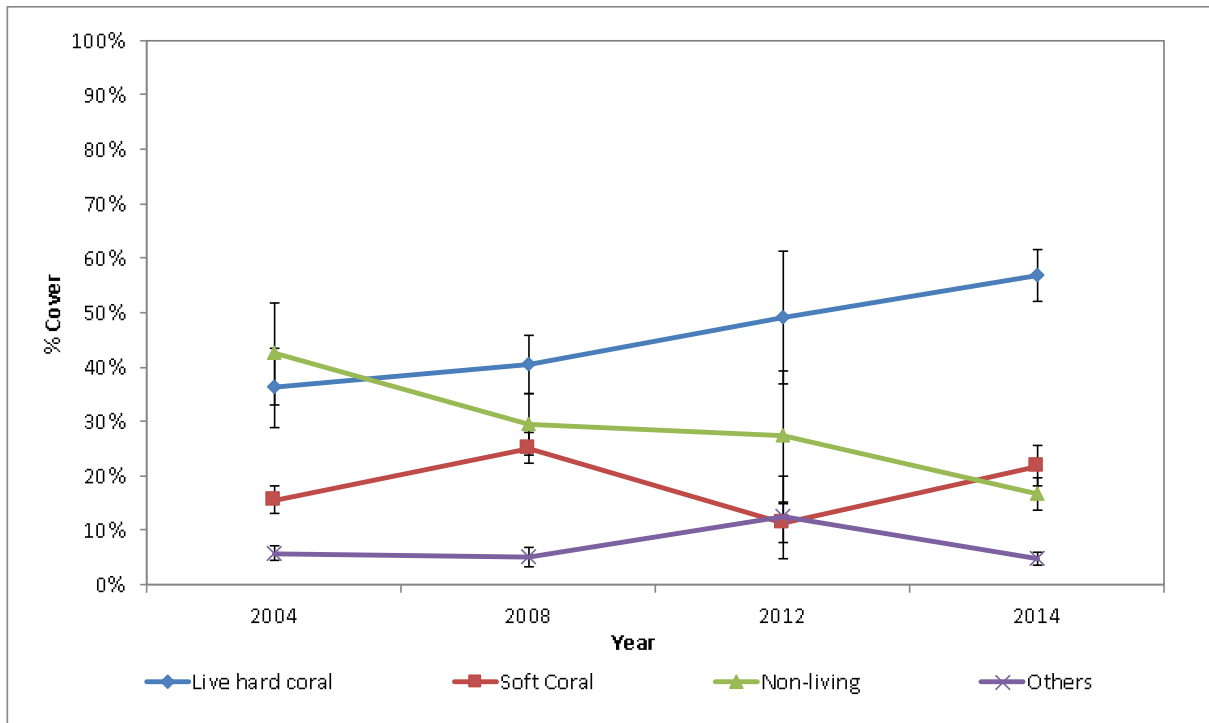


Figure 22. Changes in substrate composition (%mean  $\pm$ SE) in Jessie Beazley from 1984 to 2014, 7-10m depth.

### Fish Diversity, Abundance, and Biomass.

Since 2014 in Jessie Beazley, there were increases observed in fish species richness in both target (19.2 species/500m<sup>2</sup>) and all reef species (53.8 species/500m<sup>2</sup>) in 2014. Fish density of target species (219 fish/500m<sup>2</sup>) increased slightly in 2014 but there was a slight increase in all reef species density from 1,422.2 fish/500m<sup>2</sup> in 2012 to 1,528.6 fish/500m<sup>2</sup> in 2014. Because of its distance from the Ranger Station, it is possible that there is still some illegal fishing occurring there when patrol boats are absent or not watching the site, however, with the slight increase in fish density, the park rangers' regular patrols may be making a difference.

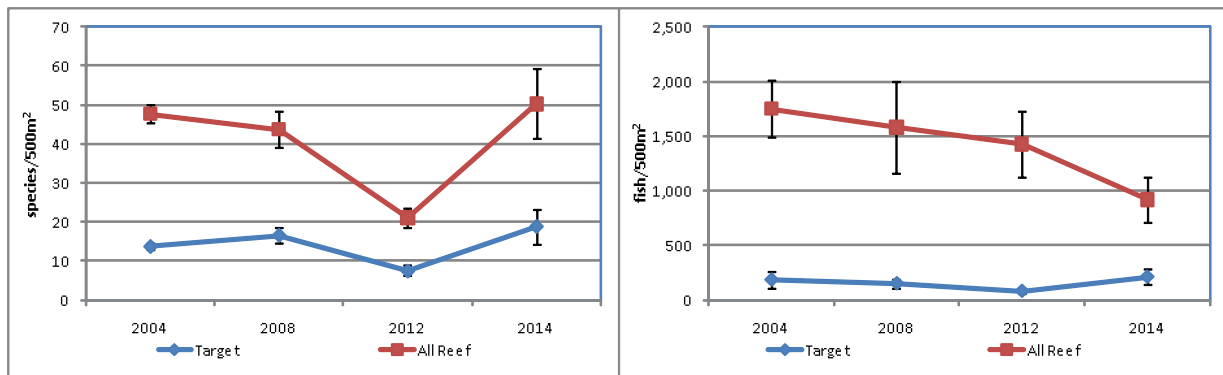


Figure 23A. Fish species richness (mean  $\pm$ SE) and Fish density (mean  $\pm$ SE) at Jessie Beazley from 2004 to 2014.

Jessie Beazley shows a significant increase in biomass from 27.8 kg/500m<sup>2</sup> in 2012 to 106.7 kg/500m<sup>2</sup>. This increase has much to do with the inclusion of Jessie Beazley reef in the Tubbataha Reef Natural Park boundaries in 2007, and therefore an inclusion of the area in the Tubbataha Rangers' regular patrolling and enforcement scope. Protection has definitely benefited the area when noting the decreases in biomass before its inclusion, from 2004 (42.9 kg/500m<sup>2</sup>) to 2008 (17.3 kg/500m<sup>2</sup>).

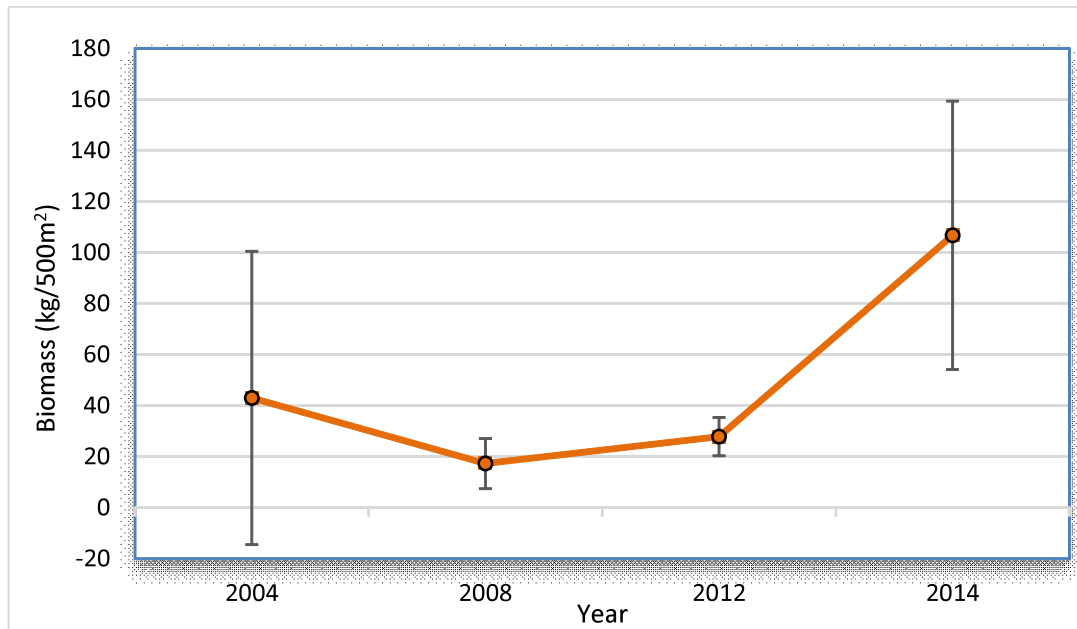


Figure 23B. Target fish biomass (mean  $\pm$ SE) at Jessie Beazley in Tubbataha Reef Natural Park from 2004 to 2014.

**Table 1. Species list of butterflyfish in Tubbataha Reefs Natural Park, Palawan from 1984 to 2014.**

Butterfly species	Common name	SR-1					SR-3					SR-4					NR-1					NR-2					NR-5					Jessie Beazley																	
		1992	1996	2000	2004	2008	2012	2014	1992	1996	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	1992	1996	2000	2004	2008	2012	2014	1992	1996	2000	2004	2008	2012	2014	1992	1996	2000	2004	2008	2012	2014								
<i>Chaetodon adiergastos</i>	Philippine butterflyfish	O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z				O	Y	X	Z	A	B	C	Z	A		C											
<i>Chaetodon auriga</i>	Threadfin butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A		C											
<i>Chaetodon baronessa</i>	Eastern triangular butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A			O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A	B	C											
<i>Chaetodon bennetti</i>	Blueelashed butterflyfish		Y	X		A		C		Y	X	Z	A		C	X	Z	A				Y		Z	A		C	O	Y	X	Z	A	B	C	Z	A		C											
<i>Chaetodon citrinellus</i>	Speckled butterflyfish	O	Y	X	Z				O	Y		Z				X	Z				O	Y	X	Z		B		O	Y	X					O	Y	X	Z		A		C							
<i>Chaetodon ephippium</i>	Saddle butterflyfish	O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z		B	C	Z		B	C				
<i>Chaetodon kleinii</i>	Klein's butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A	B	C				
<i>Chaetodon lineolatus</i>	Lined butterflyfish		Y	X	Z	A		C	O	Y	X	Z	A		C	X	Z	A		C			X	Z				O	Y	X	Z	A		B	C	O	Y	X	Z		B	C			C				
<i>Chaetodon lunula</i>	Raccoon butterflyfish	O	Y	X	Z	A		C	O	Y	X	Z		B	C	X	Z	A	B	C	O	Y	X	Z		B	C	O	Y	X	Z				O	Y	X	Z		B	C	Z	A		C				
<i>Chaetodon lunulatus</i>	Pacific redfin butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A	B	C				
<i>Chaetodon melanotus</i>	Blackback butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A			O	Y	X	Z	A		C	Z	A		C				
<i>Chaetodon mertensii</i>	Merten's butterflyfish																																																
<i>Chaetodon meyeri</i>	Meyer's butterflyfish	O																																															
<i>Chaetodon ocellicaudus</i>	Spottail butterflyfish		Y	X	Z	A		C		Y	X	Z	A	B	C	X	Z	A				Y	X																										
<i>Chaetodon octofasciatus</i>	Eightband butterflyfish		X																																														
<i>Chaetodon ornatissimus</i>	Ornate butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A	B	C	O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A		C				
<i>Chaetodon oxycephalus</i>	Spot-nape butterflyfish		Y	X	Z	A		C								X	Z					Y	X	Z																									
<i>Chaetodon plebeius</i>	Blueblotch butterflyfish																																																
<i>Chaetodon punctatofasciatus</i>	Spotband butterflyfish	O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A		C				
<i>Chaetodon rafflesi</i>	Latticed butterflyfish	O	Y	X	Z			C	O	Y	X	Z		B	C	X	Z	A			O	Y	X	Z	A		C	O	Y	X	Z	A			O	Y	X	Z		B	C	Z			C				
<i>Chaetodon reticulatus</i>	Mailed butterflyfish																																																
<i>Chaetodon selene</i>	Yellowdotted butterflyfish																																																
<i>Chaetodon semeion</i>	Dotted butterflyfish		Y																																														
<i>Chaetodon speculum</i>	Mirror butterflyfish	O	Y	X	Z	A			O	Y	X	Z	A	B		X	Z	A		C	O	Y	X	Z	A	B		O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	Z	A		C				
<i>Chaetodon trifasciatus</i>	Chevron butterflyfish	O	Y	X	Z		B	C	O	Y	X	Z			C	X	Z	A			O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z			C				
<i>Chaetodon ulletensis</i>	Pacific doublesaddle butterflyfish	O	Y	X	Z	A		C	O	Y	X	Z	A	B	C	X	Z	A			O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A		C				
<i>Chaetodon unimaculatus</i>	Teardrop butterflyfish		Y	X	Z			C		Y	X	Z				X	Z					Y	X	Z			C	O																					
<i>Chaetodon vagabundus</i>	Vagabond butterflyfish	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B		O	Y	X	Z	A	B	C	Z		B					
<i>Chaetodon xanthurus</i>	Pearscale butterflyfish																																																
<i>Chelmon rostratus</i>	Beaked coralfish																																																
<i>Forcipiger flavissimus</i>	Forcepsfish		Y	X	Z											X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	Z	A		C				
<i>Forcipiger longirostris</i>	Longnose butterflyfish		Y	X	Z											X	Z	A			O		X	Z	A			O		X	Z	A			O		X	Z	A										
<i>Hemitaenrichthys polylepis</i>	Pyramid butterflyfish	O	Y	X	Z	A	B	C								X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z	A			O		X	Z	A										
<i>Heniochus acuminatus</i>	Pennant coralfish	O	Y	X	Z			C	O	Y	X	Z				X	Z				O	Y	X	Z				O	Y	X	Z					Y	X		A										
<i>Heniochus chrysostomus</i>	Threeband pennantfish	O	Y	X	Z	A	B	C		Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z		B	C	Z	A		C				
<i>Heniochus diphreutes</i>	Schooling bannerfish																																																
<i>Heniochus pleurotaenia</i>	Phantom bannerfish																																																
<i>Heniochus monoceros</i>	Masked bannerfish																																																
<i>Heniochus singularis</i>	Singular bannerfish	O	Y	X	Z	A		C	O	Y	X	Z	A		C	X	Z	A		C	O		X	Z	A		C	O	Y	X	Z	A	B	C	O		X	Z	A	B	C	Z	A		C				
<i>Heniochus varius</i>	Horned bannerfish		Y	X	Z	A	B	C		Y	X	Z	A	B	C	X	Z	A		C	O	Y	X	Z	A	B	C	O	Y	X	Z	A	B	C	O	Y	X	Z		B	C								
<i>Coradion chrysozonum</i>	Goldengirdled coralfish																																																
Total number of species/site		21	29	29	27	21	11	24	19	28	26	31	19	21	21	28	30	25	6	20	23	25	31	27	21	18	24	23	25	31	26	25	13	22	25	26	29	29	20	21	26	27	19	8	23				

Total number of species observed in all sites surveyed in 1992: **29**  
Total number of species observed in all sites surveyed in 1996: **30**  
Total number of species observed in Tubbataha and Bastera in 2000: **38**  
Total number of species observed in Tubbataha and Jessie Beazley in 2004: **32**  
Total number of species observed in Tubbataha and Jessie Beazley in 2008: **30**  
Total number of species observed in Tubbataha and Jessie Beazley in 2012: **28**  
Total number of species observed in Tubbataha and Jessie Beazley in 2014: **31**

SR - South Reef  
NR-SL - NorthSouth ReefLagoon

**Table 2. Changes in substrate composition (%mean ±SE) in NR-5 (North Reef) Bird Islet from 1984 to 2014.**

	SCUBA SURVEYS:														SNORKEL SURVEYS:																	
	1984	1992	% Change	1996	% Change	2000	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change	1984	1989	% Change	1992	% Change	1996	% Change	2000	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change
SUBSTRATE COVER	% cover	% cover	1984-1992	% cover	1992-1996	% cover	1996-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	% cover	% cover	1984-1989	% cover	1989-1992	% cover	1992-1996	% cover	1996-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014
Sand (s) and Silt (Si)	17.6	0.0	-100.0	18.2	+	17.1	-6.0	4.3	-74.7	14.0	223.2	8.1	-42.5	4.7	-41.2	8.0	6.3	-21.9	13.0	108.0	0.0	-100.0	5.5	+	13.4	144.1	17.4	29.9	13.7	-21.1	16.3	19.0
Coral Rubble (R)	16.4	17.3	5.5	14.3	-17.3	22.6	58.0	10.7	-52.6	9.9	-8.0	9.6	-3.5	8.7	-9.2	4.2	21.4	408.3	27.4	28.3	2.5	-90.9	9.2	268.0	18.1	96.7	16.6	-8.5	7.0	-58.0	15.3	119.5
Rock and Block (RK)	16.8	1.6	-90.5	12.7	693.8	27.0	112.6	17.3	-36.0	9.9	-42.6	11.8	18.7	11.0	-6.0	9.5	17.4	83.2	3.4	-80.5	57.0	1576.5	49.8	-12.6	23.2	-53.5	16.0	-30.7	17.5	9.3	28.1	60.8
White Dead Standing Coral (DC)	6.0	11.4	90.0	2.2	-80.7	1.2	-45.5	0.2	-80.4	0.4	56.6	1.0	143.1	0.4	-59.8	3.3	16.5	400.0	3.0	-81.8	10.5	250.0	0.2	-98.1	0.2	16.5	1.4	514.1	2.3	63.1	1.1	-52.2
Dead Coral with Algae (DCA)	0.0	0.0	N/A	0.0	N/A	8.0	+	5.4	-33.1	4.7	-12.0	8.3	76.7	4.3	-47.9	0.0	0.0	N/A	0.0	N/A	0.0	N/A	9.0	+	4.4	-51.1	5.2	19.0	5.0	-3.6	1.8	-63.4
Subtotal Non-living Substrate	56.8	30.3	-46.7	47.4	56.4	75.9	60.1	37.9	-50.1	38.8	2.5	38.6	-0.4	29.2	-24.5	25.0	61.5	146.0	46.8	-23.9	70.0	49.6	73.7	5.3	59.3	-19.5	56.7	-4.4	45.5	-19.8	62.7	37.8
Branching (CB)	18.0	14.2	-21.1	25.1	76.8	9.7	-61.4	17.1	76.6	28.7	67.5	18.4	-35.9	19.3	5.2	45.0	25.3	-43.9	25.0	-1.0	17.5	-30.0	0.0	-100.0	22.6	+	27.0	19.0	26.5	-1.8	16.6	-37.4
Massive (CM)	1.2	9.0	650.0	7.3	-18.9	3.8	-47.9	7.3	91.2	7.3	0.0	5.3	-26.9	5.4	0.7	15.3	1.0	-93.5	8.0	700.0	5.0	-37.5	0.0	-100.0	11.0	+	10.1	-8.4	14.4	42.7	8.6	-40.1
Flat/Encrusting (CFD)	7.3	11.3	54.8	4.1	-63.7	4.0	-2.4	10.5	161.3	6.0	-42.9	2.1	-65.7	4.0	96.7	4.7	0.1	-97.9	4.2	4100.0	5.0	19.0	0.0	-100.0	2.2	+	1.9	-13.2	5.0	163.5	4.0	-21.0
Foliose Cup (CFO)	0.9	0.4	-55.6	2.2	450.0	1.0	-54.5	0.9	-11.8	0.6	-37.4	4.7	687.0	6.7	40.9	1.0	0.4	-65.0	1.3	271.4	0.0	-100.0	0.0	N/A	0.3	+	0.7	143.2	4.8	589.7	1.3	-72.7
Total Hard Coral	27.4	34.9	27.4	38.7	10.9	18.5	-52.2	35.7	93.1	42.5	18.9	30.5	-28.2	35.4	16.1	66.0	26.7	-59.5	38.5	44.2	27.5	-28.6	23.8	-13.5	36.1	51.8	39.6	9.7	50.8	28.2	30.5	-39.9
Total Soft Coral	15.8	34.8	120.3	13.9	-60.1	5.6	-59.7	10.1	80.8	14.9	47.1	23.0	54.2	20.4	-11.2	9.0	11.8	31.1	14.7	24.6	2.5	-83.0	2.5	0.0	2.7	8.7	3.2	16.8	3.2	-0.9	4.8	51.9
Subtotal Coral	43.2	69.7	61.3	52.6	-24.5	24.1	-54.2	45.8	90.2	57.4	25.1	53.5	-6.8	55.8	4.4	75.0	38.5	-48.7	53.2	38.2	30.0	-43.6	26.3	-12.3	38.8	47.7	42.8	10.2	53.9	26.0	35.3	-34.5
Sponges	-	-	N/A	-	N/A	-	N/A	5.9	N/A	1.6	-73.4	3.3	106.6	4.7	42.1	-	-	N/A	-	N/A	-	N/A	-	N/A	0.3	N/A	0.3	5.3	0.3	0.0	0.2	-39.4
Other animals	-	-	N/A	-	N/A	-	N/A	2.0	N/A	0.7	-64.5	1.6	130.2	3.8	136.1	-	-	N/A	-	N/A	-	N/A	-	N/A	0.1	N/A	0.0	-76.2	0.1	N/A	0.2	130.0
Algae	-	-	N/A	-	N/A	-	N/A	0.6	N/A	0.6	-14.6	0.4	-25.9	1.0	120.1	-	-	N/A	-	N/A	-	N/A	-	N/A	0.3	N/A	0.0	-93.6	0.1	N/A	0.2	172.5
Turf algae	-	-	N/A	-	N/A	-	N/A	0.6	N/A	0.2	-82.7	1.0	386.1	0.9	-10.6	-	-	N/A	-	N/A	-	N/A	-	N/A	0.1	N/A	0.0	-100.0	0.0	N/A	1.2	#DIV/0!
Fleshy algae	-	-	N/A	-	N/A	-	N/A	0.9	N/A	0.8	-88.3	1.4	80.6	4.6	220.6	-	-	N/A	-	N/A	-	N/A	-	N/A	1.1	N/A	0.1	-87.9	0.1	11.1	0.0	-100.0
Coralline algae	-	-	N/A	-	N/A	-	N/A	6.7	N/A	0.8	N/A	0.1	N/A	0.0	N/A	-	-	N/A	-	N/A	-	N/A	-	N/A	0.0	N/A	0.0	N/A	0	N/A	0.1	N/A
Seagrass	-	-	N/A	-	N/A	-	N/A	16.2	+	3.8	-76.7	7.9	107.6	15.0	89.9	0	0	N/A	0	N/A	0	N/A	0	N/A	1.9	+	0.5	-74.6	0.6	17.8	2.0	237.0
Subtotal Others	0	0	N/A	0	N/A	0	N/A	16.2	+	3.8	-76.7	7.9	107.6	15.0	89.9	0	0	N/A	0	N/A	0	N/A	0	N/A	1.9	+	0.5	-74.6	0.6	17.8	2.0	237.0
TOTAL	100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0	
Environmental Parameters																																
Mean Slope (degrees)	-	-		-		14.7		57.5		45.5		-		-		-	-		-		-		3.5		1.9		5.0		-		-	
Mean Topography (m) *	1.8	2		2.2		1.9		1.9		2.0		-		-		2.1	1.4-2.8		-5.2		-		1.1		2.5		1.3		-		-	
Mean Depth/Range (m)	1-15	2-10		5-8		5.8		7.2		7.6		-		-		2-6	3-6		2-7		2-2.7		2.5		3.2		3.4		-		-	
Horizontal Visibility (m)	-	30		20		26		21.3		31.2		-		40		-	-		20-40		25		34.1		21.3		33.0		-		40	
No. of 50 m Transects	1	3		6		22		17		19		18		23		1	2		8		2		10		14		17		18		23	
- no data available																																
* mean distance between lowest and highest point on the horizontal transect line																																

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 3. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at NR-5 (North Reef) Bird Islet from 1992 to 2014.

