

27th Saving Philippine Reefs

A Coral Reef Monitoring Expedition to
Tubbataha Reefs Natural Park, Philippines
April 21-27, 2018



Summary Field Report
"Saving Philippine Reefs"
Coral Reef Monitoring Expedition to
Tubbataha Reefs Natural Park, Sulu Sea, Philippines

A Project of:
The Coastal Conservation and Education Foundation, Inc. (CCEF)

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Coral Reef Monitoring Expedition to Tubbataha Reefs Natural Park, Sulu Sea, Philippines, April 21 – 27, 2018

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EXECUTIVE SUMMARY

The Tubbataha Reefs Natural Park is a World Heritage Site that the Philippines considers one of its greatest protected treasures. The area covers 97,000 hectares in the epicenter of global marine diversity, the Coral Triangle. Research shows that it is an important source of larvae for many fishing grounds in the Philippines and primarily in the Sulu Sea. The area is a dive and tourist destination visited by people from all over the world to enjoy its underwater beauty and diversity. The “Saving Philippine Reefs” research team made a comprehensive coral reef survey in Tubbataha on April 21-27, 2018, the results of which are summarized in this report. The surveys covered seven selected coral reef sites in the Tubbataha Park that have been visited and revisited for data collection for three decades.

The generally healthy reefs were observed to have living hard coral substrate on the shallow reef (2-3m depth) that ranged from Fair (25-50%) to Good (51-75%) overall. One site, Malayan Wreck, was slightly lower than 25% live coral mostly due to reef flats without much natural coral growth. In contrast, Jessie Beazley, the newest and most remote protected site has shown a marked increase in live hard coral in the shallow reef reflecting the positive impacts of protection and recovery. On the deeper reefs (7-10m), the trend in all sites show increasing trends in the Fair and Good categories except for 2 sites (Black Rock and Bird Islet) which appear to be due to natural variation.

Fish densities for All Reef Fish Species have generally increased in all of the sites, however, only slight increases in fish density of Target Species were recorded in 2018 for some sites, in general they stayed the same. Nevertheless, target species fish tend to be larger and thus biomass of target species has increased in all sites except one. A glitch in fish counter protocol in the 2018 survey was that 2 fish visual census researchers only collected target species data and the 2 other FVC researchers collected all species. This has been accounted for in the analysis but affected the sample size for all reef species data which showed a decline in all species numbers compared to years past due to this error.

For large marine life, the area continues to support more sightings of large marine animals such as sharks, turtles, Humphead wrasses, tuna, and Bumphead parrotfish. However, there have been fewer sightings of rays over the last 10 years which is similar to a trend outside of Tubbataha also and because most rays are probably not resident in Tubbataha.

Overall, the data in this report shows that Tubbataha Reefs Natural Park continues to be well protected from poaching and other human caused destruction due to its vigilant Rangers and the capable Tubbataha Management Office staff who oversee Park management. This important marine biodiversity area contributes to education through eco-tourism and supports food security through its input to surrounding fisheries. Assuming that the Tubbataha Reef continues to be protected from fishing and other destructive impacts, its main threat is from warming of the oceans from climate change. Coral bleaching was severe in 1998 in Tubbataha but the reefs recovered fully in about 6 years. Thus, having well managed and resilient reefs is essential to resist warming oceans and thus it is very important that management efforts continue with local and international support to maintain and inspire the managers and Rangers to fend off any challenges so that the healthy reefs will continue to thrive.

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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

The Saving Philippine Reefs expedition team and other colleagues have been collecting essential information and data on underwater coral reef and fish health of marine protected areas (MPAs) around the Philippine islands since the 1980s. Such areas are Cebu, Negros Oriental, Siquijor, Bohol, Batangas, and Palawan. This data has been used to give local MPA managers guidance on how to improve the management their MPAs, as well as how to draft policies and create approaches on how to better protect their marine resources.

The Tubbataha Reefs Natural Park (TRNP) was first researched by A. White and associates in 1984. This rich coral/marine wildlife area is 150 kilometers southeast of Puerto Princesa City, Palawan in the Sulu Sea. The area was declared by UNESCO as a World Heritage Site in 1994. Roughly 97,000 hectares is protected and makes up two prominent coral atolls that teem with marine and bird life. In the protected area there are 13 Cetaceans, 7 seagrass species, 79 algae species, and 372 coral species that abound in these reefs alone (White and Arquiza, 1999). Further, there are 11 sharks and 600 fish species (Jensen, 2012) and 100 migrating birds that live/visit the area. Notably, the *Manta alfredi* ray was identified in the Tubbataha Reefs Natural Park by Dr. Terry Aquino in 2012, which is unique only to this part of the Philippines.

As the Sulu Sea is in the heart of the Coral Triangle, TRNP plays an important role in being the storehouse of Philippine marine biodiversity. This area alone supplies the Sulu Sea and adjacent fishing grounds with fish and coral larvae, which has many implications in the country's fisheries and 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/documentated visit to Tubbataha by American colonial naturalist, Dean C. Worcester, who set foot on Bird Islet on the North Reef. |
| 1938 | The lighthouse on the South Reef atoll was built. In 1980, it 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 National Marine 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 (*Acanthaster planci*) 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 – 2018

This Saving Philippine Reefs Expedition is the tenth survey done by CCEF in Tubbataha Reefs from April 21 to 27, 2018. It was implemented and participated in by 10 CCEF staff members and 19 international volunteers. Two-thirds of the volunteers were already seasoned SPR expedition researchers and divers, who return often (if not annually) to join the research team.

The **M/Y Palau Sport** is a comfortable live-aboard designed specifically to cater to scuba divers and the SPR Team had exclusive use of the boat for the expedition. Palau Sport has 11 cabins, all air-conditioned in the upper deck and each cabin has private baths. Facilities for diving, cameras, meetings and food are all efficient. The boat and its crew offered excellent services and facilities that made the journey and the implementation of the research trip smooth and enjoyable.

The SPR research team completed the underwater surveys of seven sites within the Tubbataha Reefs Natural Park that have been historically surveyed 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 consisted of two scuba dives to collect underwater data from the site for the day and also 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 contributes 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 1m² 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 other 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

For snorkel surveys, each volunteer attempted to make at least ten or more stations on one snorkel survey. Scuba surveys were carried out at 7-9 meters depth 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 three specialists (Brian Stockwell, Jonathon Apurado, Alison Green and A. White). 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).

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. 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).

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 m². Target fish densities were compared between years where raw data is available, using 1-ANOVA or Kruskal-Wallis, whenever appropriate. When appropriate, we classified all reef fish densities to “high, mid or low” using the category of Hilomen et al. (2000), we extrapolated the 500 m² fish densities area to 1000 m². However, what is reflected in this report are the 500 m² values to be consistent with the previous years.

Hilomen et al. (2000) categories:

Fish Species Diversity (no. of species/1000 m²):				
Very Poor	Poor	Moderate	High	Very High
0 – 26	27 – 47	48 - 74	75 - 100	>100
Fish Density (no. of fish/1000 m²):				
Very Poor	Poor	Moderate	High	Very High
0 – 201	202 – 676	677 – 2,267	2,268 – 7,592	>7,592
Biomass (metric tons/km²)				
Very Poor	Poor	Moderate	High	Very High
<5.0	5.1 – 20.0	20.1 – 35.0	35.1 – 75.0	>75

Further, in the collection of data, some transects were used specifically to collect target fish species data and some transects were used to collect both target and all species data. The following table shows the specific number of transects used for each site to collect both. In the analysis, this was taken into consideration:

Site Name	# of Transects		
	Target fish species	All fish species	Total
NR5 – Bird Islet	6	3	6
NR2 – Ranger Station	7	3	7
NR1 – Malayan Wreck	8	3	8
SR1 – Lighthouse Reef	5	3	5
SR3 – Black Rock	7	3	7
SR4 – NW Corner	7	3	7
Jessie Beazley	7	3	7

Fish biomass. Fish biomass was computed using the formula: $a * Lb$ (Fishbase 2004), using the length-weight constants in FishBase (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. For this report, biomass computations were based on consensus with species-specific lengths (n = 3-10). The data was also adjusted to reflect fish/500m².

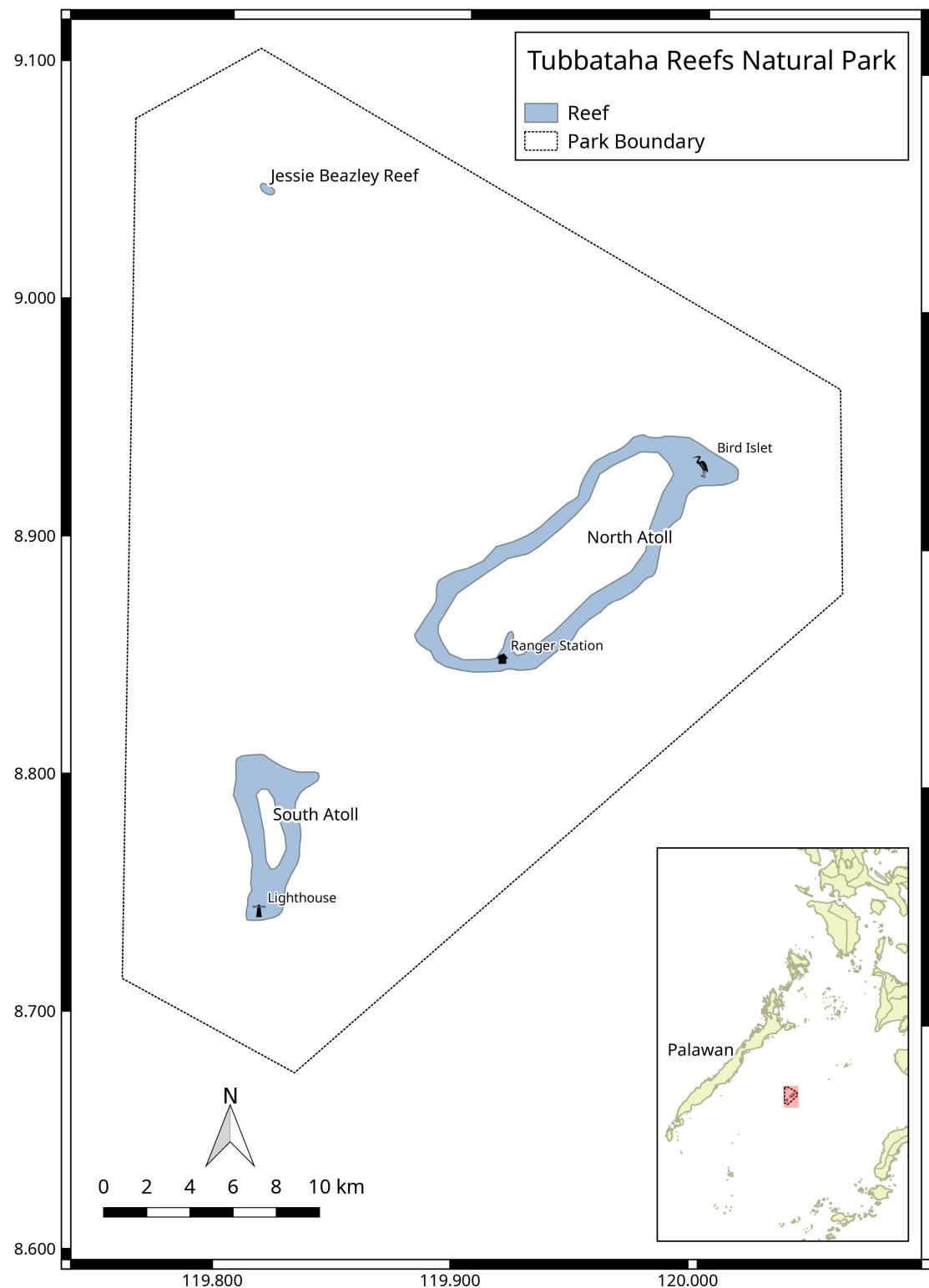


Figure 1. Location and delineation of Tubbataha Reefs Natural Park in Sulu Sea, Palawan.

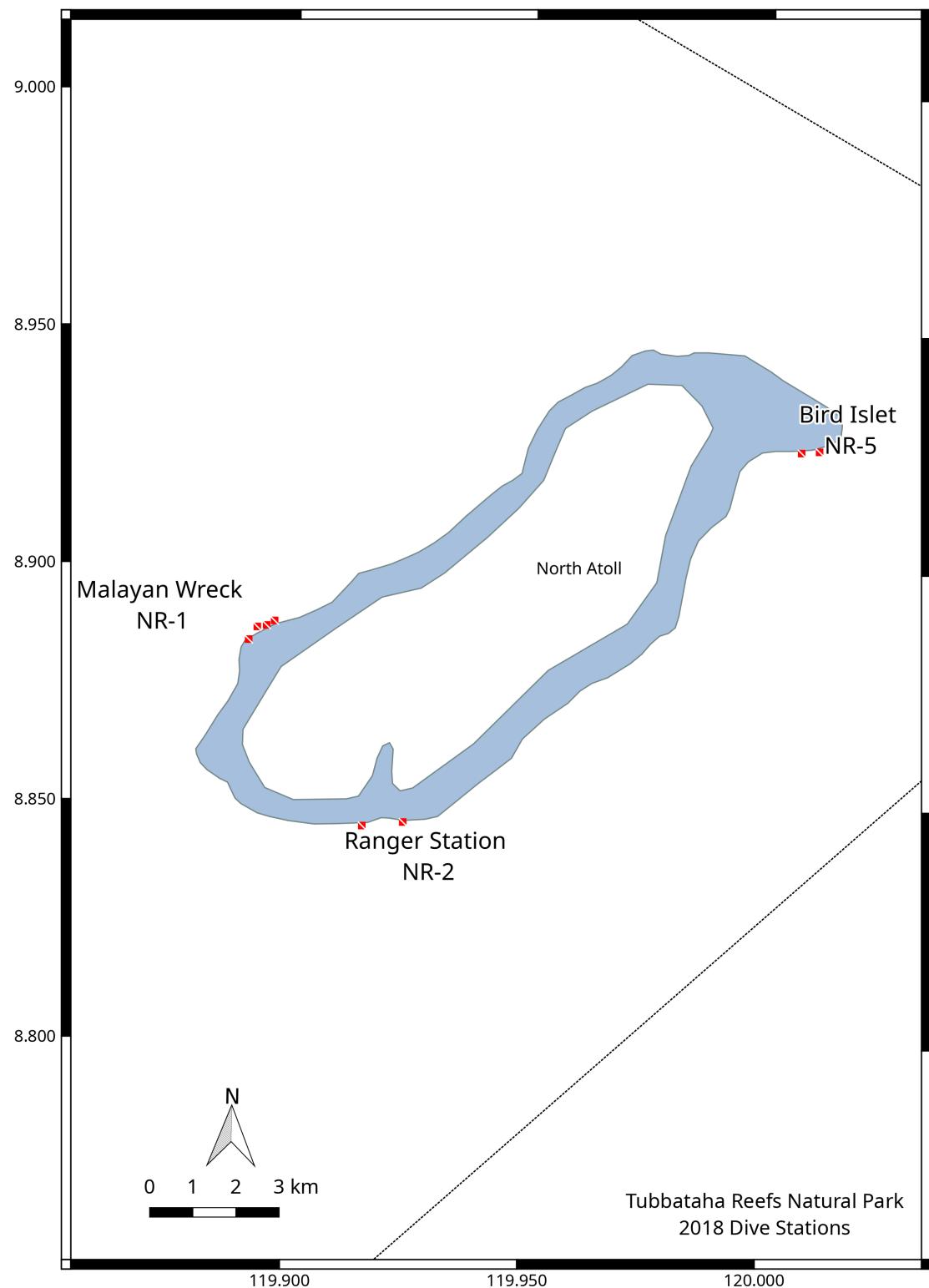


Figure 2. North Reef survey sites in Tubbataha Reef Natural Park (TRNP).

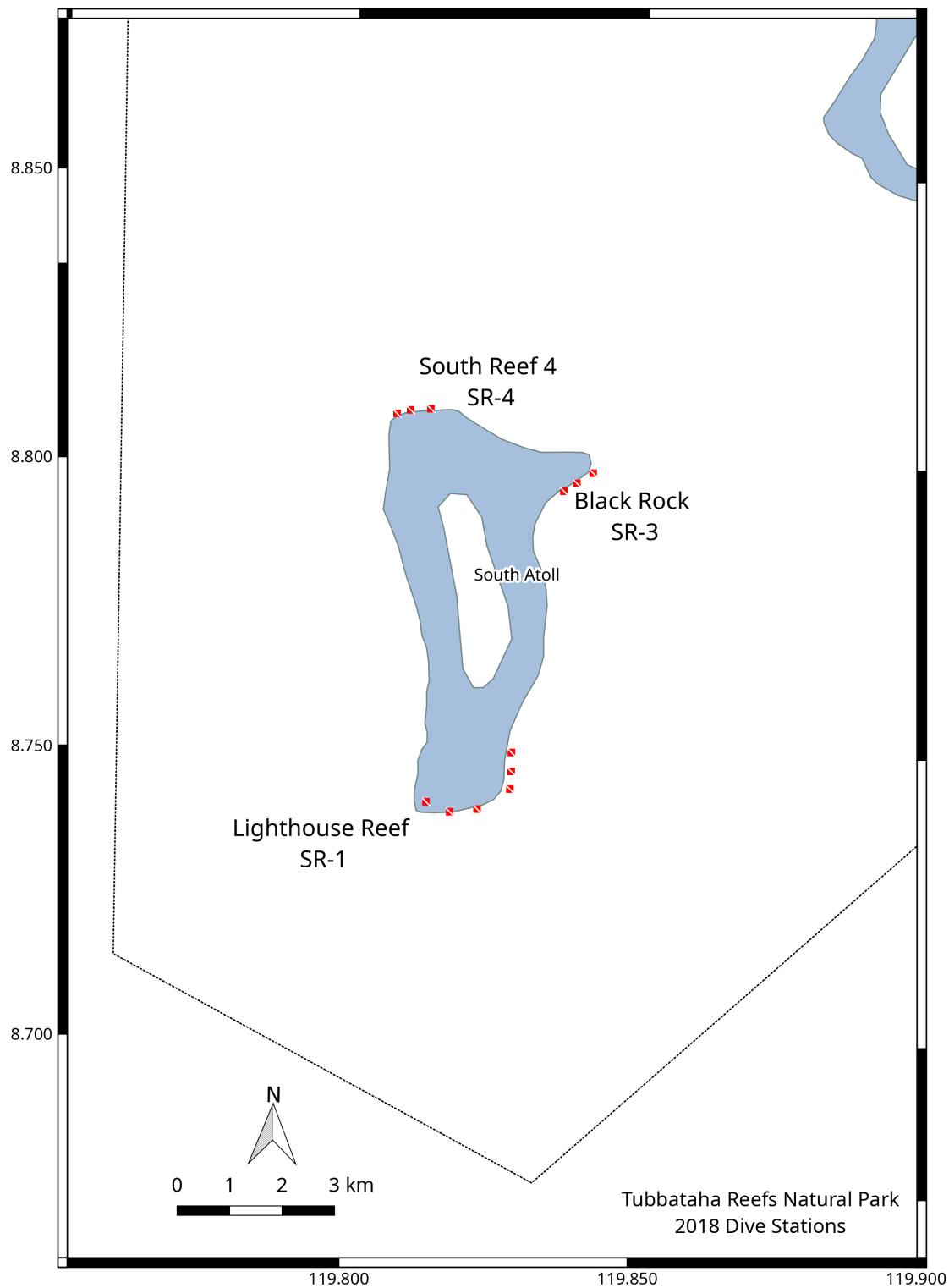


Figure 3. South Reef survey sites in Tubbataha Reef Natural Park (TRNP).

OVERVIEWS OF SITES SURVEYED

North Reef 5 (NR5: Bird Islet)

Site Overview. This coral reef is on the northeastern side of the northern atoll of TRNP. As the name of the area implies and as it is one of the few TRNP areas above sea level, Bird Islet serves as a resting place to migratory and some permanent resident bird species. One dive area is known as “Shark Airport” to divers who frequent the area as the sharks are often seen to rest on the sandy slopes. With its shallow sandy slopes, the area teems of nesting Titan triggerfish. The sandy area gradually slopes down and plummets to a reef wall where manta rays are often sited.

Substrate. NR5 has a recovering shallow reef since 2014 (LHC: $30.5\% \pm 3.6$) to 2018 (LHC: $45.4\% \pm 3.7$). This can also be seen with the corresponding decrease in non-living substrate from 2014 ($62.7\% \pm 3.9$) to 2018 ($49.1\% \pm 4.4$). However, in the deeper reef, there has been a decrease in LHC from 2014 ($35.4\% \pm 2.9$) to 2018 ($24.5\% \pm 6.7$) and a corresponding increase in non-living substrate from 2014 ($29.2\% \pm 3.5$) to 2018 ($32.6\% \pm 10.2$); but there is also an increase of soft coral from 2014 ($10.4\% \pm 2.2$) to 2018 ($36\% \pm 8.5$).

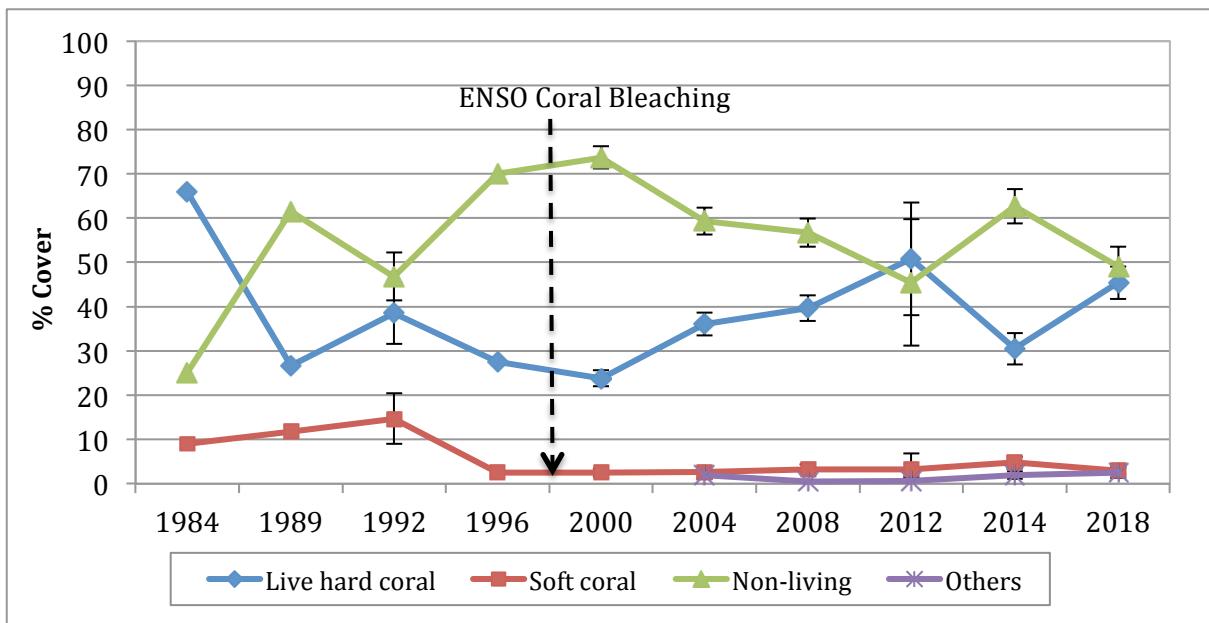


Figure 4. Changes in substrate composition (%mean \pm SE) in NR5 (Bird Islet) from 1984 to 2018, 2-3m depth.

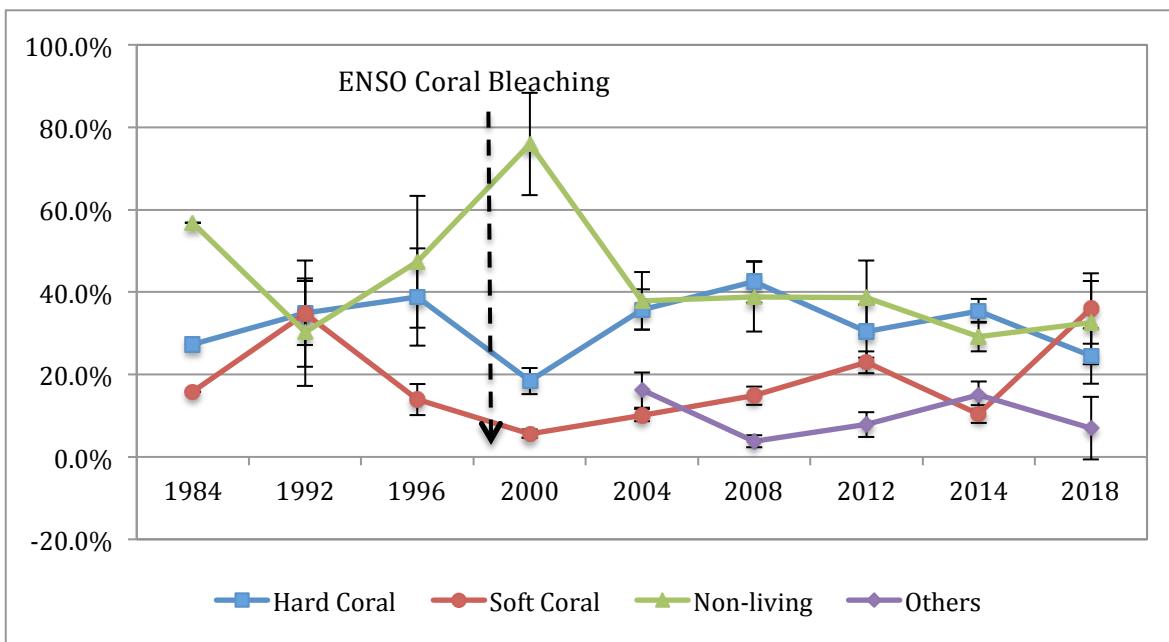


Figure 5. Changes in substrate composition (%mean \pm SE) in NR5 (Bird Islet) from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass.

