



# MARINE BIODIVERSITY OF MYEIK ARCHIPELAGO

SURVEY RESULTS 2013-2017 AND CONSERVATION RECOMMENDATIONS



EDITED BY: ROBERT HOWARD

2018

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Rear Cover- *Helcogramma striata* (Tropical striped triplefin) on *Diplosatrea* coral head. Credit Michelangelo Pignani/Fauna & Flora International©

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Credit: Coral Reef - Michelangelo Pignani-FFI



Credit: Coral reef, Robert Howard/FFI

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# I. FOREWORD

I am delighted to have the opportunity to write a foreword for the “Marine Biodiversity of Myeik Archipelago: Survey Results and Conservation Recommendations 2013-2017” report.

The Myeik Archipelago is one of Myanmar’s natural wonders rich in marine life including marine turtles, whales, sharks and rays and 100’s of fish and invertebrate species many of which live out their life on the extensive coral reefs which make the area famous. The archipelago also supports millions of Myanmar people whether through direct livelihood benefit as fishers and traders, through the many ecosystem services such as carbon absorption, as an important source of protein or for the cultural and recreational benefits of the area. However, over recent times the archipelago has faced many threats from over exploitation of its resources to impacts from climate change. Without a clear understanding of the status and threats of the area it would be difficult to direct resources to ensure this key biodiversity area is management sustainable.

This report is a collective effort of a team of scientific researchers, students, government officers and NGO staff supported by international researchers from all over the world have undertaken countless hours of surveys to ensure we understand the status of the archipelago’s habitats and species and to guide management. This has included detailed surveys of the coral reefs and its associated fish and invertebrate life, studies on the areas seagrass beds and the fished species they support as well as developing detailed recommendations for the conservation of the archipelago.

This research has culminated in a wealth of information included in a number of technical reports which has now been summarized in this Marine Biodiversity report. The report now provides the government of Myanmar with detailed knowledge of the archipelago and its marine life while providing a comprehensive list of recommendations for the government and its partner’s to use to ensure the country meets its biodiversity targets and most importantly ensuring sustainability of Myanmar’s precious marine resources.

Last but not least, I would like to express my gratitude to the Fauna & Flora International Myanmar Programme for their diligence and scientific rigor in producing this report with recommendations, which are very valuable to guide conservation, protection and sustainable management of marine biodiversity of Myanmar.



Nyi Nyi Kyaw, PhD

Director General

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The Republic of the Union of Myanmar

The Department of Fisheries (DoF) is grateful to Fauna & Flora International (FFI) for their close collaboration with DoF for the conservation and management of marine resources along Myanmar's coastal regions supporting the sustainability of fisheries management in Myanmar. Thanks also goes to Ministry of Natural Resources and Environmental Conservation, Ministry of Defense, Police Department, Navy, local communities, local NGOs, community based organizations and all international NGOs who are working collaboratively to undertake coral reef ecosystem research, seagrass research and socio-economic studies to identify the threats to these ecosystems, the threats to local communities and mapped priority areas for conservation in the Myeik Archipelago.

Because of the outstanding findings from several years of research and the subsequent recommendations for management, I believe that marine biodiversity will be conserved effectively and capacity and knowledge on marine resource management by the DoF, relevant government departments and local communities will be greatly improved. Furthermore, local communities who have strong ties with the land, marine environments and their fisheries resources are more aware of the importance of conservation and how to manage their resources such as through Locally Managed Marine Areas (LMMAs) and the unique opportunities such as ecotourism which could provide job opportunities. The Department of Fisheries recognizes the value of conservation of endemic fish species and functionally important species such as parrot fish will lead to improved ecosystems which will support the sustainability of fisheries for the future generation.



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# III. ACRONYMS AND ABBREVIATIONS

ALDFG	Trash- Abandoned, Lost or otherwise discarded fishing gear
BANCA	Biodiversity and Nature Conservation Association
BMMSY	Biomass of multi-species maximum sustainable yield
BOBLME	Bay of Bengal Large Marine Ecosystem
BRUV	Baited Remote Underwater Video
C	Carbon
CFDI	Coral Fish Diversity Index
COT	Crown of thorns starfish
FFI	Fauna & Flora International
GEF	Global Environment Facility
IOD	Indian Ocean Dipole
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated fishing
KBA	Key Biodiversity Area
LMMA	Locally Managed Marine Area
MA	Myeik Archipelago
MNP	Marine National Parks
MPA	Marine Protected Area
N	Nitrogen
NGO	Non-governmental organisation
PA	Protected Area
PES	Payment for Ecosystem Services
PIT	Point intercept transect
PMBC	Phuket Marine Biological Centre
ROM	Royal Ontario Museum
S.D	Standard Deviation
s.e.	Standard error
sp.	Species
TBA	to be defined
WCS	Wildlife Conservation Society