Family	(N=1) 1992	(N=3) 1996	% Change 1992- 1996	(N=8) 2000	% Change 1996- 2000	(N=5) 2004	% Change 2000- 2004	(N=4) 2008	% Change 2004- 2008	(N=8) 2012	% Change 2008- 2012	2014	% Change 2012- 2014
	Species	Species		Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	12.0	5.7	-52.8	7.5	32.4	6.4	-14.7	8.8	36.7	4.1	-53.4	7.2	75.6
Rabbitfish (Siganids)*	0.0	0.3	+	0.8	125.0	0.2	-73.3	0.0	-100.0	0.4	+	0.6	50.0
Groupers (Serranids)*	1.0	1.3	33.3	3.8	181.3	3.4	-9.3	4.0	17.6	2.7	-32.5	2.6	-3.7
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.0	-100.0	0.0	N/A
Snapper (Lutjanids)*	2.0	1.3	-33.3	2.1	59.4	2.4	12.9	5.0	108.3	2.2	-56.0	4.7	113.6
Sweetlips (Haemulids)*	0.0	0.7	+	0.9	31.3	0.8	-8.6	1.3	56.3	0.7	-46.2	1.4	100.0
Emperors (Lethrinids)*	0.0	0.7	+	1.0	50.0	0.8	-20.0	1.8	118.8	0.8	-55.6	0.8	0.0
Jacks (Carangids)*	1.0	0.3	-66.7	1.4	312.5	1.4	1.8	2.0	42.9	1.4	-30.0	1.5	7.1
Fusiliers (Caesionids)*	2.0	0.3	-83.3	0.6	87.5	2.8	348.0	4.3	51.8	0.9	-79.1	4.0	344.4
Spinecheeks (Nemipterids)*	0.0	0.7	+	0.5	-25.0	0.2	-60.0	0.3	25.0	0.2	-33.3	0.0	-100.0
Goatfish (Mullids)*	0.0	0.7	+	1.6	143.8	1.0	-38.5	2.5	150.0	0.7	-72.0	0.8	14.3
Parrotfish (Scarids)*	1.0	1.0	0.0	2.6	162.5	3.0	14.3	3.8	25.0	3.1	-18.4	3.4	9.7
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	+	0.1	0.0
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.6	+	0.2	-68.0	0.5	150.0	0.2	-60.0	0.4	100.0
Triggerfish (Balistids)	2.0	1.7	-16.7	2.9	72.5	1.2	-58.3	5.3	337.5	2.6	-50.9	2.7	3.8
Butterflyfish (Chaetodonids)	16.0	11.3	-29.2	11.4	0.4	7.2	-36.7	13.0	80.6	6.0	-53.8	2.0	-66.7
Angelfish (Pomacanthids)	1.0	1.3	33.3	1.6	21.9	1.8	10.8	2.3	25.0	1.2	-47.8	9.3	675.0
Wrasses (Labrids)	6.0	6.3	5.6	6.0	-5.3	5.2	-13.3	10.5	101.9	2.6	-75.2	1.7	-34.6
Humphead wrasse	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.4	33.3	5.7	1325.0
Damselfish (Pomacentrids)	14.0	8.7	-38.1	7.5	-13.5	9.8	30.7	10.8	9.7	3.2	-70.4	0.6	-81.3
Fairy Basslets (Anthids)	2.0	1.0	-50.0	1.9	87.5	4.2	124.0	2.8	-34.5	1.6	-42.9	7.2	350.0
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	1.0	0.0	0.8	-20.0	1.0	25.0	0.7	-30.0	1.0	42.9
												0.0	
<b>Total (target reef spp.):</b>	<b>19.0</b>	<b>13.0</b>	<b>-31.6</b>	<b>23.4</b>	<b>80.0</b>	<b>22.6</b>	<b>-3.4</b>	<b>18.0</b>	<b>-20.4</b>	<b>18.0</b>	<b>0.0</b>	<b>27.5</b>	<b>52.8</b>
<b>Total (all reef spp.):</b>	<b>61.0</b>	<b>44.3</b>	<b>-27.4</b>	<b>55.6</b>	<b>25.5</b>	<b>52.8</b>	<b>-5.0</b>	<b>39.3</b>	<b>-25.7</b>	<b>35.8</b>	<b>-8.9</b>	<b>57.7</b>	<b>61.2</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase



Table 4. Mean ( $\pm$ SE) fish species density (density/500m<sup>2</sup>) and percentage change between years at NR-5 (North Reef) Bird Islet from 1992 to 2014.

Family	(N=1) 1992	(N=3) 1996	% Change 1992- 1996	(N=8) 2000	% Change 1996- 2000	(N=5) 2004	% Change 2000- 2004	(N=4) 2008	% Change 2004- 2008	(N=8) 2012	% Change 2008- 2012	2014	% Change 2012- 2014
	Species	Species		Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	198.0	116.3	-41.2	150.1	29.0	105.6	-29.7	71.0	-32.8	39.3	-44.6	74.9	90.6
Rabbitfish (Siganids)*	0.0	3.0	+	1.4	-54.2	0.2	-85.5	0.0	-100.0	1.0	+	1.1	10.0
Groupers (Serranids)*	5.0	8.0	60.0	13.8	71.9	7.2	-47.6	25.8	257.6	6.6	-74.4	9.6	45.5
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	3.5	+	0.0	-100.0	0.0	N/A
Snapper (Lutjanids)*	5.0	16.0	220.0	22.9	43.0	10.8	-52.8	7.0	-35.2	24.7	252.9	27.5	11.3
Sweetlips (Haemulids)*	0.0	6.0	+	24.3	304.2	1.4	-94.2	13.8	882.1	2.3	-83.3	9.5	313.0
Emperors (Lethrinids)*	0.0	12.0	+	3.9	-67.7	1.6	-58.7	154.3	9540.6	8.6	-94.4	4.0	-53.5
Jacks (Carangids)*	9.0	1.0	-88.9	17.8	1675.0	8.6	-51.5	5.3	-39.0	9.2	73.6	6.7	-27.2
Fusiliers (Caesionids)*	162.0	11.0	-93.2	115.8	952.3	428.6	270.3	597.0	39.3	26.1	-95.6	252.5	867.4
Spinecheeks (Nemipterids)*	0.0	46.0	+	6.1	-86.7	0.2	-96.7	0.3	25.0	0.4	33.3	0.0	-100.0
Goatfish (Mullids)*	0.0	54.0	+	23.6	-56.3	1.6	-93.2	6.3	290.6	3.6	-42.9	2.1	-41.7
Parrotfish (Scarids)*	33.0	129.0	290.9	61.1	-52.6	38.6	-36.9	11.8	-69.6	19.2	62.7	14.7	-23.4
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	+	0.2	100.0
Rudderfish (Kyphosids)*	0.0	0.0	N/A	29.8	+	2.2	-92.6	0.8	-65.9	3.8	375.0	1.7	-55.3
Triggerfish (Balistids)	3.0	7.0	133.3	17.0	142.9	16.2	-4.7	27.0	66.7	18.9	-30.0	14.3	-24.3
Butterflyfish (Chaetodonids)	62.0	37.7	-39.2	28.9	-23.3	45.6	57.9	73.5	61.2	15.0	-79.6	598.0	3886.7
Angelfish (Pomacanthids)	2.0	8.0	300.0	15.1	89.1	13.0	-14.0	6.5	-50.0	2.8	-56.9	44.0	1471.4
Wrasses (Labrids)	198.0	113.0	-42.9	70.9	-37.3	83.8	18.2	39.8	-52.6	9.2	-76.9	3.6	-60.9
Humphead wrasse	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.8	166.7	25.7	3112.5
Damselfish (Pomacentrids)	1422.0	942.0	-33.8	1424.9	51.3	542.4	-61.9	3171.3	484.7	1072.1	-66.2	1.9	-99.8
Fairy Basslets (Anthids)	1026.0	385.0	-62.5	1083.9	181.5	2015.0	85.9	2600.0	29.0	1308.2	-49.7	685.4	-47.6
Moorish Idols ( <i>Zanclus cornutus</i> )	9.0	17.0	88.9	10.9	-36.0	2.4	-77.9	2.3	-6.3	2.3	0.0	5.1	121.7
												0.0	
<b>Total (target reef spp.):</b>	<b>412.0</b>	<b>402.3</b>	<b>-2.4</b>	<b>470.4</b>	<b>16.9</b>	<b>602.2</b>	<b>28.0</b>	<b>887.0</b>	<b>47.3</b>	<b>145.7</b>	<b>-83.6</b>	<b>404.5</b>	<b>177.6</b>
<b>Total (all reef spp.):</b>	<b>3134.0</b>	<b>1912.0</b>	<b>-39.0</b>	<b>3121.9</b>	<b>63.3</b>	<b>3325.0</b>	<b>6.5</b>	<b>6817.0</b>	<b>105.0</b>	<b>2574.2</b>	<b>-62.2</b>	<b>1782.5</b>	<b>-30.8</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

**Table 5. Changes in substrate composition (% mean ±SE) in NR-1 (North Reef) Malayan Wreck from 1984 to 2014.**

SUBSTRATE COVER	SCUBA SURVEYS:														SNORKEL SURVEYS:																
	1984 % cover	1996 % cover	% Change 1984-1996	2000 % cover	% Change 1996-2000	2004 % cover	% Change 2000-2004	2008 % cover	% Change 2004-2008	2012 % cover	% Change 2008-2012	2014 % cover	% Change 2012-2014	1984 % cover	1989 % cover	% Change 1984-1989	1992 % cover	% Change 1989-1992	1996 % cover	% Change 1992-1996	2000 % cover	% Change 1996-2000	2004 % cover	% Change 2000-2004	2008 % cover	% Change 2004-2008	2012 % cover	% Change 2008-2012	2014 % cover	% Change 2012-2014	
Sand (s) and Silt (SI)	7.6	10.3	35.5	7.9	-23.3	14.5	83.5	11.3	-22.0	12.5	10.3	1.7	-86.4	6.1	0.5	-91.8	5.4	980.0	3.5	-35.2	14.3	308.6	6.3	-56.1	11.4	81.1	24.9	118.3	13.4	-46.0	
Coral Rubble (R)	10.5	10.8	2.9	22.7	110.2	19.3	-15.2	9.6	-50.1	12.7	32.6	7.7	-39.5	7	31.8	353.9	12.9	-59.4	4.0	-69.0	19.3	382.5	2.9	-84.9	3.5	20.7	1.8	-47.6	5.8	217.2	
Rock and Block (RK)	36	14.4	-60.0	33.2	130.6	27.7	-16.7	21.3	-23.0	17.8	-16.6	15.9	-10.5	23.6	18.8	-20.5	27	43.8	32.8	21.3	45.9	40.2	45.0	-2.0	45.6	1.4	37.0	-18.9	40.5	9.5	
White Dead Standing Coral (DC)	5.9	0	-100.0	0.6	+	0.1	-79.2	0.6	405.3	0.4	-27.1	0.4	-20.0	6.5	9.4	44.6	6.7	-28.7	11.3	67.9	0.4	-96.4	0.1	-75.5	0.5	422.3	0.6	27.0	1.6	158.9	
Dead Coral with Algae (DCA)	0	3.3	+	11.1	236.4	2.9	-73.5	8.3	184.0	7.5	-9.1	5.5	-27.7	0	0.0	N/A	0	N/A	0	N/A	5.6	+	5.2	-7.4	6.2	19.4	8.9	44.2	3.2	-64.7	
Subtotal Non-living Substrate	60	38.8	-35.3	75.5	94.6	64.5	-14.6	51.2	-20.6	50.9	-0.5	31.1	-38.9	43.2	60.4	39.9	52	-14.0	51.5	-1.0	85.5	66.0	59.5	-30.5	67.2	13.0	73.3	9.1	64.6	-11.9	
Branching (CB)	19.4	46.6	140.2	10.5	-77.5	7.0	-33.3	17.9	156.0	12.2	-31.7	14.9	21.8	36.3	22.6	-37.7	27	19.5	42.3	56.5	~	N/A	19.5	N/A	12.8	-34.6	7.9	-38.6	9.0	14.8	
Massive (CM)	6.4	2.3	-64.1	6.2	169.6	5.5	-10.8	8.0	44.6	10.8	35.2	5.5	-49.1	7.3	2.7	-62.6	8.1	196.7	4.5	-44.4	~	N/A	8.0	N/A	10.5	31.8	7.7	-26.8	11.0	43.7	
Flat/Encrusting (CFD)	11	7	-36.4	5.8	-17.1	5.2	-9.9	8.8	68.2	2.4	-72.8	2.1	-12.3	8	2.3	-70.9	4.5	93.1	1.3	-72.2	~	N/A	3.8	N/A	3.1	-19.8	6.3	101.9	7.5	20.0	
Foliose Cup (CFO)	0.5	0	-100.0	0.5	+	0.3	-50.0	0.6	142.1	7.5	1153.5	12.4	64.9	0.5	0.6	20.0	3	400.0	0	-100.0	~	N/A	0.9	N/A	0.7	-24.7	0.4	-42.9	1.4	250.0	
Total Hard Coral	37.3	55.9	49.9	23	-58.9	18.0	-21.7	35.3	96.1	33.0	-6.6	34.9	5.9	52.1	28.3	-45.8	42.6	50.7	48	12.7	14.1	-70.6	32.3	128.8	27.1	-16.1	22.2	-18.1	29.0	30.5	
Total Soft Coral	2.7	5.3	96.3	1.5	-71.7	5.5	264.6	7.3	34.3	9.6	31.6	12.8	33.3	4.7	11.3	141.1	5.4	-52.3	0.5	-90.7	0.4	-20.0	1.5	276.8	1.7	15.9	1.0	-39.1	0.5	-54.9	
Subtotal Coral	40	61.2	53.0	24.5	-60.0	23.5	-4.2	42.7	81.7	42.6	-0.3	47.7	12.1	56.8	39.6	-30.3	48	21.2	48.5	1.0	14.5	-70.1	33.8	132.9	28.8	-14.7	23.2	-19.3	29.4	26.7	
Sponges	~	~	N/A	~	N/A	1.7	N/A	1.9	16.0	2.3	19.5	6.2	173.0	~	~	N/A	~	N/A	~	N/A	~	N/A	0.6	N/A	0.1	-80.6	0.3	230.0	0.4	21.2	
Other animals	~	~	N/A	~	N/A	0.2	N/A	1.2	674.7	0.7	-41.0	3.5	394.1	~	~	N/A	~	N/A	~	N/A	~	N/A	0.0	N/A	0.1	211.1	0.2	66.0	0.1	-46.2	
Algae	~	~	N/A	~	N/A	6.6	N/A	0.9	-85.6	1.4	50.5	1.8	32.9	~	~	N/A	~	N/A	~	N/A	~	N/A	2.9	N/A	0.2	-92.4	1.5	637.5	0.7	-50.3	
Turf algae	~	~	N/A	~	N/A	0.8	N/A	0.9	10.1	1.4	59.7	1.8	25.2	~	~	N/A	~	N/A	~	N/A	~	N/A	2.0	N/A	3.3	67.0	1.4	-58.6	4.3	212.5	
Fleshy algae	~	~	N/A	~	N/A	2.8	N/A	1.2	-58.4	0.7	-39.2	7.9	976.6	~	~	N/A	~	N/A	~	N/A	~	N/A	1.3	N/A	0.2	-80.6	0.1	-65.0	0.4	407.6	
Coralline algae	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0	N/A	0.1	N/A	~	~	N/A	~	N/A	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	N/A	0.1333	N/A	
Seagrass	~	~	N/A	~	N/A	12.1	N/A	6.2	-49.0	6.5	4.8	21.2	226.2	~	~	N/A	~	N/A	~	N/A	~	N/A	6.8	N/A	4.0	-41.0	3.5	-13.2	6.0	72.2	
Subtotal Others	~	~	N/A	~	N/A	12.1	N/A	6.2	-49.0	6.5	4.8	21.2	226.2	~	~	N/A	~	N/A	~	N/A	~	N/A	6.8	N/A	4.0	-41.0	3.5	-13.2	6.0	72.2	
TOTAL	100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		
Environmental Parameters																															
Mean Slope (degrees)	~			9.1		13.5		37.2		~		~		~	~		~		~		0.9		15.0		3.0		~		~		
Mean Topography (m) *	2.4	2.2		1.6		1.1		1.0		~		~		2.1	1.5-2		1.5-4		~		0.8		1.2		0.9		~		~		
Mean Depth/Range (m)	1.5-15	6-7		5.6		7.2		7.4		~		~		2-8	3-7		2-5		2-3		2.2		2.9		3.1		~		~		
Horizontal Visibility (m)	~	18		20.3		23.7		29.0		~		35		~	~		~		25		22.2		22.7		29.2		~		35		
No. of 50 m Transects ~ no data available	1	4		15		16.0		19.0		21		10		1	3		6		2		14		14.0		15.0		20		16		
* mean distance between lowest and highest point on the horizontal transect line																															

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 6. Mean (±SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at NR-1 (North Reef) Malayan Wreck from 1992 to 2014.

Family	(N=1) 1992	(N=3) 1996	% Change 1992- 1996	(N=8) 2000	% Change 1996- 2000	(N=5) 2004	% Change 2000- 2004	(N=4) 2008	% Change 2004- 2008	(N=8) 2012	% Change 2008- 2012	2014	% Change 2012- 2014
	Species	Species		Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	9.0	8.0	-11.1	5.6	-30.0	9.3	65.2	6.7	-27.9	4.6	-31.3	6.6	43.5
Rabbitfish (Siganids)*	0.0	1.0	+	0.6	-40.0	0.3	-58.3	0.3	33.3	0.2	-33.3	0.2	0.0
Groupers (Serranids)*	2.0	3.0	50.0	2.6	-13.3	2.4	-8.7	3.9	63.7	2.7	-30.8	2.6	-3.7
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	2.0	1.0	-50.0	2.2	120.0	1.9	-14.8	3.2	71.9	1.2	-62.5	3.6	200.0
Sweetlips (Haemulids)*	1.0	0.5	-50.0	0.0	-100.0	0.3	+	0.7	166.7	0.0	-100.0	0.6	N/A
Emperors (Lethrinids)*	0.0	0.5	+	0.8	60.0	1.0	25.0	1.1	11.1	0.7	-36.4	1.2	71.4
Jacks (Carangids)*	1.0	1.0	0.0	0.8	-20.0	0.8	-6.3	1.3	77.8	1.6	23.1	1.4	-12.5
Fusiliers (Caesionids)*	4.0	1.5	-62.5	0.4	-73.3	0.6	56.3	1.6	148.9	0.4	-75.0	1.6	300.0
Spinecheeks (Nemipterids)*	0.0	1.0	+	12.6	1160.0	0.6	-95.0	0.7	6.7	0.5	-28.6	0.2	N/A
Goatfish (Mullids)*	1.0	1.0	0.0	1.4	40.0	1.9	33.9	1.8	-5.2	1.1	-38.9	1.2	9.1
Parrotfish (Scarids)*	1.0	1.0	0.0	2.0	100.0	3.3	62.5	4.3	33.3	1.8	-58.1	3.6	100.0
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.1	+	0.5	400.0	0.4	-20.0
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.2	+	0.0	-100.0	0.3	+	0.0	-100.0	0.0	N/A
Triggerfish (Balistids)	2.0	3.5	75.0	4.2	20.0	4.3	1.2	4.7	9.8	3.4	-27.7	4.6	35.3
Butterflyfish (Chaetodonids)	11.0	11.0	0.0	9.6	-12.7	9.8	1.6	12.2	25.4	5.0	-59.0	2.0	-60.0
Angelfish (Pomacanthids)	2.0	3.0	50.0	2.6	-13.3	1.8	-32.7	2.8	58.7	1.6	-42.9	10.6	562.5
Wrasses (Labrids)	5.0	4.0	-20.0	6.6	65.0	8.6	30.7	9.3	8.2	3.6	-61.3	2.8	-22.2
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	166.7	0.5	66.7	7.8	1460.0
Damselfish (Pomacentrids)	10.0	11.0	10.0	5.2	-52.7	6.9	32.2	8.4	22.8	3.8	-54.8	0.4	-89.5
Fairy Basslets (Anthids)	2.0	2.0	0.0	1.0	-50.0	1.5	50.0	2.1	40.7	0.7	-66.7	7.4	957.1
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	1.0	0.0	0.8	-25.0	1.0	33.3	0.4	-60.0	1.0	150.0
<b>Total (target reef spp.):</b>	<b>21.0</b>	<b>19.5</b>	<b>-7.1</b>	<b>29.2</b>	<b>49.7</b>	<b>22.1</b>	<b>-24.2</b>	<b>25.9</b>	<b>17.0</b>	<b>15.8</b>	<b>-39.0</b>	<b>31.0</b>	<b>96.2</b>
<b>Total (all reef spp.):</b>	<b>54.0</b>	<b>55.0</b>	<b>1.9</b>	<b>59.4</b>	<b>8.0</b>	<b>55.8</b>	<b>-6.1</b>	<b>66.9</b>	<b>20.0</b>	<b>34.3</b>	<b>-48.7</b>	<b>59.8</b>	<b>74.3</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 7. Mean ( $\pm$ SE) fish species density (fish/500m<sup>2</sup>) and percentage change between years at NR-1 (North Reef) Malayan Wreck from 1992 to 2014.