Overall, fish species richness seems to have declined slightly in this site. There was a decline in target fish species from 2014 (24.3 species/500m² \pm 3) to 2018 (21.0 species/500m² \pm 1.7). This is the same trend for all reef species. Fish density for target fish species also declined from 2014 (398 fish/500m² \pm 46.8) to 2018 (249.7 fish/500m² \pm 91.6). All reef fish density almost doubled but considering the high standard error the change is mostly within the deviation of data. Fish biomass is stable (131 kg/500m² \pm 15.3) to (139 kg/500m² \pm 57) although the standard error is high.

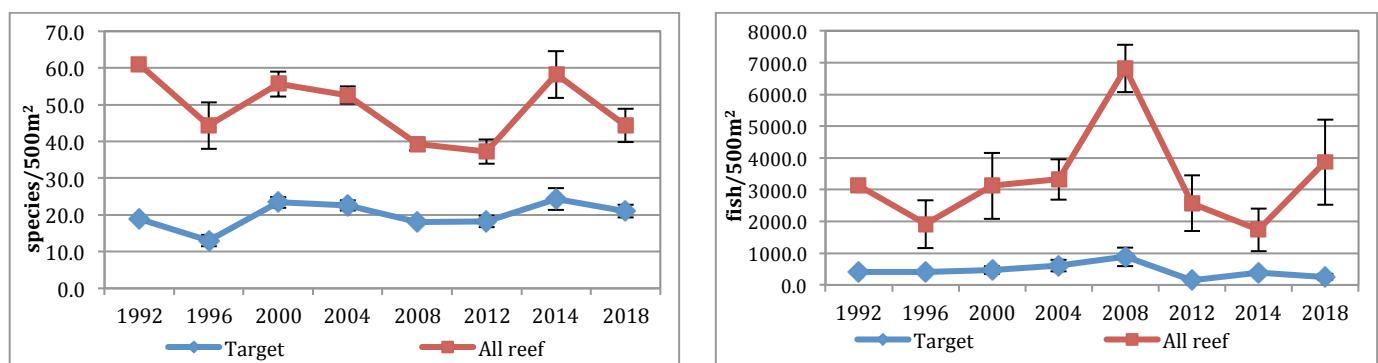


Figure 6. Fish species richness (species/500m² \pm SE) and fish density (fish/500m² \pm SE) at NR5 (Bird Islet) from 1992 to 2018.

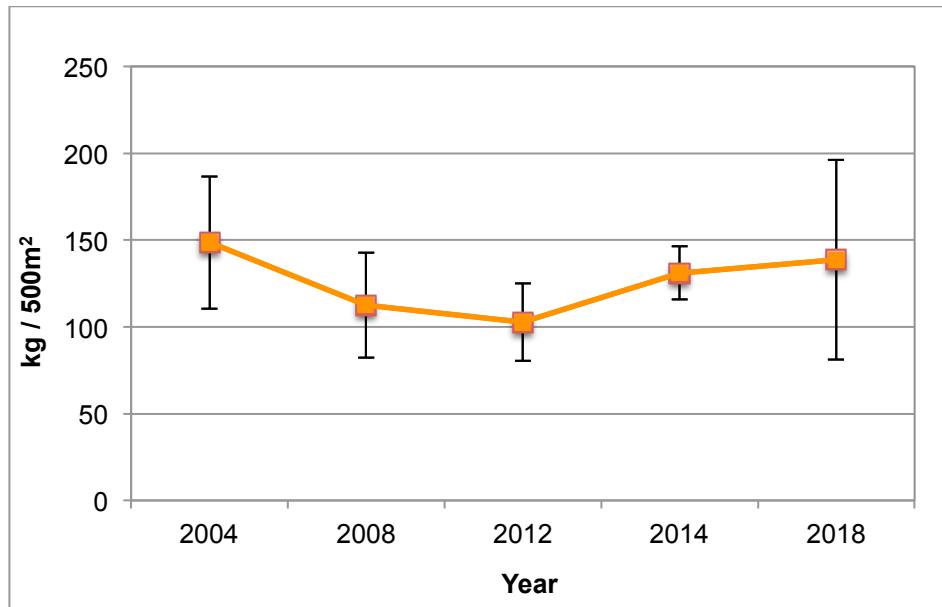


Figure 7. Target fish biomass ($\text{kg}/500\text{m}^2 \pm \text{SE}$) at NR5 (Bird Islet) from 2004 to 2018.

North Reef 1 (NR1: Amos Rock/Malayan Wreck)

Site Overview. Similar to many of the reefs in TRNP, this area is made up of a sandy slope that drops to a reef wall. Frequent divers in the area have nicknamed this area “Wall Street” due to wide diversity of marine life found along it, as well as the rush of currents that happen often along the wall. Some interesting marine life that has been sighted along the wall are Bumphead parrotfish, white-tip sharks, as well as a whale shark during the 2014 SPR expedition. On observation, the Amos Rock area is still recovering in its coral cover due to a Crown of Thorns (*Acanthaster planci*) sea-star outbreak in 2009.

Substrate.

In the shallow reef (3-4 meters depth) there was a decrease in LHC from 2014 ($29\% \pm 4.1$) to 2018 ($15.3\% \pm 2.5$). In the deep reef (7-8 meters depth) LHC is stable from 2014 ($35\% \pm 3.1$) to 2018 ($38.8\% \pm 4.6$), while soft coral decreased from 2014 ($12.8\% \pm 2.3$) to 2018 ($6.6\% \pm 1.4$). The substrate cover in the shallow is considered poor (<25%), but rates as Fair (25% to 50%) on the deeper reef.

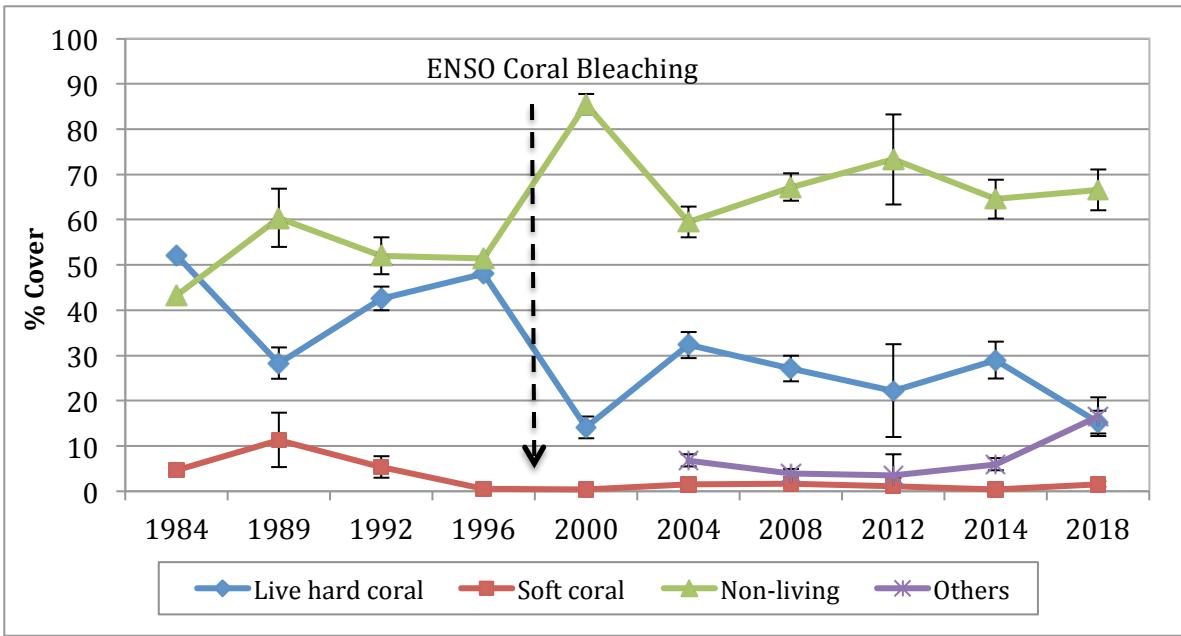


Figure 8. Changes in substrate composition (%mean \pm SE) in NR1 (Amos Rock/Malayan Wreck) from 1984 to 2018, 2-3m depth.

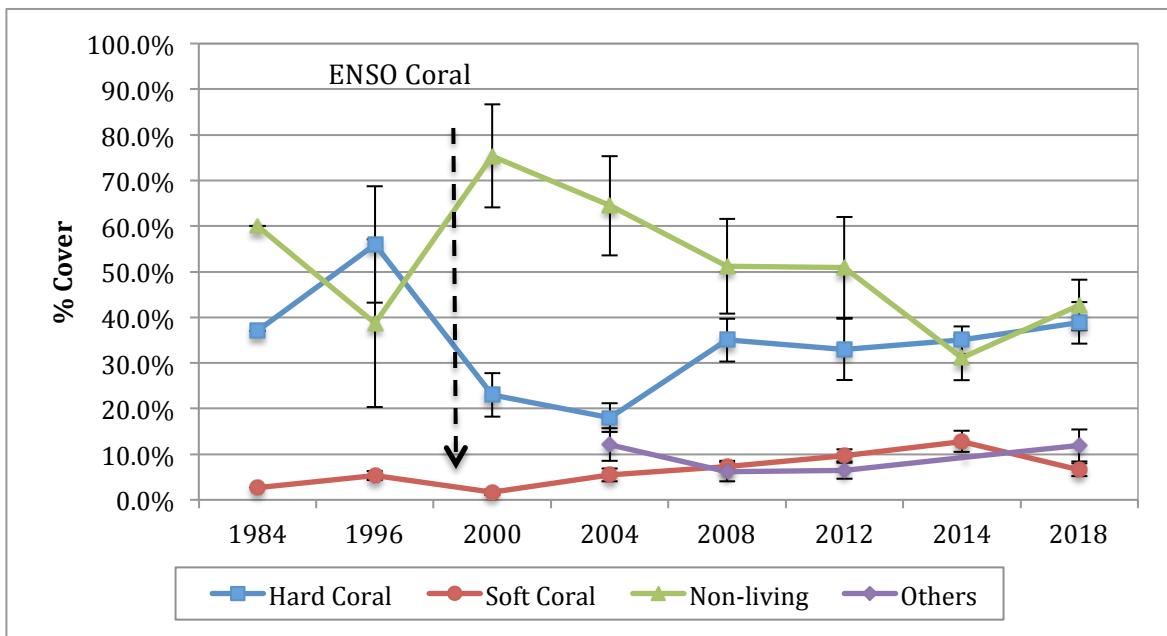


Figure 9. Changes in substrate composition (%mean \pm SE) in NR1 (Amos Rock/Malayan Wreck) from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass.

There were some mixed results in the fish data collected for 2018. Richness of target species in 2014 (23.2 species/500m² \pm 4.8) stayed the same in 2018 (23.3 species/500m² \pm 2.2). There was an increase for

all reef species richness from 2014 (59.8 species/500m² ±10.5) to 2018 (66 species/500m² ±3.6). The fish density was stable for target species from 2014 and for all reef species (253.8 fish/500m² ±18.2 to 248.5 fish/500m² ±64), there was a significant increase in 2018: 2014 (938.4 fish/500m² ± 16.1) to 2018 (5770.3 fish/500m² ± 948.4) but is mostly comprised of non-target species such as triggerfish, wrasses, damselfish, and fairy basslets.

Biomass of target fish species increased in 2018 from (95.5 kg/500m² ±16.1) to 160 kg/500m² ±36).

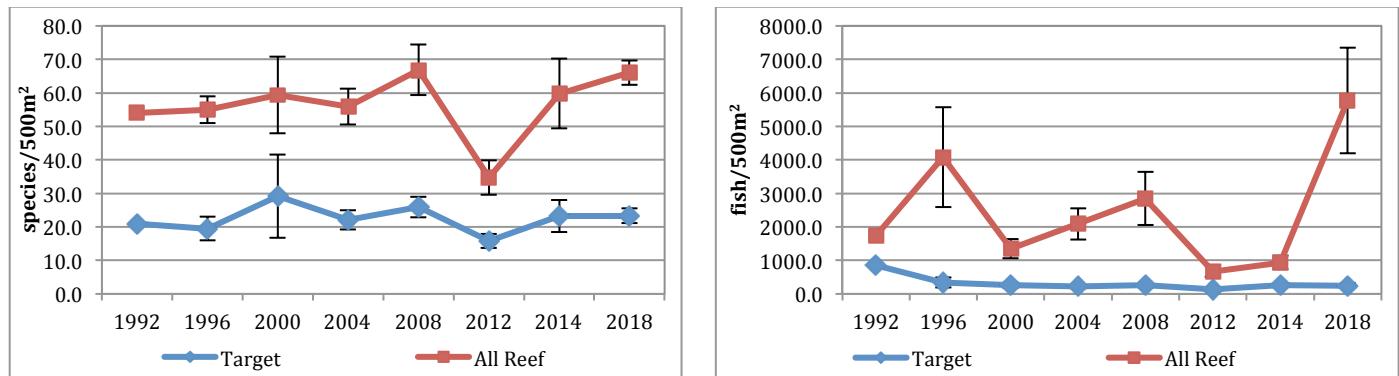


Figure 10. Fish species richness (species/500m² ±SE) and fish density (fish/500m² ±SE) at NR1 (Amos Rock/Malayan Wreck) from 1992 to 2018.

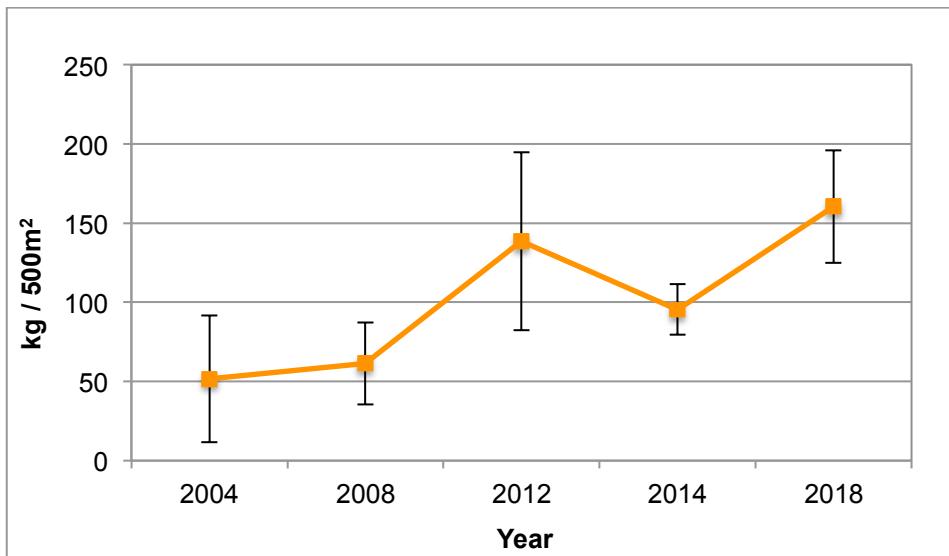


Figure 11. Target fish biomass (kg/500m² ±SE) at NR1 (Amos Rock/Malayan Wreck) from 2004 to 2018.

South Reef 3 (SR3: Black Rock)

Site Overview. The Black Rock dive site is one that divers look forward to because of the strong currents that attract a diverse collection of marine life, including green sea turtles, sharks and triggerfish. Clinging to the wall surfaces is also a colorful mixture of nudibranchs, octopuses, brittle stars, and other invertebrates. The topography of the wall is varied and provides some hiding places for sea turtles and large fish among a spectacular colony of soft corals.

Substrate

The Black Rock reef showed a decreasing trend in LHC on the shallow reef from 2014 ($52.2\% \pm 4.14$) to 2018 ($39.1\% \pm 3.5$). In the deeper reef, LHC also decreased from $52.6\% \pm 7.2$ in 2014 to $32.2\% \pm 13.6$. However, some signs of recovery are reflected in the soft coral cover that shows an increase from 2014 ($8.6\% \pm 2.3$) to 2018 ($15.9\% \pm 6.7$).

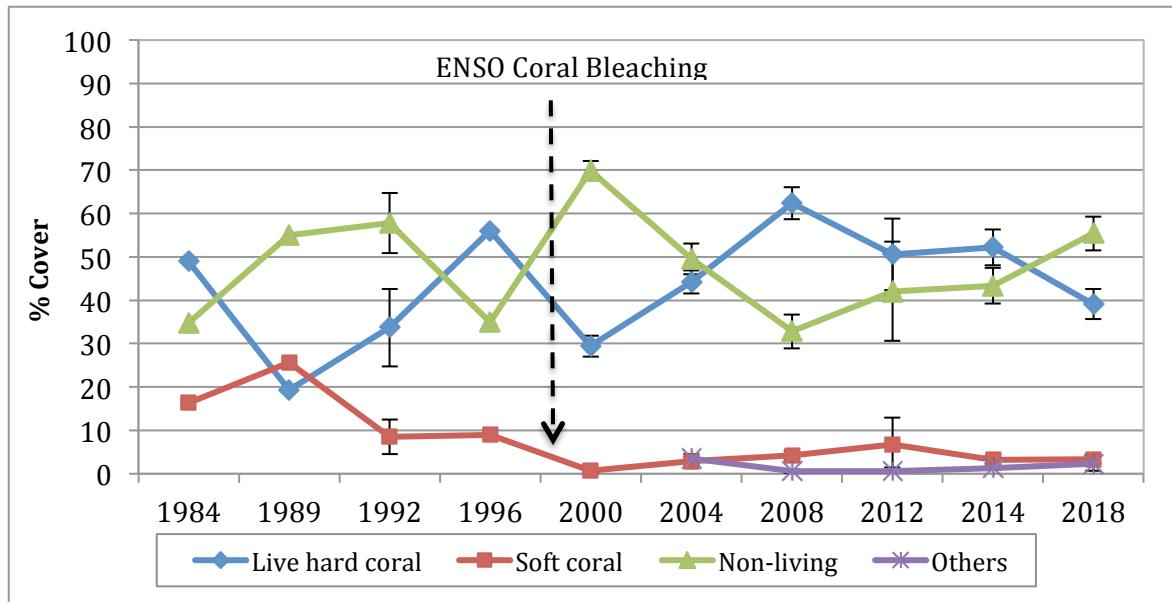


Figure 12. Changes in substrate composition (%mean \pm SE) in SR3 (Black Rock) from 1984 to 2018, 2-3m depth.

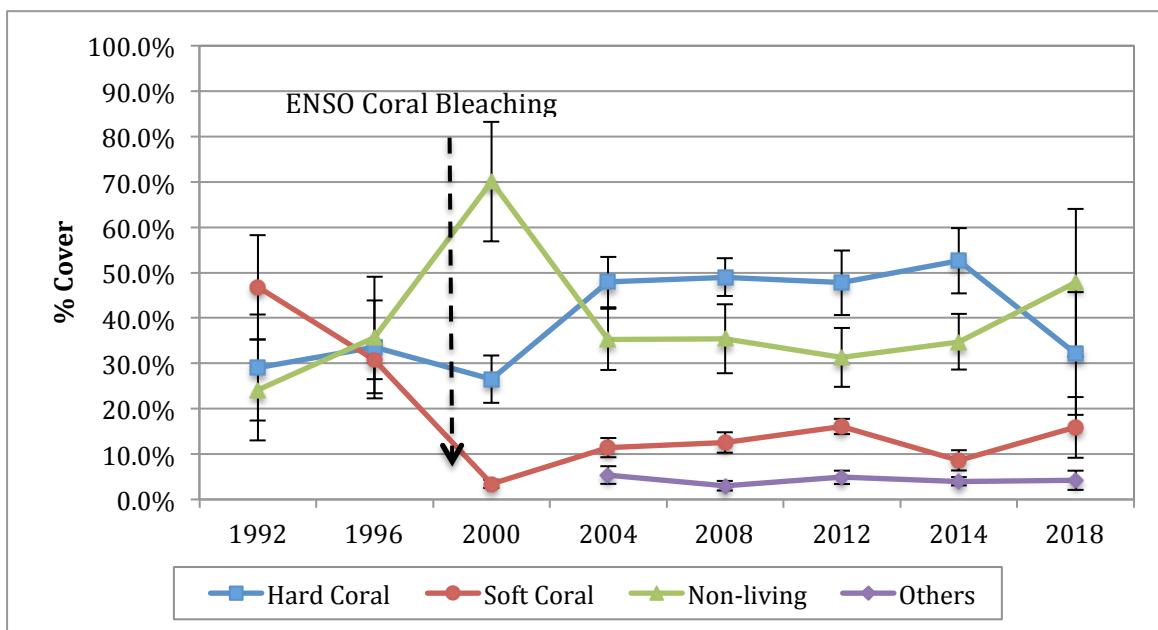


Figure 13. Changes in substrate composition (%mean \pm SE) in SR3 (Black Rock) from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass.

The fish data collected in the deep reef (7-8 meters depth) indicated that species richness decreased in both the target and all reef species. Target species richness decreased from 2014 (26.8 species/500m² ±4.2) to 2018 (20.1 species/500m² ±1.9) and for all reef species, species richness declined from 2014 (62.4 species/500m² ±8.7) to 2018 (44.3 species/500m² ±7.7). However, target fish density increased from 2014 (213 fish/500m² ±45) to 2018 (472.1 fish/500m² ±235.3) and all reef species density increased from 2014 (1857.2 fish/500m² ± 874.2) to 2018 (2,624.3 fish/500m² ± 196.5) similar to 2012 and earlier.

Overall biomass for target fish populations in the Black Rock study site increased from 2014 (141.4 kg/500m² ±18.4) to 2018 (188 kg/500m² ±46) and is showing continual increases since 2004.

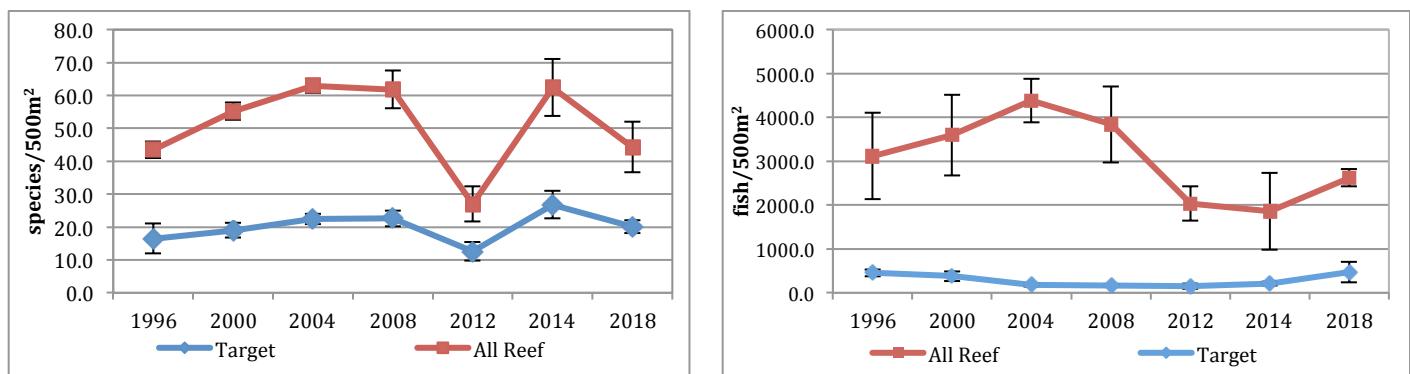


Figure 14. Fish species richness (species/500m² ±SE) and fish density (fish/500m² ±SE) at SR3 (Black Rock) from 1992 to 2018.