The IUCN categories of threat are abbreviated as follows:

CR	Critically Endangered
EN	Endangered
VU	Vulnerable
NT	Near Threatened
LC	Least Concern
DD	Data Deficient
NE	Not Evaluated

# IV. ACKNOWLEDGEMENTS

Fauna & Flora International-Myanmar (FFI) would like to thank the Government of the Republic of the Union of Myanmar, especially the Department of Fisheries (Ministry of Livestock, Agriculture and Irrigation) and the Forestry Department (Ministry of Natural Resources and Environmental Conservation). Without their assistance in organising permissions to run the work in the field and provide supporting staff to undertake surveys the research could not have taken place. Likewise a special thank you to the Myeik and Mawlymine Universities for their enthusiastic involvement in the research including participating and hosting in training events and providing support staff and students for surveys. FFI also extends its appreciation to all contributing authors to the production of this biodiversity report many of whom provided their services pro bono including field research and report writing.

A final thank you from the editor to the FFI staff who worked countless days and hours on planning and running the field research, notably FFI's marine team: U Zau Lunn, Salai Mon Nyi Nyi, Soe TintAung and Soe Thiha. The report would also not be possible without all the supporting staff both current and former including Mark Grindley, Frank Momberg, Carl Reeder, Myo Mint Aung, Thet Zaw Tun, Patrick Oswald, Antt Maung and finally Kate West for her proofreading and valuable edits.

# V. EXECUTIVE SUMMARY

Stretching over almost 4 million ha the Myeik Archipelago and associated Moscos Islands along Myanmar's most southern coastline is a biologically rich and diverse seascape abound with unique, rare and threatened flora and fauna and the lifeblood of many island and coastal communities. Over the past 30 years however this once unspoiled ecosystem has been slowly degraded from a number of anthropogenic impacts including destructive fishing gears such as dynamite and other illegal, unreported and unregulated (IUU) fishing, increased terrestrial runoff from forest clearing and coastal development, increased population and climate change. To prevent further destruction of the area and to aim towards sustainable use and management of the archipelago, surveys were initiated in 2013 to quantitatively understand the status of the habitats and species and identify priority areas for protection. In summary surveys have found:

## **Coral reefs:**

- Coral reefs in the survey area showed high levels of hard coral diversity, with 288 species observed, in 68 genera and 17 families. Species accumulation curves predicted a total of 309 species would be obtained with the same method of sampling.
- The status of hard coral cover varies greatly across the archipelago from 0% to 92% with an average of 48.9%.
- Coral communities were clearly structured by three main reef types: a) fringing reefs on relatively exposed boulder slopes of outer islands, from the surface to about 15 m depth where the boulders transitioned into sandy slopes; b) fringing reefs on relatively sheltered slopes of the inner islands with high turbidity and strong currents; and c) steeply sloping/vertical rock walls on small isolated rocks or outer island cliff faces, extending into deeper water over 20-30 m deep.
- Coral disease prevalence ranged from 0% to 15% across all sites surveyed, with a mean disease level of 4.9%. Levels of compromised coral health was very high across the archipelago, with a mean level of 23.3%.
- Overall condition of reefs in the Myeik archipelago is average, as a result of diverse impacts, including thermal stress and coral bleaching, fishing for reef fish, and trawler/pelagic fishing on the banks surrounding the islands.

## **Fish:**

- The total reef fish fauna of the Islands of the Myeik Archipelago of Myanmar consists of 495 species belonging to 62 families.
- The Coral Fish Diversity Index (CFDI) for the Myeik Archipelago predicts a total of 618 species.
- Sharks and large rays were notably absent. Larger individuals of predatory species such as groupers (*Epinephelus*, *Plectropomus*), snappers (*Lutjanus*) and emperors (*Lethrinus*) were present but only in relatively small numbers.
- Results for the nine fish categories within the archipelago (including groupers, snappers, butterfly fish and parrotfish) indicate an ecosystem heavily impacted by overfishing.
- Biomass surveys noted many sites have relatively low estimates of fishable biomass (< 3 g/m<sup>2</sup>). Global estimates of biomass below 30 g/m<sup>2</sup> present unhealthy and unsustainable fishing states.

## **Invertebrates:**

- A total of 258 reef invertebrate fauna have been collected and of these only 127 could be identified to species level. The majority of the 258 invertebrates observed were decapods with 103 specimens and gastropods with 55.
- For sponges 36 unique species were collected during this expedition, with representatives from at least nine orders.
- *Diadema* were the most common of all the invertebrates recorded with 52.01 individuals per transect. Mean invertebrate numbers per transect were generally very low with all but banded coral shrimp, collector urchin and *Diadema* recording means under one. Sea cucumbers and lobsters have been heavily impacted by an unregulated fishery.
- No reefs exhibited high numbers or outbreaks of Crown of Thorns Starfish.