Family	(N=1)	(N=3)	% Change 1992-1996	(N=8)	% Change 1996-2000	(N=5)	% Change 2000-2004	(N=4)	% Change 2004-2008	(N=8)	% Change 2008-2012		% Change 2012-2014
	1992	1996		2000		2004		2008		2012		2014	
	Density			Density		Density		Density		Density		Density	
Surgeonfish (Acanthurids)*	222	123	-44.6	104	-15.4	128.3	23.3	109.7	-14.5	55.0	-49.9	81.8	48.7
Rabbitfish (Siganids)*	0.0	3.0	+	1.0	-66.7	0.4	-62.5	0.7	77.8	0.4	-42.9	0.4	0.0
Groupers (Serranids)*	6.0	16.0	166.7	13.8	-13.8	9.8	-29.3	23.9	145.0	12.9	-46.0	12.2	-5.4
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	42.0	21.0	-50.0	15.0	-28.6	8.6	-42.5	17.7	104.8	5.7	-67.8	17.4	205.3
Sweetlips (Haemulids)*	3.0	1.5	-50.0	0.0	-100.0	0.5	+	3.8	655.6	0.0	-100.0	6.0	N/A
Emperors (Lethrinids)*	0.0	4.5	+	4.0	-11.1	7.8	93.8	15.2	96.4	8.6	-43.4	3.0	-65.1
Jacks (Carangids)*	9.0	6.0	-33.3	1.2	-80.0	24.1	1910.4	8.4	-65.0	20.6	145.2	13.2	-35.9
Fusiliers (Caesionids)*	324.0	97.5	-69.9	51.6	-47.1	50.9	-1.4	60.9	19.7	12.2	-80.0	97.0	695.1
Spinecheeks (Nemipterids)*	0.0	18.0	+	13.8	-23.3	2.4	-82.8	8.7	264.9	1.1	-87.4	0.6	-45.5
Goatfish (Mullids)*	129.0	21.0	-83.7	14.8	-29.5	21.4	44.4	14.1	-34.0	6.1	-56.7	7.0	14.8
Parrotfish (Scarids)*	129.0	33.0	-74.4	45.8	38.8	15.3	-66.7	24.0	57.4	10.0	-58.3	21.4	114.0
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	1.6	+	2.9	81.3	4.2	44.8
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.6	+	0.0	-100.0	2.2	+	0.0	-100.0	0.0	N/A
Triggerfish (Balistids)	5.0	109.5	2090.0	69.0	-37.0	326.4	373.0	420.8	28.9	91.6	-78.2	29.8	-67.5
Butterflyfish (Chaetodonids)	44.0	75.0	70.5	65.0	-13.3	44.4	-31.7	65.3	47.2	29.8	-54.4	334.6	1022.8
Angelfish (Pomacanthids)	38.0	9.0	-76.3	34.2	280.0	9.6	-71.9	15.8	63.9	4.4	-72.2	55.6	1163.6
Wrasses (Labrids)	189.0	27.0	-85.7	48.8	80.7	199.0	307.8	51.7	-74.0	28.7	-44.5	35.0	22.0
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	166.7	0.8	166.7	7.8	875.0
Damselfish (Pomacentrids)	420.0	3153.0	650.7	616.8	-80.4	834.5	35.3	1013.6	21.5	288.5	-71.5	1.4	-99.5
Fairy Basslets (Anthids)	162.0	354.0	118.5	242.0	-31.6	402.6	66.4	983.3	144.2	86.4	-91.2	207.0	139.6
Moorish Idols ( <i>Zanclus cornutus</i> )	9.0	9.0	0.0	4.8	-46.7	3.0	-37.5	5.0	66.7	1.5	-70.0	3.8	153.3
												0.0	
Total (target reef spp.):	864.0	344.5	-60.1	265.6	-22.9	228.5	-14.0	262.3	14.8	136.3	-48.0	299.2	119.5
Total (all reef spp.):	1731.0	4081.0	135.8	1346.2	-67.0	2088.9	55.2	2846.6	36.3	667.2	-76.6	938.6	40.7

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

**Table 8. Changes in substrate composition (% mean ±SE) in NR-2 (North Reef) Ranger Station from 1992 to 2014.**

	SCUBA SURVEYS:											SNORKEL SURVEYS:										
	1992	2000	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change	1992	1996	% Change	2000	% Change	2004	% Change	2008	% Change	2012	% Change
SUBSTRATE COVER	% cover	% cover	1992-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	% cover	% cover	1992-1996	% cover	1996-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012
Sand (s) and Silt (SI)	20.2	8.1	-59.9	8.8	8.8	2.2	-74.8	0.8	-65.9	5.1	574.1	20.3	22.3	9.9	16.2	-27.4	6.4	-60.7	4.6	-27.5	12.2	164.5
Coral Rubble (R)	0.5	33.3	6560.0	22.1	-33.7	21.3	-3.3	18.4	-13.4	12.9	-30.1	24.9	7.1	-71.5	17.6	147.9	18.2	3.3	10.7	-41.3	13.8	29.3
Rock and Block (RK)	38.8	11.1	-71.4	13.2	18.5	4.0	-69.6	9.8	145.3	5.5	-43.9	10	6.3	-37.0	23.1	266.7	18.7	-19.2	23.1	23.9	30.2	30.7
White Dead Standing Coral (DC)	6.3	0.9	-85.7	0.2	-82.6	1.3	716.0	0.5	-61.5	1.1	111.1	6.1	7.8	27.9	0.3	-96.2	0.8	170.7	1.1	34.1	1.6	44.4
Dead Coral with Algae (DCA)	0	32.6	+	3.5	-89.2	8.3	135.8	4.8	-42.0	3.8	-20.3	0	0	N/A	10.1	+	8.0	-20.9	12.8	59.7	6.2	-51.6
<b>Subtotal Non-living Substrate</b>	<b>65.8</b>	<b>86</b>	<b>30.7</b>	<b>47.7</b>	<b>-44.5</b>	<b>37.2</b>	<b>-22.1</b>	<b>34.3</b>	<b>-7.8</b>	<b>28.3</b>	<b>-17.4</b>	<b>61.3</b>	<b>43.5</b>	<b>-29.0</b>	<b>67.3</b>	<b>54.7</b>	<b>52.0</b>	<b>-22.7</b>	<b>52.3</b>	<b>0.5</b>	<b>64.0</b>	<b>22.3</b>
Branching (CB)	25.5	8.9	-65.1	26.9	202.7	44.3	64.5	40.2	-9.3	43.7	8.7	22.6	51	125.7	~	N/A	30.4	N/A	32.1	5.3	12.7	-60.5
Massive (CM)	1.2	1.9	58.3	6.0	214.1	3.6	-40.5	2.6	-28.8	4.4	71.3	6.5	4.7	-27.7	~	N/A	7.5	N/A	9.2	21.8	10.3	12.3
Flat/Encrusting (CFD)	5.7	1.9	-66.7	7.8	311.2	2.5	-67.7	1.9	-22.5	1.2	-39.8	4.4	0	-100.0	~	N/A	3.1	N/A	2.6	-15.9	5.5	110.3
Foliose Cup (CFO)	0	0.2	+	1.2	478.1	0.5	-56.8	11.2	2137.5	9.3	-16.6	2	0	-100.0	~	N/A	0.8	N/A	0.8	7.8	3.3	306.9
<b>Total Hard Coral</b>	<b>32.4</b>	<b>12.9</b>	<b>-60.2</b>	<b>41.9</b>	<b>224.6</b>	<b>50.9</b>	<b>21.6</b>	<b>55.9</b>	<b>9.8</b>	<b>58.6</b>	<b>4.8</b>	<b>35.5</b>	<b>55.7</b>	<b>56.9</b>	<b>31.3</b>	<b>-43.8</b>	<b>41.9</b>	<b>33.8</b>	<b>44.7</b>	<b>6.7</b>	<b>31.7</b>	<b>-29.0</b>
<b>Total Soft Coral</b>	<b>1.8</b>	<b>1.1</b>	<b>-38.9</b>	<b>1.7</b>	<b>50.6</b>	<b>9.0</b>	<b>441.9</b>	<b>3.8</b>	<b>-57.6</b>	<b>3.7</b>	<b>-3.8</b>	<b>3.2</b>	<b>0.8</b>	<b>-75.0</b>	<b>1.4</b>	<b>75.0</b>	<b>0.7</b>	<b>-51.2</b>	<b>1.4</b>	<b>111.3</b>	<b>2.7</b>	<b>92.9</b>
<b>Subtotal Coral</b>	<b>34.2</b>	<b>14</b>	<b>-59.1</b>	<b>43.5</b>	<b>210.9</b>	<b>59.9</b>	<b>37.5</b>	<b>59.7</b>	<b>-0.4</b>	<b>62.2</b>	<b>4.2</b>	<b>38.7</b>	<b>56.5</b>	<b>46.0</b>	<b>32.7</b>	<b>-42.1</b>	<b>42.6</b>	<b>30.2</b>	<b>46.2</b>	<b>8.4</b>	<b>34.4</b>	<b>-25.4</b>
Sponges	~	~	N/A	3.6	N/A	1.4	-62.4	2.3	60.7	4.1	80.2	~	~	N/A	~	N/A	0.5	N/A	0.4	-23.7	0.7	66.7
Other animals	~	~	N/A	1.0	N/A	0.6	-43.2	0.3125	-47.9	1.2	291.1	~	~	N/A	~	N/A	0.9	N/A	0.3	-69.4	0.3	0.0
Algae				0.0													0.0					
Turf algae	~	~	N/A	0.4	N/A	0.2	-40.0	1.4	587.5	0.1	-91.9	~	~	N/A	~	N/A	0.9	N/A	0.3	-66.3	0.1	-74.1
Fleshy algae	~	~	N/A	0.5	N/A	0.3	-50.0	0.1	-58.3	0.5	300.0	~	~	N/A	~	N/A	1.1	N/A	0.2	-82.1	0.0	-100.0
Coralline algae	~	~	N/A	3.3	N/A	0.6	-81.9	1.9375	222.9	3.6	83.5	~	~	N/A	~	N/A	1.6	N/A	0.4	-75.7	0.5	30.6
Seagrass	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	~	~	N/A	~	N/A	0.3	N/A	0.0	-100.0	0.0	N/A
<b>Subtotal Others</b>	<b>0</b>	<b>0</b>	<b>N/A</b>	<b>8.8</b>	<b>+</b>	<b>3.0</b>	<b>-66.0</b>	<b>6</b>	<b>100.0</b>	<b>9.4</b>	<b>57.4</b>	<b>0</b>	<b>0</b>	<b>N/A</b>	<b>0</b>	<b>N/A</b>	<b>5.4</b>	<b>+</b>	<b>1.6</b>	<b>-70.9</b>	<b>1.6</b>	<b>-2.1</b>
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>	<b>0.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>	<b>0.0</b>	<b>100.0</b>	
<b>Environmental Parameters</b>																						
Mean Slope (degrees)	~	15.6		53.6		34.2		~		~		~	~		3.4		12.2		2.0		~	
Mean Topography (m) *	4	2.9		2.1		2.5		~		~		1-3	~		1.6		1.1		1.3		~	
Mean Depth/Range (m)	5	6.5		7.4		7.7		~		~		1-10	3		2.8		3.0		3.0		~	
Horizontal Visibility (m)	~	23.8		26.2		32.3		~		40		~	25		20.8		9.9		31.9		~	
No. of 50 m Transects	1	16		16		20		8		9		6	2		13		14		15		9	
~ no data available																						
* mean distance between lowest and highest point on the horizontal transect line																						

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 09. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at NR-2 (North Reef) Ranger Station from 1992 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1992	2000		2004		2008		2012		2014	
	Species	Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	8.0	6.8	-14.6	8.1	18.9	7.8	-4.6	5.8	-25.6	4.8	-17.2
Rabbitfish (Siganids)*	1.0	1.5	50.0	1.3	-16.7	1.8	40.0	1.0	-44.4	1.0	0.0
Groupers (Serranids)*	5.0	4.3	-13.3	2.9	-33.7	3.8	30.4	2.8	-26.3	3.2	14.3
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	1.0	2.5	150.0	4.5	80.0	3.9	-13.9	3.2	-17.9	4.6	43.8
Sweetlips (Haemulids)*	0.0	0.7	+	0.9	31.3	0.8	-14.3	0.6	-25.0	1.0	66.7
Emperors (Lethrinids)*	1.0	0.7	-33.3	1.4	106.3	1.4	0.0	0.6	-57.1	1.4	133.3
Jacks (Carangids)*	0.0	2.0	+	1.3	-37.5	1.6	30.0	1.0	-37.5	1.0	0.0
Fusiliers (Caesionids)*	0.0	1.3	+	2.5	87.5	2.1	-15.0	1.8	-14.3	2.6	44.4
Spinecheeks (Nemipterids)*	1.0	0.7	-33.3	0.5	-25.0	0.6	25.0	0.4	-33.3	0.6	50.0
Goatfish (Mullids)*	1.0	1.8	83.3	1.1	-38.6	1.1	0.0	0.8	-27.3	1.0	25.0
Parrotfish (Scarids)*	1.0	3.5	250.0	2.6	-25.0	3.8	42.9	3.0	-21.1	3.2	6.7
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.2	N/A
Rudderfish (Kyphosids)*	0.0	0.2	+	0.1	-25.0	0.0	-100.0	0.2	+	0.0	-100.0
Triggerfish (Balistids)	2.0	2.7	33.3	1.9	-29.7	4.1	120.0	2.2	-46.3	4.0	81.8
Butterflyfish (Chaetodonids)	14.0	10.2	-27.4	11.4	11.9	12.4	8.8	6.0	-51.6	1.8	-70.0
Angelfish (Pomacanthids)	2.0	3.5	75.0	2.5	-28.6	3.4	35.0	2.2	-35.3	9.4	327.3
Wrasses (Labrids)	9.0	10.8	20.4	6.6	-38.8	10.4	56.6	4.6	-55.8	2.4	-47.8
Humphead wrasse	~	~	N/A	0.0	N/A	0.1	+	0.0	-100.0	5.8	N/A
Damselfish (Pomacentrids)	13.0	12.7	-2.6	12.4	-2.3	8.8	-29.3	7.8	-11.4	0.4	-94.9
Fairy Basslets (Anthids)	2.0	1.2	-41.7	2.1	82.1	1.9	-11.8	1.6	-15.8	6.4	300.0
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	0.9	-12.5	1.1	28.6	0.8	-27.3	1.0	25.0
<b>Total (target reef spp.):</b>	<b>19.0</b>	<b>26.0</b>	<b>36.8</b>	<b>27.1</b>	<b>4.3</b>	<b>28.5</b>	<b>5.1</b>	<b>21.2</b>	<b>-25.6</b>	<b>24.6</b>	<b>16.0</b>
<b>Total (all reef spp.):</b>	<b>62.0</b>	<b>68.0</b>	<b>9.7</b>	<b>64.9</b>	<b>-4.6</b>	<b>70.6</b>	<b>8.9</b>	<b>46.4</b>	<b>-34.3</b>	<b>55.8</b>	<b>20.3</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 10. Mean ( $\pm$ SE) fish species density (fish/500m<sup>2</sup>) and percentage change between years at NR-2 (North Reef) Ranger Station from 1992 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1992	2000		2004		2008		2012		2014	
	Density			Density		Density		Density		Density	
Surgeonfish (Acanthurids)*	90.0	193.7	115.2	128.5	-33.6	71.3	-44.6	51.2	-28.2	51.6	0.8
Rabbitfish (Siganids)*	4.0	5.2	29.2	2.4	-54.0	4.3	78.9	2.2	-48.8	2.0	-9.1
Groupers (Serranids)*	8.0	16.8	110.4	7.6	-54.7	15.1	98.4	5.4	-64.2	15.6	188.9
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	5.0	18.0	260.0	19.6	9.0	8.8	-55.4	28.0	218.2	26.6	-5.0
Sweetlips (Haemulids)*	0.0	3.8	+	1.8	-54.3	5.5	214.3	2.6	-52.7	4.4	69.2
Emperors (Lethrinids)*	9.0	1.3	-85.2	24.3	1718.8	8.9	-63.4	3.0	-66.3	16.4	446.7
Jacks (Carangids)*	0.0	13.0	+	9.3	-28.8	28.4	206.8	8.4	-70.4	2.8	-66.7
Fusiliers (Caesionids)*	0.0	104.0	+	1396.5	1242.8	138.0	-90.1	91.0	-34.1	131.0	44.0
Spinecheeks (Nemipterids)*	3.0	2.5	-16.7	1.4	-45.0	1.4	0.0	0.4	-71.4	1.2	200.0
Goatfish (Mullids)*	129.0	12.7	-90.2	7.8	-38.8	7.8	0.0	2.4	-69.2	3.0	25.0
Parrotfish (Scarids)*	33.0	70.7	114.1	29.5	-58.3	27.0	-8.5	27.0	0.0	23.8	-11.9
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.2	N/A
Rudderfish (Kyphosids)*	0.0	5.5	+	4.1	-25.0	0.0	-100.0	0.8	+	0.0	-100.0
Triggerfish (Balistids)	3.0	14.8	394.4	8.6	-41.9	31.9	269.6	11.2	-64.9	23.0	105.4
Butterflyfish (Chaetodonids)	50.0	30.8	-38.3	35.5	15.1	57.9	63.0	13.8	-76.2	725.2	5155.1
Angelfish (Pomacanthids)	34.0	28.2	-17.2	7.5	-73.4	15.6	108.3	5.6	-64.1	22.8	307.1
Wrasses (Labrids)	117.0	120.0	2.6	117.4	-2.2	57.4	-51.1	49.0	-14.6	4.0	-91.8
Humphead wrasse	~	~	N/A	0.0	N/A	0.1	+	0.0	-100.0	32.4	N/A
Damselfish (Pomacentrids)	1020.0	994.8	-2.5	2578.0	159.1	3423.9	32.8	367.2	-89.3	0.8	-99.8
Fairy Basslets (Anthids)	258.0	905.3	250.9	1061.8	17.3	2544.0	139.6	236.4	-90.7	938.4	297.0
Moorish Idols ( <i>Zanclus cornutus</i> )	3.0	4.0	33.3	5.3	31.3	5.0	-4.8	2.0	-60.0	3.4	70.0
										0.0	
Total (target reef spp.):	281.0	447.2	59.1	1587.0	254.9	294.8	-81.4	222.4	-24.6	278.6	25.3
Total (all reef spp.):	1766.0	2545.2	44.1	5446.6	114.0	6452.0	18.5	907.6	-85.9	2028.6	123.5

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

**Table 11. Changes in substrate composition (% mean ±SE) in SR-3 (South Reef) Black Rock from 1984 to 2014.**

	SCUBA SURVEYS:														SNORKEL SURVEYS:																
	1992	1996	% Change	2000	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change	1984	1989	% Change	1992	% Change	1996	% Change	2000	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change	
SUBSTRATE COVER	% cover	% cover	1992-1996	% cover	1996-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	% cover	% cover	1984-1989	% cover	1989-1992	% cover	1992-1996	% cover	1996-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	
Sand (s) and Silt (SI)	1.1	3.8	245.5	3.8	0.0	8.9	135.2	8.4	-5.7	3.9	-53.3	7.8	98.4	1.1	6.1	454.5	14.4	136.1	6.0	-58.3	4.1	-31.7	8.3	101.7	3.8	-54.3	3.5	-6.7	4.2	17.2	
Coral Rubble (R)	17.6	22.5	27.8	40.5	80.0	16.7	-58.8	17.0	2.0	12.2	-28.4	16.9	38.5	16.3	26.6	63.2	9.0	-66.2	6.5	-27.8	12.7	95.4	9.6	-24.7	10.7	11.8	7.9	-26.3	9.1	15.7	
Rock and Block (RK)	4.9	7.4	51.0	14.8	100.0	5.0	-66.3	3.5	-29.8	9.7	175.7	2.8	-71.1	12.2	18.3	50.0	32.3	76.5	4.5	-86.1	41.9	831.1	24.7	-41.0	11.2	-54.7	24.0	114.3	25.4	5.7	
White Dead Standing Coral (DC)	0.6	1.8	200.0	2.6	44.4	0.3	-90.4	0.4	60.0	0.4	6.3	0.1	-83.2	5.2	4.0	-23.1	2.1	-47.5	18.0	757.1	2.0	-88.9	0.4	-78.7	1.0	144.8	2.1	112.7	0.9	-58.2	
Dead Coral with Algae (DCA)	0.0	0.0	N/A	8.4	+	4.4	-47.2	6.1	37.5	5.1	-16.8	7.2	42.2	0.0	0.0	N/A	0.0	N/A	0.0	N/A	9.2	+	6.6	-28.6	6.1	-7.3	4.5	-25.9	3.8	-15.4	
Subtotal Non-living Substrate	24.2	35.5	46.7	70.1	97.5	35.3	-49.6	35.5	0.4	31.3	-12.0	34.7	11.1	34.8	55.0	58.0	57.8	5.1	35.0	-39.4	69.9	99.7	49.5	-29.1	32.8	-33.8	42.1	28.3	43.4	3.0	
Branching (CB)	17.9	27.7	54.7	17.5	-36.8	39.1	123.2	39.9	2.1	32.1	-19.5	45.9	43.0	32.7	15.7	-52.0	19.3	22.9	41.0	112.4	~	N/A	27.5	N/A	49.2	79.2	31.2	-36.5	35.5	13.7	
Massive (CM)	8.1	2.1	-74.1	3.4	61.9	2.8	-17.5	4.6	63.0	7.3	57.6	1.7	-76.4	8.8	3.6	-59.1	8.6	138.9	9.0	4.7	~	N/A	8.9	N/A	3.8	-56.9	9.6	152.4	7.8	-18.9	
Flat/Encrusting (CFD)	0.7	2.7	285.7	4.8	77.8	5.3	9.9	3.4	-35.5	1.6	-52.9	0.9	-42.0	5.4	0.0	-100.0	5.1	+	4.5	-11.8	~	N/A	6.5	N/A	3.0	-54.6	4.3	44.8	4.3	-1.8	
Foliose Cup (CFO)	2.4	1.1	-54.2	0.9	-18.2	0.8	-13.2	1.2	47.2	6.8	466.7	4.1	-40.1	2.0	0.0	-100.0	0.7	+	1.5	114.3	~	N/A	1.2	N/A	6.4	417.0	5.4	-15.6	4.6	-14.8	
Total Hard Coral	29.0	33.6	15.9	26.5	-21.1	47.9	80.8	49.0	2.2	47.8	-2.5	52.6	10.2	48.9	19.3	-60.5	33.7	74.6	56.0	66.2	29.4	-47.5	44.2	50.2	62.4	41.4	50.6	-19.0	52.2	3.1	
Total Soft Coral	46.8	30.9	-34.0	3.4	-89.0	11.4	234.6	12.6	10.3	16.1	27.6	8.6	-46.2	16.3	25.7	57.7	8.5	-66.9	9.0	5.9	0.7	-92.2	2.9	307.2	4.2	46.6	6.8	60.8	3.2	-52.3	
Subtotal Coral	75.8	64.5	-14.9	29.9	-53.6	59.3	98.3	61.6	3.8	63.9	3.7	61.3	-4.0	65.2	45.0	-31.0	42.2	-6.2	65.0	54.0	30.1	-53.7	47.0	56.2	66.6	41.7	57.3	-13.9	55.4	-3.4	
Sponges	~	~	N/A	~	N/A	1.8	N/A	1.3	-32.2	1.9	48.1	1.8	-7.2	~	~	N/A	~	N/A	~	N/A	~	N/A	0.6	N/A	0.0	-100.0	0.1	N/A	0.1	4.8	
Other animals	~	~	N/A	~	N/A	0.5	N/A	0.5	-5.9	0.175	-65.0	1.1	553.1	~	~	N/A	~	N/A	~	N/A	~	N/A	0.2	N/A	0.0	-77.0	0.4	N/A	0.7	81.8	
Algae	~	~	N/A	~	N/A	0.8	N/A	0.2	-77.6	0.5	125.0	0.0	-100.0	~	~	N/A	~	N/A	~	N/A	~	N/A	1.3	N/A	0.1	-95.0	0.0	-100.0	0.2	#DIV/0!	
Turf algae	~	~	N/A	~	N/A	0.1	N/A	0.1	-46.7	0.4	250.0	0.2	-38.8	~	~	N/A	~	N/A	~	N/A	~	N/A	0.2	N/A	0.0	-79.8	0.0	N/A	0.2	#DIV/0!	
Fleshy algae	~	~	N/A	~	N/A	2.2	N/A	1.0	-52.3	1.925	92.5	0.9	-55.5	~	~	N/A	~	N/A	~	N/A	~	N/A	1.2	N/A	0.4	-63.7	0.1	-65.9	0.1	-51.1	
Coralline algae	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	N/A	0.0	N/A	~	~	N/A	~	N/A	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.00	N/A	
Seagrass	~	~	N/A	~	N/A	5.4	+	3.0	-44.4	4.9	63.3	4.0	-18.4	0.0	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	3.5	+	0.6	-83.3	0.6	-1.5	1.3	118.0	
Subtotal Others	0.0	0.0	N/A	0.0	N/A	5.4	+	3.0	-44.4	4.9	63.3	4.0	-18.4	0.0	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	3.5	+	0.6	-83.3	0.6	-1.5	1.3	118.0	
TOTAL	100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0		
Environmental Parameters																															
Mean Slope (degrees)	~	~		16.9		32.3		38.3		~		~		~	~		~		~		5.8		11.4		2.5		~		~		
Mean Topography (m) *	1.9	2.5		2.9		1.5		2.1		~		~		1.9	~		1.5		~		1.3		0.7		1.1		~		~		
Mean Depth/Range (m)	8-15	8-9		6.8		7.3		7.3		~		~		3.5	~		2-7		1-2.7		2.6		2.7		3.5		~		~		
Horizontal Visibility (m)	~	25.0		27.9		28.8		32.5		~		40		~	~		~		~		23.9		28.7		32.9		~		40		
No. of 50 m Transects	4	4		16		16		20		20		7		1	2		3		2		12		15		15		11		5		
~ no data available																															
* mean distance between lowest and highest point on the horizontal transect line																															