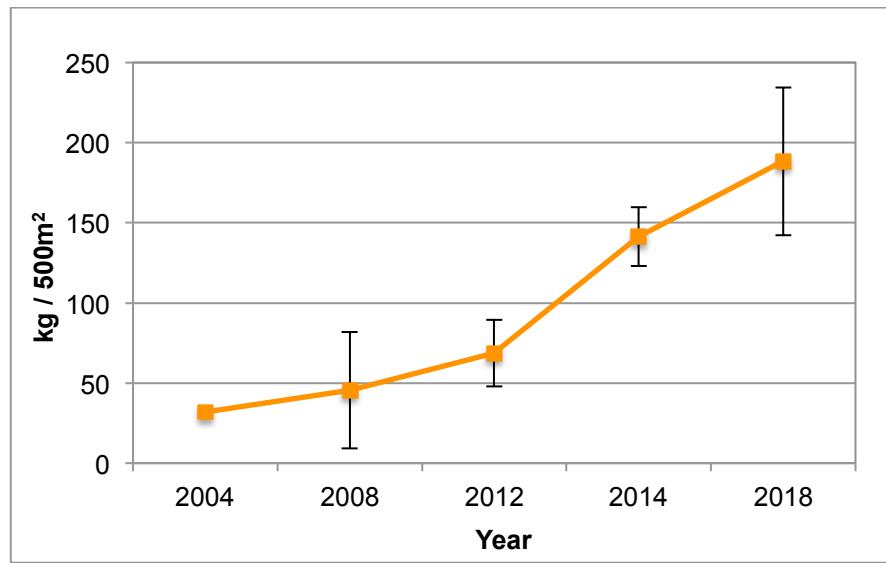


Figure 15. Target fish biomass (kg/500m² ±SE) at SR3 (Black Rock) from 2004 to 2018.

South Reef 1 (SR1: Lighthouse Reef)

Site Overview. This reef on the southern-most tip of TRNP where a lighthouse sits and is a resting place for migratory and resident birds. It is off-limits for visitors to visit the lighthouse and the inner lagoon in the interest of marine preservation. The reef is comprised of a wide and deep reef flat that drops off to a steep wall with large schools of surgeonfish among others. The reef slope is covered with large swaths of branching (*Acropora*) coral that acts as a refuge for damsels and fairy basslets. Morphologies of corals, sea fans, giant barrel sponges and crinoids decorate the reef crest. Large marine life that patrol the area are Napoleon wrasses, sharks, and sweetlips and sea turtles as well as large schools of jack fishes that swim in tornado-type swarms over the crest and reef slope.

Substrate. Lighthouse reef displayed an increase in LHC from 2014 ($51.3\% \pm 6.7$) to 2018 ($57.6\% \pm 9.0$) at a depth of 7-8 meters. Soft coral cover also increased slightly from 2014 ($5.5\% \pm 1.3$) to 2018 ($9\% \pm 5.0$) while non-living substrate decreased to $29\% \pm 8.5$. This coral cover puts this site in a Good level (50% to 75% range). The shallow reef data collected showed a stable coral cover at about 50% cover.

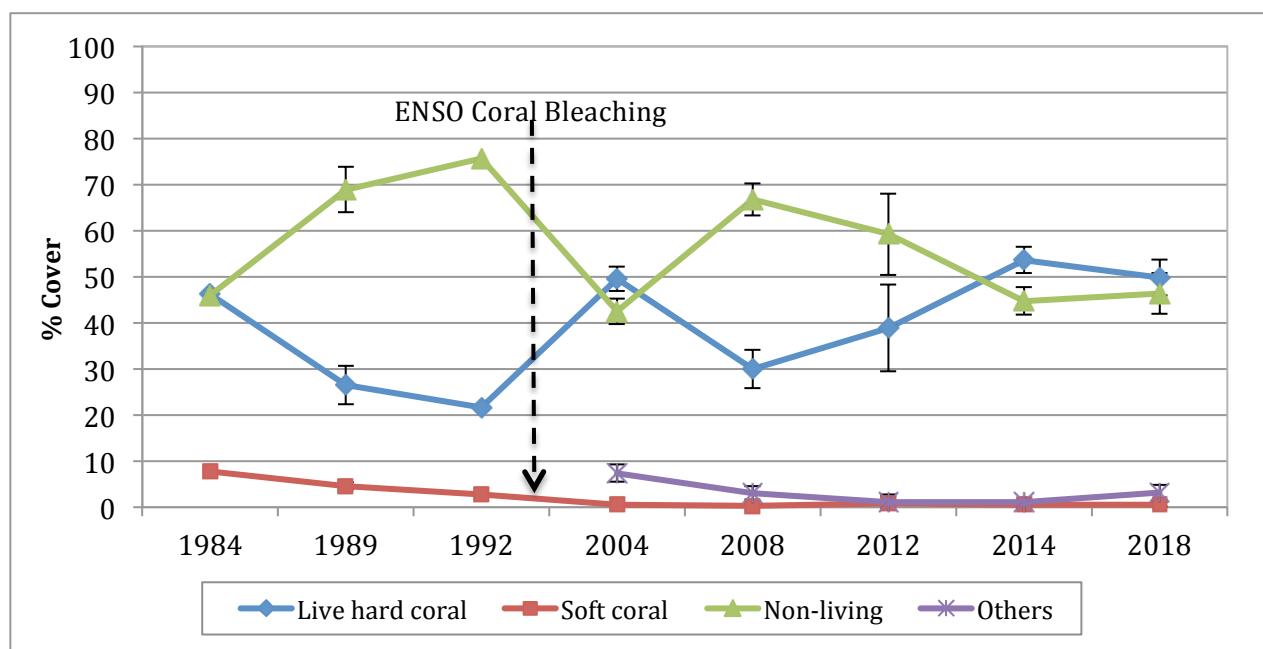


Figure 16. Changes in substrate composition (%mean \pm SE) in SR1 (Lighthouse Reef) from 1984 to 2018, 2-3m depth.

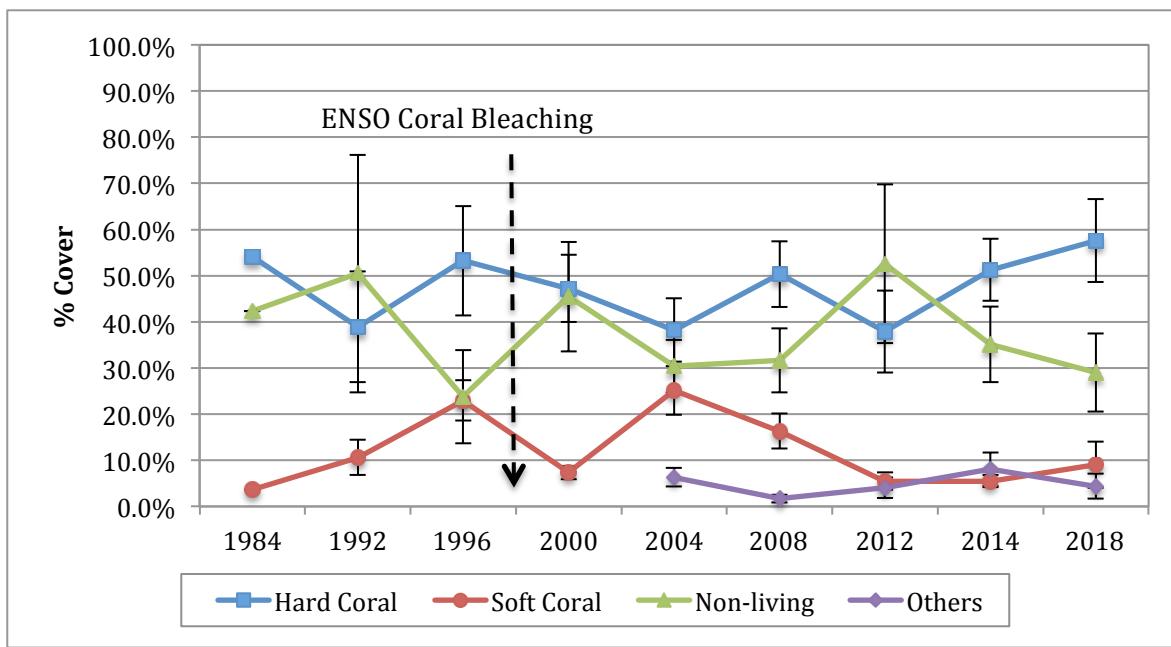


Figure 17. Changes in substrate composition (%mean \pm SE) in SR1 (Lighthouse Reef) from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass.

The trends for fish at Lighthouse Reef are positive. Species richness increased for target species from 2014 (18.4 species/500m² \pm 3.2) to 2018 (28.2 species/500m² \pm 3.0) and all reef species increased from 2014 (48.4 species/500m² \pm 7.9) to 2018 (63.7 species/500m² \pm 9.8). Target fish density increased from 2014 (218.5 fish/500m² \pm 72.2) to 2018 (462.8 fish/500m² \pm 120). Similarly, all reef species density went from 2014 (1871.8 fish/500m² \pm 777.6) to 2018 (6,098.7 fish/500m² \pm 906). But, many of the fish counted were damselfishes and fairy basslets.

Target fish biomass also increased from 2014 (76 kg/500m² \pm 12.9) to 2018 (133 kg/500m² \pm 24).

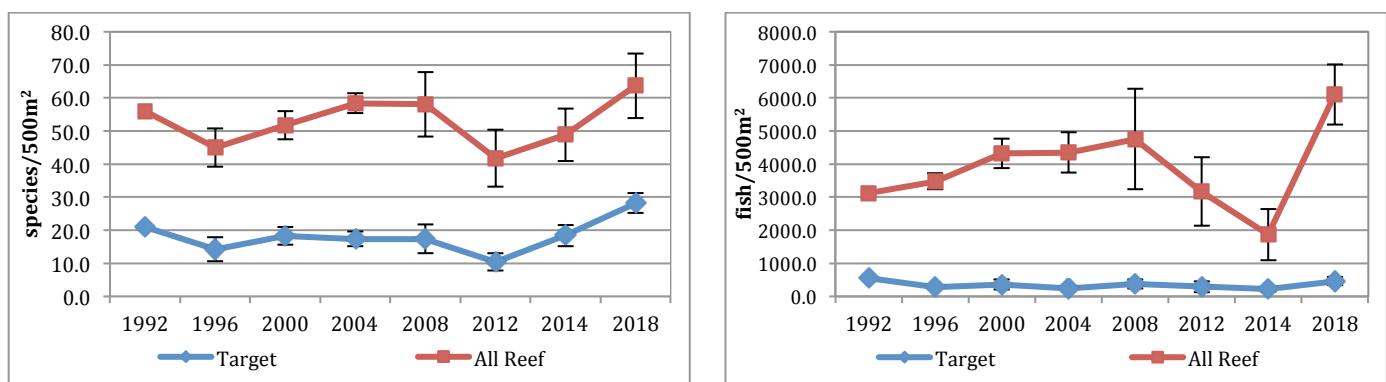


Figure 18. Fish species richness (fish/500m² \pm SE) and fish density (fish/500m² \pm SE) at SR1 (Lighthouse Reef) from 1992 to 2018.

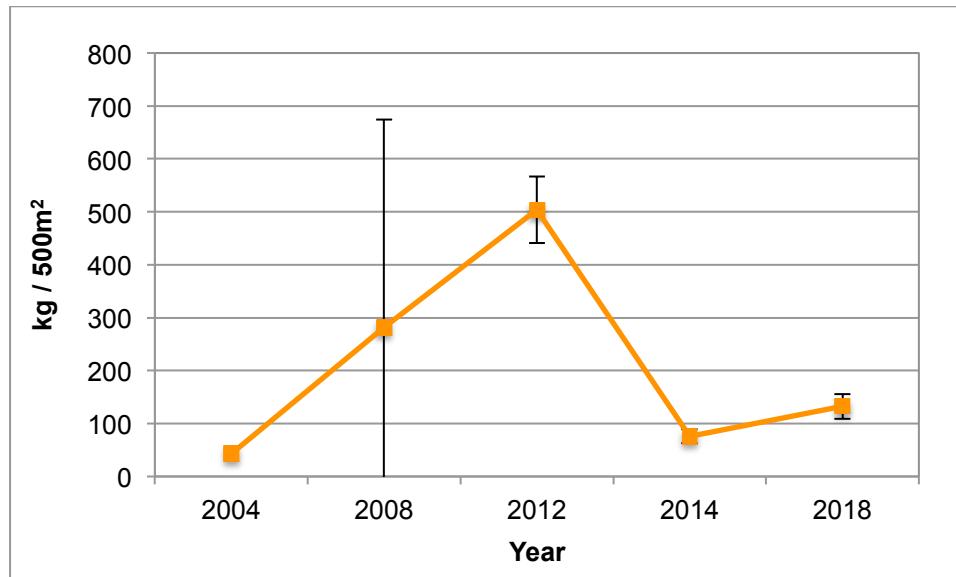


Figure 19. Target fish biomass ($\text{kg}/500\text{m}^2 \pm \text{SE}$) at SR1 (Lighthouse Reef) from 2004 to 2018.

South Reef 4 (SR4: North West Corner of South Atoll)

Site Overview. Made up of a steep reef wall, this topography and substrate of soft corals and sea fans attracts a plethora of small colorful fishes like damsels, butterflyfish, fairy basslets, and surgeonfish. The strong currents that frequent SR4 also attract an array of marine life, such as jacks, mackerel, Rainbow runners, barracuda and sharks. The wall topography also provides shelter for resting sharks and turtles.

Substrate. Living coral cover increased in this site over the last four years from 2014 ($32.6\% \pm 2.9$) to 2018 ($43.8\% \pm 7.2$). Soft coral cover remained about the same at 2014 ($8.4\% \pm 2.6$) to 2018 ($6.3\% \pm 1.8$). This site is rated as Fair (25% to 50% range).

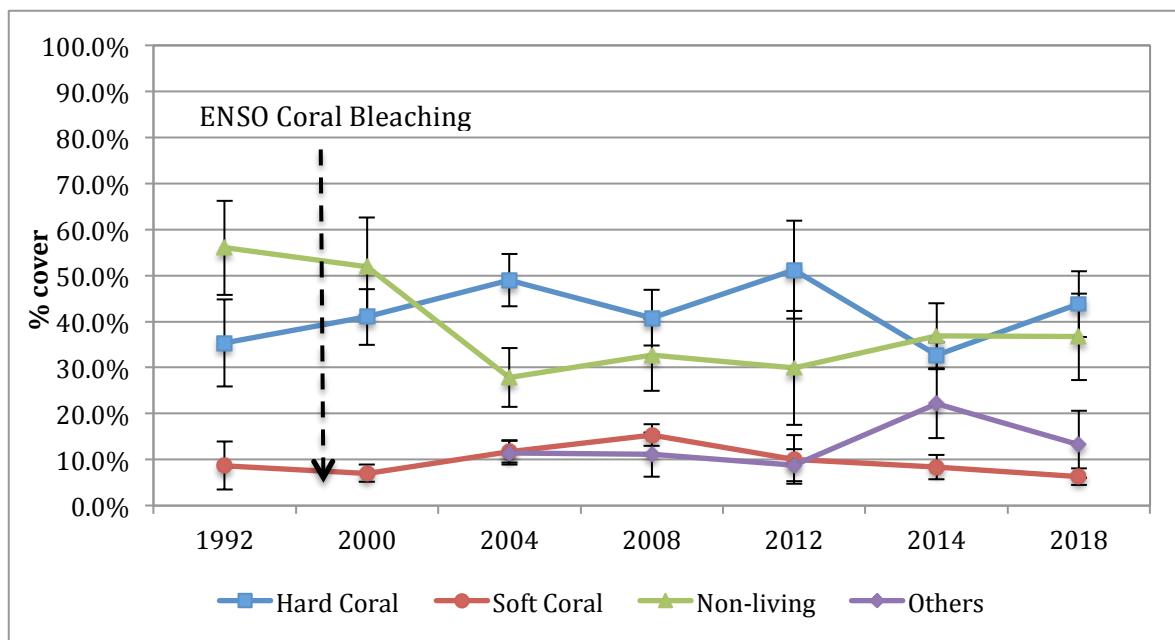


Figure 20. Substrate composition (%mean $\pm \text{SE}$) in SR4 (North West Corner), 1984 to 2018, 7-10m depth

Fish Diversity, Abundance, and Biomass. The target species richness decreased in SR4 from 2014 (25.4 species/500m² ±4.8 to 2018 (16.6 species/500m² ±2.3), but for all species richness, the number remained almost the same (55.2 species/500m²±13 to 46 species/500m²±7.1). Fish densities were stable with target fish at 210.6 fish/500m² ±52.5 (2014) to 214.4 fish/500m² ±79.2 (2018). All species density appeared to increase from 844.6 fish/500m² ±163.5 in 2014 to 2018 (1,875 fish/500m² ±470.1).

Fish biomass showed an increase from 125.6 kg/500m² ± 31.7 in 2014 to 255kg/500m² ±101, but the high standard error negates the positive increase, so in reality it remained generally stable through 4 years.

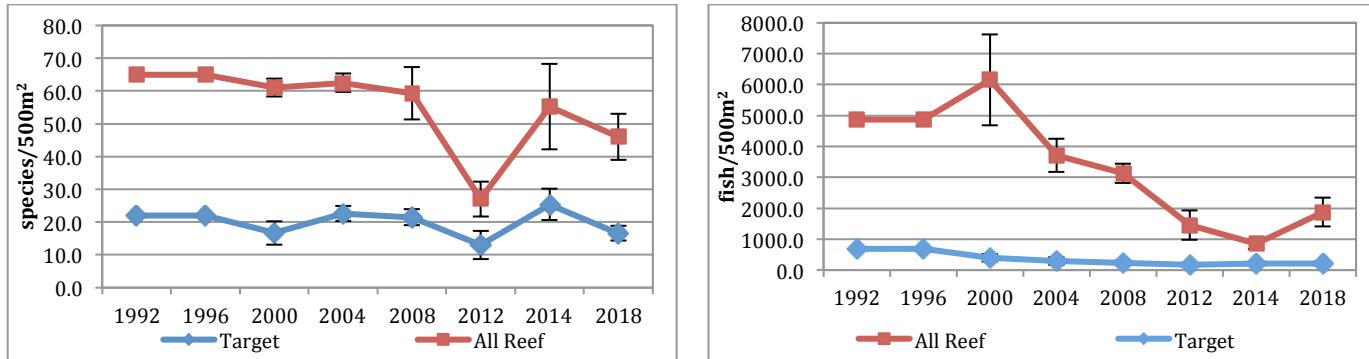


Figure 21. Fish species richness (species/500m² ±SE) and fish density (fish/500m² ±SE) at SR4 (North West Corner) from 1992 to 2018.

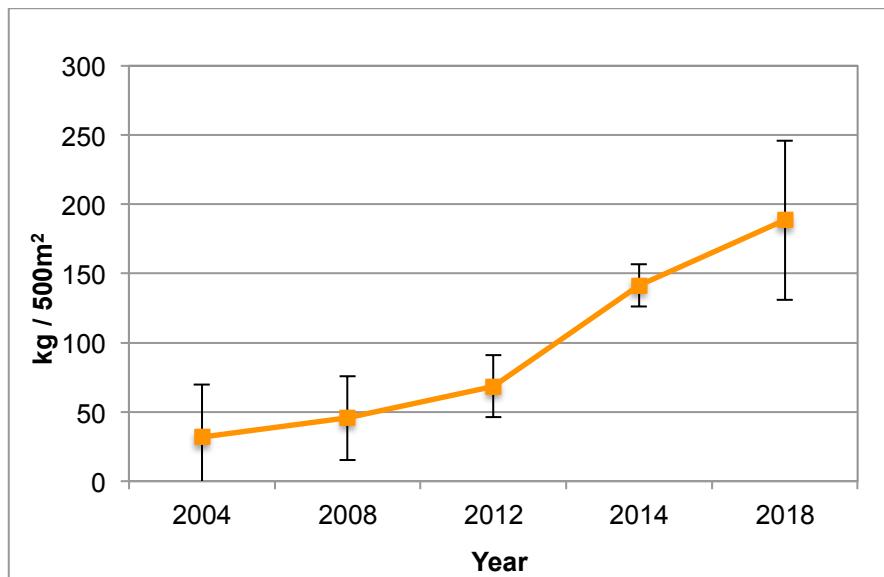


Figure 22. Target fish biomass (kg/500m² ±SE) at SR4 (North West Corner) from 2004 to 2018.

North Reef 2 (NR2: Ranger Station)

Site Overview. This site houses the Ranger Station where the TRNP park rangers live year round to protect the surrounding reefs. This station is located at the Southern end of the North Reef atoll to allow the Rangers to have a strategic view and access to most of the TRNP. The station is surrounded by a shallow sandy area that teems with young sharks, turtles, rays, triggerfish, sea-stars, and large sea cucumbers. This sandy area slopes down to a rich wall and reef crest, along a reef channel that is relatively calm and current-free.

Substrate. In the deep reef (7-8m; Figure 23), LHC has remained consistent from 2014 ($58.6\% \pm 4.6$) to 2018 ($59.3\% \pm 10.9$). Soft coral increased slightly from 2014 ($3.7\% \pm 1.5$) to 2018 ($9.5\% \pm 7.0$). Overall, the coral health in this area has remained consistently high with an overall rating of Good (50%-70% range).

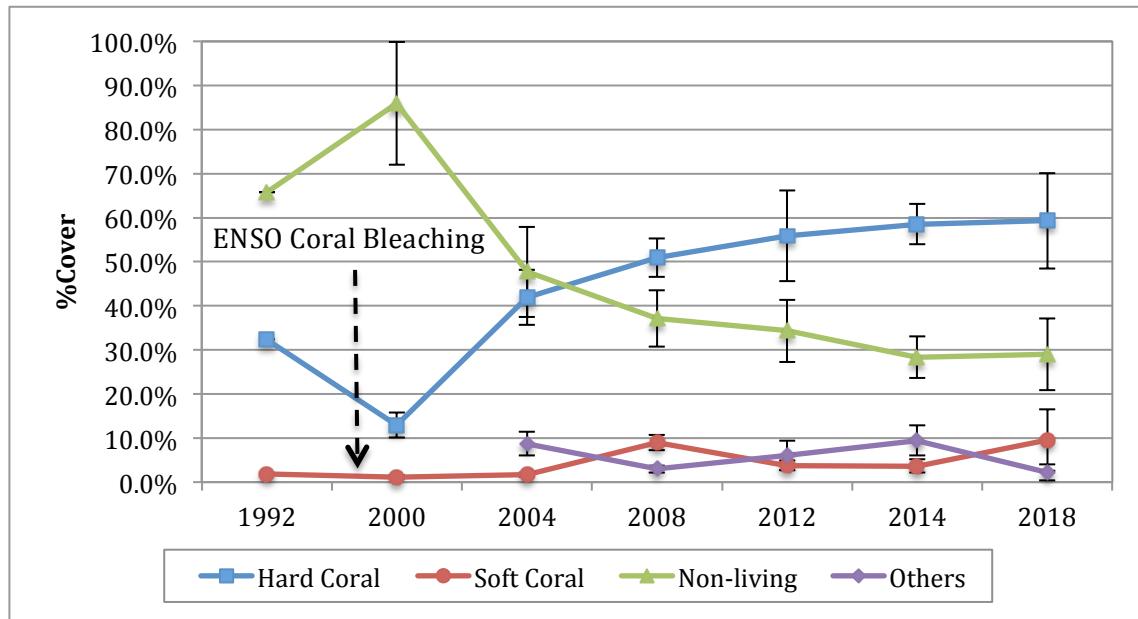


Figure 23. Changes in substrate composition (%mean \pm SE) in NR2 (Ranger Station) from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass. Fish species richness apparently decreased by half over the past four years at the Ranger Station site but this may also reflect some observer bias as noted in the methods section. Target fish species richness decreased to 15.3 species/ $500m^2 \pm 1.3$ from 25 species/ $500m^2 \pm 3$ in 2014. All reef species were counted at 43.7 species/ $500m^2 \pm 2.9$ down from 56.4 species/ $500m^2 \pm 4.5$ in 2014. Target fish density declined from 263 fish/ $500m^2 \pm 30.2$ to 74.7 fish/ $500m^2 \pm 17.2$ in 2018. All reef species density remained about the same in 2018.

Target fish biomass in the area decreased significantly from 82.7 kg/ $500m^2 \pm 15.3$ to 49 kg/ $500m^2 \pm 13$.

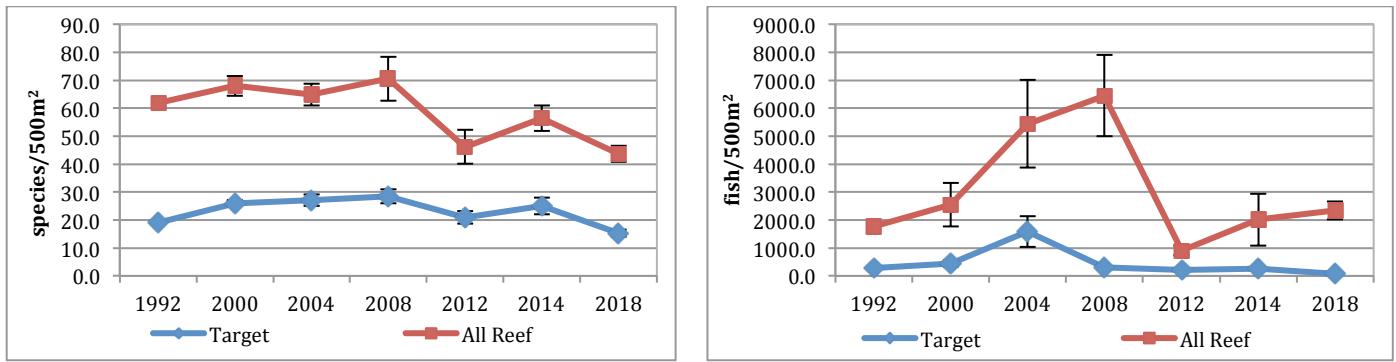


Figure 24. Fish species richness (species/500m² ±SE) and fish density (fish/500m² ±SE) at NR2 (Ranger Station) from 1992 to 2018.