## **Seagrass:**

- Seven species of seagrasses were identified, with coverage ranging from 25.75-64.57% across ten sites surveyed.

- Seagrass beds face problems such as smothering by sand. This can arise from trawlers stirring up sediments or sediment run-off from where forest areas have been cleared.
- Fish life was found to be depauperate within these seagrass beds, with an average of only 1.7 fish observed across 51 baited video samples of 30 minutes each. There was a clear lack of abundance of top predatory fish from families such as Trevally, Grouper, Snapper and Sweetlips across all samples.

## Threats:

- Five categories of impact were quantitatively surveyed including dynamite use, anchor damage, discarded fishing nets, litter and other. For impacts to the reefs overall, impact score for the archipelago for each variable was in the low damage category, although most sites recorded some level of damage and 71 of the 212 sites surveyed for impacts recording medium to high in terms of severity.

## Conservation Recommendations:

- Urgent need to curtail the main threats and at the same time move quickly to protect sites of high ecological value. For example, ban compressor fishing and undertake extensive outreach to explain to fishers why such a step is necessary.
- Undertake comprehensive land-use planning for the terrestrial landscape adjacent to the archipelago and institutionalise land-use practices which minimize runoff, erosion and the use of chemicals used in agriculture and mining.
- Seek to improve adherence to existing fisheries regulations and enforce future protective measures by instigating a patrol system that could include communities, the Department of Fisheries, the Marine Police, the Navy and other potential partners.
- Establishing an ecosystem-based approach to fisheries management and developing a network of marine protected areas (MPAs) are critical management tools in this regard.
- Assist the Myanmar government to meet their stated goal of protecting 15% of Myanmar reefs by 2020.
- There is a strong need to develop an MPA policy for Myanmar that will provide guidance to the necessary practices and principles for network development.
- Draft new protected area legislation for Myanmar based upon current international best practice that includes a chapter specifically devoted to MPA network establishment and management.
- Identify main gaps in information based on other significant habitats in the Myeik Archipelago that have yet to be addressed and prioritise future data collection. Information gaps which need to be filled include: sharks, marine mammals, as well as lesser-known species and habitats such as upwellings, species aggregations, connectivity routes, and terrestrial mammals.
- It is critical that any proposed conservation measures do not have a disproportionately negative impact on the poorer sectors of society.
- Several models are considered for network configuration, including a system of nature reserves, a system of LMMAs, a system based on marine national parks (MNPs), and an integrated regional system as represented by a biosphere reserve type of approach. These approaches are not mutually exclusive, but decisions need to be made about the optimal configuration for Myanmar.
- Design and implement a strategic tourism plan for the Myeik Archipelago that seeks to optimize conservation and community benefits.



# 1 INTRODUCTION

The Myeik Archipelago (formerly Mergui Archipelago) lies along the western coast of the Malay Peninsula in the north-eastern waters of the Andaman Sea off Myanmar's most southern coastline within the Tanintharyi Region ( Figure 1). The archipelago is estimated at 3,434,000ha (Novak et al., 2009) with around 800 islands which dot the seascape, with a further ~60,000ha of islands and reef to the north of the archipelago known as the Moscos Islands. The 800 islands vary from small rock outcrops to large forested islands including Lampi Marine National Park and Kyunsu (or King) Island which is the archipelago's largest Island that stretches over 45,000ha and includes the highest peak, French Bay Peak at 764m (Anon, 1975). Most of the islands are granite and limestone. BOBLME (2015) describes the area being mostly metamorphic rocks from the Mergui Series which follows north to south tectonic lines with the outer islands predominately granitic and those of the inshore mostly limestone.

The islands themselves are generally covered with lowland wet evergreen forest with shorelines of white sandy beaches, rocky headlands and mangrove forests and mudflats on the more inner islands. The forests support a range of wildlife including plain pouched hornbills, long-tailed macaques, wild pigs, mouse deer and small-clawed otters (BANCA and Oikos, 2011; Zöckler, 2016). However, the area is most well-known and visited for its marine environment including diverse coral reefs, seagrass meadows, mangrove habitats and mudflat areas. These support a range of rare and threatened species including hawksbill (CR), green (EN) and leatherback (VU) marine turtles, mobulid rays, potentially over 50 species of sharks including scalloped hammerhead (EN) and whale sharks (EN), and range of whales and dolphins (Smith and Tun, 2008; Howard et al., 2015; Platt et al., 2016; Howard, 2017). Its unique biodiversity and habitats have led the area to be nominated as a "Natural" UNESCO site (WHC, 2014) and classed as a Key Biodiversity Area (WCS, 2013).

O'Hara et al. (2017) describes the archipelago as having a tropical monsoon climate with the southwest monsoon (May-October) and northwest monsoon (November-April), with an annual rainfall average at 3300mm, 94% falling in the southwest monsoon season. Surface water temperature varies very little over the year with a range of 26.79 to 33.27 °C, with the lowest in September and highest in March.