\* mean distance between lowest and highest point on the horizontal transect line

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase



Table 12. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at SR-3 (South Reef) Black Rock from 1996 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1996	2000		2004		2008		2012		2014	
	Species	Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	7.5	7.2	-4.0	6.1	-14.9	6.9	12.2	4.9	-29.0	7.4	51.0
Rabbitfish (Siganids)*	1.5	1.2	-20.0	1.4	14.6	1.0	-27.3	0.4	-60.0	1.2	200.0
Groupers (Serranids)*	2.0	2.4	20.0	3.1	30.2	2.9	-8.0	1.2	-58.6	2.8	133.3
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	1.0	2.0	100.0	2.8	37.5	2.9	4.5	1.8	-37.9	4.4	144.4
Sweetlips (Haemulids)*	0.5	0.6	20.0	0.6	4.2	0.8	20.0	0.6	-25.0	1.4	133.3
Emperors (Lethrinids)*	0.0	0.6	+	1.5	150.0	1.3	-16.7	0.3	-76.9	1.0	233.3
Jacks (Carangids)*	0.0	1.0	+	1.4	37.5	1.3	-9.1	0.5	-61.5	2.0	300.0
Fusiliers (Caesionids)*	1.5	1.2	-20.0	0.1	-89.6	0.8	500.0	0.9	12.5	1.4	55.6
Spinecheeks (Nemipterids)*	0.5	0.2	-60.0	0.3	25.0	0.5	100.0	0.0	-100.0	0.6	N/A
Goatfish (Mullids)*	1.0	1.2	20.0	1.8	45.8	1.6	-7.1	0.1	-93.8	1.2	1100.0
Parrotfish (Scarids)*	1.0	0.8	-20.0	3.4	321.9	2.9	-14.8	1.4	-51.7	3.0	114.3
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.1	+	0.1	0.0	0.0	-100.0
Rudderfish (Kyphosids)*	0.0	0.6	+	0.0	-100.0	0.0	N/A	0.3	+	0.0	-100.0
Triggerfish (Balistids)	2.5	4.2	68.0	2.5	-40.5	4.9	95.0	2.3	-53.1	3.8	65.2
Butterflyfish (Chaetodonids)	8.0	12.0	50.0	11.1	-7.3	10.9	-2.2	5.1	-53.2	1.8	-64.7
Angelfish (Pomacanthids)	1.5	2.6	73.3	2.8	5.8	2.5	-9.1	0.9	-64.0	10.2	1033.3
Wrasses (Labrids)	4.5	5.4	20.0	8.6	59.7	8.8	1.4	1.1	-87.5	1.6	45.5
Humphead wrasse	~	~	N/A	0.0	N/A	0.5	+	0.1	-80.0	7.2	7100.0
Damselfish (Pomacentrids)	7.5	9.0	20.0	12.5	38.9	8.9	-29.0	4.5	-49.4	0.4	-91.1
Fairy Basslets (Anthids)	2.0	2.0	0.0	2.1	6.3	1.6	-23.5	1.2	-25.0	9.0	650.0
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	0.9	-12.5	1.0	14.3	0.4	-60.0	1.0	150.0
										0.0	
<b>Total (target reef spp.):</b>	<b>16.5</b>	<b>19.0</b>	<b>15.2</b>	<b>22.4</b>	<b>17.8</b>	<b>22.6</b>	<b>1.1</b>	<b>12.6</b>	<b>-44.2</b>	<b>26.4</b>	<b>109.5</b>
<b>Total (all reef spp.):</b>	<b>43.5</b>	<b>55.2</b>	<b>26.9</b>	<b>62.9</b>	<b>13.9</b>	<b>61.8</b>	<b>-1.8</b>	<b>28.1</b>	<b>-54.5</b>	<b>61.4</b>	<b>118.5</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 13. Mean ( $\pm$ SE) fish species density (fish/500m<sup>2</sup>) and percentage change between years at SR-3 (South Reef) Black Rock from 1996 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1996	2000		2004		2008		2012		2014	
	Density			Density		Density		Density		Density	
Surgeonfish (Acanthurids)*	84.5	156.6	85.3	97.6	-37.7	72.8	-25.5	58.7	-19.4	65.8	12.1
Rabbitfish (Siganids)*	7.5	3.0	-60.0	4.5	50.0	3.4	-25.0	2.0	-41.2	2.8	40.0
Groupers (Serranids)*	3.5	11.6	231.4	15.6	34.7	17.0	8.8	8.9	-47.6	13.6	52.8
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	9.0	7.2	-20.0	11.8	63.2	18.0	53.2	12.1	-32.8	24.8	105.0
Sweetlips (Haemulids)*	1.5	3.0	100.0	3.5	16.7	5.6	60.7	3.0	-46.4	19.8	560.0
Emperors (Lethrinids)*	0.0	2.6	+	20.3	678.8	8.1	-59.9	0.8	-90.1	8.6	975.0
Jacks (Carangids)*	0.0	9.8	+	7.3	-26.0	4.8	-34.5	9.9	106.3	8.4	-15.2
Fusiliers (Caesionids)*	193.5	81.4	-57.9	4.1	-94.9	32.3	681.8	37.5	16.1	57.0	52.0
Spinecheeks (Nemipterids)*	16.5	0.2	-98.8	0.8	275.0	1.3	66.7	0.0	-100.0	1.6	N/A
Goatfish (Mullids)*	66.0	28.2	-57.3	10.9	-61.4	6.1	-43.7	0.5	-91.8	4.0	700.0
Parrotfish (Scarids)*	69.0	58.2	-15.7	23.6	-59.4	15.0	-36.5	9.5	-36.7	16.0	68.4
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.1	+	7.0	6900.0	0.0	-100.0
Rudderfish (Kyphosids)*	0.0	17.8	+	0.0	-100.0	0.0	N/A	1.0	+	0.0	-100.0
Triggerfish (Balistids)	3.5	21.6	517.1	8.6	-60.1	32.3	273.9	31.3	-3.1	17.2	-45.0
Butterflyfish (Chaetodonids)	25.5	24.8	-2.7	32.5	31.0	33.0	1.5	20.0	-39.4	583.6	2818.0
Angelfish (Pomacanthids)	3.5	16.2	362.9	9.4	-42.1	8.9	-5.3	5.4	-39.3	30.0	455.6
Wrasses (Labrids)	67.5	154.2	128.4	85.5	-44.6	31.3	-63.5	7.6	-75.7	8.4	10.5
Humphead wrasse	~	~	N/A	0.0	N/A	0.8	+	0.1	-87.5	22.0	21900.0
Damselfish (Pomacentrids)	919.5	2096.8	128.0	2309.9	10.2	2424.3	5.0	1070.5	-55.8	0.8	-99.9
Fairy Basslets (Anthids)	1618.5	890.8	-45.0	1733.5	94.6	1117.5	-35.5	747.6	-33.1	967.0	29.3
Moorish Idols ( <i>Zanclus cornutus</i> )	33.0	9.4	-71.5	5.3	-44.1	8.5	61.9	1.3	-84.7	5.0	284.6
Total (target reef spp.):	451.0	379.6	-15.8	175.5	-53.8	169.4	-3.5	151.0	-10.9	222.4	47.3
Total (all reef spp.):	3122.0	3593.4	15.1	4384.5	22.0	3840.8	-12.4	2034.7	-47.0	1856.4	-8.8

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

**Table 14. Changes in substrate composition (% mean  $\pm$ SE) in SR-4 (South Reef) North West Corner of the South Atoll from 1992 to 2014.**

	SCUBA SURVEYS:											SNORKEL SURVEY:									
	1992	2000	% Change	2004	% Change	2008	%Change	2012	% Change	2014	% Change	1992	2004	%Change	2008	% Change	2012	% Change	2014	% Change	
SUBSTRATE COVER	% cover	% cover	1992-2000	% cover	2000-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	% cover	% cover	1992-2004	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	
Sand (s) and Silt (SI)	2.3	1.7	-26.1	4.0	137.0	3.0	-26.3	0.6	-79.6	4.8	683.1	4.3	3.9	-9.0	4.1	3.7	4.0	-1.3	9.2	127.9	
Coral Rubble (R)	11.8	10.3	-12.7	8.9	-14.0	14.1	59.8	12.7	-9.8	17.9	40.4	5.0	3.1	-37.7	5.2	67.0	0.4	-92.3	2.7	567.0	
Rock and Block (RK)	41.6	26.5	-36.3	11.5	-56.5	9.0	-21.9	12.4	38.3	7.3	-41.5	21.0	36.0	71.4	45.7	26.8	37.2	-18.5	40.4	8.4	
White Dead Standing Coral (DC)	~	0.8	N/A	0.2	-74.3	0.2	-14.3	0.1	-44.4	0.4	285.7	3.0	0.0	-100.0	0.1	+	1.3	1226.7	0.0	-100.0	
Dead Coral with Algae (DCA)	0.3	12.7	4133.3	3.2	-74.8	6.5	101.8	4.0	-38.5	6.5	62.5	0.0	2.7	+	2.3	-16.0	3.9	71.3	2.4	-39.0	
Subtotal Non-living Substrate	56.0	52.0	-7.1	27.8	-46.5	32.8	17.8	29.9	-8.9	36.9	23.3	33.3	45.8	37.3	57.3	25.3	47.0	-18.1	54.7	16.4	
Branching (CB)	19.2	20.0	4.2	27.2	36.0	18.1	-33.6	22.1	21.9	14.3	-35.2	37.3	17.0	-54.4	10.4	-39.2	19.2	84.6	21.2	10.4	
Massive (CM)	7.7	9.6	24.7	10.3	6.9	8.8	-14.6	12.4	41.4	6.1	-51.2	15.3	13.4	-12.9	16.0	19.9	15.8	-1.5	9.9	-37.5	
Flat/Encrusting (CFD)	6.0	10.6	76.7	10.5	-0.9	12.9	22.7	1.6	-87.5	1.2	-24.6	12.2	15.8	29.8	8.0	-49.6	11.8	47.5	8.0	-31.9	
Foliose Cup (CFO)	2.3	0.8	-65.2	1.0	25.0	1.1	8.8	15.2	1278.8	11.1	-27.0	0.7	2.8	314.3	0.4	-83.9	2.0	406.7	3.2	57.9	
Total Hard Coral	35.2	41.0	16.5	49.0	19.4	40.8	-16.7	51.3	25.7	32.6	-36.3	65.5	48.9	-25.3	34.8	-28.9	48.8	40.2	42.3	-13.3	
Total Soft Coral	8.8	7.0	-20.5	11.7	67.6	15.3	30.6	10.1	-34.3	8.4	-16.9	1.2	1.0	-12.4	1.1	10.6	1.1	-1.2	0.1	-86.9	
Subtotal Coral	44.0	48.0	9.1	60.7	26.5	56.1	-7.6	61.3	9.3	41.0	-33.2	66.7	49.9	-25.1	35.9	-28.1	49.9	38.9	42.4	-14.9	
Sponges	~	~	N/A	3.2	N/A	2.9	-10.2	3.9	34.1	6.1	56.1	~	0.4	N/A	0.2	-55.6	0.7	233.3	1.9	190.1	
Other animals	~	~	N/A	1.1	N/A	3.1	191.7	0.4	-87.5	10.4	2581.6	~	0.1	N/A	0.3	296.1	0.6	115.6	0.9	40.1	
Algae																					
Turf algae	~	~	N/A	0.5	N/A	1.2	127.8	0.3	-72.2	2.1	521.4	~	0.2	N/A	0.7	223.2	0.4	-49.5	0.0	-100.0	
Fleshy algae	~	~	N/A	0.9	N/A	0.9	0.0	1.3	42.0	1.0	-21.7	~	0.0	N/A	4.9	24249.2	0.0	-100.0	0.1	#DIV/0!	
Coralline algae	~	~	N/A	5.9	N/A	3.1	-46.7	2.9	-6.8	2.4	-15.9	~	3.6	N/A	0.7	-81.4	1.5	116.2	0.0	-100.0	
Seagrass	~	~	N/A	0.0	N/A	0.0	N/A	0.0	#DIV/0!	0.1	N/A	~	0.0	N/A	0.0	+	0.0	N/A	0	N/A	
Subtotal Others	0.0	0.0	N/A	11.5	+	11.1	-3.1	8.8	-20.9	22.1	152.3	0.0	4.3	+	6.8	57.1	3.2	-53.2	2.9	-8.6	
TOTAL	100.0	100.0		100.0		100.0		100.0		100.0		100.0	100.0		100.0		100.0		100.0		
Environmental Parameters																					
Mean Slope (degrees)	~	21.8		46.5		55.0		~		~		~	6.3		1.4		~		~		
Mean Topography (m) *	2.0	1.6		1.4		1.3		~		~		~	1.3		0.9		~		~		
Mean Depth/Range (m)	2-7	6.5		7.6		7.5		~		~		2.0	2.4		2.5		~		~		
Horizontal Visibility (m)	~	27.8		28.5		27.3		~		35		~	28.7		28.6		~		35		
No. of 50 m Transects	3	18		17		17		9		8		3	15		15		15		5		
~ no data available																					
* mean distance between lowest and highest point on the horizontal transect line																					

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 15. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at SR-4 (South Reef) Northwest Corner of the South Atoll from 1992 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=5)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1992	2000		2004		2008		2012			
	Species			Species		Species		Species			
Surgeonfish (Acanthurids)*	12.0	7.0	-41.7	7.8	10.7	5.8	-24.7	3.4	-41.4	6.3	83.8
Rabbitfish (Siganids)*	0.0	0.8	+	1.0	20.0	0.3	-66.7	0.6	100.0	1.0	66.7
Groupers (Serranids)*	3.0	4.3	44.4	3.4	-22.1	3.8	13.6	1.8	-52.6	3.3	80.6
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	3.0	1.2	-61.1	3.1	167.9	2.0	-36.0	2.0	0.0	1.3	-37.5
Sweetlips (Haemulids)*	1.0	0.2	-83.3	0.3	50.0	1.0	300.0	0.2	-80.0	2.0	900.0
Emperors (Lethrinids)*	0.0	0.5	+	0.9	75.0	0.8	-4.8	0.2	-75.0	0.3	25.0
Jacks (Carangids)*	1.0	0.5	-50.0	1.6	225.0	1.5	-7.7	1.4	-6.7	1.8	25.0
Fusiliers (Caesionids)*	1.0	0.5	-50.0	0.4	-25.0	1.5	300.0	1.6	6.7	2.8	71.9
Spinecheeks (Nemipterids)*	0.0	1.0	+	0.4	-62.5	0.2	-55.6	0.0	-100.0	0.5	N/A
Goatfish (Mullids)*	0.0	1.7	+	1.1	-32.5	0.8	-25.9	0.0	-100.0	0.3	N/A
Parrotfish (Scarids)*	1.0	2.5	150.0	2.1	-15.0	3.7	72.5	1.4	-62.2	3.8	167.9
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.0	0.0	N/A	1	+	0	-100.0	0.0	N/A	0.0	N/A
Triggerfish (Balistids)	5.0	5.0	0.0	3.0	-40.0	3.8	27.8	1.8	-52.6	2.5	38.9
Butterflyfish (Chaetodonids)	17.0	13.8	-18.6	12.5	-9.6	9.5	-24.0	3.2	-66.3	1.8	-45.3
Angelfish (Pomacanthids)	2.0	3.7	83.3	2.5	-31.8	3.5	40.0	1.2	-65.7	6.3	420.8
Wrasses (Labrids)	5.0	8.3	66.7	8.5	2.0	9.7	13.7	3.2	-67.0	1.8	-45.3
Humphead wrasse	~	~	N/A	0.4	N/A	0.3	-11.1	0.2	-33.3	5.0	2400.0
Damselfish (Pomacentrids)	10.0	7.8	-21.7	10.8	37.2	7.5	-30.2	3.4	-54.7	0.3	-92.6
Fairy Basslets (Anthids)	3.0	1.2	-61.1	1.5	28.6	2.5	66.7	1.0	-60.0	4.0	300.0
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	0.8	-25.0	1.0	33.3	0.4	-60.0	0.5	25.0
										0.0	
Total (target reef spp.):	22.0	16.7	-24.1	22.6	35.5	21.5	-5.0	12.8	-40.5	23.0	79.7
Total (all reef spp.):	65.0	61.0	-6.2	62.5	2.5	59.3	-5.1	27.0	-54.5	45.0	66.7

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 16. Mean ( $\pm$ SE) fish species density (fish/500m<sup>2</sup>) and percentage change between years at SR-4 (South Reef) Northwest Corner of the South Atoll from 1992 to 2014.

Family	(N=1)	(N=6)	% Change 1992-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014
	1992	2000		2004		2008		2012		2014	
	Density			Density		Density		Density		Density	
Surgeonfish (Acanthurids)*	324.0	215.2	-33.6	106.3	-50.6	45.0	-57.6	33.2	-26.2	49.5	49.1
Rabbitfish (Siganids)*	0.0	2.7	+	2.1	-20.3	0.3	-84.3	1.6	433.3	1.8	9.4
Groupers (Serranids)*	17.0	21.5	26.5	15.0	-30.2	20.7	37.8	4.8	-76.8	11.3	134.4
Barramundi cod	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	75.0	7.2	-90.4	28.6	299.4	9.7	-66.2	8.0	-17.5	17.3	115.6
Sweetlips (Haemulids)*	3.0	0.5	-83.3	0.5	0.0	9.2	1733.3	0.2	-97.8	13.3	6525.0
Emperors (Lethrinids)*	0.0	27.2	+	12.9	-52.6	2.2	-83.2	3.2	45.5	2.5	-21.9
Jacks (Carangids)*	9.0	22.2	146.3	13.6	-38.5	5.3	-60.9	4.2	-20.8	6.8	60.7
Fusiliers (Caesionids)*	129.0	15.8	-87.7	5.5	-65.3	116.5	2018.2	105.8	-9.2	62.5	-40.9
Spinecheeks (Nemipterids)*	0.0	24.3	+	5.5	-77.4	0.5	-90.9	0.0	-100.0	1.0	N/A
Goatfish (Mullids)*	0.0	20.0	+	8.4	-58.1	14.7	75.1	0.0	-100.0	0.5	N/A
Parrotfish (Scarids)*	129.0	39.5	-69.4	24.9	-37.0	18.2	-27.0	11.0	-39.6	95.3	765.9
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.0	0.0	N/A	128	+	0	-100.0	0.0	N/A	0.0	N/A
Triggerfish (Balistids)	537.0	1422.5	164.9	491.5	-65.4	157.0	-68.1	80.6	-48.7	14.5	-82.0
Butterflyfish (Chaetodonids)	86.0	62.8	-26.9	48.6	-22.6	25.5	-47.6	50.2	96.9	280.5	458.8
Angelfish (Pomacanthids)	36.0	63.7	76.9	12.9	-79.8	8.3	-35.3	4.2	-49.4	66.0	1471.4
Wrasses (Labrids)	213.0	123.8	-41.9	111.5	-10.0	48.8	-56.2	22.0	-54.9	3.8	-83.0
Humphead wrasse	~	~	N/A	0.6	N/A	0.3	-46.7	0.2	-33.3	31.0	15400.0
Damselfish (Pomacentrids)	978.0	2508.8	156.5	1010.4	-59.7	1059.0	4.8	707.2	-33.2	1.5	-99.8
Fairy Basslets (Anthids)	2307.0	1558.8	-32.4	1679.0	7.7	1582.0	-5.8	421.6	-73.4	176.5	-58.1
Moorish Idols ( <i>Zanclus cornutus</i> )	33.0	7.7	-76.8	3.6	-52.7	5.8	60.9	1.2	-79.3	3.3	170.8
										0.0	
Total (target reef spp.):	686.0	395.8	-42.3	292.6	-26.1	239.7	-18.1	172.2	-28.2	261.5	51.9
Total (all reef spp.):	4876.0	6144.2	26.0	3709.0	-39.6	3129.0	-15.6	1459.2	-53.4	838.5	-42.5