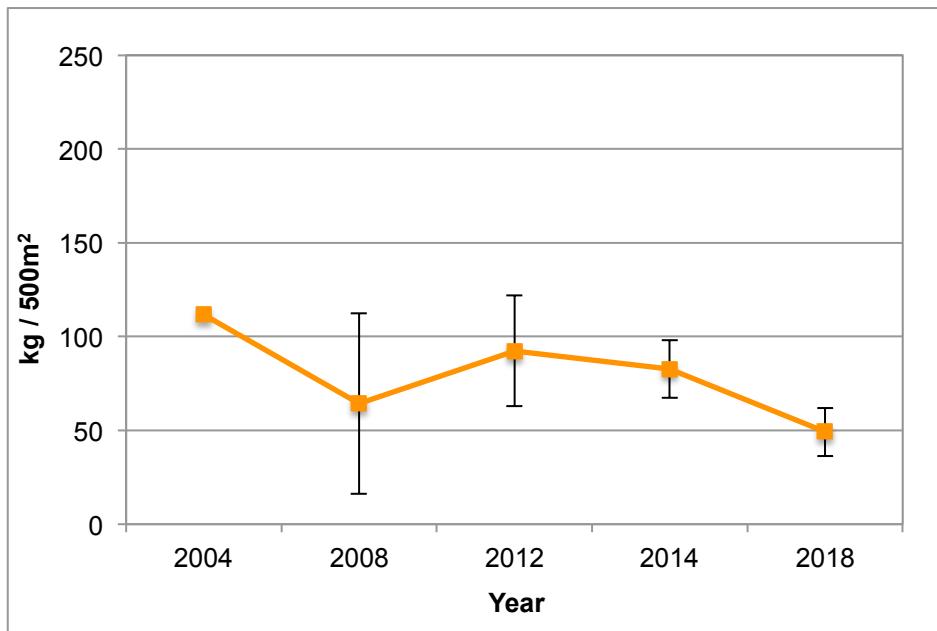


Figure 25. Target fish biomass (mean ±SE) at NR2 (Ranger Station) from 2004 to 2018.

Jessie Beazley

Site Overview. Jessie Beazley lies 20 kilometers from TRNP's North reef atoll and is an isolated pinnacle reef that was included in the TRNP in 2007 by Presidential Executive Order. The inclusion of Jessie Beazley reef more than doubled the total reef area of the TRNP. This rich reef has undergone its share of dynamite fishing and overfishing prior to protection. After the protection the reef has shown a strong recovery of substrate growth and fish diversity and abundance. There are gray reef and white tip sharks in the area and the occasional whale shark that swims by. The very shallow portion of the reef tends to have rubble due to the waves and currents that swirl around the islet but the slightly deeper shallow reef teems with butterflyfish, surgeonfish among others and some giant clams reside with relatively good branching coral cover. Parts of the reef slope to a reef wall and crest that creates protective crevices for snappers, barracuda, mackerel, triggerfish, unicornfish, angelfish, and hawkfish. Deeper crevices also house formations of sponges, coralline algae, sea fans, and soft coral.

Substrate. The substrate has remained consistent over the years in the deep areas (7-8 m) with LHC

cover in 2018 ($57.6\% \pm 5.3$) as compared to 2014 ($56.7\% \pm 4.8$). Soft coral has slightly decreased, although not so significantly, in 2018 ($16.9\% \pm 7.0$) as compared to 2014 ($21.8\% \pm 3.7$). In the shallow reef (Figure 26), there has been an increase in LHC from 2014 ($45.7\% \pm 4.1$) to ($51.8\% \pm 3.4$). Other sea life has increased from 2014 ($0.1\% \pm 0.1$) as compared to 2018 ($6\% \pm 2.3$), which further strengthens the observation of recovery of the reef. The reef rating is Good (50%-75%).

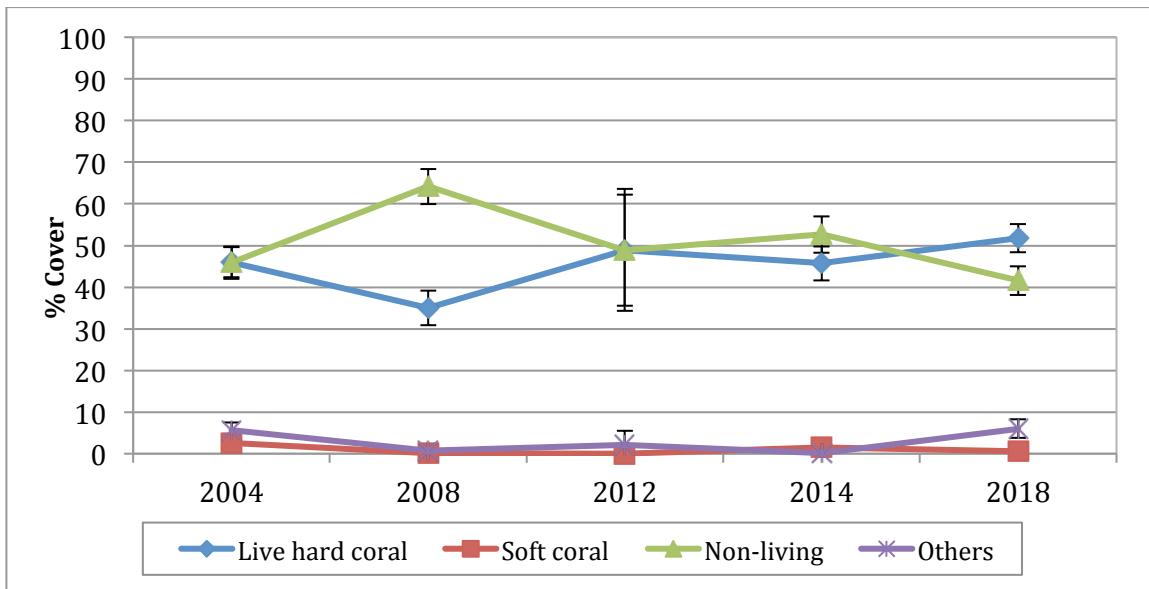


Figure 26. Changes in substrate composition (%mean \pm SE) in Jessie Beazley from 1984 to 2018, 2-3m depth.

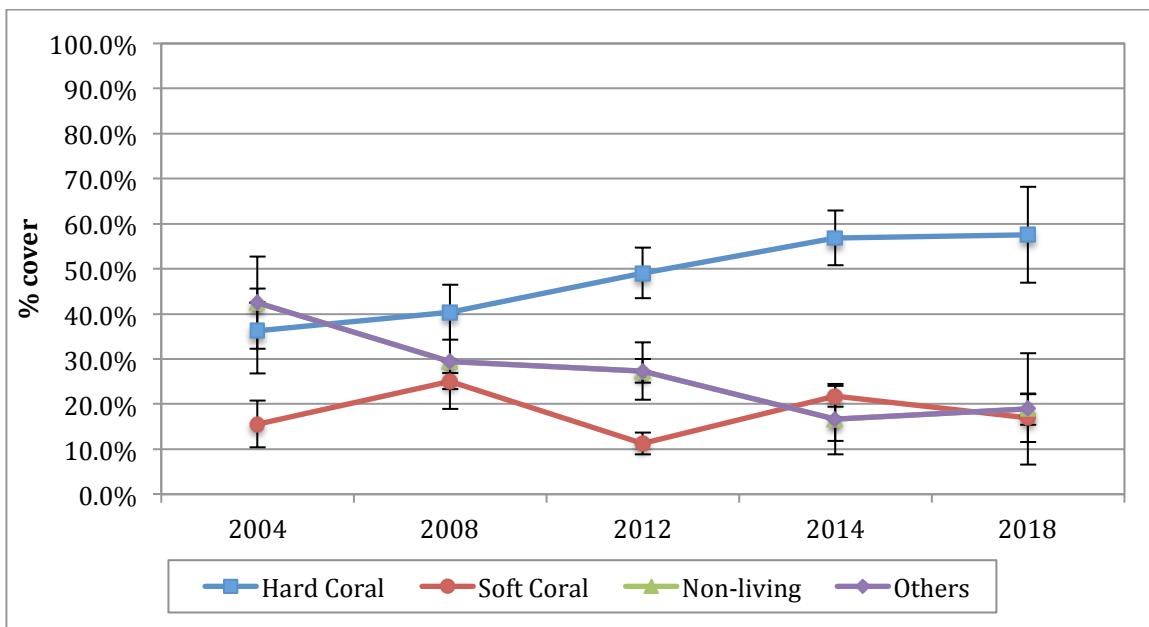


Figure 27. Changes in substrate composition (%mean \pm SE) in Jessie Beazley from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass. On the deeper reef (7-8 m), the target species richness has remained relatively consistent at 19.2 species/ $500m^2 \pm 3.4$ to 17 species/ $500m^2 \pm 2.2$. However, for all

reef species, there has been a marked decline from 2014 (53.6 species/500m² \pm 7.5) as compared to 2018 (39 species/500m² \pm 9.7). For target fish density, a similar trend emerges with a consistent 207 fish/500m² \pm 53.1 in 2014 and 202 fish/500m² \pm 65.5 in 2018. However, the density of all species increased from 2,756 fish/500m² \pm 1,377 in 2014 to 6,143.3 fish/500m² \pm 1,796.8 in 2018. But it must be noted that many of the fish counted were mainly damselfishes and fairy basslets.

Target fish biomass significantly increased from 43.3 kg/500m² \pm 13.2 to 123 kg/500m² \pm 36 in 2018. Jessie Beazley data shows that improved protection has allowed more and larger fish to populate the reef.

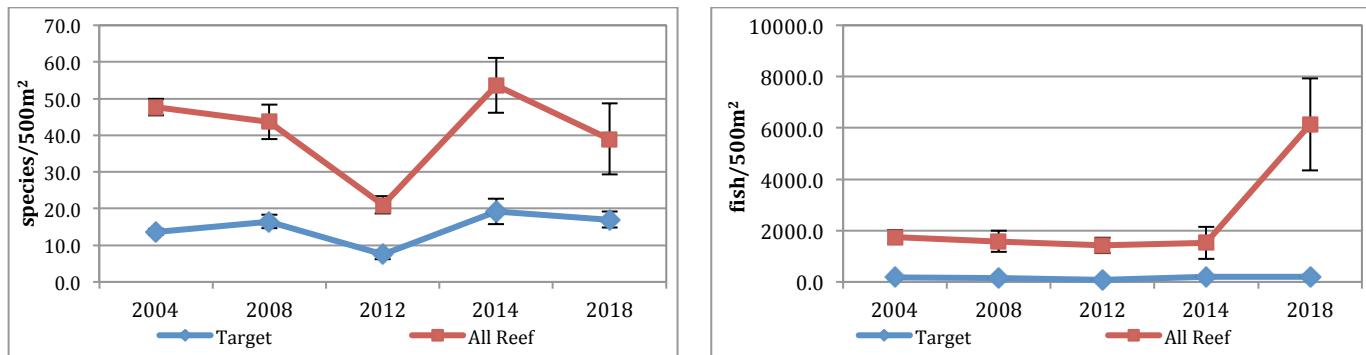


Figure 28. Fish species richness (species/500m² \pm SE) and fish density (fish/500m² \pm SE) at Jessie Beazley from 1992 to 2018.

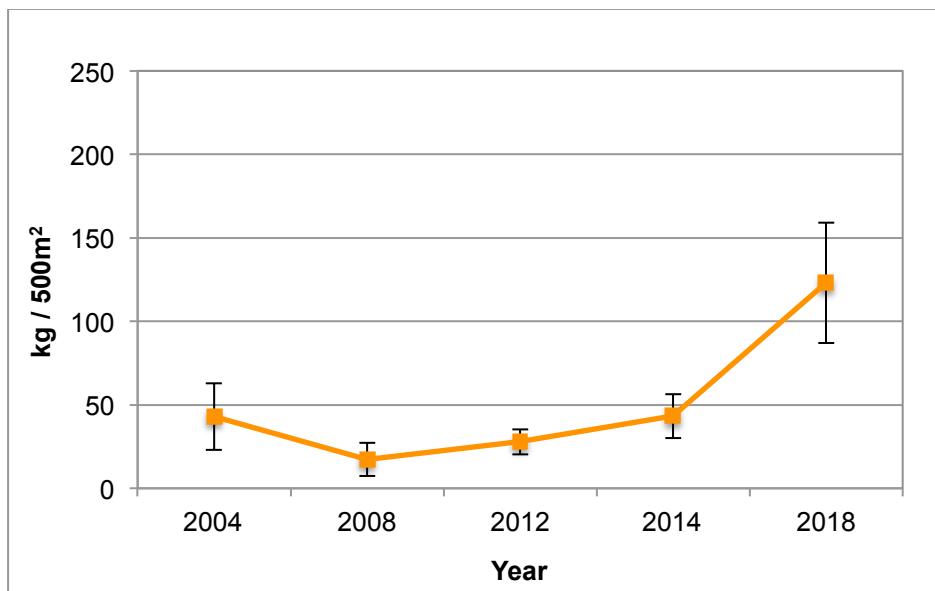


Figure 29. Target fish biomass (kg/500m² \pm SE) at Jessie Beazley from 2004 to 2018.

SUMMARY OF RESULTS AND TRENDS

Large Marine Life

Tubbataha reefs are well known for large marine life. Over the years, large marine animals have generally increased except for the sightings of manta rays and whale sharks, which have declined. This probably reflects fishing and threats outside the boundaries of the park. The presence of such marine life indicates reef health through effective protection within the park boundaries. This also reflects the ecosystem health of the area (Green et al. 2003). Figure 24 illustrates the gradual increases and fluctuations in number of large marine life sightings in Tubbataha Reefs. It is notable that there have been significant increases in the number of large tuna and mackerel, and various species of reef sharks are very abundant as compared to 10 years ago as well as sea turtles, which are seen on almost every scuba dive.

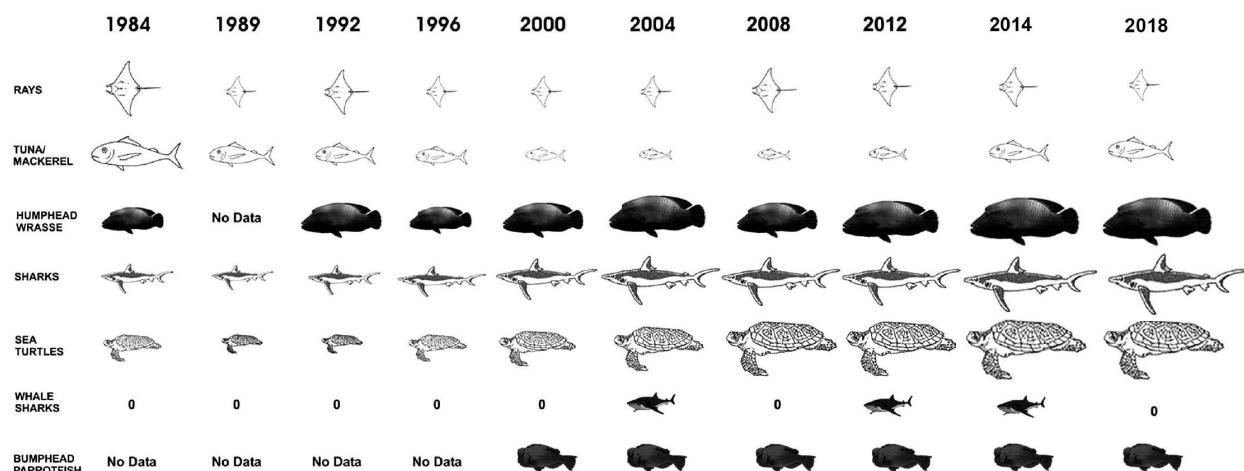


Figure 30. Changes in abundance of large marine life from 1984 to 2018.

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 and most sites show stable living coral cover. Only 2 shallow sites showed some decrease, NR-1 – Malayan Wreck ($15.4\% \pm 2.53$ from $29\% \pm 4.1$) in the shallow reef (Figure 31) and in SR-3 – Black Rock that declined to $39.1\% \pm 3.49$ from $52.2\% \pm 4.1$. These changes are most likely due to wave action in the shallow areas following bleaching in the past and can be attributed to natural variation. Overall, the shallow reefs display increasing trends in live hard coral cover, the highest of which was in Jessie Beazley, $51.8\% \pm 3.43$ in 2018 from $45.7\% \pm 4.1$ in 2014 (Figures 31).

For the deeper reef (7-8 m), trends in coral cover were also generally increasing, except for two sites NR-5 Bird Islet ($24.5\% \pm 6.73$ in 2018 from $35.4\% \pm 2.9$ in 2014) and SR-3 – Black Rock ($32.2\% \pm 13.55$ in 2018 to $52.6\% \pm 7.2$ in 2014) that showed some decline since 2014. While

both of these sites are popular dive sites, the declines can most likely be attributed to natural variation in the dynamics of the reef. In 2018, the site with the largest increase in coral cover was SR-4 Northwest corner with a LHC of $43.8\% \pm 7.2$ in 2018 from $32.6\% \pm 2.9$ in 2014 (Figure 31). The site with the highest coral cover at 7-8 m was in NR-2 Ranger Station at $59.3\% \pm 10.85$, which may be due to the calm waters and lack of exposure to waves and storms (Figure 31).

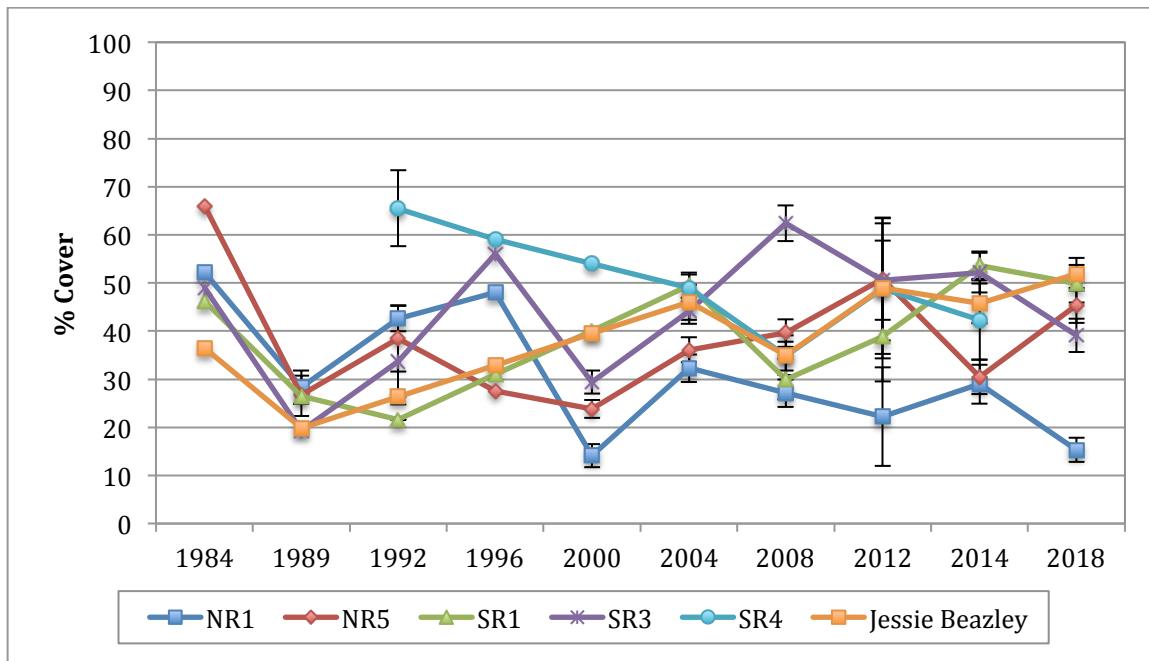


Figure 31. Changes in substrate composition (%mean \pm SE) in Tubbataha Reefs Marine Park from 1984 to 2018, 3-4m depth.

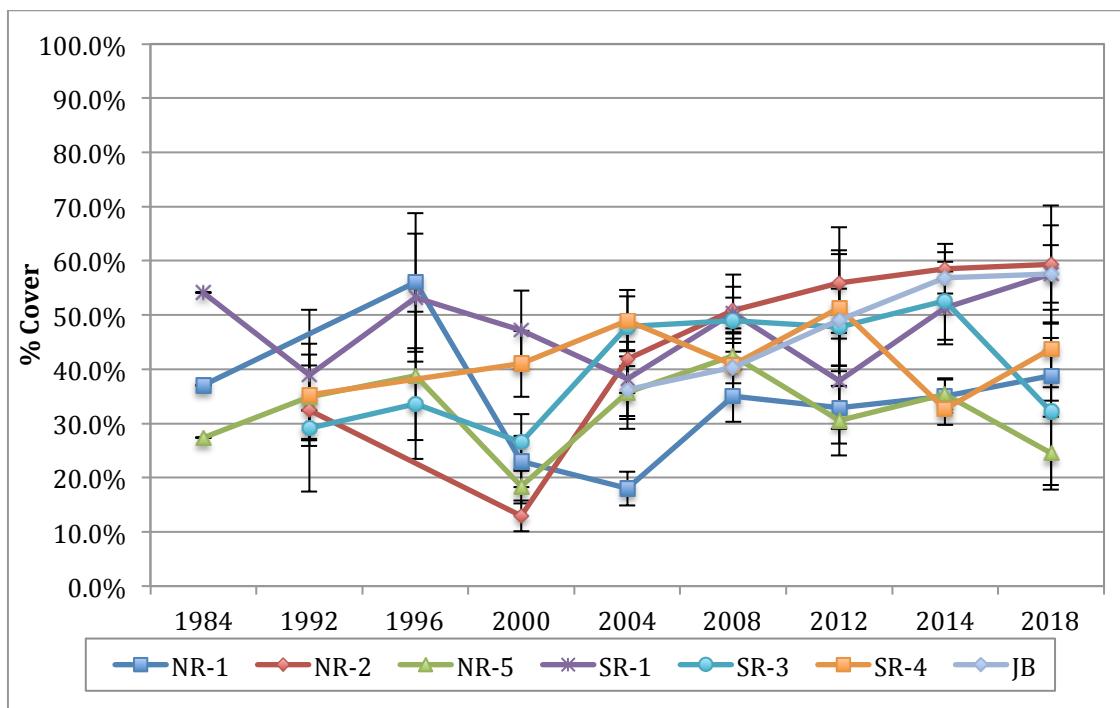


Figure 32. Changes in substrate composition (%mean \pm SE) in Tubbataha Reefs Marine Park from 1984 to 2018, 7-10m depth.

Fish Diversity, Abundance, and Biomass

In 2018, there have been increases in fish density for all reef species in most sites. For example, SR4 Northwest Corner increased from $844.6 \text{ fish}/500\text{m}^2 \pm 163.5$ in 2014 to $1,875.0 \text{ fish}/500\text{m}^2 \pm 470.1$. Figure 34 shows the increases in all reef species in all the sites from 2014 to 2018 and indicates that protection of the area effective for allowing more fish to thrive in the area.

Target species density increases are not as marked since two sites, NR2 Ranger Station and NR5 Bird Islet, show that there has been a decrease in target fish species populations. Target fish density in NR2 Ranger station decreased from $263.4 \text{ fish}/500\text{m}^2$ in 2014 to $74.7 \text{ fish}/500\text{m}^2$ in 2018 and in NR5 Bird Islet there was a decrease from $398.2 \text{ fish}/500\text{m}^2 \pm 46.8$ in 2014 to $249.7 \text{ fish}/500\text{m}^2 \pm 91.6$ in 2018. This is mostly natural variation on the reef and to some degree a result of having more and larger predators on the reef that feed on the smaller fish so that total numbers of fish will decline in some areas.

Fish species richness increased for target species in most sites (Figure 35). However, species counts for all reef species tended to show a decrease in most sites (Figure 36) due to observer bias because half of the fish counters were only looking at target species in their data collection and didn't count every species on the transect. Thus, the data is skewed lower for all species richness compared to years past.

The biomass in the sites of Tubbataha, as seen in Figure 37, will show a marked increase in biomass from 2014 to 2018 for all the sites, except for NR-2 (Ranger Station) where there was also a corresponding decrease in target species and density.