In terms of social dynamics the area has been home to the Moken (*Salon* in Burmese; Sea Gypsies in English), a seafaring ethnic minority who have been living among the islands of the archipelago for at least two hundred years (Ivanoff and Jacques, 2002). The Moken lived a subsistence lifestyle spending a majority of the year on their traditional sailing boats, the *Kabang*, spearfishing and gleaning the reefs for a range of marine products which are eaten or traded. Although Moken livelihoods are still heavily reliant on fishing they have become more sedentary over the past 20 years with permanent houses on the islands following restrictions on their movement by the former Myanmar government (Chambless, 2015).

Although most islands are unpopulated there are still a number of large settlements on several of the islands and smaller hamlets dotted throughout the archipelago. Beside from the Moken these are predominately made up of both Burmese (Bamar) and Karen (Kayin) peoples (Schneider et al., 2014). The main livelihood of these people is from artisanal fishing using stationary and driftnets, cage fishing and spear fishing using compressors targeting a wide range of marine resources including mullet, sand crab, mackerel, grouper, snapper, parrotfish, tunas, threadfin, sea cucumber and chiton (Saw Han Shein 2013; Schneider et al., 2014; BOBLME 2015). Artisanal fishers also operate out of small towns and cities along the Tanintharyi coast with an estimated 8000-10000 inshore vessels (ILO, 2015). There is also a considerable commercial fishing fleet operating a number of gears including trawl, purse seine, driftnets, lightboats and cages; 623 and 262 licences alone were given to trawl and purse seine gears respectively in 2016-2017 (ILO, 2015; DoF, 2017).

Although laws exist to govern the fishery such as mesh sizes, closed seasons, spatial restrictions etc. (FAO, 2006) the current government is under resourced to manage such a huge seascape and deal with the constant threat of Illegal, Unreported and Unregulated (IUU) fishing (Howard, 2017). As a result the region, and much of Myanmar has seen a dramatic decline in marine resources over the past 30 years and once untouched coral reefs being degraded from blast fishing and anchor damage (Krakstad et al., 2014; BOBLME, 2015; Howard, 2017). Given the

importance of coral reefs both ecologically and socially in terms of protein and income there was an obvious need to protect and conserve the archipelago's marine environment for future generations. Therefore in 2013 following the training of Myanmar's first research scuba team, Fauna & Flora International (FFI) began surveys to gain an understanding of the status of the marine environment, notably coral reefs and from there identify sites to focus conservation efforts including proposed Marine Protected Areas (MPA). This report details the results of these surveys which includes work by FFI's marine team, Myanmar scientists from Myeik and Mawlymine Universities, staff from Myanmar's Forestry Department and Department of Fisheries and a number of international researchers, many of whom volunteered their time to undertake the surveys.

The report covers 1) coral reef ecosystems, the most comprehensive chapter of the report and as such divided into three main sections covering taxonomy and resilience, disease and recruitment and coral cover; 2) fish taxonomy and biomass; 3) marine invertebrate taxonomy and abundance of a set of indicator species; 4) a special chapter on sponges, a group useful for monitoring water quality; 5) seagrass taxonomy, including extent and associates; 6) anthropogenic threats to the coral reefs; and 7) recommendations on a protected area network for the archipelago based on the results of the above information. Many of the chapters are summaries of more comprehensive technical reports provided by researchers and references to these reports are provided.