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

**Table 17. Changes in substrate composition (% mean ±SE) in SR-1 (South Reef) Lighthouse Islet from 1984 to 2014.**

SUBSTRATE COVER	SCUBA SURVEYS:															SNORKEL SURVEYS:												
	1984 % cover	1992 % cover	% Change 1984-1992	1996 % cover	% Change 1992-1996	2000 % cover	% Change 1996-2000	2004 % cover	% Change 2000-2004	2008 % cover	% Change 2004-2008	2012 % cover	% Change 2008-2012	2014 % cover	% Change 2012-2014	1984 % cover	1989 % cover	% Change 1984-1989	1992 % cover	% Change 1989-1992	2004 % cover	% Change 1992-2004	2008 % cover	% Change 2004-2008	2012 % cover	% Change 2008-2012	2014 % cover	% Change 2012-2014
Sand (s) and Silt (SI)	1.7	2.0	17.6	0.0	-100.0	2.9	+	1.3	-54.4	2.4	84.9	15.8	558.7	0.8	-95.1	0.5	3.6	620.0	14.6	305.6	3.0	-79.5	12.6	321.6	8.5	-32.3	5.0	-40.8
Coral Rubble (R)	8.3	13.1	57.8	16.7	27.5	16.6	-0.6	18.4	10.7	20.9	13.7	23.2	10.8	22.0	-5.0	3.5	20.6	488.6	20.5	-0.5	0.5	-97.7	8.6	1734.9	8.9	2.9	1.0	-88.2
Rock and Block (RK)	32.1	35.1	9.3	9.5	-72.9	3.4	-64.2	7.2	112.1	2.0	-71.9	8.8	342.3	6.3	-28.4	37.0	39.6	7.0	40.2	1.4	36.4	-9.3	40.1	10.1	38.5	-3.9	36.1	-6.4
White Dead Standing Coral (DC)	0.2	0.3	50.0	2.5	733.3	3.3	32.0	0.4	-86.6	0.8	80.0	0.6	-23.1	0.2	-63.9	5.0	5.1	2.0	0.5	-90.2	0.3	-37.9	2.8	812.1	0.3	-88.7	0.7	125.6
Dead Coral with Algae (DCA)	0.0	0.0	N/A	0.0	N/A	19.3	+	3.0	-84.4	5.5	81.3	4.2	-23.8	5.8	37.8	0.0	0.0	N/A	0.0	N/A	2.3	+	2.5	6.7	3.0	19.6	1.9	-37.9
<b>Subtotal Non-living Substrate</b>	<b>42.3</b>	<b>50.5</b>	<b>19.4</b>	<b>28.7</b>	<b>-43.2</b>	<b>45.5</b>	<b>58.5</b>	<b>30.4</b>	<b>-33.2</b>	<b>31.6</b>	<b>4.1</b>	<b>52.6</b>	<b>66.5</b>	<b>35.1</b>	<b>-33.3</b>	<b>46.0</b>	<b>68.9</b>	<b>49.8</b>	<b>75.8</b>	<b>9.9</b>	<b>42.5</b>	<b>-43.9</b>	<b>66.6</b>	<b>56.7</b>	<b>59.2</b>	<b>-11.1</b>	<b>44.7</b>	<b>-24.5</b>
Branching (CB)	33.6	29.5	-12.2	51.6	74.9	41.6	-19.4	25.9	-37.8	47.3	83.1	25.5	-46.1	34.1	33.8	25.0	15.2	-39.2	15.1	-0.7	13.2	-12.3	18.5	39.5	24.3	31.2	29.7	22.2
Massive (CM)	10.1	6.5	-35.6	3.0	-53.8	1.9	-36.7	6.5	243.3	1.3	-80.6	5.7	340.8	6.6	14.4	10.2	7.2	-29.4	3.8	-47.9	16.6	341.5	8.7	-47.4	9.6	10.4	13.7	43.1
Flat/Encrusting (CFD)	10.3	1.5	-85.4	3.8	153.3	3.3	-13.2	5.3	61.5	1.4	-74.6	1.2	-12.1	0.8	-36.8	9.2	3.2	-65.2	0.0	-100.0	17.4	+	2.1	-87.7	3.6	70.1	8.3	132.8
Foliose Cup (CFO)	0.1	1.1	1000.0	0.9	-18.2	0.5	-44.4	0.5	-1.2	0.4	-22.6	5.4	1246.2	9.8	82.6	1.8	0.9	-50.0	2.8	205.6	2.3	-16.8	0.7	-68.0	1.4	105.6	1.9	33.5
<b>Total Hard Coral</b>	<b>54.1</b>	<b>38.9</b>	<b>-28.1</b>	<b>59.3</b>	<b>52.4</b>	<b>47.3</b>	<b>-20.2</b>	<b>38.2</b>	<b>-19.2</b>	<b>50.3</b>	<b>31.7</b>	<b>37.8</b>	<b>-24.8</b>	<b>51.3</b>	<b>35.5</b>	<b>46.2</b>	<b>26.5</b>	<b>-42.6</b>	<b>21.6</b>	<b>-18.5</b>	<b>49.5</b>	<b>129.0</b>	<b>30.0</b>	<b>-39.3</b>	<b>38.9</b>	<b>29.6</b>	<b>53.6</b>	<b>37.9</b>
<b>Total Soft Coral</b>	<b>3.6</b>	<b>10.6</b>	<b>194.4</b>	<b>12.0</b>	<b>13.2</b>	<b>7.2</b>	<b>-40.0</b>	<b>25.1</b>	<b>248.9</b>	<b>16.3</b>	<b>-35.0</b>	<b>5.5</b>	<b>-66.3</b>	<b>5.5</b>	<b>0.0</b>	<b>7.8</b>	<b>4.6</b>	<b>-41.0</b>	<b>2.7</b>	<b>-42.4</b>	<b>0.6</b>	<b>-77.8</b>	<b>0.3</b>	<b>-48.9</b>	<b>0.8</b>	<b>181.5</b>	<b>0.6</b>	<b>-28.6</b>
<b>Subtotal Coral</b>	<b>57.7</b>	<b>49.5</b>	<b>-14.2</b>	<b>71.3</b>	<b>44.0</b>	<b>54.5</b>	<b>-23.6</b>	<b>63.3</b>	<b>16.2</b>	<b>66.7</b>	<b>5.3</b>	<b>43.3</b>	<b>-35.0</b>	<b>56.8</b>	<b>31.0</b>	<b>54.0</b>	<b>31.1</b>	<b>-42.4</b>	<b>24.3</b>	<b>-22.0</b>	<b>50.0</b>	<b>106.4</b>	<b>30.3</b>	<b>-39.4</b>	<b>39.7</b>	<b>31.1</b>	<b>54.2</b>	<b>36.5</b>
Sponges	~	~	N/A	~	N/A	~	N/A	1.7	N/A	0.5	-70.4	1.6	223.1	3.5	116.7	~	~	N/A	~	N/A	0.8	N/A	0.2	-74.1	0.1	-63.9	0.2	207.9
Other animals	~	~	N/A	~	N/A	~	N/A	1.0	N/A	0.5	-53.8	0.6	23.1	2.3	270.1	~	~	N/A	~	N/A	0.4	N/A	0.0	-90.6	0.19	N/A	0.4	96.2
Algae																												
Turf algae	~	~	N/A	~	N/A	~	N/A	0.8	N/A	0.2	-74.6	0.5	169.2	0.0	-100.0	~	~	N/A	~	N/A	1.1	N/A	0.7	-31.0	0.0	-94.4	0.0	-59.6
Fleshy algae	~	~	N/A	~	N/A	~	N/A	0.3	N/A	0.3	1.9	0.2	-23.1	0.0	-100.0	~	~	N/A	~	N/A	1.2	N/A	1.5	28.6	0.4	-72.2	0.1	-84.8
Coralline algae	~	~	N/A	~	N/A	~	N/A	2.5	N/A	0.2	-91.6	1	400.0	2.3	133.3	~	~	N/A	~	N/A	4.0	N/A	0.5	-86.8	0.3	-35.6	0.3	8.3
Seagrass	~	~	N/A	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0	N/A
<b>Subtotal Others</b>	<b>0.0</b>	<b>0.0</b>	<b>N/A</b>	<b>0.0</b>	<b>N/A</b>	<b>0.0</b>	<b>N/A</b>	<b>6.3</b>	<b>+</b>	<b>1.7</b>	<b>-72.9</b>	<b>4.0</b>	<b>137.6</b>	<b>8.1</b>	<b>100.8</b>	<b>0.0</b>	<b>0.0</b>	<b>N/A</b>	<b>0.0</b>	<b>N/A</b>	<b>7.4</b>	<b>+</b>	<b>3.0</b>	<b>-59.1</b>	<b>1.0</b>	<b>-65.2</b>	<b>1.0</b>	<b>-1.2</b>
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100</b>		<b>100.0</b>		<b>100.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>	
<b>Environmental Parameters</b>																												
Mean Slope (degrees)	~	~		~		16.2		21.7		27.2		~		~		~	~		~		8.3		2.5		~		~	
Mean Topography (m) *	1.5	4.0		2.3		2.7		1.6		1.7		~		~		1.5	1.5		0.5		0.6		1.6		~		~	
Mean Depth/Range (m)	1.5-15	5-10		7-10		7.5		7.7		7.6		~		~		2-7	2-7		1.5		2.9		2.3		~		~	
Horizontal Visibility (m)	~	30.0		25.0		27.8		25.0		31.3		~		50		~	~		~		25.9		28.8		~		50	
No. of 50 m Transects	1	4		8		16		17		17		13		9		1	3		2		17		10		18		21	
~ no data available																												

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 18. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at SR-1 (South Reef) Lighthouse from 1992 to 2014.

Family	(N=1) 1992	(N=3) 1996	% Change 1992- 1996	(N=8) 2000	% Change 1996- 2000	(N=5) 2004	% Change 2000- 2004	(N=4) 2008	% Change 2004- 2008	(N=8) 2012	% Change 2008- 2012	(N=10) 2014	% Change 2012- 2014
	Species	Species		Species		Species		Species		Species		Species	
Surgeonfish (Acanthurids)*	8.0	5.0	-37.5	5.7	13.3	5.9	3.7	6.6	11.9	5.3	-19.7	5.6	5.7
Rabbitfish (Siganids)*	2.0	1.0	-50.0	1.8	83.3	0.3	-86.4	0.9	242.9	0.5	-44.4	0.4	-20.0
Groupers (Serranids)*	4.0	2.3	-43.8	2.5	11.1	2.6	5.0	4.0	52.4	3.3	-17.5	3.8	15.2
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	2.0	0.8	-62.5	0.8	11.1	1.6	95.0	3.1	93.4	1.0	-67.7	4.2	320.0
Sweetlips (Haemulids)*	1.0	0.0	-100.0	0.2	+	0.1	-25.0	0.3	128.6	0.5	66.7	0.5	0.0
Emperors (Lethrinids)*	0.0	0.3	+	1.0	300.0	1.0	0.0	1.3	28.6	0.3	-76.9	1.0	233.3
Jacks (Carangids)*	1.0	0.5	-50.0	1.0	100.0	0.9	-12.5	1.9	112.2	2.0	5.3	1.8	-10.0
Fusiliers (Caesionids)*	1.0	1.0	0.0	0.3	-66.7	0.6	87.5	1.4	128.6	0.5	-64.3	1.7	240.0
Spinecheeks (Nemipterids)*	0.0	0.8	+	0.5	-33.3	0.6	25.0	0.7	14.3	0.0	-100.0	0.3	N/A
Goatfish (Mullids)*	1.0	0.8	-25.0	0.5	-33.3	1.5	200.0	0.1	-90.5	1.0	900.0	0.5	-50.0
Parrotfish (Scarids)*	1.0	2.0	100.0	4.0	100.0	2.3	-43.8	2.3	1.6	2.8	21.7	2.5	-10.7
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.2	N/A
Triggerfish (Balistids)	4.0	1.8	-56.3	4.3	147.6	4.1	-4.8	3.6	-13.4	3.5	-2.8	3.4	-2.9
Butterflyfish (Chaetodonids)	8.0	12.3	53.1	10.2	-17.0	12.0	18.0	11.4	-4.8	6.0	-47.4	1.7	-71.7
Angelfish (Pomacanthids)	2.0	1.5	-25.0	2.8	88.9	3.9	36.8	2.6	-33.6	2.5	-3.8	7.3	192.0
Wrasses (Labrids)	5.0	4.8	-5.0	5.8	22.8	9.4	60.7	6.9	-26.9	4.0	-42.0	2.0	-50.0
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	128.6	0.5	66.7	4.3	760.0
Damselfish (Pomacentrids)	13.0	7.0	-46.2	7.3	4.8	8.5	15.9	7.9	-7.6	6.3	-20.3	0.5	-92.1
Fairy Basslets (Anthids)	2.0	2.5	25.0	1.8	-26.7	2.1	15.9	2.1	0.8	1.5	-28.6	6.0	300.0
Moorish Idols ( <i>Zanclus cornutus</i> )	1.0	1.0	0.0	1.0	0.0	0.9	-12.5	0.9	-2.0	0.5	-44.4	0.9	80.0
												0.0	
<b>Total (target reef spp.):</b>	<b>21.0</b>	<b>14.3</b>	<b>-31.9</b>	<b>18.3</b>	<b>28.0</b>	<b>17.4</b>	<b>-5.1</b>	<b>17.4</b>	<b>0.3</b>	<b>17.5</b>	<b>0.6</b>	<b>22.5</b>	<b>28.6</b>
<b>Total (all reef spp.):</b>	<b>56.0</b>	<b>45.0</b>	<b>-19.6</b>	<b>51.7</b>	<b>14.9</b>	<b>58.4</b>	<b>12.9</b>	<b>58.1</b>	<b>-0.4</b>	<b>41.8</b>	<b>-28.1</b>	<b>48.6</b>	<b>16.3</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 19. Mean ( $\pm$ SE) fish species density (density/500m<sup>2</sup>) and percentage change between years at SR-1 (South Reef) Lighthouse from 1992 to 2014.

Family	(N=1) 1992	(N=3) 1996	% Change 1992- 1996	(N=8) 2000	% Change 1996- 2000	(N=5) 2004	% Change 2000- 2004	(N=4) 2008	% Change 2004- 2008	(N=8) 2012	% Change 2008- 2012	(N=10) 2014	% Change 2012- 2014
	Density	Density		Density		Density		Density		Density		Species	
Surgeonfish (Acanthurids)*	232.0	82.0	-64.7	158.0	92.7	145.1	-8.1	66.6	-54.1	55.0	-17.4	58.6	6.5
Rabbitfish (Siganids)*	2.0	4.5	125.0	4.5	0.0	0.6	-86.1	1.9	197.1	1.0	-47.4	1.0	0.0
Groupers (Serranids)*	13.0	8.3	-36.5	17.8	116.2	13.4	-25.0	18.4	37.8	5.5	-70.1	11.9	116.4
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	18.0	11.3	-37.5	1.8	-83.7	6.6	261.4	11.3	70.4	2.0	-82.3	14.8	640.0
Sweetlips (Haemulids)*	9.0	0.0	-100.0	0.3	+	5.6	1587.5	2.1	-61.9	4.0	90.5	2.3	-42.5
Emperors (Lethrinids)*	0.0	0.8	+	11.5	1433.3	46.6	305.4	6.0	-87.1	0.3	-95.0	6.7	2133.3
Jacks (Carangids)*	9.0	2.5	-72.2	3.7	46.7	7.6	108.0	118.3	1451.3	170.3	44.0	93.6	-45.0
Fusiliers (Caesionids)*	129.0	21.0	-83.7	5.2	-75.4	29.6	473.4	162.6	448.8	18.8	-88.4	112.4	497.9
Spinecheeks (Nemipterids)*	0.0	42.8	+	0.8	-98.1	1.3	50.0	2.6	105.7	0.0	-100.0	1.0	N/A
Goatfish (Mullids)*	9.0	66.8	641.7	22.2	-66.8	10.3	-53.8	0.7	-93.0	5.8	728.6	1.6	-72.4
Parrotfish (Scarids)*	129.0	43.5	-66.3	140.2	222.2	14.0	-90.0	6.9	-51.0	30.5	342.0	11.1	-63.6
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.0	N/A	1.1	N/A
Triggerfish (Balistids)	148.0	45.3	-69.4	129.8	186.9	333.3	156.7	20.4	-93.9	36.0	76.5	38.3	6.4
Butterflyfish (Chaetodonids)	33.0	35.3	6.8	34.0	-3.5	45.4	33.5	45.7	0.7	34.5	-24.5	646.5	1773.9
Angelfish (Pomacanthids)	34.0	14.0	-58.8	26.8	91.7	17.9	-33.4	10.4	-41.7	5.3	-49.0	27.1	411.3
Wrasses (Labrids)	87.0	40.0	-54.0	179.0	347.5	62.4	-65.2	52.1	-16.4	17.0	-67.4	4.5	-73.5
Humphead wrasse	~	~	N/A	~	N/A	0.3	N/A	0.4	71.4	0.8	100.0	17.9	2137.5
Damselfish (Pomacentrids)	1221.0	2232.0	82.8	2805.2	25.7	2042.5	-27.2	2282.6	11.8	2102.5	-7.9	1.0	-100.0
Fairy Basslets (Anthids)	1026.0	802.5	-21.8	762.0	-5.0	1557.3	104.4	1945.7	24.9	678.3	-65.1	887.0	30.8
Moorish Idols ( <i>Zanclus cornutus</i> )	33.0	27.0	-18.2	13.8	-48.8	4.9	-64.8	3.4	-29.7	1.8	-47.1	4.5	150.0
												0.0	
<b>Total (target reef spp.):</b>	<b>550.0</b>	<b>283.3</b>	<b>-48.5</b>	<b>366.0</b>	<b>29.2</b>	<b>235.5</b>	<b>-35.7</b>	<b>372.9</b>	<b>58.3</b>	<b>293.8</b>	<b>-21.2</b>	<b>316.1</b>	<b>7.6</b>
<b>Total (all reef spp.):</b>	<b>3132.0</b>	<b>3479.3</b>	<b>11.1</b>	<b>4316.7</b>	<b>24.1</b>	<b>4344.5</b>	<b>0.6</b>	<b>4758.1</b>	<b>9.5</b>	<b>3169.0</b>	<b>-33.4</b>	<b>1942.9</b>	<b>-38.7</b>

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase



**Table 20. Changes in substrate composition (% mean  $\pm$ SE) in Jessie Beazley from 1984 to 2014.**

	SCUBA SURVEYS							SNORKEL SURVEYS:										
	2004	2008	% Change	2012	% Change	2014	% Change	1984	1989	% Change	2004	% Change	2008	% Change	2012	% Change	2014	% Change
SUBSTRATE COVER	% cover	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014	% cover	% cover	1992-1996	% cover	1996-2000	% cover	2004-2008	% cover	2008-2012	% cover	2012-2014
Sand (s) and Silt (SI)	7.0	3.7	-47.4	9.4	154.5	2.9	-69.7	5.0	3.0	-40.0	5.4	78.5	10.2	90.0	7.7	-24.2	9.3	19.8
Coral Rubble (R)	16.0	6.3	-60.7	6.4	1.9	3.5	-45.5	11.9	10.6	-10.9	3.6	-65.9	15.8	338.1	5.1	-68.0	14.5	187.0
Rock and Block (RK)	13.1	14.4	9.6	7.8	-45.6	5.1	-35.5	35.9	48.0	33.7	33.5	-30.3	33.3	-0.6	32.9	-1.1	26.3	-20.0
White Dead Standing Coral (DC)	2.0	0.3	-85.0	0.4	38.9	0.9	104.0	7.0	6.3	-10.0	0.1	-98.8	0.5	600.0	1.2	143.6	0.3	-78.2
Dead Coral with Algae (DCA)	4.3	4.8	11.1	<b>3.3</b>	-32.3	4.4	35.4	0.0	0.0	N/A	3.4	+	4.4	28.6	<b>2.0</b>	-55.6	2.3	16.0
<b>Subtotal Non-living Substrate</b>	<b>42.5</b>	<b>29.5</b>	<b>-30.6</b>	<b>27.3</b>	<b>-7.3</b>	<b>16.7</b>	<b>-39.1</b>	<b>59.8</b>	<b>67.9</b>	<b>13.5</b>	<b>45.9</b>	<b>-32.4</b>	<b>64.2</b>	<b>39.8</b>	<b>48.9</b>	<b>-23.8</b>	<b>52.7</b>	<b>7.7</b>
Branching (CB)	18.4	18.5	0.5	22.5	21.6	29.2	29.8	14.6	4.3	-70.5	14.1	228.0	18.4	30.6	23.1	25.3	21.5	-6.6
Massive (CM)	5.9	6.7	12.8	10.8	61.7	7.7	-28.9	10.5	9.3	-11.4	6.9	-26.0	9.3	35.4	12.0	28.6	9.3	-22.5
Flat/Encrusting (CFD)	10.6	13.7	28.7	1.6	-88.4	5.5	247.4	10.5	4.0	-61.9	24.2	503.8	5.1	-78.7	9.3	82.4	9.0	-3.2
Foliose Cup (CFO)	1.3	1.5	17.1	<b>14.2</b>	844.4	14.5	2.0	0.8	2.3	187.5	0.8	-64.3	2.2	163.0	<b>4.6</b>	109.5	5.9	28.7
<b>Total Hard Coral</b>	<b>36.3</b>	<b>40.4</b>	<b>11.4</b>	<b>49.1</b>	<b>21.5</b>	<b>56.9</b>	<b>15.8</b>	<b>36.4</b>	<b>19.8</b>	<b>-45.6</b>	<b>46.0</b>	<b>132.1</b>	<b>35.0</b>	<b>-23.8</b>	<b>48.9</b>	<b>39.8</b>	<b>45.7</b>	<b>-6.5</b>
<b>Total Soft Coral</b>	<b>15.6</b>	<b>25.1</b>	<b>61.3</b>	<b>11.3</b>	<b>-55.2</b>	<b>21.8</b>	<b>93.3</b>	<b>3.8</b>	<b>12.3</b>	<b>223.7</b>	<b>2.5</b>	<b>-79.9</b>	<b>0.1</b>	<b>-97.9</b>	<b>0.0</b>	<b>-100.0</b>	<b>1.5</b>	#DIV/0!
<b>Subtotal Coral</b>	<b>51.8</b>	<b>65.5</b>	<b>26.4</b>	<b>60.3</b>	<b>-7.9</b>	<b>78.6</b>	<b>30.3</b>	<b>40.2</b>	<b>32.1</b>	<b>-20.1</b>	<b>48.4</b>	<b>50.9</b>	<b>35.1</b>	<b>-27.6</b>	<b>48.9</b>	<b>39.4</b>	<b>47.2</b>	<b>-3.5</b>
Sponges	1.4	1.3	-11.1	2.6	98.7	1.6	-40.0	~	~	N/A	0.5	N/A	0.5	1.5	0.6	21.8	0.0	-100.0
Other animals	0.5	0.9	86.7	0.5	-44.4	1.2	140.0	~	~	N/A	0.0	N/A	0.1	+	0.2	136.4	0.1	-43.3
Algae																		
Turf algae	0.2	0.7	332.0	0.2	-76.2	0.2	20.0	~	~	N/A	1.3	N/A	0.0	-100.0	0.8	N/A	0.0	-100.0
Fleshy algae	0.3	0.1	-60.0	1.8	1650.0	0.1	-94.3	~	~	N/A	1.7	N/A	0.1	-97.0	0.3	172.7	0.0	-100.0
Coralline algae	3.4	2.2	-37.5	7	218.2	1.7	-75.7	~	~	N/A	2.1	N/A	0.1	-97.3	0.3	163.6	0.0	-100.0
Seagrass	0.0	0.0	N/A	<b>0.3</b>	N/A	0.00	N/A	~	~	N/A	0.0	N/A	0.0	N/A	<b>0.0</b>	N/A	0.0	N/A
<b>Subtotal Others</b>	<b>5.7</b>	<b>5.1</b>	<b>-11.7</b>	<b>12.3</b>	<b>141.8</b>	<b>4.8</b>	<b>-61.5</b>	~	~	<b>N/A</b>	<b>5.6</b>	<b>N/A</b>	<b>0.7</b>	<b>-86.9</b>	<b>2.2</b>	<b>210.4</b>	<b>0.1</b>	<b>-93.8</b>
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>		<b>100</b>		<b>100.0</b>		<b>100.0</b>	<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>	
<b>Environmental Parameters</b>																		
Mean Slope (degrees)	17.3	46.7		~		~					7		3.5		~		~	
Mean Topography (m) *	0.7	0.7		~		~					1.5		0.7		~		~	
Mean Depth/Range (m)	6.9	7.2		~		~					2.7		2.5		~		~	
Horizontal Visibility (m)	29.7	29.7		~		30					26.7		28.5		~		30	
No. of 50 m Transects	16.0	20.0		6		10					13		13.0		11		13	
~ no data available																		

% change = [(Yr 2/Yr 1)-1] x 100

(-) = decrease

(+) = increase

Table 21. Mean ( $\pm$ SE) fish species richness (species/500m<sup>2</sup>) and percentage change between years at Jessie Beazley from 2004 to 2014.