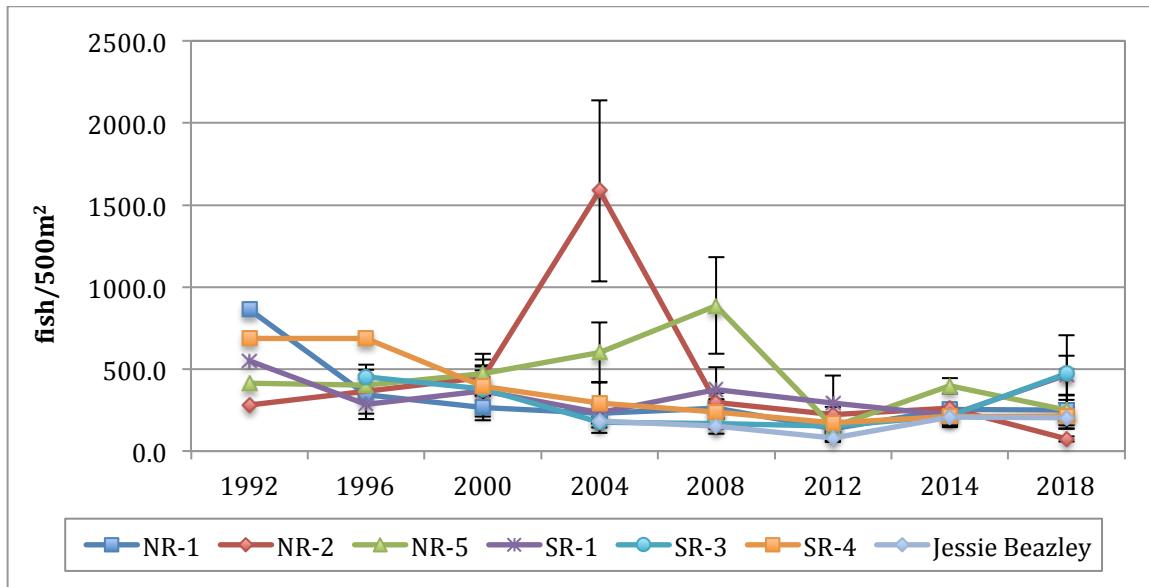


Figure 33. Mean (\pm SE) fish density (fish/ 500 m^2) of target fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2018.

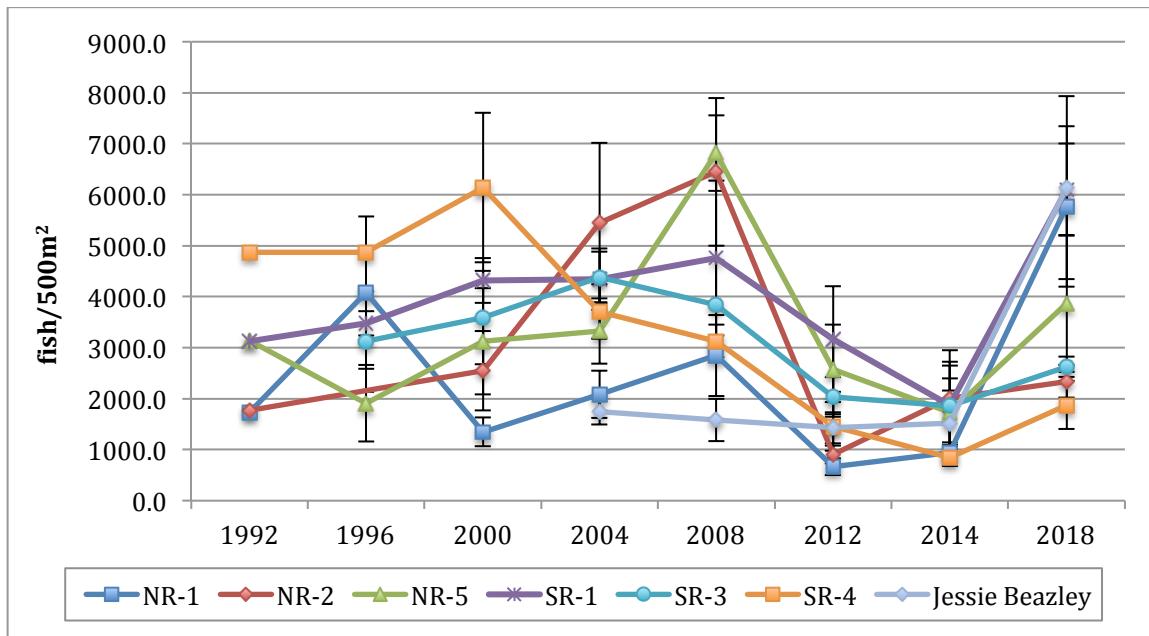


Figure 34. Mean (\pm SE) fish density (fish/ 500 m^2) of all reef fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2018.

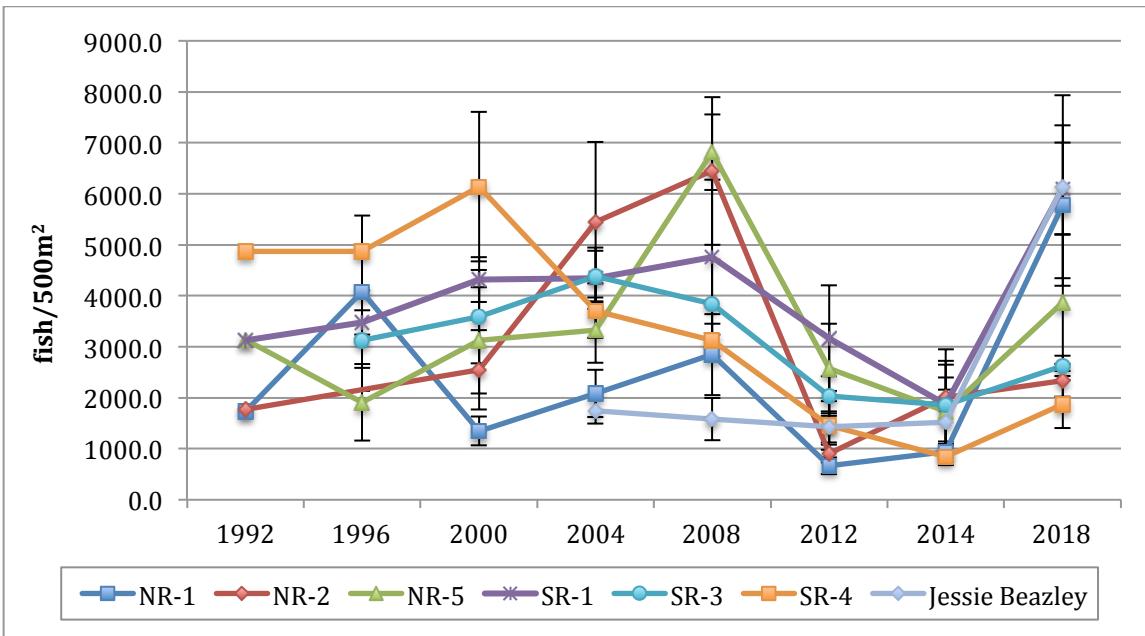


Figure 35. Mean (\pm SE) species (species/500 m²) of target fish species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2018.

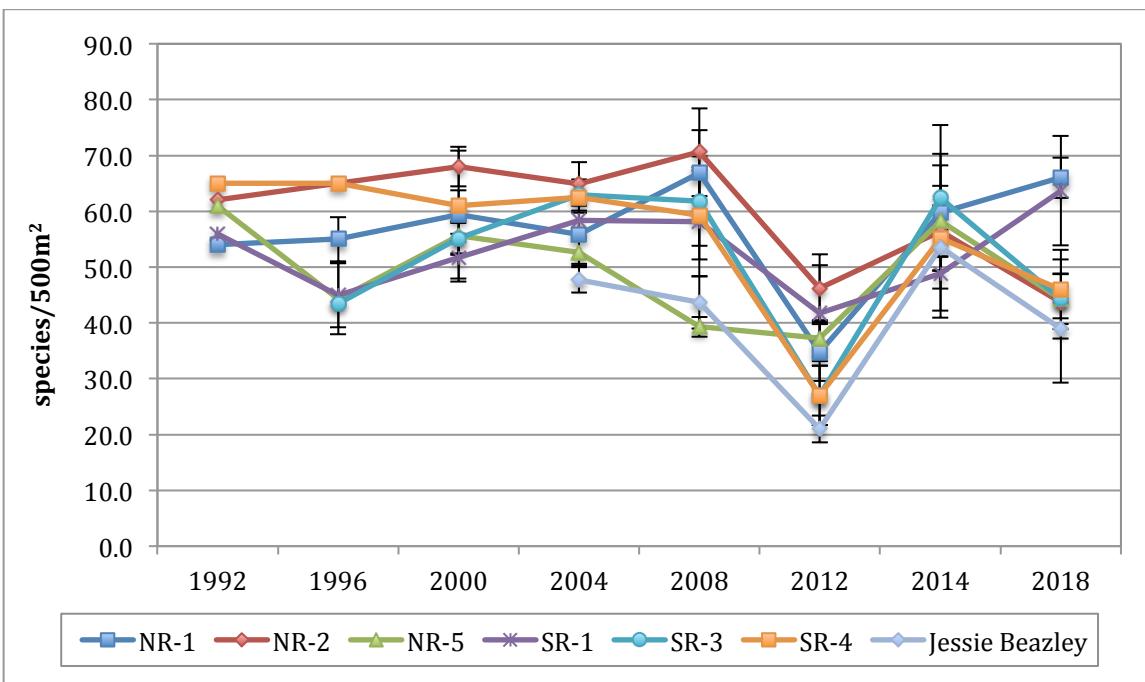


Figure 36. Mean (\pm SE) species (species/500 m²) of all reef species at seven sites in Tubbataha Reefs National Marine Park from 1992 to 2018.

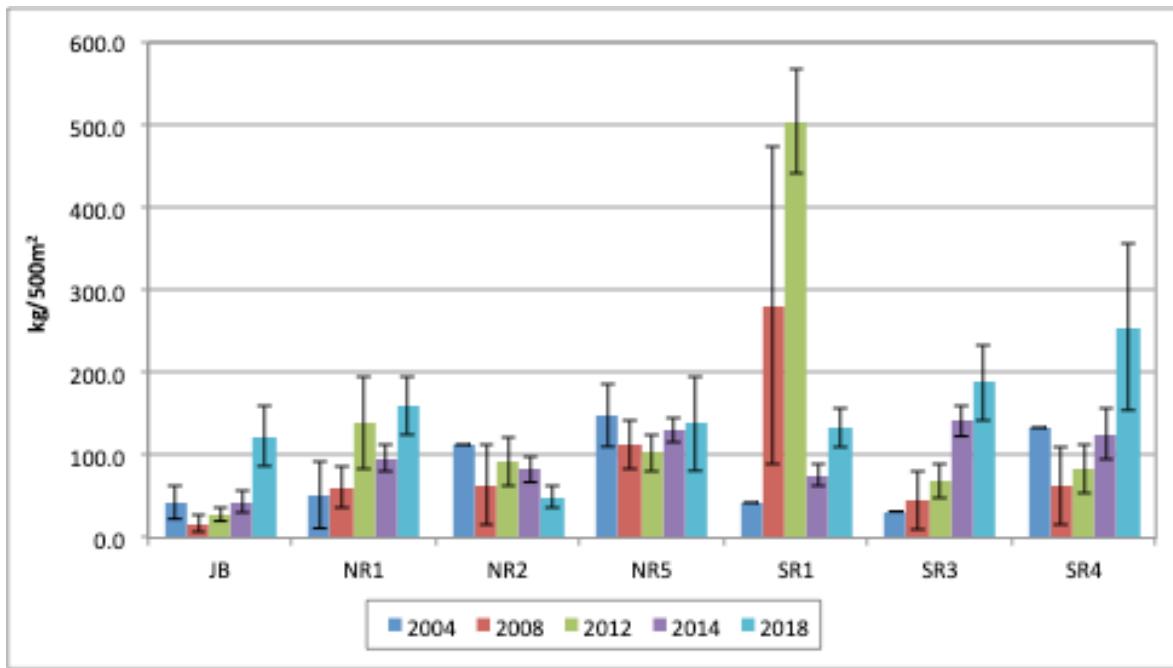


Figure 37. Fish biomass ($\text{kg}/500\text{m}^2 \pm \text{SE}$) per family at all sites in Tubbataha Reef Natural Park from 2004 to 2018.

RECOMMENDATIONS FOR IMPROVED SURVEYS AND PARK MANAGEMENT

After almost 3 decades of park management, the TRNP management group has learned to be adaptive and to adjust their strategy for what is needed for effective Park protection and management. There are always challenges, new and old, but overall the TRNP is a remarkable example of protection in the Philippines and across the Coral Triangle where it provides one of the best examples of effective coral reef protection and sustainable management of threats and a growing tourism industry. Below are a few suggestions to contribute to park management and further improvement based on observations during this 2018 survey.

Ongoing and continuing support for Park Rangers. The Rangers are a hard working group that focus 100% of their energies on protection of the area as they are based there for months, despite the season. They have expressed a need to create a lookout station on Bird Islet which would allow them to have a stop for patrolling as well as assisting researchers in bird censuses.

Addressing tourism challenges within the park. As the park gains more recognition as an excellent dive site, so has tourism increased over the years, thus increasing human intervention and presence in the area. Continuous and improved training should be done with local tour guides, dive operators, dive boats, etc. to assist in minimizing negative impacts of human presence in the protected waters. This would include providing materials such as visual aids and educational materials to visitors to teach them and to remind them of how they can have a positive or negative impact in the park. It is also important to monitor impact of these materials and educational activities so that TRNP management can further improve and modify them based on regular impact assessment.

Continued sharing of monitoring and evaluation reports to local stakeholders of TRNP. As time passes, researchers come and go to the TRNP and conduct studies looking at biodiversity, impact assessment, and overall TRNP conditions. The results of these studies should continue to be shared with local managers and stakeholders so that they understand the goals of TRNP management and contribute to its further success. Sharing such information with local and national policy makers may also help them understand what they need to do as lawmakers and budget allocators to contribute to further improvement in TRNP protection for the benefit of future generations.

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Table 1. Changes in substrate composition (%mean ±SE) in NR-5 (Bird Islet) from 1984 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS:										SNORKEL SURVEYS:											
	1984	1992	1996	2000	2004	2008	2012	2014	2018	% Change	1984	1989	1992	1996	2000	2004	2008	2012	2014	2018	% Change	
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	
Sand (s) and Silt (SI)	17.6	0.0	18.2	17.1	4.3	14.0	8.1	4.7	13.7	189.5	8.0	6.3	13.0	0.0	5.5	13.4	17.4	13.7	16.3	9.7	-40.5	
Coral Rubble (R)	16.4	17.3	14.3	22.6	10.7	9.9	9.6	8.7	12.2	40.3	4.2	21.4	27.4	2.5	9.2	18.1	16.6	7.0	15.3	6.9	-54.8	
Rock and Block (RK)	16.8	1.6	12.7	27.0	17.3	9.9	11.8	11.0	3.3	-70.3	9.5	17.4	3.4	57.0	49.8	23.2	16.0	17.5	28.1	28.5	1.2	
White Dead Standing Coral (DC)	6.0	11.4	2.2	1.2	0.2	0.4	1.0	0.4	0.1	-84.7	3.3	16.5	3.0	10.5	0.2	0.2	1.4	2.3	1.1	0.7	-38.6	
Dead Coral with Algae (DCA)	0.0	0.0	0.0	8.0	5.4	4.7	8.3	4.3	3.3	-23.0	0.0	0.0	0.0	9.0	4.4	5.2	5.0	1.8	3.3	81.7		
Subtotal Non-living Substrate	56.8	30.3	47.4	75.9	37.9	38.8	38.6	29.2	32.6	11.6	25.0	61.5	46.8	70.0	73.7	59.3	56.7	45.5	62.7	49.1	-21.7	
Branching (CB)	18.0	14.2	25.1	9.7	17.1	28.7	18.4	19.3	15.4	-20.5	45.0	25.3	25.0	17.5	0.0	22.6	27.0	26.5	16.6	25.9	55.9	
Massive (CM)	1.2	9.0	7.3	3.8	7.3	7.3	5.3	5.4	3.3	-38.9	15.3	1.0	8.0	5.0	0.0	11.0	10.1	14.4	8.6	11.2	29.3	
Flat/Encrusting (CFD)	7.3	11.3	4.1	4.0	10.5	6.0	2.1	4.0	2.1	-49.1	4.7	0.1	4.2	5.0	0.0	2.2	1.9	5.0	4.0	6.5	63.1	
Foliose Cup (CFO)	0.9	0.4	2.2	1.0	0.9	0.6	4.7	6.7	3.7	-44.1	1.0	0.4	1.3	0.0	0.0	0.3	0.7	4.8	1.3	1.9	41.9	
Total Hard Coral	27.4	34.9	38.7	18.5	35.7	42.5	30.5	35.4	24.5	-31.0	66.0	26.7	38.5	27.5	23.8	36.1	39.6	50.8	30.5	45.4	48.7	
Total Soft Coral	15.8	34.8	13.9	5.6	10.1	14.9	23.0	20.4	36.0	76.5	9.0	11.8	14.7	2.5	2.5	2.7	3.2	3.2	4.8	3.0	-36.9	
Subtotal Coral	43.2	69.7	52.6	24.1	45.8	57.4	53.5	55.8	60.5	8.3	75.0	38.5	53.2	30.0	26.3	38.8	42.8	53.9	35.3	48.4	37.0	
Sponges	~	~	~	~	5.9	1.6	3.3	4.7	2.7	-43.1	~	~	~	~	~	0.3	0.3	0.3	0.2	0.6	213.5	
Other animals	~	~	~	~	2.0	0.7	1.6	3.8	3.0	-21.1	~	~	~	~	~	0.1	0.0	0.1	0.2	0.2	-9.4	
Algae																						
Turf algae	~	~	~	~	0.6	0.6	0.4	1.0	0.4	-55.0	~	~	~	~	~	0.3	0.0	0.1	0.2	0.6	194.7	
Fleshy algae	~	~	~	~	0.9	0.2	1.0	0.9	0.3	-67.8	~	~	~	~	~	0.1	0.0	0.0	1.2	0.0	-96.8	
Coralline algae	~	~	~	~	~	6.7	0.8	1.4	4.6	0.6	-86.8	~	~	~	~	~	1.1	0.1	0.1	0.0	1.1	+
Seagrass	~	~	~	~	0.0	0.0	0.1	0.0	0.0	N/A	~	~	~	~	~	0.0	0.0	0	0.1	0.0	-100	
Subtotal Others	0	0	0	0	16.2	3.8	7.9	15.0	7.0	-53.3	0	0	0	0	0	1.9	0.5	0.6	2.0	2.5	26.0	
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	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	~	~	8.40		2-6	3.6	2-7	2-2.7	2.5	3.2	3.4	~	~	3.27		
Horizontal Visibility (m)	~	30	20	26	21.3	31.2	~	40	23.7		~	~	20-40	25	34.1	21.3	33.0	~	40	24.55		
No. of 50 m Transects	1	3	6	22	17	19	18	23	9		1	2	8	2	10	14	17	18	23	18		
~ 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 2. Mean (\pm SE) fish species density (fish/500m²) and percentage change between years at NR-5 (Bird Islet) from 1992 to 2018.

Family	(N=1)	(N=3)	% Change 1992-1996	(N=8)	% Change 1996-2000	(N=5)	% Change 2000-2004	(N=4)	% Change 2004-2008	(N=6)	% Change 2008-2012	(N=5)	% Change 2012-2014	(N=6)	% Change 2012-2014
	1992	1996		2000		2004		2008		2012		2014		2018	
	Density			Density											
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	99.3	32.6
Rabbitfish (Siganids)*	0.0	3.0	+	1.4	-54.2	0.2	-85.5	0.0	-100.0	1.0	+	1.1	10.0	1.2	6.1
Groupers (Serranids)*	5.0	8.0	60.0	13.8	71.9	7.2	-47.6	25.8	257.6	6.6	-74.4	9.3	40.9	8.0	-14.0
Baramundi cod	~	~	N/A	~	N/A	0.0	N/A	3.5	+	0.0	-100.0	0.0	N/A	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	12.5	-54.5
Sweetlips (Haemulonids)*	0.0	6.0	+	24.3	304.2	1.4	-94.2	13.8	882.1	2.3	-83.3	9.5	313.0	10.2	7.0
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	4.0	0.0
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	7.0	4.5
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	70.8	-71.9
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	0.3	N/A
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	1.7	-20.6
Parrotfish (Scarids)*	33.0	129.0	290.9	61.1	-52.6	38.6	-36.9	11.8	-69.6	19.2	62.7	15.2	-20.8	9.5	-37.5
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	+	0.0	-100.0	0.0	N/A
Rudderfish (Kyphosids)*	0.0	0.0	N/A	30	+	2	-92.6	0.8	-65.9	3.8	375.0	1.7	-55.3	26.7	1468.6
Triggerfish (Balistids)	3.0	7.0	133.3	17.0	142.9	16.2	-4.7	27.0	66.7	18.9	-30.0	15.3	-19.0	17.7	15.5
Butterflyfish (Chaetodontids)	62.0	37.7	-39.2	28.9	-23.3	45.6	57.9	73.5	61.2	15.0	-79.6	43.0	186.7	37.7	-12.4
Angelfish (Pomacanthids)	2.0	8.0	300.0	15.1	89.1	13.0	-14.0	6.5	-50.0	2.8	-56.9	3.6	28.6	5.0	38.9
Wrasses (Labrids)	198.0	113.0	-42.9	70.9	-37.3	83.8	18.2	39.8	-52.6	9.2	-76.9	25.7	179.3	29.0	12.8
Humphead wrasse	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.8	166.7	1.9	137.5	0.7	-64.9
Damselfish (Pomacentrids)	1422.0	942.0	-33.8	1424.9	51.3	542.4	-61.9	3171.3	484.7	1072.1	-66.2	680.4	-36.5	2016.7	196.4
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	553.0	-57.7	1319.3	138.6
Moorish Idols (Zanclus cornutus)	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	4.3	-15.0
Total (target reef spp.):	412.0	402.3	-2.4	470.4	16.9	602.2	28.0	887.0	47.3	145.7	-83.6	398.2	173.3	249.7	-37.3
Total (all reef spp.):	3134.0	1912.0	-39.0	3121.9	63.3	3325.0	6.5	6817.0	105.0	2574.2	-62.2	1732.5	-32.7	3869.7	123.4

* Target species/families* Target species/families (Note: Acanthurids<= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 3. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at NR-5 (Bird Islet) from 1992 to 2018.

Family	(N=1)		(N=3)		% Change 1992-1996	(N=8)		% Change 1996-2000	(N=5)		% Change 2000-2004	(N=4)		% Change 2004-2008	(N=6)		% Change 2008-2012	(N=5)		% Change 2012-2014	(N=6)		% Change 2014-2018			
	1992	1996	Species	2000		Species	2004		Species	2008		Species	2012	Species	2014	Species	2018									
Surgeonfish (Acanthurids)*	12.0	5.7	-52.8	7.5	32.4	6.4	-14.7	8.8	36.7	4.1	-53.4	7.4	80.5	5.5	-25.7											
Rabbitfish (Siganids)*	0.0	0.3	+	0.8	125.0	0.2	-73.3	0.0	-100.0	0.4	+	0.6	50.0	0.8	38.9											
Groupers (Serranids)*	1.0	1.3	33.3	3.8	181.3	3.4	-9.3	4.0	17.6	2.7	-32.5	2.8	3.7	2.8	1.2											
Barramundi cod	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.0	-100.0	0.0	N/A	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	4.6	109.1	2.8	-38.4											
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	0.8	-40.5											
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	0.8	4.2											
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	0.7	-55.6											
Fusiliers (Caesionids)*	2.0	0.3	-83.3	0.6	87.5	2.8	348.0	4.3	51.8	0.9	-79.1	4.1	355.6	1.5	-63.4											
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	0.3	N/A											
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	0.8	4.2											
Parrotfish (Scarids)*	1.0	1.0	0.0	2.6	162.5	3.0	14.3	3.8	25.0	3.1	-18.4	3.5	12.9	3.7	4.8											
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.0	N/A	0.1	+	0.0	-100.0	0.0	N/A											
Rudderfish (Kyphosids)*	0.0	0.0	N/A	1	+	0	-68.0	0.5	150	0.2	-60.0	0.4	100.0	0.3	-16.7											
Triggerfish (Balistids)	2.0	1.7	-16.7	2.9	72.5	1.2	-58.3	5.3	337.5	2.6	-50.9	3.2	23.1	2.0	-37.5											
Butterflyfish (Chaetodontids)	16.0	11.3	-29.2	11.4	0.4	7.2	-36.7	13.0	80.6	6.0	-53.8	8.8	46.7	7.0	-20.5											
Angelfish (Pomacanthids)	1.0	1.3	33.3	1.6	21.9	1.8	10.8	2.3	25.0	1.2	-47.8	1.7	41.7	1.0	-41.2											
Wrasses (Labrids)	6.0	6.3	5.6	6.0	-5.3	5.2	-13.3	10.5	101.9	2.6	-75.2	5.8	123.1	1.3	-77.0											
Humphead wrasse	~	~	N/A	~	N/A	0.0	N/A	0.3	+	0.4	33.3	0.6	50.0	0.3	-44.4											
Damselfish (Pomacentrids)	14.0	8.7	-38.1	7.5	-13.5	9.8	30.7	10.8	9.7	3.2	-70.4	7.3	128.1	6.3	-13.2											
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	1.9	18.8	4.0	110.5											
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	1.0	0.0											
Total (target reef spp.):	19.0	13.0	-31.6	23.4	80.0	22.6	-3.4	18.0	-20.4	18.0	0.0	24.3	35.0	21.0	-13.6											
Total (all reef spp.):	61.0	44.3	-27.4	55.6	25.5	52.8	-5.0	39.3	-25.7	35.8	-8.9	58.2	62.6	44.3	-23.8											

* Target species/families

% change = [(Yr₂/Yr₁)-1] x 100

(-) = decrease

(+) = increase

Table 4. Changes in substrate composition (% mean ±SE) in NR-1 (Malayan Wreck) from 1984 to 2018.