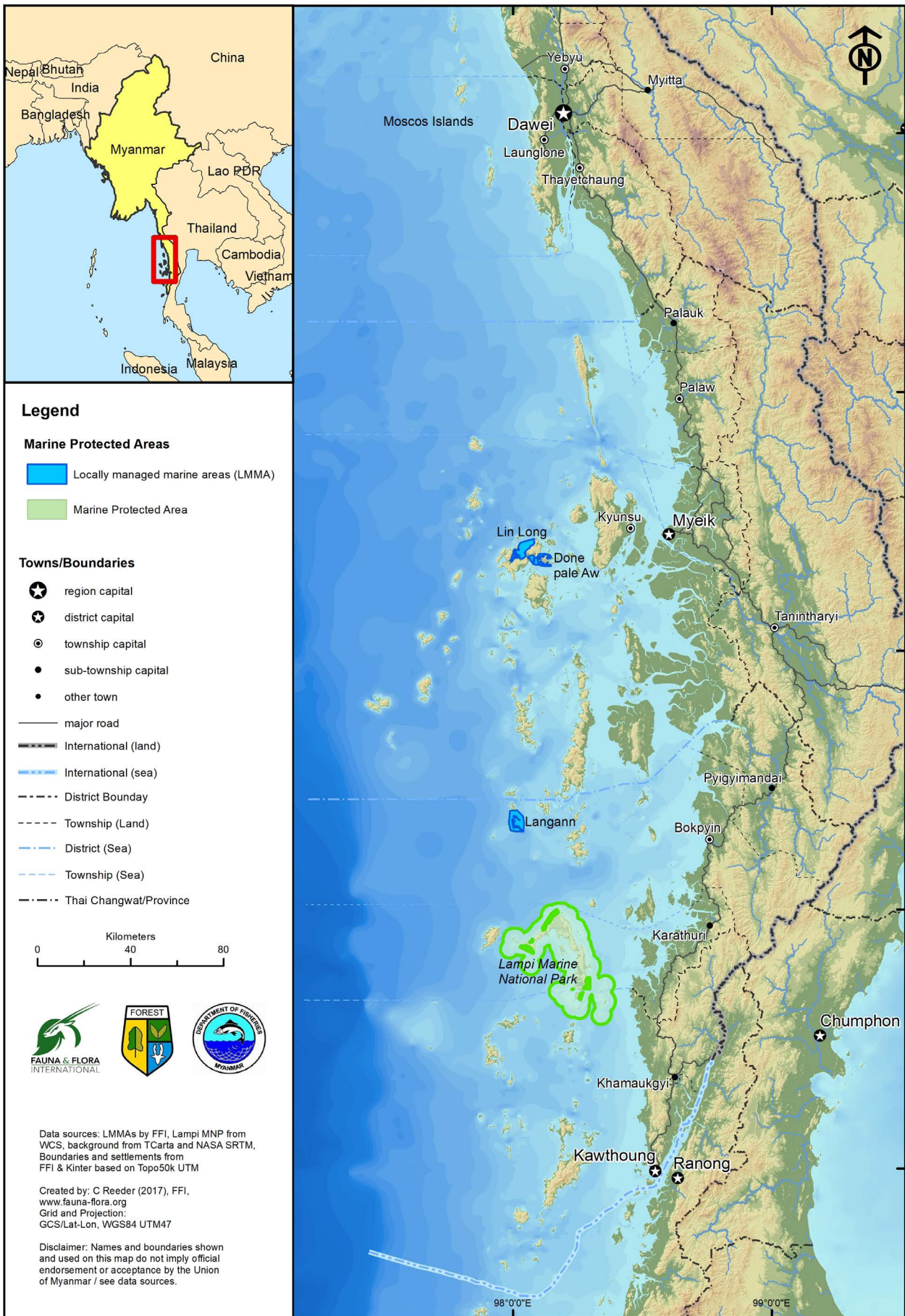


Figure 1. Myeik Archipelago and the Moscos Islands, Tanintharyi Region, Myanmar. Map by FFI.





# 2 CORAL ECOSYSTEMS

# SECTION 1

## Diversity and Reef Resilience

Dr David Obura, Sophie Benbow and U Zau Lunn

### INTRODUCTION

#### **Coral diversity**

Scleractinian corals are the architects of coral reefs, supporting the full range of biodiversity and ecosystem services that reefs sustain. The diversity of corals at a location is indicative of the diversity and robustness of other reef fauna, and corals have been the focus of biodiversity conservation and research for decades, such as in the delineation of the Coral Triangle (e.g. Roberts et al., 2002; Hoeksma, 2007). The coral reefs of Myanmar have been little studied over 50 years, and are among the gap regions in global databases of coral diversity (C. Veron, pers. comm.). The objective of this survey was to develop a list of coral species of the Myeik archipelago as a resource for conservation planning (e.g. in next steps in establishing Key Biodiversity Areas (KBAs), Holmes et al. (2013)), as well as to identify the biogeographic relationships and patterns of this region as a transition zone between the Indian Ocean (Spalding et al., 2007; Obura, 2012) and the Coral Triangle (Hoeksma, 2007; Rudi, 2012).

#### **Reef resilience**

An issue of primary concern for coral reefs is climate change, now recognized as one of the greatest threats to coral reefs worldwide (Hoegh-Guldberg et al., 2007; Hoegh-Guldberg and Bruno, 2010). Mass coral bleaching remains one of the most immediate impacts of climate change on corals reefs, as abnormally high water temperatures trigger the breakdown of the coral-algal symbiosis and can lead to mass coral mortality (Coles and Brown, 2003). Other factors that affect reefs in the region include cyclones, terrestrial sediment run-off, predator outbreaks such as crown of thorns sea stars, and anthropogenic threats such as fishing, pollution, and nutrient additions.

Each of these factors affects the ecological state of reefs, and alone or in concert they can act to drive the reef from a highly diverse system capable of providing sustenance for many people to a degraded state that supports few species and sustains few people. The likelihood that a given reef will succumb to these factors and slide down this scale of “reef health” can be explained in terms of the reef’s ecological resilience – i.e. its ability to resist threats and to recover to a healthy state when an impact does occur, and a number of studies increasingly focus on applications of resilience surveys to reef management (Obura and Grimsditch, 2009; Maynard et al., 2010, 2012). Of immediate significance to government in Myanmar at local and national levels is the very high dependence on marine resources at multiple levels – small scale and subsistence fishing, large scale industrial fishing, and growing opportunities for tourism and economic diversification. An understanding of the different factors that affect the health of individual sites can contribute to the long term sustainability and growth in the region around Myeik archipelago.