Family	(N=7)	(N=8)	% Change 2004-2008	(N=5)	% Change 2008-2012	(N=5)	% Change 2012-2014
	2004	2008		2012		2014	
	Species			Species		Species	
Surgeonfish (Acanthurids)*	5.9	5.5	-6.1	3.2	-41.8	7.4	131.3
Rabbitfish (Siganids)*	0.3	0.2	-41.7	0.2	0.0	0.0	-100.0
Groupers (Serranids)*	2.3	2.2	-5.2	1.4	-36.4	3.4	142.9
Barramundi cod	0.0	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	0.6	0.8	45.8	1.2	50.0	1.6	33.3
Sweetlips (Haemulids)*	0.1	0.0	-100.0	0.6	N/A	0.4	-33.3
Emperors (Lethrinids)*	1.3	0.7	-48.1	0.2	-71.4	0.8	300.0
Jacks (Carangids)*	0.1	1.0	600.0	0.0	-100.0	0.4	N/A
Fusiliers (Caesionids)*	0.4	1.7	288.9	1.2	-29.4	2.0	66.7
Spinecheeks (Nemipterids)*	0.0	0.0	N/A	0.0	N/A	0.4	N/A
Goatfish (Mullids)*	1.4	1.3	-6.7	0.6	-53.8	1.2	100.0
Parrotfish (Scarids)*	1.1	1.3	16.7	1.0	-23.1	1.4	40.0
Bumphead parrotfish	0.0	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.1	0.0	-100.0	0.2	N/A	0.2	0.0
Triggerfish (Balistids)	3.6	3.3	-6.7	1.6	-51.5	4.2	162.5
Butterflyfish (Chaetodonids)	7.6	6.2	-18.6	4.6	-25.8	2.4	-47.8
Angelfish (Pomacanthids)	2.4	3.0	23.5	1.2	-60.0	10.4	766.7
Wrasses (Labrids)	9.0	7.5	-16.7	2.4	-68.0	2.6	8.3
Humphead wrasse	0.0	0.0	N/A	0.0	N/A	6.6	N/A
Damselfish (Pomacentrids)	9.0	6.2	-31.5	4.6	-25.8	0.4	-91.3
Fairy Basslets (Anthids)	1.7	2.0	16.7	1.4	-30.0	7.0	400.0
Moorish Idols ( <i>Zanclus cornutus</i> )	0.7	0.8	16.7	0.8	0.0	1.0	25.0
Total (target reef spp.):	13.7	16.5	20.3	9.8	-40.6	19.2	95.9
Total (all reef spp.):	47.7	43.7	-8.5	26.4	-39.6	53.8	103.8

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

Table 22. Mean ( $\pm$ SE) fish species density (fish/500m<sup>2</sup>) and percentage change between years at Jessie Beazley from 2004 to 2014.

Family	(N=7)	(N=8)	% Change 2004-2008	(N=5)	% Change 2008-2012	(N=5)	% Change 2012-2014
	2004	2008		2012		2014	
	Density			Density		Density	
Surgeonfish (Acanthurids)*	172.9	81.0	-53.1	28.2	-65.2	106.2	276.6
Rabbitfish (Siganids)*	0.7	0.3	-53.3	0.4	33.3	0.0	-100.0
Groupers (Serranids)*	12.0	12.3	2.8	3.4	-72.4	11.8	247.1
Barramundi cod	0.0	0.0	N/A	0.0	N/A	0.0	N/A
Snapper (Lutjanids)*	3.1	1.5	-52.3	2.4	60.0	7.8	225.0
Sweetlips (Haemulids)*	0.4	0.0	-100.0	0.8	N/A	0.8	0.0
Emperors (Lethrinids)*	4.6	2.2	-52.6	1.2	-45.5	13.2	1000.0
Jacks (Carangids)*	0.1	8.5	5850.0	0.0	-100.0	1.8	N/A
Fusiliers (Caesionids)*	20.3	68.3	236.9	35.2	-48.5	65.2	85.2
Spinecheeks (Nemipterids)*	0.0	0.0	N/A	0.0	N/A	0.6	N/A
Goatfish (Mullids)*	12.9	3.8	-70.2	1.6	-57.9	4.4	175.0
Parrotfish (Scarids)*	3.7	4.3	16.7	1.8	-58.1	7.0	288.9
Bumphead parrotfish	0.0	0.0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.1	0.0	-100.0	0.4	N/A	0.2	-50.0
Triggerfish (Balistids)	192.9	110.2	-42.9	36.4	-67.0	36.8	1.1
Butterflyfish (Chaetodonids)	34.9	46.7	33.9	41.4	-11.3	817.6	1874.9
Angelfish (Pomacanthids)	17.6	8.8	-49.7	1.8	-79.5	97.0	5288.9
Wrasses (Labrids)	105.4	48.5	-54.0	8.6	-82.3	4.0	-53.5
Humphead wrasse	0.0	0.0	N/A	0.0	N/A	20.2	N/A
Damselfish (Pomacentrids)	592.3	295.2	-50.2	640.2	116.9	0.4	-99.9
Fairy Basslets (Anthids)	564.9	881.3	56.0	614.6	-30.3	326.6	-46.9
Moorish Idols ( <i>Zanclus cornutus</i> )	12.4	6.8	-45.0	3.8	-44.1	7.0	84.2
						0.0	
Total (target reef spp.):	185.4	150.8	-18.7	75.4	-50.0	219.0	190.5
Total (all reef spp.):	1751.1	1579.8	-9.8	1422.2	-10.0	1528.6	7.5

\* Target species/families

% change = [(Yr2/Yr1)-1] x 100

(-) = decrease

(+) = increase

## SUMMARY OF RESULTS AND TRENDS

### Large Marine Life

Known for its large marine life, Tubbataha has attracted tourists internationally to enjoy the sightings of turtles, Humphead wrasses, Bumphead parrotfish, manta rays, sharks, whalesharks, and other large marine species that are not commonly sighted in reefs around the Philippines. The presence of such marine life indicates reef health and relatively good protection from fishing pressure wherein changes of this kind of fauna can be used as a gauge of ecosystem health and/or fishing pressure of an area (Green et al. 2003). During the 2014 SPR expedition, there was a significant number of large marine animals seen that appeared to have increased in number when compared to previous years, the most recent comparison being 2012. Figure 24 illustrates the gradual increase and fluctuations in number of large marine life sightings in Tubbataha Reefs from 1984 to 2014. It is notable that there have been significant increases in the number of turtles, sharks, and Humphead wrasse sightings in 2014 as compared to earlier years. In contrast, large rays, tuna and mackerel are not as abundant as in the past, which possibly reflects heavier fishing pressure in areas outside the boundaries of Tubbataha Park.

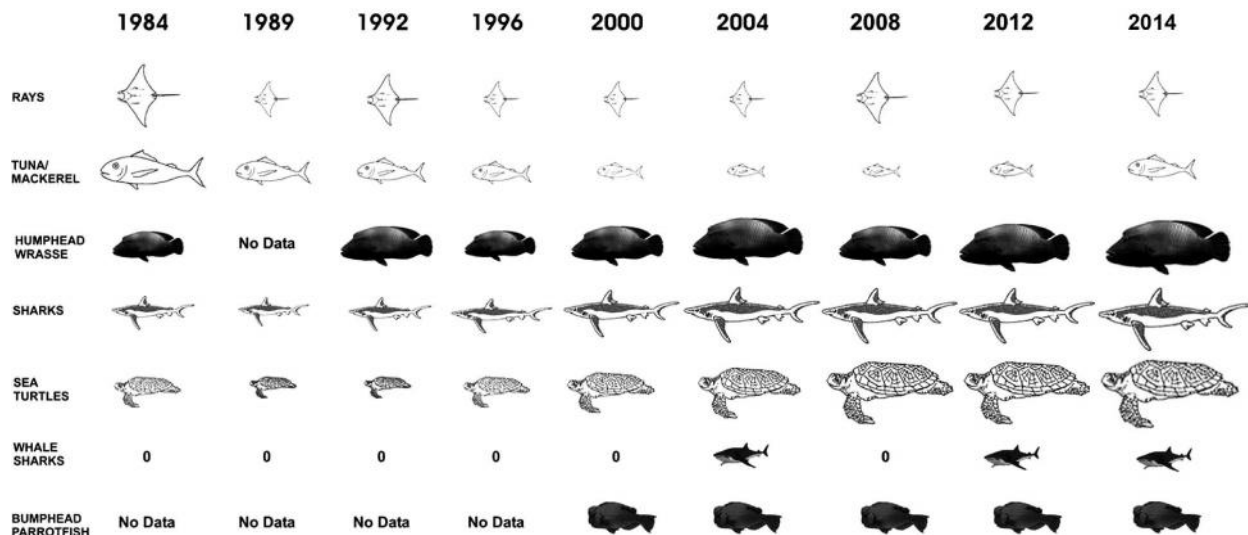


Figure 24. Changes in abundance of large marine life from 1984 to 2014.

### Coral Reef and Other Substrate

Tubbataha Reefs Natural Park's live hard coral cover in all dive sites range between fair and good in both the deep and shallow areas. However, since 2012, several sites showed small decreases, such as SR-4 ( $42.28\% \pm 8.24$ ) and Jessie Beazley ( $45.73\% \pm 4.12$ ) in the shallow reefs (Figure 25). SR-4 experienced a decline in LHC ( $32.64\% \pm 2.91$ ) in the deep reef from 2012 when it recorded at  $51.28\% \pm 10.66$  (Figure 26). Overall the survey sites display increasing trends in live hard coral cover, the highest of which was in SR-1 ( $53.63\% \pm 2.84$ ) for the shallow reef and NR-2 ( $58.56\% \pm 4.59$ ) for the deep reef as shown in Figures 25 and 26.

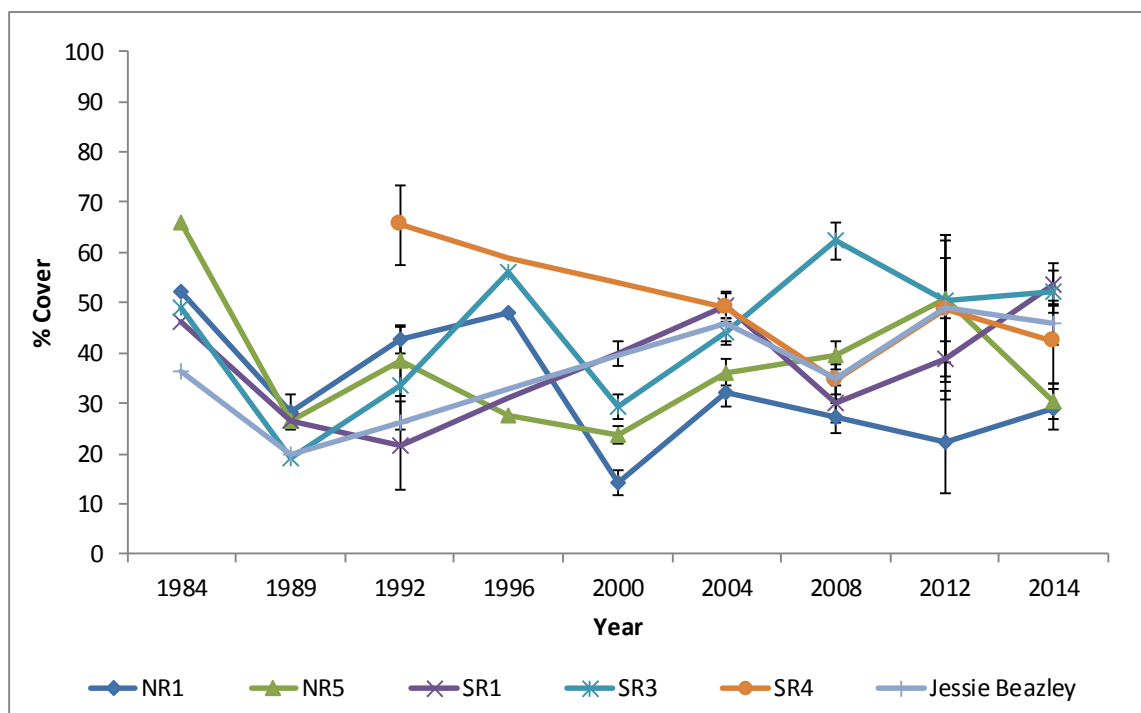


Figure 25. Changes in substrate composition (%mean  $\pm$ SE) in Tubbataha Reefs Marine Park from 1984 to 2014, 3-4m depth.

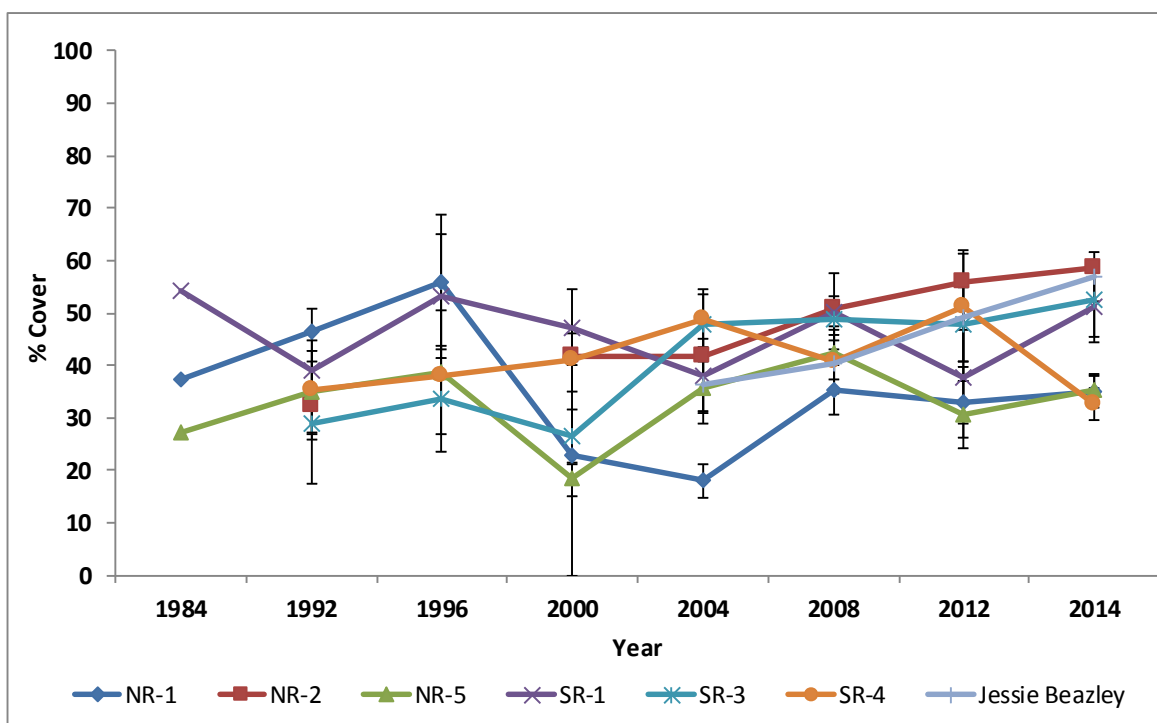


Figure 26. Changes in substrate composition (%mean  $\pm$ SE) in Tubbataha Reefs Marine Park from 1984 to 2014, 7-10m depth.

## Fish Diversity, Abundance, and Biomass

In 2014 there was a slight rise in target fish/500m<sup>2</sup> in all study sites of Tubbataha reefs from 2012 to 2014. However, the general trend in the mean fish density for all reef fish species was a decline (Figure 28), except for Jessie Beazley (1,528.6 fish/500m<sup>2</sup>), NR-2 (2,028.6 fish/500m<sup>2</sup>), and NR-1 (938.6 fish/500m<sup>2</sup>) where there were slight increases (Figure 27). But in terms of fish species richness for target fish species and all reef fish species, there have been significant increases since 2012 (Figure 29 and Figure 30). This is the same for the general trend in fish density of target fish species for all sites when compared to 2012 data (Figure 27). The area that has shown a consistently high, as well as increasing, biomass from 2004 to 2014 is in SR-1, Lighthouse Islet reef where the survey team has consistently encountered large schools of jacks and snappers. In 2014, a massive school of jacks pushed up the biomass significantly (Figure 31).

A general trend for fish among all the sites is to see fewer total fish, especially of the species with small adults that tend to be food for larger predators. At the same time the total biomass of fish has increased in all the sites reflecting the more and larger target species and especially predator species such as jacks, grouper, sharks, barracuda and a few others.

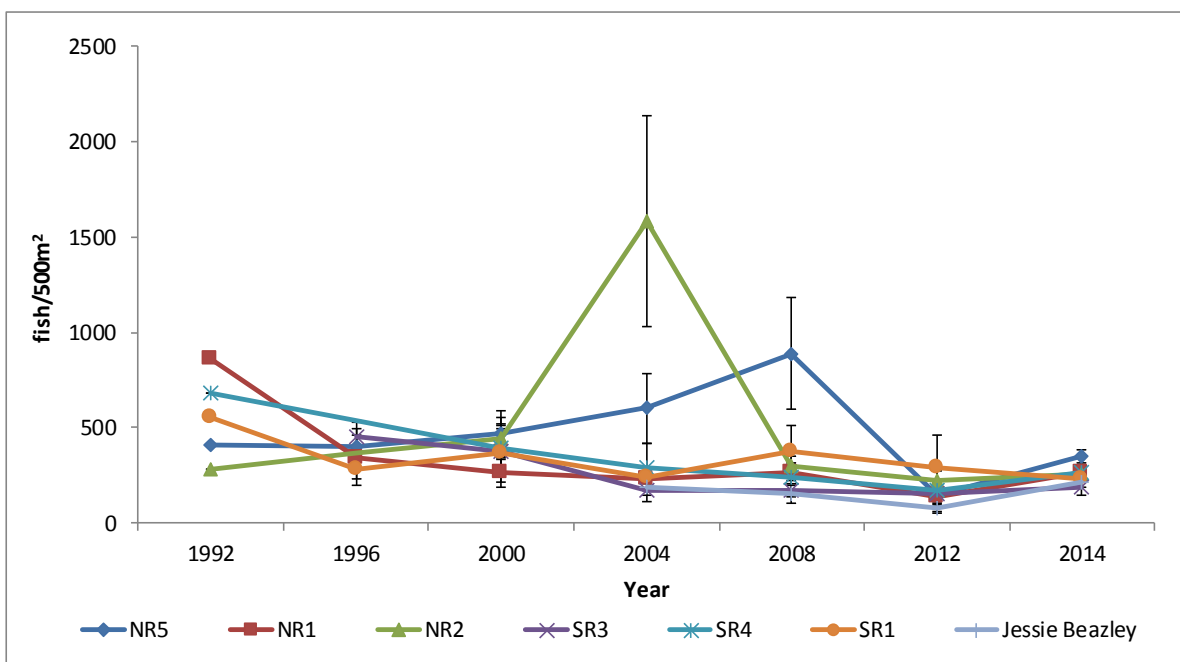


Figure 27. Mean (mean  $\pm$ SE) fish density (fish/500 m<sup>2</sup>) of target fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2014.

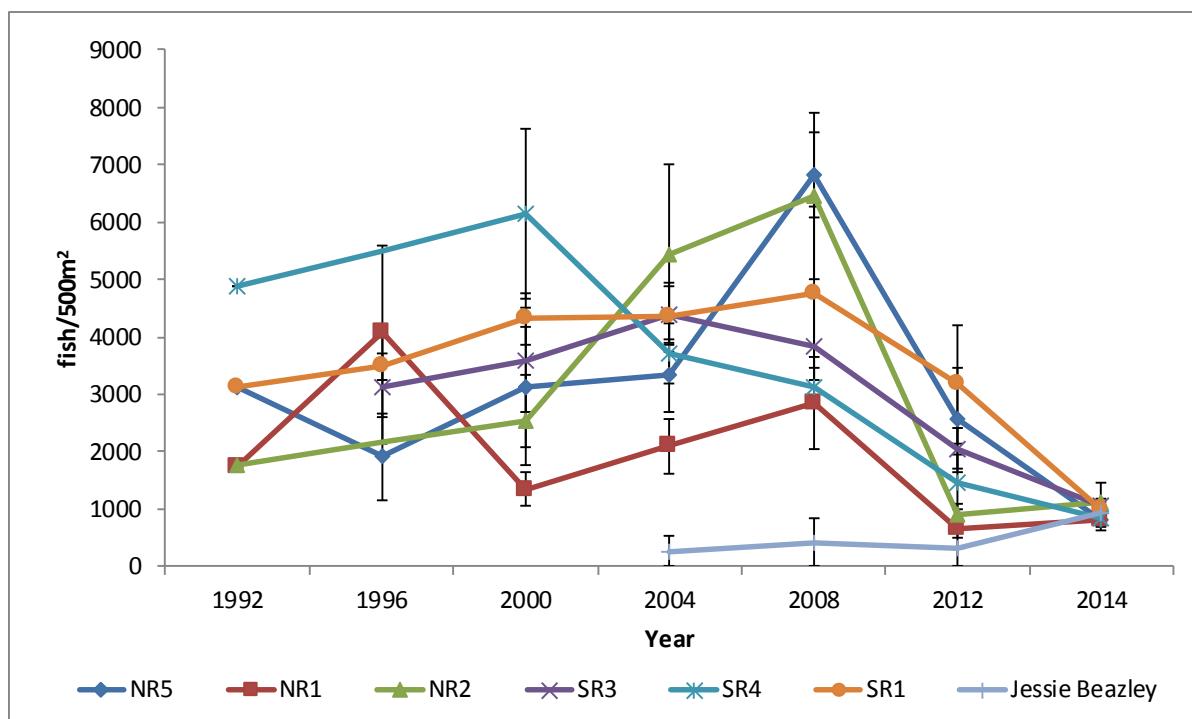


Figure 28. Mean (mean  $\pm$  SE) fish density (fish/500 m<sup>2</sup>) of all reef fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2014.