	SCUBA SURVEYS:										SNORKEL SURVEYS:										
	1984	1996	2000	2004	2008	2012	2014	2018	% Change	1984	1989	1992	1996	2000	2004	2008	2012	2014	2018	% Change	
SUBSTRATE COVER	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018		
Sand (s) and Silt (SI)	7.6	10.3	7.9	14.5	11.3	12.5	1.7	8.6	406.5	6.1	0.5	5.4	3.5	14.3	6.3	11.4	24.9	13.4	11.7	-12.8	
Coral Rubble (R)	10.5	10.8	22.7	19.3	9.6	12.7	7.7	7.3	-5.6	7	31.8	12.9	4.0	19.3	2.9	3.5	1.8	5.8	1.1	-81.4	
Rock and Block (RK)	36	14.4	33.2	27.7	21.3	17.8	15.9	20.4	28.4	23.6	18.8	27	32.8	45.9	45.0	45.6	37.0	40.5	51.1	26.0	
White Dead Standing Coral (DC)	5.9	0	0.6	0.1	0.6	0.4	0.4	0.4	8.6	6.5	9.4	6.7	11.3	0.4	0.1	0.5	0.6	1.6	0.4	-74.5	
Dead Coral with Algae (DCA)	0	3.3	11.1	2.9	8.3	7.5	5.5	6.0	10.1	0	0.0	0	5.6	5.2	6.2	8.9	3.2	2.3	2.3	-26.8	
Subtotal Non-living Substrate	60	38.8	75.5	64.5	51.2	50.9	31.1	42.7	37.2	43.2	60.4	52	51.5	85.5	59.5	67.2	73.3	64.6	66.6	3.1	
Branching (CB)	19.4	46.6	10.5	7.0	17.9	12.2	14.9	12.8	-14.0	36.3	22.6	27	42.3	~	19.5	12.8	7.9	9.0	4.5	-50.2	
Massive (CM)	6.4	2.3	6.2	5.5	8.0	10.8	5.5	11.2	104.2	7.3	2.7	8.1	4.5	~	8.0	10.5	7.7	11.0	5.4	-51.1	
Flat/Encrusting (CFD)	11	7	5.8	5.2	8.8	2.4	2.1	3.0	43.8	8	2.3	4.5	1.3	~	3.8	3.1	6.3	7.5	5.4	-28.5	
Foliose Cup (CFO)	0.5	0	0.5	0.3	0.6	7.5	12.4	11.8	-5.2	0.5	0.6	3	0	~	0.9	0.7	0.4	1.4	0.1	-94.3	
Total Hard Coral	37.3	55.9	23	18.0	35.3	33.0	34.9	38.8	11.2	52.1	28.3	42.6	48	14.1	32.3	27.1	22.2	29.0	15.3	-47.1	
Total Soft Coral	2.7	5.3	1.5	5.5	7.3	9.6	12.8	6.6	-48.4	4.7	11.3	5.4	0.5	0.4	1.5	1.7	1.0	0.5	1.6	238.6	
Subtotal Coral	40	61.2	24.5	23.5	42.7	42.6	47.7	45.4	-4.8	56.8	39.6	48	48.5	14.5	33.8	28.8	23.2	29.4	16.9	-42.5	
Sponges	~	~	~	~	1.7	1.9	2.3	6.2	4.0	-35.6	~	~	~	~	~	0.6	0.1	0.3	0.4	1.0	137.5
Other animals	~	~	~	~	0.2	1.2	0.7	3.5	1.1	-68.0	~	~	~	~	~	0.0	0.1	0.2	0.1	0.4	291.8
Algae	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	
Turf algae	~	~	~	~	6.6	0.9	1.4	1.8	2.7	50.6	~	~	~	~	~	2.9	0.2	1.5	0.7	11.2	1423.2
Fleshy algae	~	~	~	~	0.8	0.9	1.4	1.8	0.7	-61.1	~	~	~	~	~	2.0	3.3	1.4	4.3	3.2	-24.3
Coraline algae	~	~	~	~	2.8	1.2	0.7	7.9	3.4	-57.2	~	~	~	~	~	1.3	0.2	0.1	0.4	0.8	111.1
Seagrass	~	~	~	~	0.0	0.0	0	0.05	0.0	-40	~	~	~	~	~	0.0	0.0	0.1	0.0	-70	
Subtotal Others	~	~	~	~	12.1	6.2	6.5	21.2	11.9	-43.8	~	~	~	~	~	6.8	4.0	3.5	6.0	16.5	175.9
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	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	~	~	7.9		2-8	3-7	2-5	2-3	2.2	2.9	3.1	~	~	3.1		
Horizontal Visibility (m)	~	18	20.3	23.7	29.0	~	35	23		~	~	~	25	22.2	22.7	29.2	~	35	22.9		
No. of 50 m Transects	1	4	15	16.0	19.0	21	10	20		1	3	6	2	14	14.0	15.0	20	16	16		
~ no data available																					
* mean distance between lowest and highest point on the horizontal transect line																					

% change = [(Yr 2/Yr 1)-1] × 100

(-) = decrease

(+) = increase

Table 5. Mean (\pm SE) fish species density (fish/500m²) and percentage change between years at NR-1 (Malayan Wreck) from 1992 to 2018.

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	(N=5)	% Change 2012-2014	(N=10)	% Change 2012-2014
	1992	1996		2000		2004		2008		2012		2014		2018	
	Density			Density		Density		Density		Density		Density		Density	
Surgeonfish (Acanthurids)*	222.0	123.0	44.6	104.0	15.4	128.3	23.3	109.7	14.5	55.0	-49.9	81.8	48.7	139.8	70.8
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	1.0	150.0
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	10.8	-11.9
Baramundi cod	~	~	N/A	~	N/A	0.0	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	14.1	-18.8
Sweetlips (Haemululids)*	3.0	1.5	-50.0	0.0	-100.0	0.5	+	3.8	655.6	0.0	-100.0	6.0	N/A	2.8	-54.2
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	8.8	191.7
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	36.9	179.4
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	20.0	-79.4
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	0.0	-100.0
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	3.3	-53.6
Parrotfish (Scarids)*	129.0	33.0	-74.4	45.8	38.8	15.3	-66.7	24.0	57.4	10.0	-58.3	21.2	112.0	17.9	-15.7
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	1.6	+	2.9	81.3	4.2	44.8	0.0	-100.0
Rudderfish (Kyphosids)*	0.0	0.0	N/A	1	+	0	-100.0	2.2	+	0.0	-100.0	0.0	N/A	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	511.0	1614.8
Butterflyfish (Chaetodontids)	44.0	75.0	70.5	65.0	-13.3	44.4	-31.7	65.3	47.2	29.8	-54.4	55.6	86.6	46.3	-16.7
Angelfish (Pomacanthids)	38.0	9.0	-76.3	34.2	280.0	9.6	-71.9	15.8	63.9	4.4	-72.2	7.0	59.1	26.7	281.0
Wrasses (Labrids)	189.0	27.0	-85.7	48.8	80.7	199.0	307.8	51.7	-74.0	28.7	-44.5	35.2	22.6	456.7	1197.3
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	166.7	0.8	166.7	1.4	75.0	2.0	42.9
Damselfish (Pomacentrids)	420.0	3153.0	650.7	616.8	-80.4	834.5	35.3	1013.6	21.5	288.5	-71.5	207.0	-28.2	2724.7	1216.3
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	334.6	287.3	1572.3	369.9
Moorish Idols (Zanclus cornutus)	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	9.0	136.8
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	253.8	86.2	248.5	-2.1
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	938.4	40.6	5770.3	514.9

* Target species/families (Note: Acanthurids <= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 6. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at NR-1 (Malayan Wreck) from 1992 to 2018.

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	(N=5)		% Change 2012-2014	(N=10)		% Change 2014-2018			
	1992	1996	Species	2000		Species	2004		Species	2008		2008	Species	2012	Species	2014	Species	2018	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	6.8	47.8	7.5	10.3											
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	0.4	87.5											
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	3.3	25.0											
Barramundi cod	~	~	N/A	~	N/A	0.0	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	2.3	-37.5											
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	0.5	-16.7											
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	0.8	-37.5											
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	2.3	60.7											
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	0.3	-84.4											
Spinecheeks (Nemipterids)*	0.0	1.0	+	12.6	1160.0	0.6	-95.0	0.7	6.7	0.5	-28.6	0.2	-60.0	0.0	-100.0											
Goatfish (Mullids)*	1.0	1.0	0	1.4	40.0	1.9	33.9	1.8	-5.2	1.1	-38.9	1.2	9.1	0.9	-27.1											
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	5.3	45.8											
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A	0.1	+	0.5	400.0	0.4	-20.0	0.0	-100.0											
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0	+	0	-100.0	0.3	+	0.0	-100.0	0.0	N/A	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	5.7	23.2											
Butterflyfish (Chaetodontids)	11.0	11.0	0.0	9.6	-12.7	9.8	1.6	12.2	25.4	5.0	-59.0	10.6	112.0	10.7	0.6											
Angelfish (Pomacanthids)	2.0	3.0	50.0	2.6	-13.3	1.8	-32.7	2.8	58.7	1.6	-42.9	2.8	75.0	4.0	42.9											
Wrasses (Labrids)	5.0	4.0	-20.0	6.6	65.0	8.6	30.7	9.3	8.2	3.6	-61.3	7.6	111.1	6.0	-21.1											
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	166.7	0.5	66.7	0.0	-100.0	0.7	N/A											
Damselfish (Pomacentrids)	10.0	11.0	10.0	5.2	-52.7	6.9	32.2	8.4	22.8	3.8	-54.8	7.8	105.3	7.7	-1.7											
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	2.0	185.7	3.0	50.0											
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	1.0	0.0											
Total (target reef spp.):	21.0	19.5	-7.1	29.2	49.7	22.1	-24.2	25.9	17.0	15.8	-39.0	23.2	46.8	23.3	0.2											
Total (all reef spp.):	54.0	55.0	1.9	59.4	8.0	55.8	-6.1	66.9	20.0	34.3	-48.7	59.8	74.3	66.0	10.4											

* Target species/families

% change = [(Yr₂/Yr₁)-1] x 100

(-) = decrease

(+) = increase

Table 7. Changes in substrate composition (% mean ±SE) in SR-3 (Black Rock) from 1984 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS:										SNORKEL SURVEYS:									
	1992	1996	2000	2004	2008	2012	2014	2018	% Change	1984	1989	1992	1996	2000	2004	2008	2012	2014	2018	% Change
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018
Sand (s) and Silt (SI)	1.1	3.8	3.8	8.9	8.4	3.9	7.8	13.6	74.8	1.1	6.1	14.4	6.0	4.1	8.3	3.8	3.5	4.2	5.4	30.7
Coral Rubble (R)	17.6	22.5	40.5	16.7	17.0	12.2	16.9	21.1	25.1	16.3	26.6	9.0	6.5	12.7	9.6	10.7	7.9	9.1	16.4	79.2
Rock and Block (RK)	4.9	7.4	14.8	5.0	3.5	9.7	2.8	3.8	35.7	12.2	18.3	32.3	4.5	41.9	24.7	11.2	24.0	25.4	27.0	6.4
White Dead Standing Coral (DC)	0.6	1.8	2.6	0.3	0.4	0.4	0.1	1.1	1384.0	5.2	4.0	2.1	18.0	2.0	0.4	1.0	2.1	0.9	2.0	121.5
Dead Coral with Algae (DCA)	0.0	0.0	8.4	4.4	6.1	5.1	7.2	8.3	14.8	0.0	0.0	0.0	9.2	6.6	6.1	4.5	3.8	4.6	20.7	
Subtotal Non-living Substrate	24.2	35.5	70.1	35.3	35.5	31.3	34.7	47.8	37.7	34.8	55.0	57.8	35.0	69.9	49.5	32.8	42.1	43.4	55.4	27.7
Branching (CB)	17.9	27.7	17.5	39.1	39.9	32.1	45.9	24.7	-46.2	32.7	15.7	19.3	41.0	~	27.5	49.2	31.2	35.5	21.5	-39.6
Massive (CM)	8.1	2.1	3.4	2.8	4.6	7.3	1.7	3.1	81.4	8.8	3.6	8.6	9.0	~	8.9	3.8	9.6	7.8	6.4	-17.5
Flat/Encrusting (CFD)	0.7	2.7	4.8	5.3	3.4	1.6	0.9	2.0	110.0	5.4	0.0	5.1	4.5	~	6.5	3.0	4.3	4.3	10.1	135.6
Foliose Cup (CFO)	2.4	1.1	0.9	0.8	1.2	6.8	4.1	2.4	-41.3	2.0	0.0	0.7	1.5	~	1.2	6.4	5.4	4.6	1.2	-74.1
Total Hard Coral	29.0	33.6	26.5	47.9	49.0	47.8	52.6	32.2	-38.9	48.9	19.3	33.7	56.0	29.4	44.2	62.4	50.6	52.2	39.1	-25.0
Total Soft Coral	46.8	30.9	3.4	11.4	12.6	16.1	8.6	15.9	83.5	16.3	25.7	8.5	9.0	0.7	2.9	4.2	6.8	3.2	3.3	0.9
Subtotal Coral	75.8	64.5	29.9	59.3	67.6	63.9	61.3	48.0	-21.7	65.2	45.0	42.2	65.0	30.1	47.0	66.6	57.3	55.4	42.4	-23.5
Sponges	~	~	~	1.8	1.3	1.9	1.8	1.7	-6.5	~	~	~	~	~	0.6	0.0	0.1	0.1	0.1	80.0
Other animals	~	~	~	0.5	0.5	0.175	1.1	0.1	-90.4	~	~	~	~	~	0.2	0.0	0.4	0.7	0.4	-50.8
Algae																				
Turf algae	~	~	~	0.8	0.2	0.5	0.0	1.1	+	~	~	~	~	~	1.3	0.1	0.0	0.2	0.7	219.8
Fleshy algae	~	~	~	0.1	0.1	0.4	0.2	0.0	-100.0	~	~	~	~	~	0.2	0.0	0.0	0.2	0.3	30.6
Coralline algae	~	~	~	2.2	1.0	1.925	0.9	1.3	56.3	~	~	~	~	~	1.2	0.4	0.1	0.1	0.8	1100.0
Seagrass	~	~	~	0.0	0.0	0.1	0.0	0.0	+	~	~	~	~	~	0.0	0.0	0.0	0.00	+	
Subtotal Others	0.0	0.0	0.0	5.4	3.0	4.9	4	4.2	4.5	0.0	0.0	0.0	0.0	3.5	0.6	0.6	1.3	2.3	76.2	
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	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	~	~	8.25		3.5	~	2-7	1-2.7	2.6	2.7	3.5	~	~	3.43	
Horizontal Visibility (m)	~	25.0	27.9	28.8	32.5	~	40	28.1		~	~	~	23.9	28.7	32.9	~	40	29.4		
No. of 50 m Transects	4	4	16	16	20	20	7	9		1	2	3	2	12	15	15	11	5	17	
~ 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 8. Mean (\pm SE) fish species density (fish/500m 2) and percentage change between years at SR-3 (South Reef) Black Rock from 1996 to 2018.

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	(N=7)	% Change 2014-2018
	1996	2000		2004		2008		2012		2014		2018	
	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	334.1	407.8
Rabbitfish (Siganids)*	7.5	3.0	-60.0	4.5	50.0	3.4	-25.0	2.0	-41.2	2.8	40.0	1.3	-54.1
Groupers (Serranids)*	3.5	11.6	231.4	15.6	34.7	17.0	8.8	8.9	-47.6	13.6	52.8	9.1	-32.8
Barramundi cod	~	~	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	25.0	106.6	8.1	-67.4
Sweetlips (Haemulids)*	1.5	3.0	100.0	3.5	16.7	5.6	60.7	3.0	-46.4	19.8	560.0	6.4	-67.5
Emperors (Lethrinids)*	0.0	2.6	+	20.3	678.8	8.1	-59.9	0.8	-90.1	8.6	975.0	16.7	94.4
Jacks (Carangids)*	0.0	9.8	+	7.3	-26.0	4.8	-34.5	9.9	106.3	8.4	-15.2	3.6	-57.5
Fusiliers (Caesionids)*	193.5	81.4	-57.9	4.1	-94.9	32.3	681.8	37.5	16.1	57.0	52.0	74.7	31.1
Spinecheeks (Nemipterids)*	16.5	0.2	-98.8	0.8	275.0	1.3	66.7	0.0	-100.0	1.6	N/A	0.6	-64.3
Goatfish (Mullids)*	66.0	28.2	-57.3	10.9	-61.4	6.1	-43.7	0.5	-91.8	4.2	740.0	3.6	-15.0
Parrotfish (Scarids)*	69.0	58.2	-15.7	23.6	-59.4	15.0	-36.5	9.5	-36.7	16.0	68.4	15.4	-3.6
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.1	+	7.0	6900.0	0.0	-100.0	0.0	N/A
Rudderfish (Kyphosids)*	0.0	17.8	+	0.0	-100.0	0.0	N/A	1.0	+	0.0	-100.0	0.0	N/A
Triggerfish (Balistids)	3.5	21.6	517.1	8.6	-60.1	32.3	273.9	31.3	-3.1	17.2	-45.0	7.3	-57.4
Butterflyfish (Chaetodontids)	25.5	24.8	-2.7	32.5	31.0	33.0	1.5	20.0	-39.4	30.2	51.0	15.0	-50.3
Angelfish (Pomacanthids)	3.5	16.2	362.9	9.4	-42.1	8.9	-5.3	5.4	-39.3	8.6	59.3	12.3	43.4
Wrasses (Labrids)	67.5	154.2	128.4	85.5	-44.6	31.3	-63.5	7.6	-75.7	21.2	178.9	16.7	-21.4
Humphead wrasse	~	~	N/A	0.0	N/A	0.8	+	0.1	-87.5	1.6	1500.0	0.3	-79.2
Damselfish (Pomacentrids)	919.5	2096.8	128.0	2309.9	10.2	2424.3	5.0	1070.5	-55.8	967.0	-9.7	1057.7	9.4
Fairy Basslets (Anthids)	1618.5	890.8	-45.0	1733.5	94.6	1117.5	-35.5	747.6	-33.1	583.6	-21.9	512.7	-12.2
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	3.3	-33.3
Total (target reef spp.):	451.0	379.6	-15.8	175.5	-53.8	169.4	-3.5	151.0	-10.9	213.0	41.1	472.1	121.7
Total (all reef spp.):	3122.0	3593.4	15.1	4384.5	22.0	3840.8	-12.4	2034.7	-47.0	1857.2	-8.7	2624.3	41.3

* Target species/families (Note: Acanthurids<= 10cm in length not counted in Target species population)

% change = $[(Y_{t2}/Y_{t1}) - 1] \times 100$

(-) = decrease

(+) = increase

Table 9. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at SR-3 (South Reef) Black Rock from 1996 to 2018.

Family	(N=1)	(N=6)	% Change 1996-2000	(N=8)	% Change 2000-2004	(N=8)	% Change 2004-2008	(N=4)	% Change 2008-2012	(N=5)	% Change 2012-2014	(N=7)	% Change 2014-2018							
	1996	2000		2004		Species		2008		2014		2018								
	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	4.4	-40.2							
Rabbitfish (Siganids)*	1.5	1.2	-20.0	1.4	14.6	1.0	-27.3	0.4	-60.0	1.2	200.0	0.6	-52.4							
Groupers (Serranids)*	2.0	2.4	20.0	3.1	30.2	2.9	-8.0	1.2	-58.6	3.2	166.7	3.3	2.7							
Barramundi cod	~	~	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	4.2	133.3	1.9	-55.8							
Sweetlips (Haemulids)*	0.5	0.6	20.0	0.6	4.2	0.8	20.0	0.6	-25.0	1.4	133.3	0.9	-38.8							
Emperors (Lethrinids)*	0.0	0.6	+	1.5	150.0	1.3	-16.7	0.3	-76.9	1.0	233.3	1.1	14.3							
Jacks (Carangids)*	0.0	1.0	+	1.4	37.5	1.3	-9.1	0.5	-61.5	2.0	300.0	0.9	-57.1							
Fusiliers (Caesionids)*	1.5	1.2	-20.0	0.1	-89.6	0.8	500.0	0.9	12.5	1.4	55.6	1.1	-18.4							
Spinecheeks (Nemipterids)*	0.5	0.2	-60.0	0.3	25.0	0.5	100.0	0.0	-100.0	0.6	N/A	0.4	-28.6							
Goatfish (Mullids)*	1.0	1.2	20.0	1.8	45.8	1.6	-7.1	0.1	-93.8	1.2	1100.0	0.9	-28.6							
Parrotfish (Scarids)*	1.0	0.8	-20.0	3.4	321.9	2.9	-14.8	1.4	-51.7	3.2	128.6	4.7	47.3							
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.1	+	0.1	0.0	0.0	-100.0	0.0	N/A							
Rudderfish (Kyphosids)*	0.0	0.6	+	0.0	-100.0	0.0	N/A	0.3	+	0.0	-100.0	0.0	N/A							
Triggerfish (Balistids)	2.5	4.2	68.0	2.5	-40.5	4.9	95.0	2.3	-53.1	3.8	65.2	2.0	-47.4							
Butterflyfish (Chaetodontids)	8.0	12.0	50.0	11.1	-7.3	10.9	-2.2	5.1	-53.2	10.2	100.0	5.7	-44.4							
Angelfish (Pomacanthids)	1.5	2.6	73.3	2.8	5.8	2.5	-9.1	0.9	-64.0	1.8	100.0	1.0	-44.4							
Wrasses (Labrids)	4.5	5.4	20.0	8.6	59.7	8.8	1.4	1.1	-87.5	7.0	536.4	2.7	-61.9							
Humphead wrasse	~	~	N/A	0.0	N/A	0.5	+	0.1	-80.0	0.6	500.0	0.3	-44.4							
Damselfish (Pomacentrids)	7.5	9.0	20.0	12.5	38.9	8.9	-29.0	4.5	-49.4	9.4	108.9	7.0	-25.5							
Fairy Basslets (Anthids)	2.0	2.0	0.0	2.1	6.3	1.6	-23.5	1.2	-25.0	1.8	50.0	2.3	29.6							
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	0.7	-33.3							
Total (target reef spp.):	16.5	19.0	15.2	22.4	17.8	22.6	1.1	12.6	-44.2	26.8	112.7	20.1	-24.8							
Total (all reef spp.):	43.5	55.2	26.9	62.9	13.9	61.8	-1.8	28.1	-54.5	62.4	122.1	44.3	-29.0							