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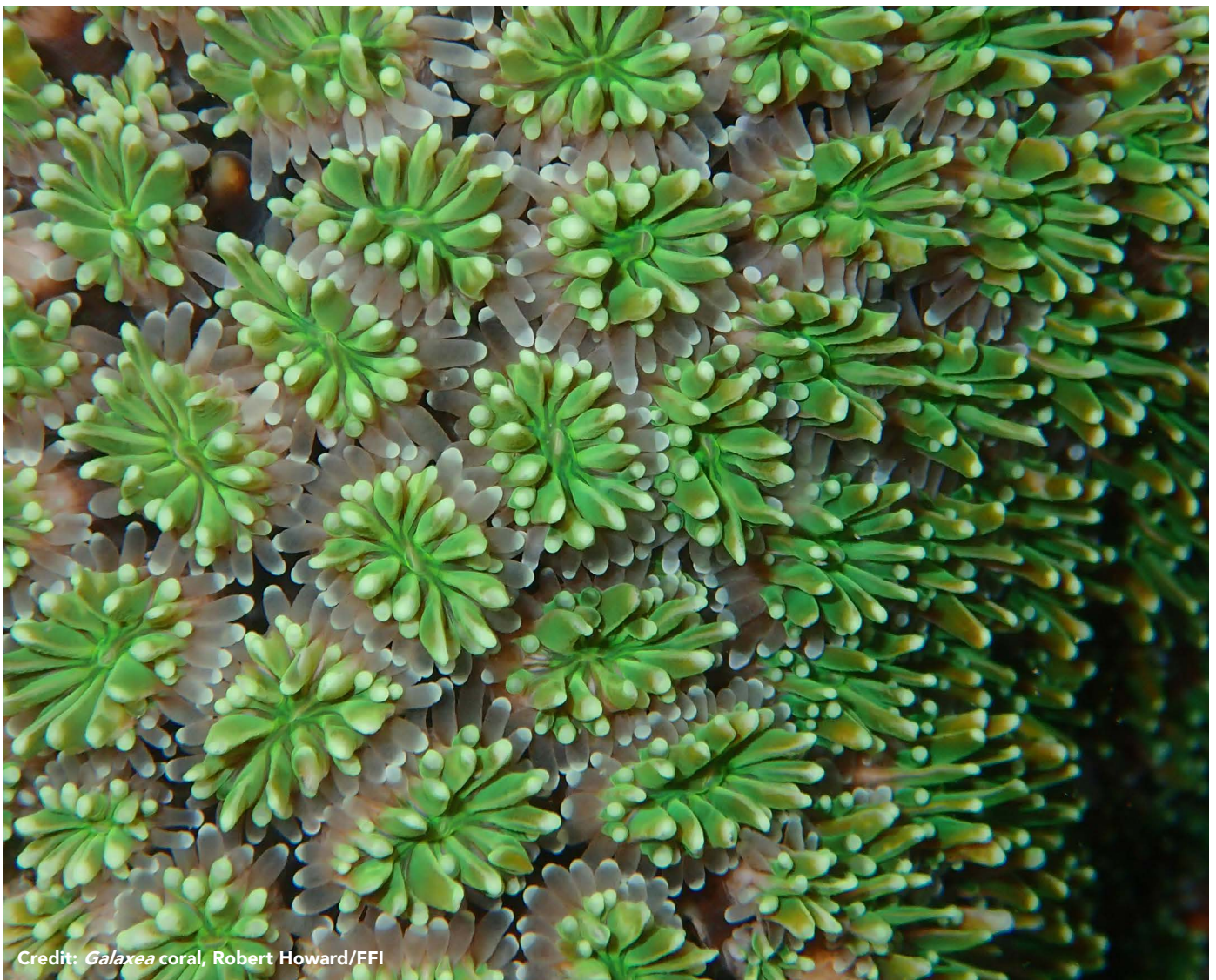
For full report see: Obura, D.O., Benbow, S. and Zau Lunn (2014) Coral Diversity and Reef Resilience in the Northern Myeik Archipelago, Myanmar. Report No. 3 of the Tanintharyi Conservation Programme, a joint initiative of Fauna and Flora International (FFI) and the Myanmar Forest Department. FFI, Yangon

## Methods

Thirty five sites were surveyed for corals and resilience indicators, spread across 11 days from 11 – 22 March 2014 (Figure 2). Complementing earlier work in 2013 in two separate survey efforts (Tun, 2013; Cox et al., 2013), this expedition targeted the more remote and harder to reach outer islands in the north of the archipelago.