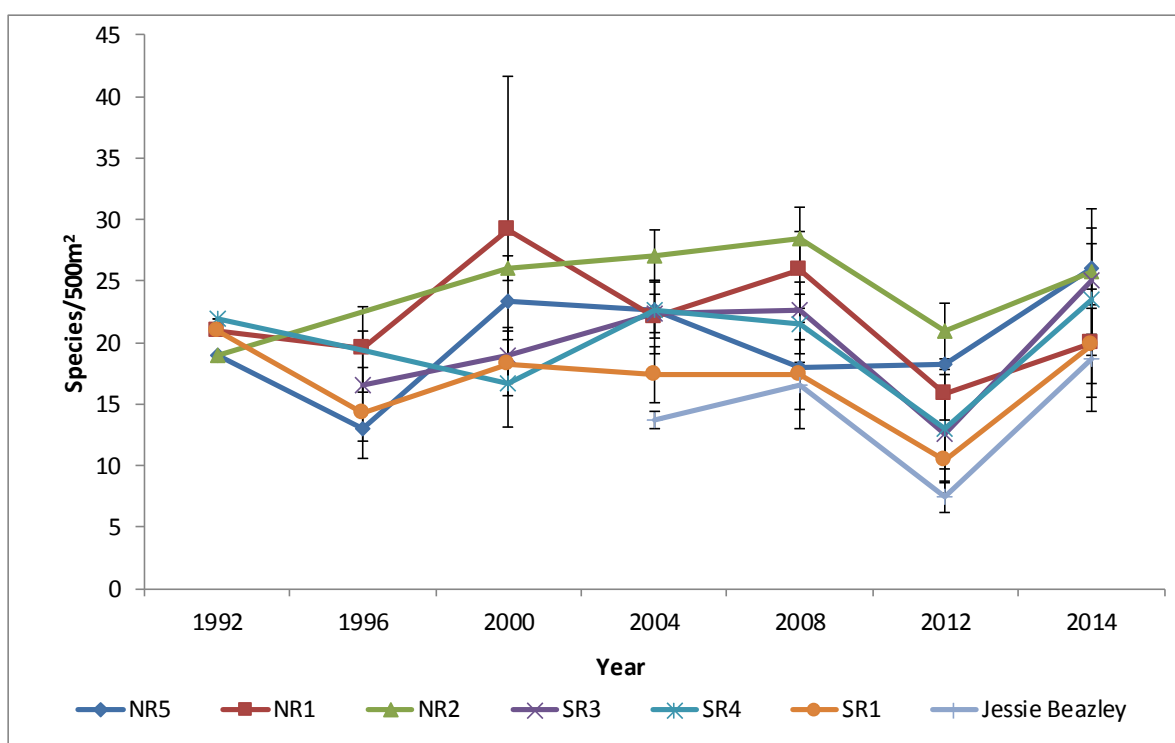


Figure 29. Mean ( $\pm$  SE) species (species/500 m<sup>2</sup>) of target fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2014.

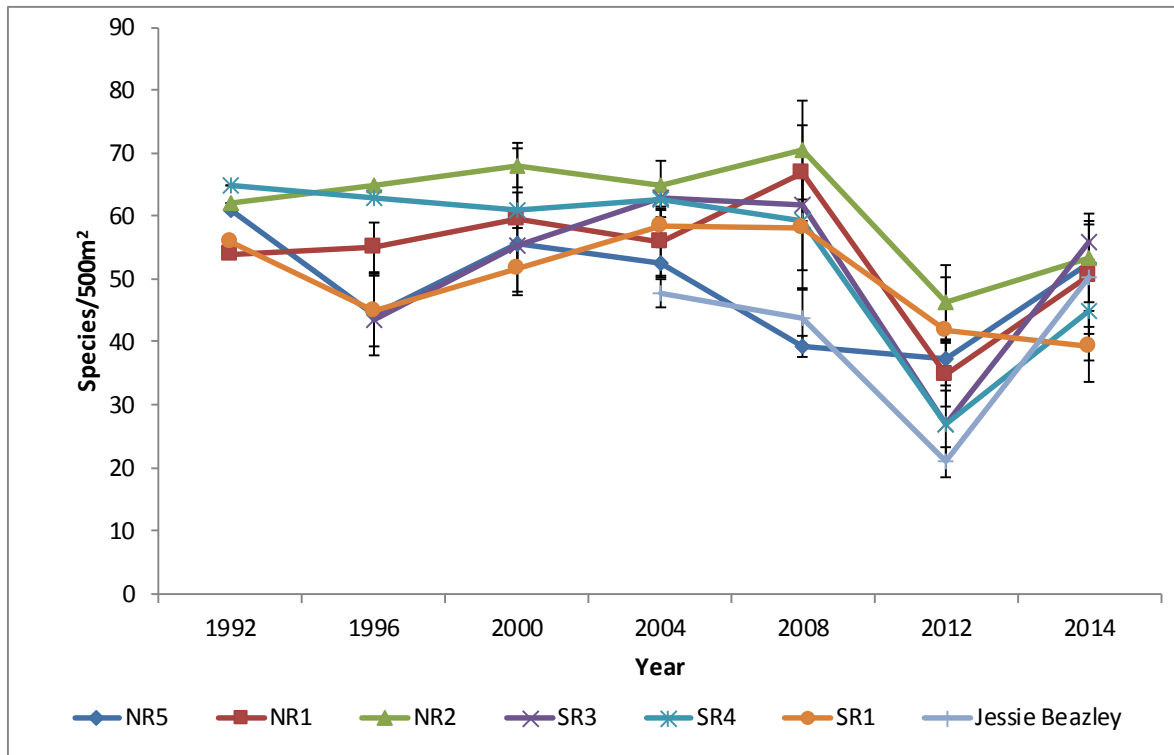


Figure 30. Mean (±SE) species (species/500 m<sup>2</sup>) of all reef species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2014.

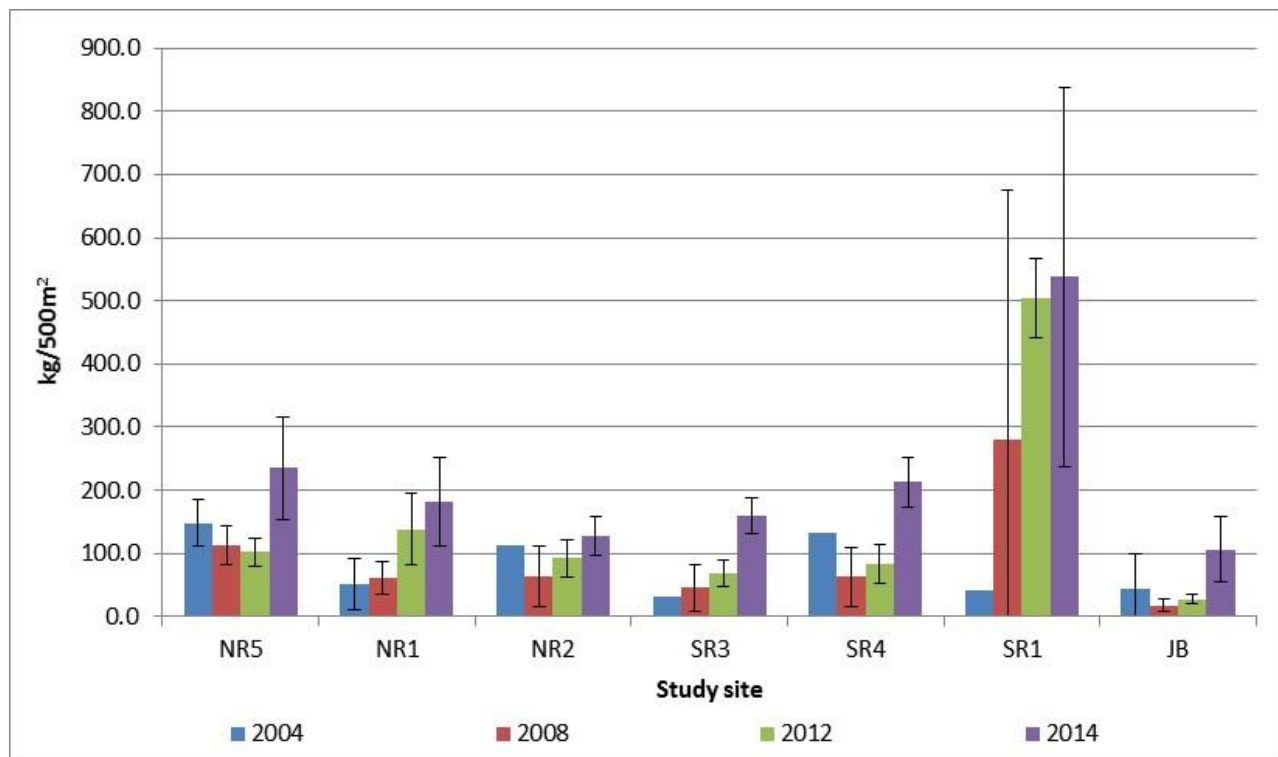


Figure 31. Target fish biomass (mean ±SE) at all sites in Tubbataha Reef Natural Park from 2004 to 2014.



## RECOMMENDATIONS FOR IMPROVED SURVEYS AND PARK MANAGEMENT

The Tubbataha Reefs Natural Park management group has much experience after more than 20 years of protecting the Tubbataha Reefs and thus is well aware of its successes and areas where it needs improvement. The suggestions below are intended to help the Park management team and reflect a few observations from our 2014 visit to the area.

**Rangers require ongoing support systems so their work is consistent.** The fish wardens have boats but additional higher-speed boats may be required to make patrolling more efficient and effective, especially during the non-tourist season from June to February. The Park Rangers have expressed how helpful a small lookout station would be at Bird Islet. There they can maintain a watch as well as assist researchers that do regular bird censuses.

**Tourism activity to Tubbataha Reefs Natural Park is always a challenge and needs to be managed.** Every year, visitors to TRNP increases because it is getting more recognition as an excellent dive site. With this increase comes more responsibility to coordinate dive operators, dive boats, visitors and the activities that they do in the Park. This is why it is important to educate boat operators, visitors, and divers on park regulations and objectives. There has been tremendous improvement in this area and an additional idea might be to start a dive guide certification program for Tubbataha Park to more consistently increase the quality of dive tour operators and their dive guides.

**Stakeholders should be regularly informed of monitoring and evaluation reports and results.** Research in Tubbataha has been collected since 1984 by several organizations and conservation groups. This information is often updated every year, so it is essential that the results are shared to increase awareness about the protected area with locals and to encourage policy formulation to benefit protection. However, this information still needs to be shared among stakeholders in a manner that they understand and appreciate. We might also collectively consider compiling another book on Tubbataha to summarize all past data on the area which would tell a very interesting story of conservation success in the Sulu Sea. This would also help provincial and national policy makers appreciate the excellent work being done to protect Tubbataha and also that their support has been very beneficial but still needed.

**Regular monitoring and more research to sustain and inform management.** There have been past ENSO bleaching episodes and the *Acanthaster planci* outbreaks. It is important for managers to monitor different parameters that may be the cause of such episodes which will allow them to plan better responses to minimize or prevent damage. Innovative research in the area can benefit the park and allow managers to learn more about the importance of their marine resources (e.g. larval distribution, etc). Investigating the declines in fish densities recorded in this survey, that presumably are connected to an increasing biomass of large predator type of fish, may be useful.

**Conduct assessments with experienced fish visual census specialists.** Expedition surveys would benefit from more collaborative work with fish visual census specialists that have previously monitored Tubbataha. For repeated long-term monitoring, members of the team need to be well-versed and experienced with the fish fauna of the area. This helps to minimize observer variation and builds consistency and confidence in the data collected.

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## Appendix 1. Expedition Itinerary

### ITINERARY OF EVENTS Saving Philippine Reefs, April 17 - 23, 2014

DAY	DATE & SITE	TIME	ACTIVITIES
1	Thursday, April 17 Hibiscus Garden Inn Puerto Princesa	9:00 AM  11:00  12:00 1:00 PM  7:00 8:00	Rendezvous at Hibiscus Garden Inn Welcome and Briefing About Tubbataha: Angelique Songco, Tubbataha Park Manager Lunch Start loading of luggage Transfer to the Discovery Fleet Boat Boat Orientation Dinner Slide show/Quiz and Identification Presentation (CCEF and Tubbataha)
2	Friday, April 18 North Reef 5 (Bird Islet)	7:00 AM  8:30 12:00 PM 1:30 5:00 7:00	Breakfast Morning briefing Conduct surveys (scuba and snorkel) Lunch Conduct scuba survey Compile and submit completed data e-forms Dinner Presentation
3	Saturday, April 19 NR 1 Amos Rock (Malayan Wreck)	7:00 AM 8:30 12:00 PM 1:30 5:00 7:00	Breakfast Morning briefing Conduct surveys (snorkel and scuba) Lunch Conduct survey (scuba) Compile and submit completed data forms Dinner Optional night dive
4	Sunday, April 20 South Reef 3 (Black Rock) and South Reef 4	7:00 AM 8:30 12:00 PM 1:30 5:00 7:00	Breakfast Morning briefing Conduct surveys (snorkel and scuba) Lunch Conduct surveys (scuba) Compile and submit completed data forms Dinner Presentation Slide show of volunteer pictures
5	Monday, April 21 SR1 (Lighthouse Reef)	7:00 AM 8:30 12:00 PM 1:30 5:00 7:00	Breakfast and briefing Conduct surveys (snorkel and scuba) Lunch Conduct surveys (scuba) Compile and submit completed data forms Dinner Optional night dive (can be done dusk time/before dinner)
6	Tuesday, April 22 SR 4 (Ranger Station) and/or Jessie Beasley Reef	7:00 AM 8:30 12:00 PM 1:30 5:00 7:00	Breakfast Conduct surveys (snorkel and scuba) Lunch Conduct surveys (scuba) Compile and submit completed data forms Dinner Summary of Impressions and Debriefing (Alan) Travel back to Puerto Princesa
7	Wednesday, April 23 Puerto Princesa	6:00 AM 7:00	Arrive Puerto Princesa Breakfast Closing/Summary Depart boat for airport

## Appendix 2. Expedition Volunteers and Staff

**Saving Philippine Reefs Volunteers**  
**April 17 - 23, 2014**  
**Tubbataha Reefs Natural Park**  
**Sulu Sea, Philippines**

	<b>Name/Address</b>	<b>Contact numbers/fax/email</b>	<b>Profession/Affiliations/Interests</b>
1	<b>Denise Illing</b>  34 Oakland Drive Warrandyte 3113 Australia	(mobile) +61 419307653  Email: <a href="mailto:denise@illing.com.au">denise@illing.com.au</a>	Part of UNICO Computer Systems finance dept. BA in Geography and Sociology. Interested in marine life, reefs, and diving. 11th Saving Philippine Reefs expedition. Wildlife artist. Watercolourist. Amateur photographer.
2	<b>Geoff Illing</b>  34 Oakland Drive Warrandyte, VIC 3113 Australia	Mobile: +61419307653  Email : <a href="mailto:geoff@illing.com.au">geoff@illing.com.au</a>	Occupation: Technical Director Unico Computer Systems Interests: Amateur musician (woodwind player)
3	<b>Thomas J. Mueller</b>  29905 Rainbow Crest Drive Agoura Hills, CA 91301 U.S.A.	Mobile Phone: +1-917-592-7074  Email: <a href="mailto:tj@tjmueller.com">tj@tjmueller.com</a>	Educational Consultant; Retired College Professor; PhD in Biology; small boat experience, especially sail; underwater photographer; SCUBA instructor; CCE Foundation, Institutional Development Advisor – Board Member. 15 <sup>th</sup> Saving Philippine Reefs Expedition. Retired and enjoying it.
4	<b>Alexander Douglas Robb</b>  4 Nevada Retreat, Bulleen, Victoria 3105 Australia	Hm: 398505497  Email: <a href="mailto:sandyrobb@bigpond.com">sandyrobb@bigpond.com</a>	IP Researcher ; Civil Engineer BSC (Hons) Edinburgh; MSC Melbourne – History & Philosophy of Science; Interest - History & Philosophy of Science. 9 <sup>th</sup> Saving Philippine Reefs Expedition.
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	Name/Address	Contact numbers/fax/email	Profession/Affiliations/Interests
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9	<b>Julia Cichowski</b>  41 Gray Street Boston, MA 02116 U.S.A.	Cell Phone: (617) 671-8865  Email: <a href="mailto:julia.cichowski@gmail.com">julia.cichowski@gmail.com</a>	Leads a user experience design team for a financial services company in the U.S., Fidelity Investments. We design web-based and mobile digital user experiences; On the Board of Directors for a Massachusetts based non-profit, Oceanic Research Group; On the production team for Jonathan Bird's Blue World, an educational underwater adventure series on Public Television in the U.S.; Formal education in Computer Science and economics; Amateur underwater photographer; Favorite ways to relax – yoga, scuba diving, traveling; This will be my 15th Saving Philippine Reefs Expedition, and I've loved them all.
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18	<b>Tom Matula</b>  766 6th Avenue Honolulu, HI 96816 U.S.A.	Email: <a href="mailto:tmatula@me.com">tmatula@me.com</a>	Occupation: Anesthesiology Interests: Marine science
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**Saving Philippine Reefs Staff**  
**April 17 – 23, 2014**  
**Tubbataha Reefs Natural Park**  
**Sulu Sea, Philippines**

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FISH SPECIES LIST	Malayan Wreck NR-1	Ranger Station NR-2					Bird Islet NR-5					Lighthouse Islet SR-1					Black Rock SR-3					Black Rock An. SR-4					Jessie Beazley Reef				Baatera Reef		sites excluding Jessie Beazley		All Sites including Jessie Beazley in 1992/1996		All Sites including Jessie Beazley in 2012		All Sites including Jessie Beazley in 2014	
Tubbataha Reef National Marine Park																																								
Fish Species List as of April 2012																																								
Family and species/site	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	1992/1996	2008	2012	2014									
CHONDRICHTHYES: Cartilaginous fishes																																								
SHARKS																																								
I Carcharhinidae - Requiem sharks																																								
Carcharhinus melanopterus			1						1	1				1					1		1									1				1						
Carcharhinus albimarginatus					1					1					1					1																				
Carcharhinus amblyrhchos														1						1										1										
II Ginglymostomatidae - Nurse sharks																																								
Nebrius ferrugineus														1						1										1										
III Hemigaleidae - White-tip reef sharks																																								
Trienodon obesus			1	1					1	1		1	1		1		1	1					1	1									1		1					
IV Rhincodontidae - Whale sharks																																								
Rhincodon typus																										1										1				
V Sphyrnidae - Hammerhead sharks																																								
Sphyrna mokarran																								1																
VI Stegostomatidae - Zebra/Leopard Shark																																								
Stegostoma fasciatum																		1														1								
RAYs																																								
VII Dasyatidae - Sting rays																																								
Dasyatis kuhli																		1															1							
Himantura uarnak									1																															
Taeniura lymma									1																															
Taeniura meyeri										1	1																					1								
VIII Mobulidae - Manta/Devil rays																																								
Manta birostris				1						1							1															1								
IX Myliobatidae - Eagle ray																																								
Aetobatus narinari																																	1							
X Rhinobatidae - Guitarfishes																																								
Rhynchobatus djiddensis																																	1							
OSTEICHTHYES: Bony fishes																																								
XI Acanthuridae - Surgeonfishes																																								
Acanthurus achilles																																	1							
Acanthurus auranticavus															1	1										1								1	1					
Acanthurus bleekeri										1																							1							
Acanthurus dussumieri				1				1		1	1					1												1					1	1	1	1				
Acanthurus guttatus																																	1							
Acanthurus japonicus	1			1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1					
Acanthurus leucocheilus					1	1	1				1	1	1			1	1								1									1	1					
Acanthurus lineatus	1	1			1				1			1	1			1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1					
Acanthurus mata						1								1			1		1		1		1		1						1	1		1	1					
Acanthurus nigricans	1	1						1				1			1	1										1						1			1					
Acanthurus nigricauda		1						1				1					1	1																	1					
Acanthurus nigrofuscus																																								
Acanthurus olivaceus	1			1	1			1																	1	1	1	1				1	1		1	1				
Acanthurus pyroferus	1	1	1	1	1	1	1	1	1	1	1			1		1	1	1	1	1	1	1	1	1	1	1	1		1			1	1	1	1					
Acanthurus sp.						1					1																						1	1	1					
Acanthurus thompsoni	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1					
Acanthurus triostegus				1	1		1						1					1		1	1	1				1	1					1	1	1	1					
Acanthurus xanthopterus				1				1				1			1																	1			1	1				
Ctenochaetus binotatus	1	1	1	1	1		1	1	1	1		1		1		1								1	1	1	1	1			1	1		1	1					
Ctenochaetus cyanocheilus						1																											1							
Ctenochaetus striatus	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1					
Ctenochaetus strigosus																																								
Ctenochaetus tominiensis	1							1				1																					1			1				
Naso annulatus											1		1															1					1			1				
Naso brachycentron												1								1	1											1	1			1				





FISH SPECIES LIST	Malayan Wreck NR-1	Ranger Station NR-2					Bird Islet NR-5					Lighthouse Islet SR-1					Black Rock SR-3					Black Rock An. SR-4					Jessie Beazley Reef					Baatera Reef		sites excluding Jessie Beazley	All Sites including Jessie Beazley in 1992/1996	All Sites including Jessie Beazley in 2012	All Sites including Jessie Beazley in 2014
Tubbataha Reef National Marine Park																																					
Fish Species List as of April 2012																																					
Family and species/site	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2004	2008	2012	2014	2000	1992/1996	2008	2012	2014		
<i>Chaetodon selene</i>		1																																			
<i>Chaetodon semeion</i>		1	1											1																		1					
<i>Chaetodon speculum</i>		1	1	1		1	1		1	1	1	1	1	1			1		1	1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	
<i>Chaetodon trifascialis</i>	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1		1		1	1	1	1	1	1	1	
<i>Chaetodon ulietensis</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1	1	1	1	1	1		
<i>Chaetodon unimaculatus</i>	1		1			1	1	1				1	1	1		1	1	1				1								1	1				1		
<i>Chaetodon vagabundus</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	1		
<i>Chaetodon xanthurus</i>		1																																			
<i>Chelmon rostratus</i>		1																																			
<i>Coradion chrysozonus</i>																																					
<i>Coradion melanopus</i>																																					
<i>Forcipiger flavissimus</i>	1	1	1	1	1	1	1		1	1	1	1	1				1	1	1	1		1	1	1		1	1	1		1	1	1	1	1	1		
<i>Forcipiger longirostris</i>		1		1			1	1	1			1	1				1	1				1		1			1				1	1		1	1		
<i>Hemitaenichthys polylepis</i>	1	1	1	1			1	1	1		1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
<i>Heniochus acuminatus</i>		1					1				1	1				1	1					1					1				1	1			1		
<i>Heniochus chrysostomus</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	1		
<i>Heniochus diphreutes</i>																			1	1											1	1	1	1	1		
<i>Heniochus monoceros</i>						1		1			1									1						1								1	1		
<i>Heniochus pleurotaenia</i>						1					1															1									1		
<i>Heniochus singularis</i>	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1		1	1	1	1	1	1		
<i>Heniochus varius</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1	1	1	1	1	1		
XXII <b>Chanidae - Milkfish</b>																																					
<i>Chanos chanos</i>																	1																				
XXIII <b>Cirrhitidae - Hawkfishes</b>																																					
<i>Cirrhitichthys aprinus</i>																																					
<i>Cirrhitichthys falco</i>	1			1	1	1	1		1	1	1	1	1	1		1			1		1					1		1		1	1	1	1	1	1		
<i>Cirrhitichthys oxycephalus</i>																											1	1						1			
<i>Cirrhitus pinnulatus</i>																																					
<i>Oxyrrhites typus</i>																																					
<i>Paracirrhites arcatus</i>		1					1	1	1			1	1	1		1	1	1	1		1	1	1				1	1		1	1	1	1	1	1		
<i>Paracirrhites forsteri</i>	1	1		1	1	1		1	1		1	1	1	1	1	1		1	1	1		1	1	1		1	1	1		1	1	1	1	1	1		
<i>Paracirrhites hemistictus</i>																																	1				
XXIV <b>Clupeidae - Herrings and Sardines</b>																																					
<i>Spratelloides delicatulus</i>												1																									
XXV <b>Diodontidae - Porcupinefishes</b>																																					
<i>Chilomycterus reticulatus</i>							1																														
<i>Diodon hystrix</i>												1	1				1																1				
<i>Diodon liturosus</i>		1															1										1										
XXVI <b>Echeneidae - Shark suckers</b>																																					
<i>Echeneis naucrates</i>																	1																1				
XXVII <b>Ephippidae - Batfishes</b>																																					
<i>Platax boersii</i>																																					
<i>Platax orbicularis</i>		1		1			1		1		1					1																	1	1	1		
<i>Platax pinnatus</i>								1																													
<i>Platax teira</i>					1																												1		1	1	
XXVIII <b>Fistulariidae - Cornetfishes</b>																																					
<i>Fistularia commersonii</i>													1														1					1	1		1		
XXIX <b>Heterocongridae - Garden eels</b>																																					