* Target species/families

% change = $[(Y_{t2}/Y_{t1}) - 1] \times 100$

(-) = decrease

(+) = increase

Table 10. Changes in substrate composition (% mean ±SE) in SR-1 (Lighthouse) from 1984 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS:										SNORKEL SURVEYS:									
	1984	1992	1996	2000	2004	2008	2012	2014	2018	% Change	1984	1989	1992	2004	2008	2012	2014	2018	% Change	
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	
Sand (s) and Silt (SI)	1.7	2.0	0.0	2.9	1.3	2.4	15.8	0.8	4.3	456.7	0.5	3.6	14.6	3.0	12.6	8.5	5.0	7.2	42.5	
Coral Rubble (R)	8.3	13.1	16.7	16.6	18.4	20.9	23.2	22.0	12.7	-42.3	3.5	20.6	20.5	0.5	8.6	8.9	1.0	8.2	681.8	
Rock and Block (RK)	32.1	35.1	9.5	3.4	7.2	2.0	8.8	6.3	2.9	-53.6	37.0	39.6	40.2	36.4	40.1	38.5	36.1	27.0	-25.0	
White Dead Standing Coral (DC)	0.2	0.3	2.5	3.3	0.4	0.8	0.6	0.2	0.6	174.5	5.0	5.1	0.5	0.3	2.8	0.3	0.7	0.5	-25.8	
Dead Coral with Algae (DCA)	0.0	0.0	0.0	19.3	3.0	5.5	4.2	5.8	8.4	46.1	0.0	0.0	0.0	2.3	2.5	3.0	1.9	3.5	86.8	
Subtotal Non-living Substrate	42.3	50.5	28.7	45.5	30.4	31.6	52.6	35.1	29.0	-17.4	46.0	68.9	75.8	42.5	66.6	59.2	44.7	46.4	3.8	
Branching (CB)	33.6	29.5	51.6	41.6	25.9	47.3	25.5	34.1	45.2	32.5	25.0	15.2	15.1	13.2	18.5	24.3	29.7	23.2	-21.7	
Massive (CM)	10.1	6.5	3.0	1.9	6.5	1.3	5.7	6.6	5.3	-18.7	10.2	7.2	3.8	16.6	8.7	9.6	13.7	10.7	-22.2	
Flat/Encrusting (CFD)	10.3	1.5	3.8	3.3	5.3	1.4	1.2	0.8	0.6	-21.6	9.2	3.2	0.0	17.4	2.1	3.6	8.3	11.4	37.3	
Foliose Cup (CFO)	0.1	1.1	0.9	0.5	0.5	0.4	5.4	9.8	6.4	-34.5	1.8	0.9	2.8	2.3	0.7	1.4	1.9	4.5	133.7	
Total Hard Coral	54.1	38.9	59.3	47.3	38.2	50.3	37.8	51.3	57.6	12.3	46.2	26.5	21.6	49.5	30.0	38.9	53.6	49.8	-7.1	
Total Soft Coral	3.6	10.6	12.0	7.2	25.1	16.3	5.5	5.5	9.0	63.1	7.8	4.6	2.7	0.6	0.3	0.8	0.6	0.6	-7.2	
Subtotal Coral	57.7	49.5	71.3	54.5	63.3	66.7	43.3	56.8	66.5	17.2	54.0	31.1	24.3	50.0	30.3	39.7	54.2	50.4	-7.1	
Sponges	~	~	~	~	1.7	0.5	1.6	3.5	2.5	-27.7	~	~	~	0.8	0.2	0.1	0.2	0.3	25.9	
Other animals	~	~	~	~	1.0	0.5	0.6	2.3	0.4	-82.9	~	~	~	0.4	0.0	0.19	0.38	0.4	4.9	
Algae																				
Turf algae	~	~	~	~	0.8	0.2	0.5	0.0	0.4	+	~	~	~	1.1	0.7	0.0	0.0	2.0	4.9	
Fleshy algae	~	~	~	~	0.3	0.3	0.2	0.0	0.4	+	~	~	~	1.2	1.5	0.4	0.1	0.1	121.1	
Coralline algae	~	~	~	~	2.5	0.2	1	2.3	0.7	-70.4	~	~	~	4.0	0.5	0.3	0.3	0.4	14.6	
Seagrass	~	~	~	~	0.0	0.0	0.0	0.0	N/A	~	~	~	0.0	0.0	0.0	0.0	0.0	N/A		
Subtotal Others	0.0	0.0	0.0	0.0	6.3	1.7	4.0	8.1	4.4	-45.6	0.0	0.0	0.0	7.4	3.0	1.0	1.0	3.2	208.2	
TOTAL	100.0	100.0	100.0	100.0	100.0	100	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)	~	~	~	16.2	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	~	~	8.40	2-7	2-7	1.5	2.9	2.3	~	~	~	3.14		
Horizontal Visibility (m)	~	30.0	25.0	27.8	25.0	31.3	~	50	27.4	~	~	~	25.9	28.8	~	50	27.3			
No. of 50 m Transects	1	4	8	16	17	17	13	9	18		1	3	2	17	10	18	21	19		
~ 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 11. Mean (\pm SE) fish species density (density/500m²) and percentage change between years at SR-1 (South Reef) Lighthouse from 1992 to 2018.

Family	(N=1)	(N=3)	% Change 1992-1996	(N=8)	% Change 2000- Density	(N=5)	% Change 2004- Density	(N=4)	% Change 2008- Density	(N=8)	% Change 2012- Density	(N=10)	% Change 2014- Species	(N=10)	% Change 2018- Species	% Change 2014-2018
	1992	1996		2000	1996-2000	2004		2008	2004-2008	2012	2008-2012	2014	2012-2014	2018	2014-2018	
		Density														
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	221.8	278.5	
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	2.4	140.0	
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	17.4	46.2	
Barramundi cod	~	~	N/A	~	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	14.4	620.0	122.0	747.2	
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	2.0	-13.0	
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	8.0	19.4	
Jacks (Carangids)*	9.0	2.5	-72.2	3.7	46.7	7.6	108.0	118.3	1451.3	170.3	44.0	4.1	-97.6	13.0	217.1	
Fusiliers (Caesionids)*	129.0	21.0	-83.7	5.2	-75.4	29.6	473.4	162.6	448.8	18.8	-88.4	113.9	505.9	10.0	-91.2	
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	0.2	-80	
Goatfish (Muluids)*	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	5.8	262.5	
Parrotfish (Scarids)*	129.0	43.5	-66.3	140.2	222.2	14.0	-90.0	6.9	-51.0	30.5	342.0	11.2	-63.3	52.6	369.6	
Bumphead parrotfish	~	~	N/A	~	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	12.6	1045.5	
Triggerfish (Balistids)	148.0	45.3	-69.4	129.8	186.9	333.3	156.7	20.4	-93.9	36.0	76.5	39.9	10.8	78.7	97.2	
Butterflyfish (Chaetodontids)	33.0	35.3	6.8	34.0	-3.5	45.4	33.5	45.7	0.7	34.5	-24.5	27.1	-21.4	72.7	168.1	
Angelfish (Pomacanthids)	34.0	14.0	-58.8	26.8	91.7	17.9	-33.4	10.4	-41.7	5.3	-49.0	4.5	-15.1	8.3	85.2	
Wrasses (Labrids)	87.0	40.0	-54.0	179.0	347.5	62.4	-65.2	52.1	-16.4	17.0	-67.4	33.4	96.5	62.7	87.6	
Humphead wrasse	~	~	N/A	~	N/A	0.3	N/A	0.4	71.4	0.8	100.0	1.3	62.5	1.3	2.6	
Damselfish (Pomacentrids)	1221.0	2232.0	82.8	2805.2	25.7	2042.5	-27.2	2282.6	11.8	2102.5	-7.9	887.0	-57.8	3816.0	330.2	
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	646.5	-4.7	1457.0	125.4	
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	4.3	138.9	9.3	117.1	
															N/A	
Total (target reef spp.):	550.0	283.3	-48.5	366.0	29.2	235.5	-35.7	372.9	58.3	293.8	-21.2	218.5	-25.6	462.8	111.8	
Total (all reef spp.):	3132.0	3479.3	11.1	4316.7	24.1	4344.5	0.6	4758.1	9.5	3169.0	-33.4	1871.8	-40.9	6098.7	225.8	

* Target species/families (Note: Acanthurids <= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 12. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at SR-1 (South Reef) Lighthouse from 1992 to 2018.

Family	(N=1)	(N=3)	% Change 1992-1996	(N=8)	% Change 2000-2000	(N=5)	% Change 2004-2004	(N=4)	% Change 2008-2008	(N=8)	% Change 2012-2012	(N=10)	% Change 2014-2014	(N=10)	% Change 2018-2018	% Change 2014-2018
	1992	1996		Species	2000	Species		2004	Species	2008	Species	2014		2018	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	7.8	39.3	
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	1.0	150.0	
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	3.4	-10.5	
Barramundi cod	~	~	N/A	~	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	3.6	-14.3	
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	1.0	100.0	
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	0.6	-40.0	
Jacks (Carangids)*	1.0	0.5	-50.0	1.0	100.0	0.9	-12.5	1.9	112.2	2.0	5.3	1.1	-45.0	2.2	100.0	
Fusiliers (Caesionids)*	1.0	1.0	0.0	0.3	-66.7	0.6	87.5	1.4	128.6	0.5	-64.3	2.0	300.0	0.2	-90.0	
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	0.2	-33.3	
Goatfish (Mullids)*	1.0	0.8	-25.0	0.5	-33.3	1.5	200.0	0.1	-90.5	1.0	900.0	0.4	-60.0	1.4	250.0	
Parrotfish (Scarids)*	1.0	2.0	100.0	4.0	100.0	2.3	-43.8	2.3	1.6	2.8	21.7	2.6	-7.1	6.2	138.5	
Bumphead parrotfish	~	~	N/A	~	N/A	0.0	N/A									
Rudderfish (Kyphosids)*	0.0	0.0	N/A	0.2	N/A	0.6	200.0									
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	3.0	-11.8	
Butterflyfish (Chaetodontids)	8.0	12.3	53.1	10.2	-17.0	12.0	18.0	11.4	-4.8	6.0	-47.4	7.3	21.7	11.7	59.8	
Angelfish (Pomacanthids)	2.0	1.5	-25.0	2.8	88.9	3.9	36.8	2.6	-33.6	2.5	-3.8	2.0	-20.0	2.0	0.0	
Wrasses (Labrids)	5.0	4.8	-5.0	5.8	22.8	9.4	60.7	6.9	-26.9	4.0	-42.0	4.7	17.5	3.7	-22.0	
Humphead wrasse	~	~	N/A	~	N/A	0.1	N/A	0.3	128.6	0.5	66.7	0.6	20.0	0.7	11.1	
Damselfish (Pomacentrids)	13.0	7.0	-46.2	7.3	4.8	8.5	15.9	7.9	-7.6	6.3	-20.3	6.2	-1.6	12.0	93.5	
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	1.7	13.3	3.0	76.5	
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	0.8	60.0	1.3	66.7	
Total (target reef spp.):	21.0	14.3	-31.9	18.3	28.0	17.4	-5.1	17.4	0.3	17.5	0.6	18.4	5.1	28.2	53.3	
Total (all reef spp.):	56.0	45.0	-19.6	51.7	14.9	58.4	12.9	58.1	-0.4	41.8	-28.1	48.8	16.7	63.7	30.5	

* Target species/families

% change = [(Yr2/Yr1)-1] × 100

(-) = decrease

(+) = increase

Table 13. Changes in substrate composition (% mean ±SE) in SR-4 (Northwest Corner) from 1992 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS:								SNORKEL SURVEY:				
	1992	2000	2004	2008	2012	2014	2018	% Change	1992	2004	2008	2012	2014
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover
Sand (s) and Silt (SI)	2.3	1.7	4.0	3.0	0.6	4.8	3.1	-36.3	4.3	3.9	4.1	4.0	9.2
Coral Rubble (R)	11.8	10.3	8.9	14.1	12.7	17.9	9.9	-44.8	5.0	3.1	5.2	0.4	2.7
Rock and Block (RK)	41.6	26.5	11.5	9.0	12.4	7.3	11.4	56.5	21.0	36.0	45.7	37.2	40.4
White Dead Standing Coral (DC)	~	0.8	0.2	0.2	0.1	0.4	0.3	-30.0	3.0	0.0	0.1	1.3	0.0
Dead Coral with Algae (DCA)	0.3	12.7	3.2	6.5	4.0	6.5	12.1	86.2	0.0	2.7	2.3	3.9	2.4
Subtotal Non-living Substrate	56.0	52.0	27.8	32.8	29.9	36.9	36.7	-0.4	33.3	45.8	57.3	47.0	54.7
Branching (CB)	19.2	20.0	27.2	18.1	22.1	14.3	13.0	-9.0	37.3	17.0	10.4	19.2	21.2
Massive (CM)	7.7	9.6	10.3	8.8	12.4	6.1	11.9	96.0	15.3	13.4	16.0	15.8	9.9
Flat/Encrusting (CFD)	6.0	10.6	10.5	12.9	1.6	1.2	4.8	291.2	12.2	15.8	8.0	11.8	8.0
Foliose Cup (CFO)	2.3	0.8	1.0	1.1	15.2	11.1	14.1	27.4	0.7	2.8	0.4	2.0	3.2
Total Hard Coral	35.2	41.0	49.0	40.8	51.3	32.6	43.8	34.0	65.5	48.9	34.8	48.8	42.3
Total Soft Coral	8.8	7.0	11.7	15.3	10.1	8.4	6.3	-24.6	1.2	1.0	1.1	1.1	0.1
Subtotal Coral	44.0	48.0	60.7	56.1	61.3	41.0	50.1	22.1	66.7	49.9	35.9	49.9	42.4
Sponges	~	~	3.2	2.9	3.9	6.1	4.7	-23.4	~	0.4	0.2	0.7	1.9
Other animals	~	~	1.1	3.1	0.4	10.4	1.5	-86.1	~	0.1	0.3	0.6	0.9
Algae													
Turf algae	~	~	0.5	1.2	0.3	2.1	2.3	8.6	~	0.2	0.7	0.4	0.0
Fleshy algae	~	~	0.9	0.9	1.3	1.0	0.8	-25.0	~	0.0	4.9	0.0	0.1
Coralline algae	~	~	5.9	3.1	2.9	2.4	4.2	70.9	~	3.6	0.7	1.5	0.0
Seagrass	~	~	0.0	0.0	0.0	0.1	0.0	-100	~	0.0	0.0	0.0	0.0
Subtotal Others	0.0	0.0	11.5	11.1	8.8	22.1	13.3	-40.2	0.0	4.3	6.8	3.2	2.9
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
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	~	~	8.22		2.0	2.4	2.5	~	~
Horizontal Visibility (m)	~	27.8	28.5	27.3	~	35	21		~	28.7	28.6	~	35
No. of 50 m Transects	3	18	17	17	9	8	10		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] × 100

(-) = decrease

(+) = increase

Table 14. Mean (\pm SE) fish species density (fish/500m²) and percentage change between years at SR-4 (South Reef) Northwest Corner from 1992 to 2018.

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	(N=7)	% Change 2018	% Change 2014-2018	
	1992	2000		2004		2008		2012		2014		2018			
	Density					Density				Density					
Surgeonfish (Acanthurids)*	324.0	215.2	-33.6	106.3	-50.6	45.0	-57.6	33.2	-26.2	71.6	115.7	121.7	70.0		
Rabbitfish (Siganids)*	0.0	2.7	+	2.1	-20.3	0.3	-84.3	1.6	433.3	1.8	12.5	0.6	-68.3		
Groupers (Serranids)*	17.0	21.5	26.5	15.0	-30.2	20.7	37.8	4.8	-76.8	17.0	254.2	5.4	-68.1		
Barramundi cod	~	~	N/A	0.0	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	18.2	127.5	23.6	29.5		
Sweetlips (Haemulids)*	3.0	0.5	-83.3	0.5	0.0	9.2	1733.3	0.2	-97.8	12.8	6300.0	12.3	-4.0		
Emperors (Lethrinids)*	0.0	27.2	+	12.9	-52.6	2.2	-83.2	3.2	45.5	3.0	-6.3	11.9	295.2		
Jacks (Carangids)*	9.0	22.2	146.3	13.6	-38.5	5.3	-60.9	4.2	-20.8	5.6	33.3	4.6	-18.4		
Fusiliers (Caesionids)*	129.0	15.8	-87.7	5.5	-65.3	116.5	2018.2	105.8	-9.2	78.8	-25.5	21.4	-72.8		
Spinecheeks (Nemipterids)*	0.0	24.3	+	5.5	-77.4	0.5	-90.9	0.0	-100.0	1.2	N/A	0.0	-100.0		
Goatfish (Mullids)*	0.0	20.0	+	8.4	-58.1	14.7	75.1	0.0	-100.0	2.4	N/A	0.4	-82.1		
Parrotfish (Scarids)*	129.0	39.5	-69.4	24.9	-37.0	18.2	-27.0	11.0	-39.6	14.4	30.9	11.4	-20.6		
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	1.4	N/A	0.0	-100.0		
Rudderfish (Kyphosids)*	0.0	0.0	N/A	128	+	0	-100.0	0.0	N/A	0.0	N/A	3.1	N/A		
Triggerfish (Balistids)	537.0	1422.5	164.9	491.5	-65.4	157.0	-68.1	80.6	-48.7	18.6	-76.9	103.0	453.8		
Butterflyfish (Chaetodontids)	86.0	62.8	-26.9	48.6	-22.6	25.5	-47.6	50.2	96.9	70.6	40.6	135.3	91.7		
Angelfish (Pomacanthids)	36.0	63.7	76.9	12.9	-79.8	8.3	-35.3	4.2	-49.4	3.8	-9.5	12.0	215.8		
Wrasses (Labrids)	213.0	123.8	-41.9	111.5	-10.0	48.8	-56.2	22.0	-54.9	29.4	33.6	10.0	-66.0		
Humphead wrasse	~	~	N/A	0.6	N/A	0.3	-46.7	0.2	-33.3	1.8	800.0	1.3	-25.9		
Damselselfish (Pomacentrids)	978.0	2508.8	156.5	1010.4	-59.7	1059.0	4.8	707.2	-33.2	146.2	-79.3	315.7	115.9		
Fairy Basslets (Anthids)	2307.0	1558.8	-32.4	1679.0	7.7	1582.0	-5.8	421.6	-73.4	342.4	-18.8	912.3	166.5		
Moorish Idols (<i>Zanclus cornutus</i>)	33.0	7.7	-76.8	3.6	-52.7	5.8	60.9	1.2	-79.3	3.6	200.0	6.7	85.2		
Total (target reef spp.):	686.0	395.8	-42.3	292.6	-26.1	239.7	-18.1	172.2	-28.2	210.6	22.3	214.4	1.8		
Total (all reef spp.):	4876.0	6144.2	26.0	3709.0	-39.6	3129.0	-15.6	1459.2	-53.4	844.6	-42.1	1875.0	122.0		

* Target species/families (Note: Acanthurids <= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 15. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at SR-4 (South Reef) Northwest Corner from 1992 to 2018.

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	(N=7)	% Change 2014-2018
	1992	2000		2004		2008		2012		2014		2018	
	Species			Species									
Surgeonfish (Acanthurids)*	12.0	7.0	-41.7	7.8	10.7	5.8	-24.7	3.4	-41.4	6.8	100.0	5.6	-18.1
Rabbitfish (Siganids)*	0.0	0.8	+	1.0	20.0	0.3	-66.7	0.6	100.0	1.0	66.7	0.3	-71.4
Groupers (Serranids)*	3.0	4.3	44.4	3.4	-22.1	3.8	13.6	1.8	-52.6	3.8	111.1	1.9	-51.1
Barramundi cod	~	~	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	2.0	0.0	2.1	7.1
Sweetlips (Haemulids)*	1.0	0.2	-83.3	0.3	50.0	1.0	300.0	0.2	-80.0	2.0	900.0	1.0	-50.0
Emperors (Lethrinids)*	0.0	0.5	+	0.9	75.0	0.8	-4.8	0.2	-75.0	0.6	200.0	0.9	42.9
Jacks (Carangids)*	1.0	0.5	-50.0	1.6	225.0	1.5	-7.7	1.4	-6.7	1.8	28.6	0.6	-68.3
Fusiliers (Caesionids)*	1.0	0.5	-50.0	0.4	-25.0	1.5	300.0	1.6	6.7	3.2	100.0	0.1	-95.5
Spinecheeks (Nemipterids)*	0.0	1.0	+	0.4	-62.5	0.2	-55.6	0.0	-100.0	0.6	N/A	0.0	-100.0
Goatfish (Mullids)*	0.0	1.7	+	1.1	-32.5	0.8	-25.9	0.0	-100.0	0.4	N/A	0.1	-64.3
Parrotfish (Scarids)*	1.0	2.5	150.0	2.1	-15.0	3.7	72.5	1.4	-62.2	3.2	128.6	3.9	20.5
Bumphead parrotfish	~	~	N/A	0.0	N/A	0.0	N/A	0.0	N/A	0.4	N/A	0.0	-100.0
Rudderfish (Kyphosids)*	0.0	0.0	N/A	1	+	0	-100.0	0.0	N/A	0.0	N/A	0.1	N/A
Triggerfish (Balistids)	5.0	5.0	0.0	3.0	-40.0	3.8	27.8	1.8	-52.6	3.0	66.7	4.3	44.4
Butterflyfish (Chaetodontids)	17.0	13.8	-18.6	12.5	-9.6	9.5	-24.0	3.2	-66.3	8.2	156.3	8.3	1.6
Angelfish (Pomacanthids)	2.0	3.7	83.3	2.5	-31.8	3.5	40.0	1.2	-65.7	1.8	50.0	1.7	-7.4
Wrasses (Labrids)	5.0	8.3	66.7	8.5	2.0	9.7	13.7	3.2	-67.0	6.0	87.5	1.7	-72.2
Humphead wrasse	~	~	N/A	0.4	N/A	0.3	-11.1	0.2	-33.3	0.4	100.0	0.3	-16.7
Damselselfish (Pomacentrids)	10.0	7.8	-21.7	10.8	37.2	7.5	-30.2	3.4	-54.7	7.2	111.8	4.3	-39.8
Fairy Basslets (Anthids)	3.0	1.2	-61.1	1.5	28.6	2.5	66.7	1.0	-60.0	2.2	120.0	3.0	36.4
Moorish Idols (<i>Zanclus cornutus</i>)	1.0	1.0	0.0	0.8	-25.0	1.0	33.3	0.4	-60.0	0.6	50.0	1.0	66.7
Total (target reef spp.):	22.0	16.7	-24.1	22.6	35.5	21.5	-5.0	12.8	-40.5	25.4	98.4	16.6	-34.8
Total (all reef spp.):	65.0	61.0	-6.2	62.5	2.5	59.3	-5.1	27.0	-54.5	55.2	104.4	46.0	-16.7

* Target species/families

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

(-) = decrease

(+) = increase

Table 16. Changes in substrate composition (% mean ±SE) in NR-2 (Ranger Station) from 1992 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS:								SNORKEL SURVEYS:					
	1992	2000	2004	2008	2012	2014	2018	% Change	1992	1996	2000	2004	2008	2012
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover
Sand (s) and Silt (SI)	20.2	8.1	8.8	2.2	0.8	5.06	1.8	-63.8	20.3	22.3	16.2	6.4	4.6	12.2
Coral Rubble (R)	0.5	33.3	22.1	21.3	18.4	12.89	15.1	17.2	24.9	7.1	17.6	18.2	10.7	13.8
Rock and Block (RK)	38.8	11.1	13.2	4.0	9.8	5.50	2.0	-63.6	10	6.3	23.1	18.7	23.1	30.2
White Dead Standing Coral (DC)	6.3	0.9	0.2	1.3	0.5	1.06	0.1	-94.3	6.1	7.8	0.3	0.8	1.1	1.6
Dead Coral with Algae (DCA)	0	32.6	3.5	8.3	4.8	3.83	10.0	160.9	0	0	10.1	8.0	12.8	6.2
Subtotal Non-living Substrate	65.8	86	47.7	37.2	34.3	28.33	29.0	2.4	61.3	43.5	67.3	52.0	52.3	64.0
Branching (CB)	25.5	8.9	26.9	44.3	40.2	43.67	52.3	19.7	22.6	51	~	30.4	32.1	12.7
Massive (CM)	1.2	1.9	6.0	3.6	2.6	4.39	2.9	-34.2	6.5	4.7	~	7.5	9.2	10.3
Flat/Encrusting (CFD)	5.7	1.9	7.8	2.5	1.9	1.17	0.8	-33.1	4.4	0	~	3.1	2.6	5.5
Foliose Cup (CFO)	0	0.2	1.2	0.5	11.2	9.33	3.3	-64.3	2	0	~	0.8	0.8	3.3
Total Hard Coral	32.4	12.9	41.9	50.9	55.9	58.56	59.3	1.2	35.5	55.7	31.3	41.9	44.7	31.7
Total Soft Coral	1.8	1.1	1.7	9.0	3.8	3.67	9.5	159.1	3.2	0.8	1.4	0.7	1.4	2.7
Subtotal Coral	34.2	14	43.5	59.9	59.7	62.22	68.8	10.5	38.7	56.5	32.7	42.6	46.2	34.4
Sponges	~	~	3.6	1.4	2.3	4.06	1.1	-72.6	~	~	~	0.5	0.4	0.7
Other animals	~	~	1.0	0.6	0.3125	1.22	0.1	-91.0	~	~	~	0.9	0.3	0.3
Algae			0.0									0.0		
Turf algae	~	~	0.4	0.2	1.4	0.11	0.1	-46.0	~	~	~	0.9	0.3	0.1
Fleshy algae	~	~	0.5	0.3	0.1	0.50	0.3	-34.0	~	~	~	1.1	0.2	0.0
Coralline algae	~	~	3.3	0.6	1.9375	3.56	0.6	-82.8	~	~	~	1.6	0.4	0.5
Seagrass	~	~	0.0	0.0	0.0	0.00	0.0	N/A	~	~	~	0.3	0.0	0.0
Subtotal Others	0	0	8.8	3.0	6	9.44	2.2	-76.5	0	0	0	5.4	1.6	1.6
TOTAL	100.0	100.0	100.0	100.0	100.0	100.00	100.0		100.0	100.0	100.0	100.0	100.0	100.0
Environmental Parameters														
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	~	~	8.25		1-10	3	2.8	3.0	3.0	~
Horizontal Visibility (m)	~	23.8	26.2	32.3	~	40.00	20.88		~	25	20.8	9.9	31.9	~
No. of 50 m Transects	1	16	16	20	8	9.00	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] × 100

(-) = decrease

(+) = increase

Table 17. Mean (\pm SE) fish species density (fish/500m²) and percentage change between years at NR-2 (Ranger Station) from 1992 to 2018.