Reef type – three basic reef types were sampled:

1. Fringing reefs on outer islands in which the boulder slopes of the islands down to a base of 10-15 m depth covered with corals, generally on sheltered sides of the islands.
2. Rock reefs, typically vertical or steeply sloping surfaces of rock/island pinnacles, with encrusting corals, with the base of the reefs extending below 20-30 m into deeper water. Typically, these reefs are highly exposed to currents and waves, and often dominated by filter feeders and other invertebrates, particularly with increasing depth.
3. Inner fringing reefs, on islands close to the mainland and sheltered from high wave energy by the outer islands and bank systems – with high turbidity and strong currents through narrower channels. These are strongly influenced by terrestrial influences, including settlement in villages, small scale fishing, and river discharge.



Credit: *Galaxea* coral, Robert Howard/FFI

#	Name	Depth (m)	Reef type
1	Katat Aw	6	fringe
2	Kyat Mi Thar Su	21	rock
3	Saw Pu I.	16	rock
4	Black Rock	31	rock
5	Sular Nge	26	rock
6	West Sular	18	fringe
7	West Sular	21	fringe
8	Kunn Thee Is	20	fringe
9	East Sular (S)	18	fringe
10	East Sular (N)	18	fringe
11	West Islet	33	rock
12	Dana Theik Di island	22	fringe
13	Prinsep Island (Sular Khamouk)	33	rock
14	Double island	33	rock
15	Tower Rock	31	rock
16	NW Bay, Sular Khamouk Is. (Prinsep Island)	16	fringe
17	Bailey Island	12	fringe
18	Bailey Island, North shore	16	fringe
19	West Spur	21	fringe
20	Metcalfe I, (beach)	18	fringe
21	Blundell I, W (beach)	14	fringe
22	Chevalier Rock	24	rock
23	Tanangthayi Is. (W bay)	18	fringe
24	North Pinnacle	24	rock
25	Kabuzya Island, SW	14	fringe
26	Kabuzya Island, E	25	fringe
27	Shar Aw, Thayawthadangyi Island	11	inner
28	Sack Island	10	inner
29	Mee Sein I.	18	inner
30	Hlwa Sar Gyi island	12	inner
31	Khin Pyi Son (I.)	21	inner
32	A Pha Island	24	inner
33	Wa Ale Kyunn	14	inner
34	Bo Ywe island	14	rock
35	Zar Det Nge Kyunn	10	inner