FISH SPECIES LIST	Malayan Wreck NR-1	Ranger Station NR-2					Bird Islet NR-5					Lighthouse Islet SR-1					Black Rock SR-3					Black Rock An. SR-4					Jessie Beazley Reef					Bastera Reef		sites excluding Jessie Beazley	All Sites including Jessie Beazley in 1992/1996	All Sites including Jessie Beazley in 2008	All Sites including Jessie Beazley in 2012	All Sites including Jessie Beazley in 2014
Tubbataha Reef National Marine Park																																						
Fish Species List as of April 2012																																						
		2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2004	2008	2012	2014	2000	1992/1996	2008	2012	2014							
Family and species/site																																						
Pteroletris heteroptera			1																																			
Pteroletris zebra																																						
XL Monacanthidae - Leatherjackets																																						
Aluterus scriptus						1		1						1																1	1				1			
Amanses scopas				1									1	1						1												1						
Cantherhines dumerilii																				1																		
Cantherhines pardalis																					1																	
Oxymonacanthus longirostris																																						
Paraluteres prionurus																				1																		
Pervagor janthinosoma																					1																	
XLI Mullidae - Goatfishes																																						
Mulloidichthys flavolineatus			1										1																					1				
Mulloidichthys vanicolensis																						1																
Parupeneus barberinoides	1									1	1	1				1				1												1	1		1			
Parupeneus barberinus	1	1	1					1				1	1		1		1	1	1		1					1					1	1		1				
Parupeneus bifasciatus			1	1	1	1	1					1																										
Parupeneus ciliatus															1																							
Parupeneus cyclostomus	1	1	1	1		1		1	1	1		1	1							1	1												1	1				
Parupeneus indicus														1	1																							
Parupeneus multifasciatus	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1					1	1	1	1	1		1	1		1			
Parupeneus pleurostigma			1																	1	1																	
Upeneus tragula																																						
XLII Muraenidae - Moray eels																																						
Gymnothorax flavimarginatus																																						
Gymnothorax javanicus									1											1	1																	
Gymnothorax melanospilus																																						
Gymnothorax meleagris																																						
XLIII Nemipteridae - Breams																																						
Pentapodus bifasciatus																																						
Scolopsis bilineatus	1	1	1	1	1	1		1	1	1	1			1	1		1			1	1														1			
Scolopsis lineatus							1							1																								
Scolopsis margaritifer			1	1																																		
Scolopsis monogramma				1																																		
Scolopsis trilineatus				1										1																								
XLIV Ostraciidae - boxfishes																																						
Ostracion cubicus			1	1							1																											
Ostracion meleagris					1																																	
Ostracion solorensis																																						
XLV Pempheridae - Sweepers																																						
Pempheris oulensis										1																												
Pholidichthyidae																																						
Pholidichthys leucotaenia																																						
XLVI Pinguipedidae - sandperches																																						
Clathrata multipunctata																																						
Clathrata tetracantha				1																																		
Parapercis clathrata				1	1																																	
Parapercis cylindrica																																						
Parapercis hexophthalma																																						
Pholidichthys leucotaenia																																						
Parapercis millipunctata				1																																		
Parapercis sp.																																						
XLVII Pomacanthidae - Angelfishes																																						
Apomelichthys trimaculatus	1														1																							
Centropyge bicolor			1	1	1					1			1	1			1																					
Centropyge bispinosus			1	1	1	1	1			1	1																											











FISH SPECIES LIST	Malayan Wreck NR-1	Ranger Station NR-2					Bird Islet NR-5					Lighthouse Islet SR-1					Black Rock SR-3					Black Rock An. SR-4					Jessie Beazley Reef					Bastera Reef	sites excluding Jessie Beazley	All Sites including Jessie Beazley in 1992/1996	All Sites including Jessie Beazley in 2008	All Sites including Jessie Beazley in 2012	All Sites including Jessie Beazley in 2014
Tubbataha Reef National Marine Park																																					
Fish Species List as of April 2012																																					
Family and species/site	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	2004	2008	2012	2014	2000	1992/1996	2008	2012	2014						
<i>Arothron nigropunctatus</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
<i>Arothron stellatus</i>					1		1									1																					
<i>Canthigaster bennetti</i>																																					
<i>Canthigaster compressa</i>																																					
<i>Canthigaster papua</i>					1																																
<i>Canthigaster solandri</i>							1																														
<i>Canthigaster valentini</i>			1						1																												
LXI <b>Zanclidae - Moorish idol</b>											1																										
<i>Zanclus cornutus</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
<b>TOTAL</b>	<b>165</b>	<b>171</b>	<b>185</b>	<b>190</b>	<b>110</b>	<b>152</b>	<b>221</b>	<b>144</b>	<b>155</b>	<b>133</b>	<b>188</b>	<b>170</b>	<b>152</b>	<b>164</b>	<b>87</b>	<b>180</b>	<b>141</b>	<b>205</b>	<b>175</b>	<b>97</b>	<b>158</b>	<b>156</b>	<b>190</b>	<b>168</b>	<b>70</b>	<b>163</b>	<b>130</b>	<b>152</b>	<b>63</b>	<b>150</b>	<b>119</b>	<b>329</b>	<b>281</b>	<b>244</b>	<b>306</b>		

333 species in 57 families in 1992 and 1996

327 species in 44 families in 1999

329 species in 43 families in 2004

285 species in 43 families in 2008

244 species in 32 families in 2012

306 species in 37 families in 2014

## Appendix 4. Statistics Tables

Target density over the years							
Source of Variation	Test	DF	SS	MS	F	P	Tukey's
NR-1	1-ANOVA	4	155.000	38.800	1.900	0.135	
NR-2	Kruskal-Wallis	4				0.007	
NR-5	1-ANOVA	4	571.9	143	3.27	0.025	2008>2012
SR-1	1-ANOVA	5	0.12	0.024	0.17	0.972	
SR-3	1-ANOVA	4	218	54.5	1.92	0.134	
SR-4	1-ANOVA	4	145.9	36.5	0.75	0.566	
Jessie Beazley	1-ANOVA	3	67.6	22.5	1.64	0.216	

All reef density over the years							
Source of Variation	Test	DF	SS	MS	F	P	Tukey's
NR-1	Kruskal-Wa	4				0.003	
NR-2	1-ANOVA	4	3.1591	0.7898	10.25	0.001	2008>2012=2014
NR-5	1-ANOVA	4	1.686	0.421	3.06	0.032	2008=2012, 2008>2012
SR-1	1-ANOVA	5	5993	1199	3.97	0.007	2000=2008>2014
SR-3	1-ANOVA	4	5170	1293	5.25	0.003	2004=2008>2014
SR-4	1-ANOVA	4	6982	1754	6.62	0.001	2000=2004>2014
Jessie Beazley	1-ANOVA	3	451	150	1.31	0.303	

Target diversity over the years							
Source of Variation	Test	DF	SS	MS	F	P	Tukey's
NR-1	1-ANOVA	4	0.3529	0.0882	1.64	0.189	
NR-2	1-ANOVA	4	185.1	46.3	1.18	0.343	
NR-5	1-ANOVA	4	650.4	162.6	3.76	0.014	1996<2014
SR-1	1-ANOVA	4	221.1	44.4	0.67	0.649	
SR-3	Kruskal-Wallis	4				0.126	
SR-4	1-ANOVA	4	169.1	42.3	0.61	0.661	
Jessie Beazley	1-ANOVA	3	254.8	84.9	2.64	0.081	

All reef diversity over the years							
Source of Variation	Test	DF	SS	MS	F	P	Tukey's
NR-1	1-ANOVA	4	5269	1317	3.52	0.018	2008>2012
NR-2	1-ANOVA	4	2425	606	2.6	0.06	2008>2012
NR-5	1-ANOVA	4	4413	1103	5.95	0.001	2008>2012
SR-1	Kruskal-Wa	5				0.166	
SR-3	1-ANOVA	4	73009	1827	12.56	0.001	2008>2012<2014
SR-4	Kruskal-Wa	4				0.012	
Jessie Beazley	1-ANOVA	3	1800	600	3.59	0.034	2008>2012

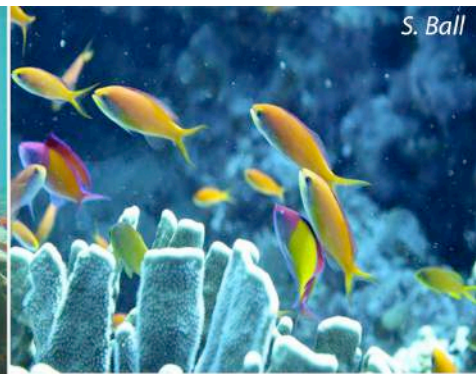
Substrate					
Source of Variation	Test	p	F	df	Tukey's Test
LHC Between sites (deep)	1-ANOVA	0	6.35	6	JB=NR2>NR1=NR5=SR4
Sites (2014)					
LHC within sites (shallow)					
NR1 (Amos Rock)	1-ANOVA	0.000	6.26	6	1992=1994=2000; 2000<2012>2014
NR5 (Bird Islet)	1-ANOVA	0.000	6.41	5	1992=1994=2000; 2000<2008=2012>2014
SR1 (Lighthouse)	1-ANOVA	0.000	10.24	4	1989<1994>2008; 1989=2008=2012<2014
SR3 (Black Rock)	1-ANOVA	0.000	10.41	5	1994>2000<2008=2012=2014
SR4 (Black rock anchorage)	1-ANOVA	0.001	5.43	4	1994>2008<2012
Jessie Beazley	1-ANOVA	NS	2.3	3	
LHC within sites (deep)					
NR1 (Amos Rock)	1-ANOVA	0.000	6.31	5	1996>2000<2008=2012=2014
NR2 (Ranger Station)	1-ANOVA	0.003	3.28	3	2004<2014, 2004=2008=2012
NR5 (Bird Islet)	Kruskal-Wallis	0.000		6	
SR1 (Lighthouse)	1-ANOVA	NS	1.25	6	
SR3 (Black Rock)	1-ANOVA	0.000	5.55	6	1992=1996=2000<2008=2012=2014
SR4 (Black rock anchorage)	1-ANOVA	0.009	3.35	5	1992=2012>2014
Jessie Beazley	1-ANOVA	0.006	4.66	3	2004=2008=2012; 2004<2014

#### Appendix 4. Expedition Photos



*SPR team (top). Briefing in Puerto Princesa before heading to Tubbataha, led by Alan White and staff from Tubbataha Management Office (bottom left). An appreciation plaque was presented by TMO to Alan for his support to Tubbataha over the years (bottom right). (photos by: V. White)*



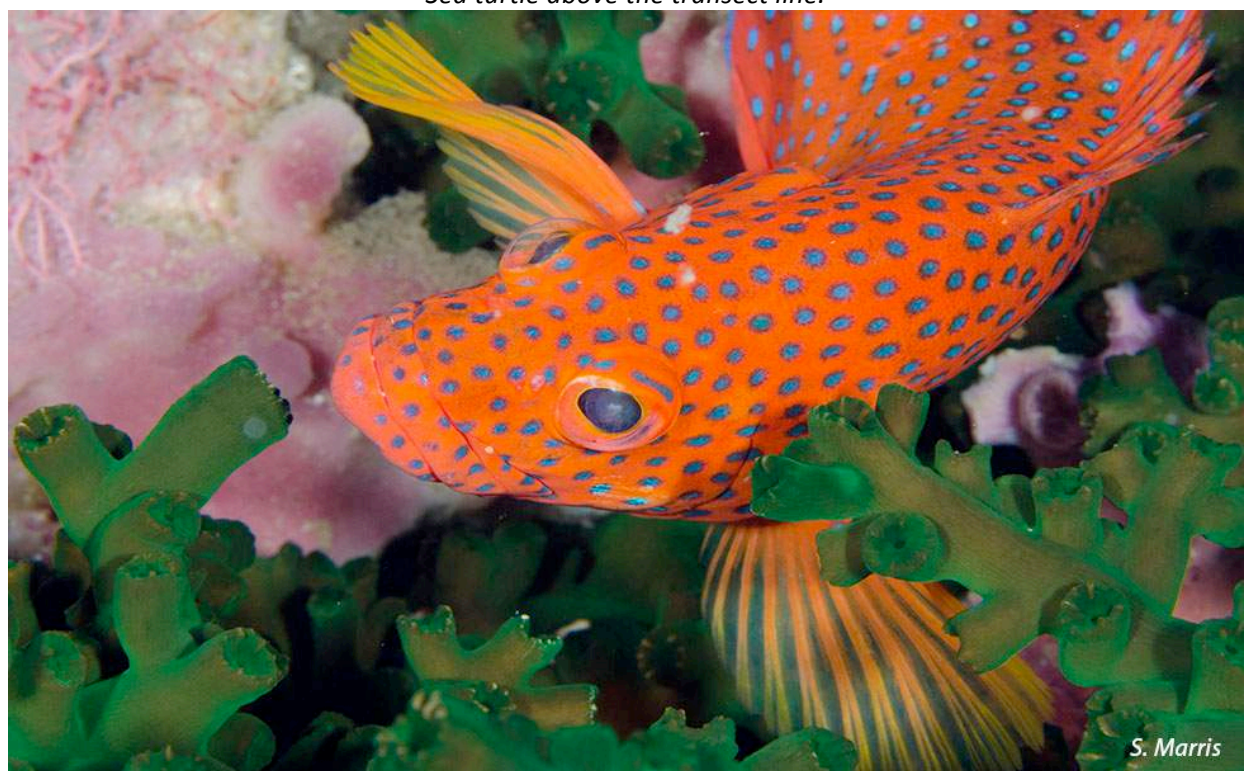


*There are about 360 species of corals found in Tubbataha Reefs Natural Park.*





*Sea turtle above the transect line.*



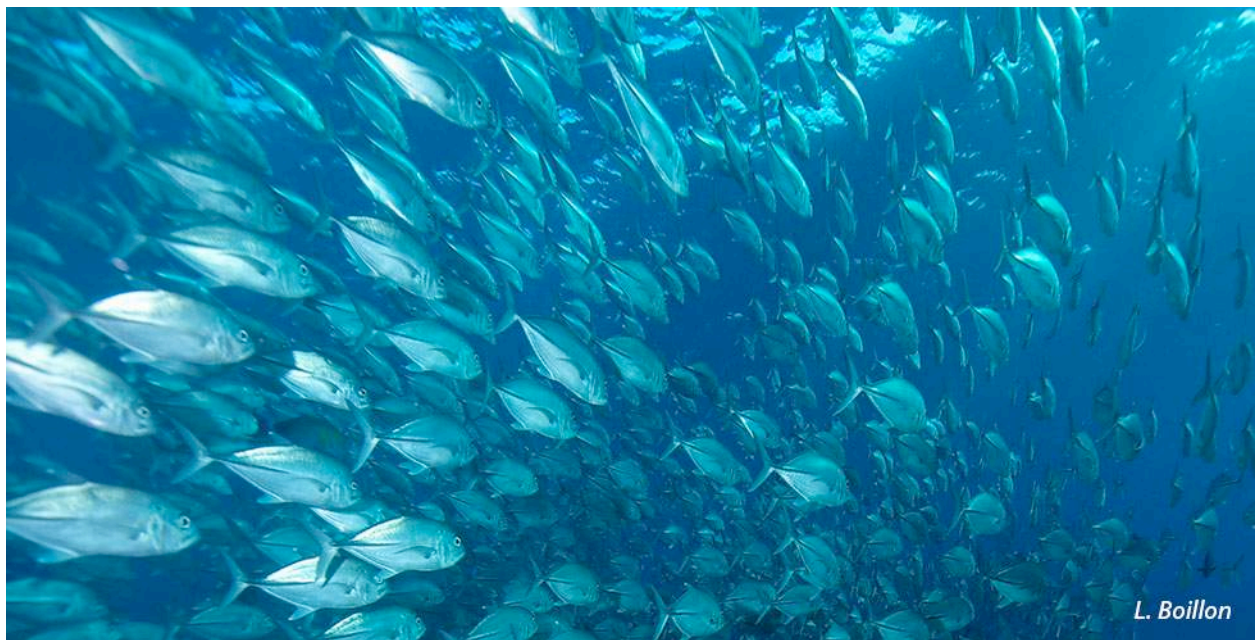
*Pretty as a picture, this grouper! There are about 640 species of fish found in Tubbataha Reefs.*





*There are 19 species of rays and sharks found in TRNP. This year, there were 29 SPR team members on the expedition (including CCEF staff). Geoff Illing (bottom left)) is one of the very supportive team members!*





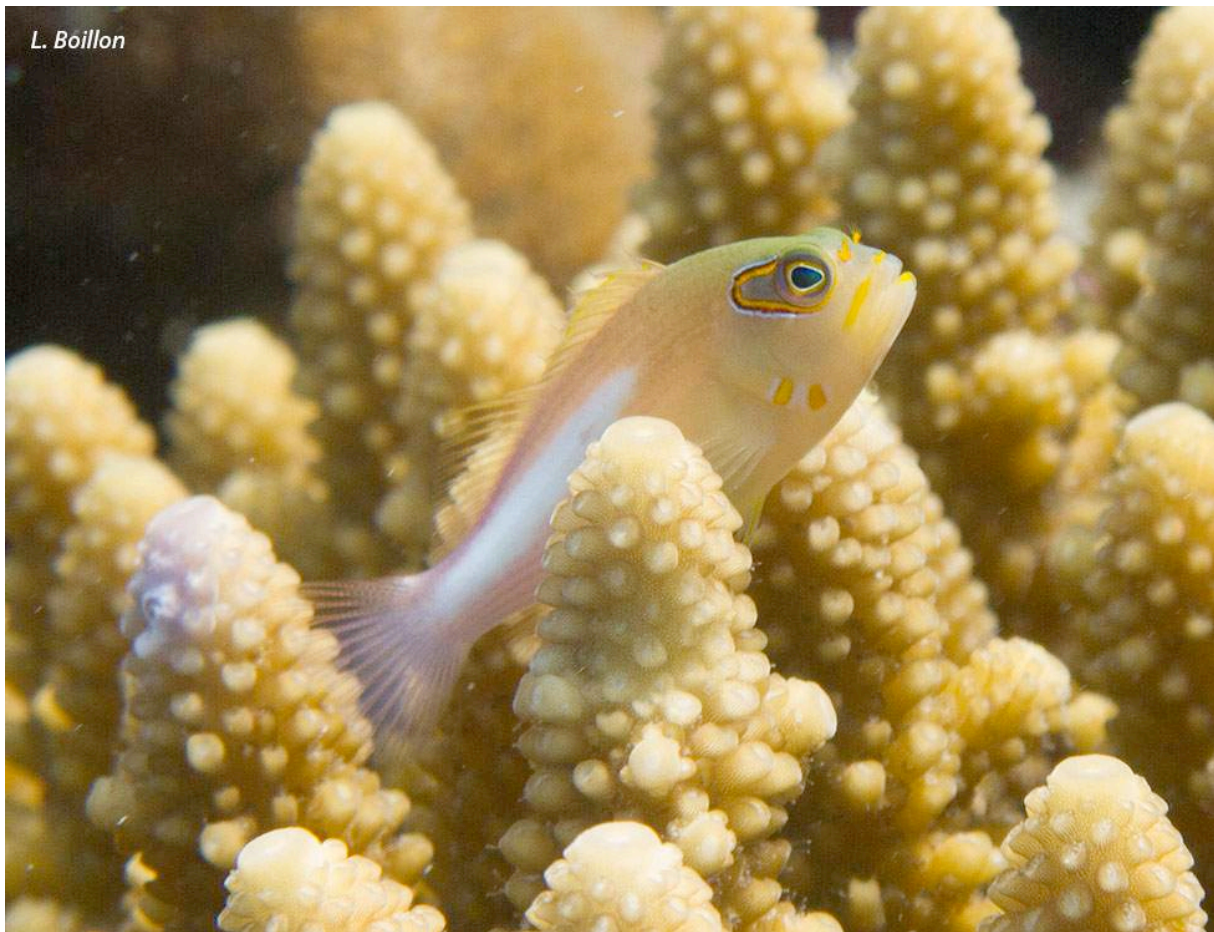
*A big school of Jack fish amazingly swam around our transect line! (bottom) Above is a hawkfish (top left), and a damselfish enjoying the company of a cleaner wrasse (top right).*





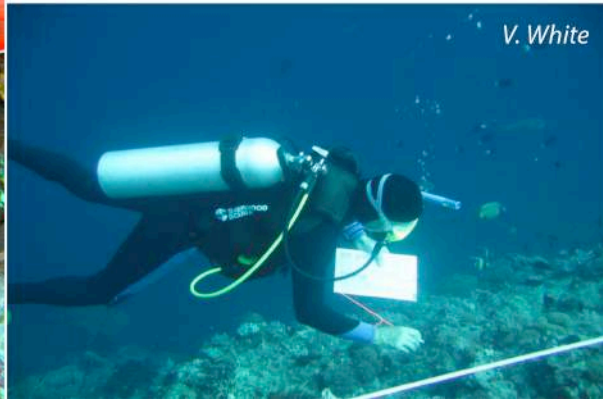
*A Maori wrasse (top) and Peacock grouper (bottom) posing for the photographers!*





*Two butterflyfish species and a hawkfish (above) depend on healthy corals for their habitat.*





*Shark napping (left). SPR diver doing coral monitoring survey (right).*



*Soft corals provide a colorful alternative to the generally hard coral habitat in Tubbataha Reef.*





*All dives in Tubbataha are assisted by rubber chase boats manned by very capable boatmen and divemasters - a happy team! (Photos by L. Boillon, D. Illing, and S. Wells)*





A. Pennycook



A. Pennycook

*Polyps extended from a massive coral head and a pair of *Chaetodon punctatofasciatus* watching their territory.*





*Expedition volunteers happily did their surveys, enjoyed their meals, took lots of photos, and even helped with the morning dive briefings! (Photos by V. White)*



*A visit to the Ranger Station to hear stories from and share with the Rangers was enjoyed by all, and the only chance to walk on sand during the 7-day journey around Tubbataha (Photos by V. White.)*