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	(N=7)	% Change 2014-2018
	1992	2000		2004		Density		2008		2014		2018	
	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	41.0	-20.5
Rabbitfish (Siganids)*	4.0	5.2	29.2	2.4	-54.0	4.3	78.9	2.2	-48.8	2.0	-9.1	3.9	92.9
Groupers (Serranids)*	8.0	16.8	110.4	7.6	-54.7	15.1	98.4	5.4	-64.2	15.6	188.9	3.9	-75.3
Barramundi cod	~	~	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	4.3	-83.9
Sweetlips (Haemulids)*	0.0	3.8	+	1.8	-54.3	5.5	214.3	2.6	-52.7	4.4	69.2	0.7	-83.8
Emperors (Lethrinids)*	9.0	1.3	-85.2	24.3	1718.8	8.9	-63.4	3.0	-66.3	16.4	446.7	3.3	-80.0
Jacks (Carangids)*	0.0	13.0	+	9.3	-28.8	28.4	206.8	8.4	-70.4	2.8	-66.7	11.9	323.5
Fusiliers (Caesionids)*	0.0	104.0	+	1396.5	1242.8	138.0	-90.1	91.0	-34.1	131.0	44.0	0.0	-100.0
Spinecheeks (Nemipterids)*	3.0	2.5	-16.7	1.4	-45.0	1.4	0.0	0.4	-71.4	1.2	200.0	0.6	-52.4
Goatfish (Mullids)*	129.0	12.7	-90.2	7.8	-38.8	7.8	0.0	2.4	-69.2	3.0	25.0	0.9	-71.4
Parrotfish (Scarids)*	33.0	70.7	114.1	29.5	-58.3	27.0	-8.5	27.0	0.0	13.0	-51.9	14.0	7.7
Bumphead parrotfish	~	~	N/A	0.0	N/A								
Rudderfish (Kyphosids)*	0.0	5.5	+	4	-25	0	-100.0	0.8	+	0.0	-100.0	0.0	N/A
Triggerfish (Balistids)	3.0	14.8	394.4	8.6	-41.9	31.9	269.6	11.2	-64.9	23.0	105.4	35.0	52.2
Butterflyfish (Chaetodontids)	50.0	30.8	-38.3	35.5	15.1	57.9	63.0	13.8	-76.2	22.4	62.3	17.7	-21.1
Angelfish (Pomacanthids)	34.0	28.2	-17.2	7.5	-73.4	15.6	108.3	5.6	-64.1	4.0	-28.6	1.3	-66.7
Wrasses (Labrids)	117.0	120.0	2.6	117.4	-2.2	57.4	-51.1	49.0	-14.6	32.4	-33.9	102.7	216.9
Humphead wrasse	~	~	N/A	0.0	N/A	0.1	+	0.0	-100.0	0.8	N/A	0.0	-100.0
Damselselfish (Pomacentrids)	1020.0	994.8	-2.5	2578.0	159.1	3423.9	32.8	367.2	-89.3	936.4	155.0	1492.0	59.3
Fairy Basslets (Anthids)	258.0	905.3	250.9	1061.8	17.3	2544.0	139.6	236.4	-90.7	725.2	206.8	564.3	-22.2
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	2.7	-21.6
Total (target reef spp.):	281.0	447.2	59.1	1587.0	254.9	294.8	-81.4	222.4	-24.6	263.4	18.4	74.7	-71.6
Total (all reef spp.):	1766.0	2545.2	44.1	5446.6	114.0	6452.0	18.5	907.6	-85.9	2015.2	122.0	2341.7	16.2

* Target species/families (Note: Acanthurids <= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 18. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at NR-2 (Ranger Station) from 1992 to 2018.

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	(N=7)	% Change 2018	Species	
	1992	2000		2004		2008		2012		2014		2018			
	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	5.0	4.2		
Rabbitfish (Siganids)*	1.0	1.5	50	1.3	-16.7	1.8	40.0	1.0	-44.4	1.0	0.0	1.4	42.9		
Groupers (Serranids)*	5.0	4.3	-13.3	2.9	-33.7	3.8	30.4	2.8	-26.3	3.6	28.6	1.4	-60.3		
Barramundi cod	~	~	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	1.9	-59.6		
Sweetlips (Haemulids)*	0.0	0.7	+	0.9	31.3	0.8	-14.3	0.6	-25.0	1.0	66.7	0.1	-85.7		
Emperors (Lethrinids)*	1.0	0.7	-33.3	1.4	106.3	1.4	0.0	0.6	-57.1	1.4	133.3	0.6	-59.2		
Jacks (Carangids)*	0.0	2.0	+	1.3	-37.5	1.6	30.0	1.0	-37.5	1.0	0.0	1.1	14.3		
Fusiliers (Caesionids)*	0.0	1.3	+	2.5	87.5	2.1	-15.0	1.8	-14.3	2.6	44.4	0.0	-100.0		
Spinecheeks (Nemipterids)*	1.0	0.7	-33.3	0.5	-25.0	0.6	25.0	0.4	-33.3	0.6	50.0	0.3	-52.4		
Goatfish (Mullids)*	1.0	1.8	83.3	1.1	-38.6	1.1	0.0	0.8	-27.3	1.0	25.0	0.3	-71.4		
Parrotfish (Scarids)*	1.0	3.5	250.0	2.6	-25.0	3.8	42.9	3.0	-21.1	3.4	13.3	3.1	-7.6		
Bumphead parrotfish	~	~	N/A	0.0	N/A										
Rudderfish (Kyphosids)*	0.0	0.2	+	0	-25	0	-100.0	0.2	+	0.0	-100.0	0.0	N/A		
Triggerfish (Balistids)	2.0	2.7	33.3	1.9	-29.7	4.1	120.0	2.2	-46.3	4.0	81.8	3.0	-25.0		
Butterflyfish (Chaetodontids)	14.0	10.2	-27.4	11.4	11.9	12.4	8.8	6.0	-51.6	9.2	53.3	7.0	-23.9		
Angelfish (Pomacanthids)	2.0	3.5	75.0	2.5	-28.6	3.4	35.0	2.2	-35.3	2.4	9.1	0.7	-72.2		
Wrasses (Labrids)	9.0	10.8	20.4	6.6	-38.8	10.4	56.6	4.6	-55.8	6.0	30.4	4.0	-33.3		
Humphead wrasse	~	~	N/A	0.0	N/A	0.1	+	0.0	-100.0	0.4	N/A	0.0	-100.0		
Damselfish (Pomacentrids)	13.0	12.7	-2.6	12.4	-2.3	8.8	-29.3	7.8	-11.4	6.6	-15.4	9.0	36.4		
Fairy Basslets (Anthids)	2.0	1.2	-41.7	2.1	82.1	1.9	-11.8	1.6	-15.8	1.8	12.5	2.0	11.1		
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	0.7	-33.3		
Total (target reef spp.):	19.0	26.0	36.8	27.1	4.3	28.5	5.1	21.2	-25.6	25.0	17.9	15.3	-38.9		
Total (all reef spp.):	62.0	68.0	9.7	64.9	-4.6	70.6	8.9	46.4	-34.3	56.4	21.6	43.7	-22.6		

* Target species/families

% change = [(Yr2/Yr1)-1] × 100

(-) = decrease

(+) = increase

Table 19. Changes in substrate composition (% mean ±SE) in Jessie Beazley from 1984 to 2018.

SUBSTRATE COVER	SCUBA SURVEYS						SNORKEL SURVEYS:							
	2004	2008	2012	2014	2018	% Change	1984	1989	2004	2008	2012	2014	2018	% Change
	% cover	% cover	% cover	% cover	% cover	2014-2018	% cover	% cover	% cover	% cover	% cover	% cover	% cover	2014-2018
Sand (s) and Silt (SI)	7.0	3.7	9.4	2.9	3.0	5.3	5.0	3.0	5.4	10.2	7.7	9.3	8.6	-6.8
Coral Rubble (R)	16.0	6.3	6.4	3.5	5.0	42.9	11.9	10.6	3.6	15.8	5.1	14.5	3.8	-74.2
Rock and Block (RK)	13.1	14.4	7.8	5.1	5.1	0.2	35.9	48.0	33.5	33.3	32.9	26.3	25.3	-4.0
White Dead Standing Coral (DC)	2.0	0.3	0.4	0.9	0.0	-100.0	7.0	6.3	0.1	0.5	1.2	0.3	0.7	174.4
Dead Coral with Algae (DCA)	4.3	4.8	3.3	4.4	5.8	32.5	0.0	0.0	3.4	4.4	2.0	2.3	3.2	38.9
Subtotal Non-living Substrate	42.5	29.5	27.3	16.7	18.9	13.5	59.8	67.9	45.9	64.2	48.9	52.7	41.6	-21.1
Branching (CB)	18.4	18.5	22.5	29.2	24.6	-15.7	14.6	4.3	14.1	18.4	23.1	21.5	21.2	-1.6
Massive (CM)	5.9	6.7	10.8	7.7	9.1	17.7	10.5	9.3	6.9	9.3	12.0	9.3	10.8	16.8
Flat/Encrusting (CFD)	10.6	13.7	1.6	5.5	4.8	-12.2	10.5	4.0	24.2	5.1	9.3	9.0	16.1	78.6
Foliose Cup (CFO)	1.3	1.5	14.2	14.5	19.1	31.9	0.8	2.3	0.8	2.2	4.6	5.9	3.8	-36.8
Total Hard Coral	36.3	40.4	49.1	56.9	57.6	1.2	36.4	19.8	46.0	35.0	48.9	45.7	51.8	13.3
Total Soft Coral	15.6	25.1	11.3	21.8	16.9	-22.1	3.8	12.3	2.5	0.1	0.0	1.5	0.6	-57.1
Subtotal Coral	51.8	65.5	60.3	78.6	74.5	-5.2	40.2	32.1	48.4	35.1	48.9	47.2	52.5	11.1
Sponges	1.4	1.3	2.6	1.6	2.2	43.2	~	~	0.5	0.5	0.6	0.0	0.6	+
Other animals	0.5	0.9	0.5	1.2	0.7	-44.2	~	~	0.0	0.1	0.2	0.1	0.5	288.1
Algae														
Turf algae	0.2	0.7	0.2	0.2	1.7	760.0	~	~	1.3	0.0	0.8	0.0	4.2	+
Fleshy algae	0.3	0.1	1.8	0.1	0.6	460.0	~	~	1.7	0.1	0.3	0.0	0.4	+
Coralline algae	3.4	2.2	7	1.7	1.4	-15.3	~	~	2.1	0.1	0.3	0.0	0.2	+
Seagrass	0.0	0.0	0.3	0.0	0.00	N/A	~	~	0.0	0.0	0.0	0.0	0.1	+
Subtotal Others	5.7	5.1	12.3	4.8	6.6	39.2	~	~	5.6	0.7	2.2	0.1	6.0	288.1
TOTAL	100.0	100.0	100	100	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Environmental Parameters														
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	~	~	7.33				2.7	2.5	~	~	2.5	
Horizontal Visibility (m)	29.7	29.7	~	30	30.78				26.7	28.5	~	30	33.5	
No. of 50 m Transects	16.0	20.0	6	10	9				13	13.0	11	13	16	
~ 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 20. Mean (\pm SE) fish species density (fish/500m²) and percentage change between years at Jessie Beazley from 1992 to 2018.

Family	(N=1)	(N=6)	% Change 2004-2008	(N=8)	% Change 2008-2012	(N=8)	% 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	0.2	-50.0
Groupers (Serranids)*	12.0	12.3	2.8	3.4	-72.4	11.8	247.1
Barramundi cod	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	13.4	1016.7
Jacks (Carangids)*	0.1	8.5	5850.0	0.0	-100.0	0.8	N/A
Fusiliers (Caesionids)*	20.3	68.3	236.9	35.2	-48.5	66.2	88.1
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	4.2	162.5
Parrotfish (Scarids)*	3.7	4.3	16.7	1.8	-58.1	7.0	288.9
Bumphead parrotfish	0	0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.1	0.0	-100	0	N/A	0	-100.0
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	97.0	134.3
Angelfish (Pomacanthids)	17.6	8.8	-49.7	1.8	-79.5	4.0	122.2
Wrasses (Labrids)	105.4	48.5	-54.0	8.6	-82.3	20.2	134.9
Humphead wrasse	0	0	N/A	0.0	N/A	0.4	N/A
Damselfish (Pomacentrids)	592.3	295.2	-50.2	640.2	116.9	323.6	-49.5
Fairy Basslets (Anthids)	564.9	881.3	56.0	614.6	-30.3	817.6	33.0
Moorish Idols (<i>Zanclus cornutus</i>)	12.4	6.8	-45.0	3.8	-44.1	7.0	84.2
							N/A
Total (target reef spp.):	185.4	150.8	-18.7	75.4	-50.0	207.0	174.5
Total (all reef spp.):	1751.1	1579.8	-9.8	1422.2	-10.0	1525.6	7.3

* Target species/families (Note: Acanthurids <= 10cm in length not counted in Target species population)

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

(-) = decrease

(+) = increase

Table 21. Mean (\pm SE) fish species richness (species/500m²) and percentage change between years at Jessie Beazley from 1992 to 2018.

Family	(N=1)	(N=6)	% Change 2004-2008	(N=8)	% Change 2008-2012	(N=8)	% 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	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	1.0	400.0
Jacks (Carangids)*	0.1	1.0	600.0	0.0	-100.0	0.2	N/A
Fusiliers (Caesionids)*	0.4	1.7	288.9	1.2	-29.4	2.2	83.3
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	1.0	66.7
Parrotfish (Scarids)*	1.1	1.3	16.7	1.0	-23.1	1.4	40.0
Bumphead parrotfish	0	0	N/A	0.0	N/A	0.0	N/A
Rudderfish (Kyphosids)*	0.1	0.0	-100	0	N/A	0	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	10.4	126.1
Angelfish (Pomacanthids)	2.4	3.0	23.5	1.2	-60.0	2.6	116.7
Wrasses (Labrids)	9.0	7.5	-16.7	2.4	-68.0	6.6	175.0
Humphead wrasse	0	0	N/A	0.0	N/A	0.4	N/A
Damsel (Pomacentrids)	9.0	6.2	-31.5	4.6	-25.8	7.0	52.2
Fairy Basslets (Anthids)	1.7	2.0	16.7	1.4	-30.0	2.2	57.1
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	53.6	103.0

* Target species/families

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

(-) = decrease

(+) = increase

Table 22. Species list of butterflyfish in Tubbataha Reefs, Palawan from 1992 to 2018

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 Bastera in 2000: 36

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 2008: 30

Total number of species observed in Tubbataha and Jessie Beazley in 2012: 2
Total number of species observed in Tubbataha and Jessie Beazley in 2014: 3

Total number of species observed in Tubbataha and Jessie Beazley in 2014: 3
Total number of species observed in Tubbataha and Jessie Beazley in 2018: 3

APPENDIX 3. Expedition Itinerary

DAY	DATE & SITE	TIME	ACTIVITIES
1	Saturday, April 21 Ipil Suites Puerto Princesa	9:00 AM 11:00 12:00 1:00 PM 7:00 8:00	Rendezvous at Ipil Suites Welcome and Briefing: Alan White, SPR Principal Investigator About Tubbataha: Angelique Songco, Tubbataha Park Manager Lunch Review of SPR research methods: Dean Apistar, Brian Stockwell and Agnes Sabonsolin Dive Safety, Jon Apurado/Dean Apistar, SPR Dive Masters Start loading of luggage Transfer to the M/Y PalauSport; Boat Orientation Dinner Slide show/Quiz and Identification Presentation (CCEF and Tubbataha)
2	Sunday, April 22 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 Encode data on the CCEF Monitoring Database Dinner and Presentation
3	Monday, April 23 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) Encode data on the CCEF Monitoring Database Dinner Optional night dive (can be done dusk time/before dinner)
4	Tuesday, April 24 South Reef 3 (Black Rock)	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) Encode data on the CCEF Monitoring Database Dinner/Presentation /Slide show of volunteer pictures
5	Wednesday, April 25 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) Encode data on the CCEF Monitoring Database Dinner Optional night dive (can be done dusk time/before dinner)
6	Thursday, April 26 SR 4 (Ranger Station)	7:00 AM 8:30 12:00 PM 1:30 5:00 7:00	Breakfast Conduct surveys (snorkel and scuba) Lunch Conduct surveys (scuba) Encode data on the CCEF Monitoring Database Dinner Summary of Impressions and Debriefing (Alan) Travel back to Puerto Princesa
7	Friday, April 27 Puerto Princesa	6:00 AM 7:00 AM	Arrive Puerto Princesa/Breakfast Closing/Summary

APPENDIX 4. Expedition Volunteers

	Name/Address	Profession/Affiliations/Interests
1	Denise Illing	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. Amateur photographer.
2	Geoff Illing	Occupation: Technical Director Unico Computer Systems Interests: Amateur musician (woodwind player) 11 th SPR Expedition
3	Alexander Douglas Robb	IP Researcher ; Civil Engineer BSC (Hons) Edinburgh; MSC Melbourne – History & Philosophy of Science; Interest - History & Philosophy of Science. 9 th Saving Philippine Reefs Expedition.
4	Barbara Best	Natural resource management and environmental specialist and manager, USAID Washington DC. First SPR expedition
5	Alastair Pennycook	Professor of Language Studies, University of Technology Sydney Yachting Australia Coastal Skipper, PADI Master Diver, underwater photography. 7 th Saving Philippine Reefs Expedition.
6	Dominique Estival	Linguist/ researcher University of Western Sydney Flight instructor, glider pilot
7	Laurent Boillon	Pastry Chef; Certified SSI Advanced Open water; Advanced Nitrox; Advanced Decompression: Deep; Night. 6 th SPR Expedition.
8	Vittoria Thornley	12th SPR expedition; 5th Tubbataha expedition; BA (Hons) Human Sciences (Oxon). MSc Ecology (Univ. of Bristol). Advanced PADI Open Water. Office Manager, Thornley Kelham Ltd. Conservation volunteer; interest in conservation, horticulture, classic cars; travel writing, yoga.
9	Julia Cichowski	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; 15th SPR Expedition and loved them all.
10	Tom Costopoulos	Australia business consultant
11	Susanne Ball	Artist; 2nd Saving Philippine Reefs Expedition. Kailua, Hawaii
12	Tom Matula	Occupation: Anesthesiology. Interests: Marine science. 2 nd SPR
13	Stacey Tighe	Marine resource and international development specialist. First SPR
14	Alison Green	Marine ecologist and conservationist. First SPR
15	Natalie Moltschanowskyj	Marine ecologist/biologist and conservationist. First SPR
16	Catherine McLuckie	Australia
17	John McLuckie	Australia

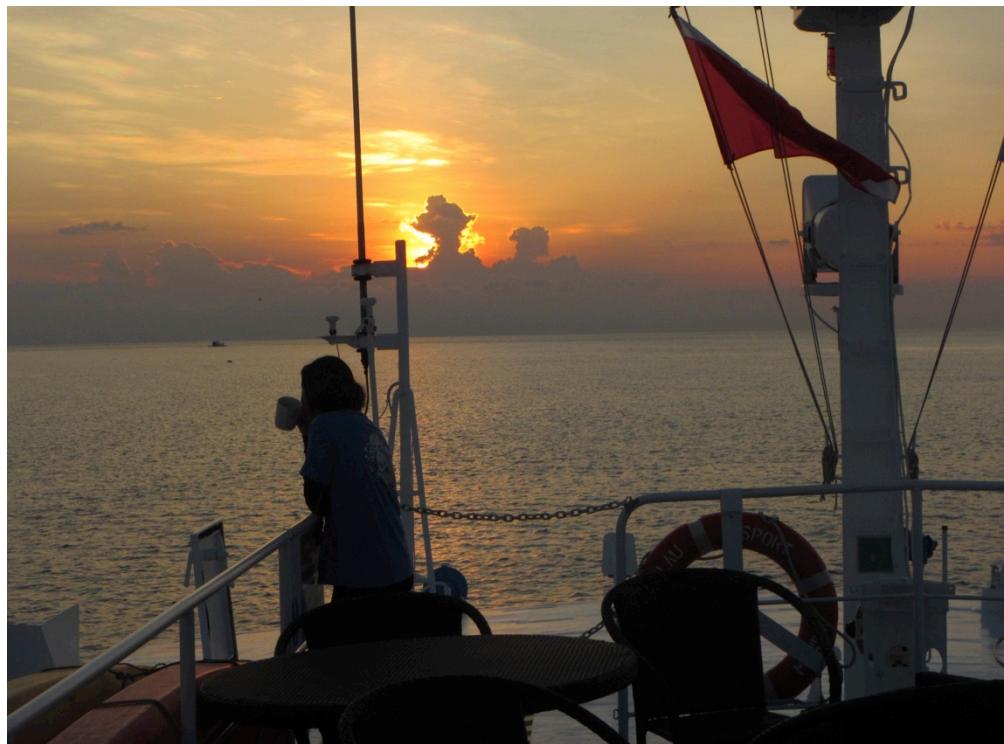
APPENDIX 5. Expedition Photos



The clear waters of Tubbataha give picture of an underwater sky. (A. Sabonsolin)



A large sweetlips poses for an expedition researcher. (A.J. Lozada)



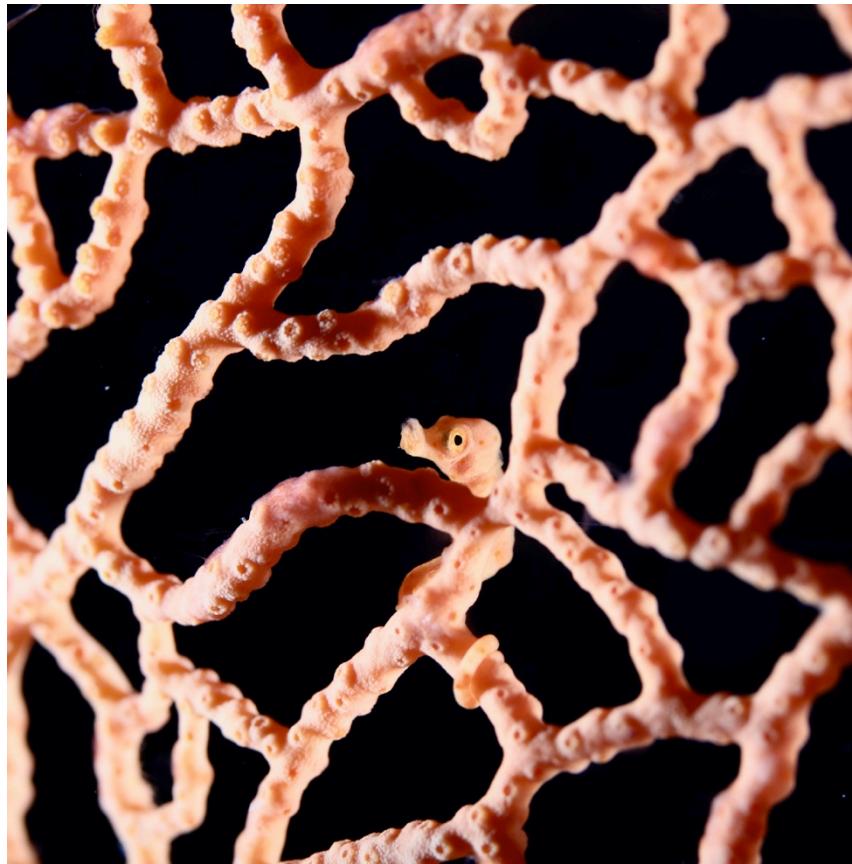
The beautiful sunrise in the middle of Tubbataha is ideal for morning meditation. (A. White)



This sea turtle seems to want to help the researchers with their transects. (B. Best)



This booby is evidence of beauty above Tubbataha waters, not just beneath. (D. Illing)



This tiny little seahorse thought it could escape a researcher's notice. (L. Boillon)



Every day begins with a team of smiles at Tubbataha. (S. Ball)



The best kind of tornado to be in – a tornado of jacks! (N. Moltschaniwskyj)



These two fire gobies prove that it takes two to do a beautiful tango. (V. Thornley)



Traffic underwater – researchers and triggerfish go on their busy ways. (J. Cichowski)



A welcome survey challenge in a busy reef! (E. White)



Our home for a week. (T. Costopoulos)