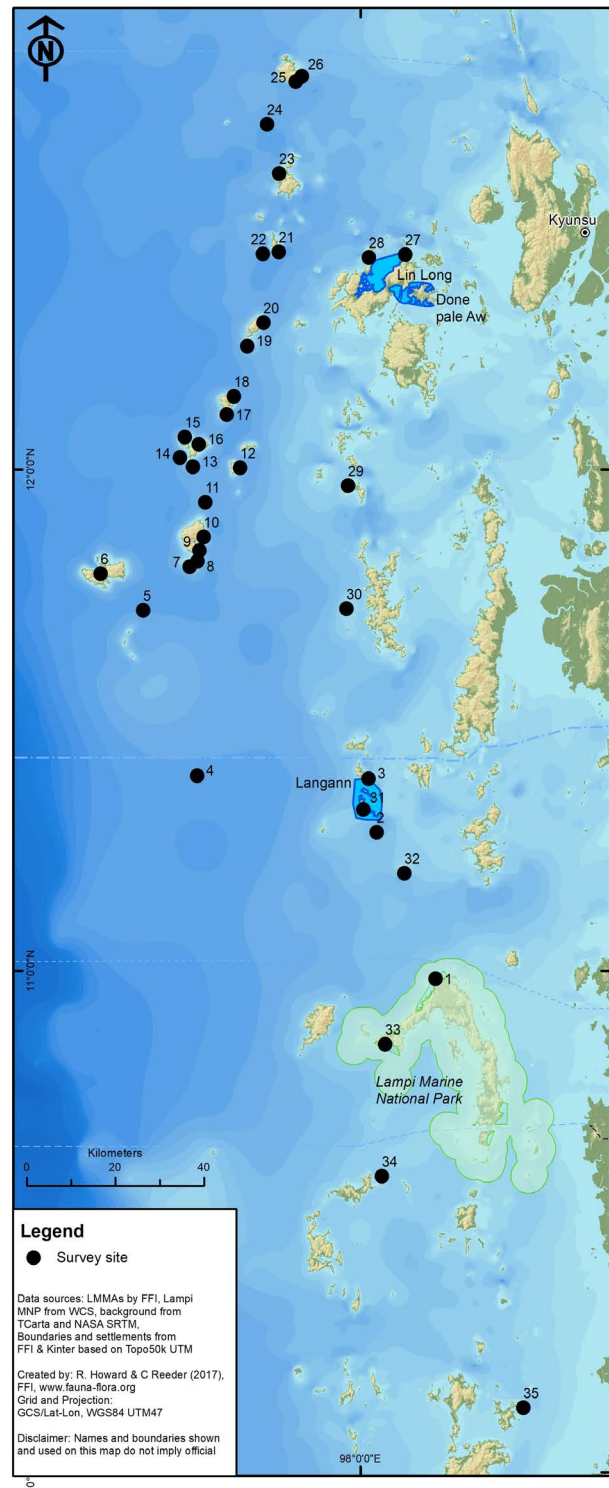


Figure 2 Survey sites (and island names in table) in the Myeik archipelago sampled for taxonomy and reef resilience. (For full map legend see Figure 1).

Coral genera and species were identified in the field, and a full species list was developed based on field IDs using digital photography as a primary reference and references that include underwater photographs (see Obura, 2012). Note that for the purposes of this report, which is to assist management and planning, the familiar old genus names for corals are used, though some of them are superseded and replaced by new names. For reef resilience the methods that we applied in this study were developed by the IUCN working group on Climate Change and Coral Reefs, as a rapid assessment of the resilience of coral reefs to climate change and its most immediate consequence, high seawater temperature (Obura and Grimsditch, 2009). The full set of indicators estimated are shown in Table 1. Indicators were estimated either in the natural quantity (e.g. % cover, for the dominant cover types), or on a semi-quantitative scale from 1 to 5. Indicators estimated on quantitative scales were transformed to the 5-point scale during analysis, and all indicators were transformed so that a score of 1 indicates poor conditions for corals, and 5 indicates good conditions for corals. Both sea surface temperature (SST) and chlorophyll (mg m<sup>-3</sup>) were obtained from MODIS night time images at a spatial resolution of 4 km.

Table 1. Resilience Indicators recorded in this survey, and their grouping into resilience factors

Factor	Variable	Factor	Variable	Factor	Variable
<b>1-Coral population</b>	Hard Coral Dominant size class Largest corals	<b>4-Substrate condition</b>	Rubble Consolidation Top. Compl.- micro Top. Compl.- mid Top. Compl.- macro	<b>7-Impacts on corals</b>	Fragmentation Bleaching Mortality-recent Coral disease Mortality-old
<b>2-Algal community</b>	Fleshy Algae-cov Fleshy Algae-canopy Turf Algae	<b>5-Cool</b>	Currents Wave exposure Deep water (30-50m) Depth of reef base Ponding/pooling	<b>8-Sediment infl.</b>	Sediment texture Sediment layer
<b>3-Inter-actions</b>	Soft Coral Inverts-other Branching residents Competitors Bioeroders (external) Bioeroders (internal) Corallivores (negative)	<b>6-Screen</b>	Depth Visibility (m) Compass direction/ aspect Slope (degrees) Physical shading Canopy corals	<b>9-Recovery potential</b>	Recruitment Recovery-old CCA

## RESULTS

### Genus diversity and abundance

Sampling of corals at each site yielded a total of 288 species and 68 genera in 17 families (Appendix A). The most diverse site, East Sular (9) had 46 genera, while the least diverse, Double Island (14) had 29 genera. Highest generic diversity was found on the outer fringing reefs, these reefs had a median of about 40 genera per site, with some low outliers (17-Bailey Rock and 8-Kunn Thee Island), and inner reefs had comparatively high diversity with a median of about 39 genera, while rock reefs had a median of about 36 genera per site. The high genus diversity and even slope of the Relative Abundance (RA) line indicates coral communities of high consistency across the full range of sites, in spite of the differences in coral genus diversity between reef types mentioned above. This consistency in the coral assemblages likely reflects an abundant source pool of larvae for recruitment from the broader Andaman Sea, and potentially strong linkages with larval sources from the core regions of the Coral Triangle to the east.

Using a species accumulation curve method that predicts total richness if sampling is continued indefinitely, a prediction of 309 species is obtained (see Obura (2012) for methods). The most species rich site was Mee Sein (29) with 113 species, followed by 3 other inner reef sites and Chevalier Rock (22, a rock assemblage) with >100 species. By contrast with genus diversity, species diversity was higher in the inner reefs than the outer fringing reefs. This may be a result of two factors: a) the high diversity and abundance of the genus *Acropora* in the inner reefs results in low genus richness but high species richness; and b) with shallower reef bases in the outer reefs (generally ending at 12-15 m on sandy slopes), and apparent impact from coral bleaching in the recent years, species may have been lost from the outer reefs, or be present at very low abundance. As with the genus distributions, the rock assemblages showed low species diversity, with a minimum of 42 species at Black Rock.

# Temperature

Sea surface temperature across the archipelago is remarkably uniform. MODIS satellite data shows strong inter-annual differences (Figure 3), with a highest maximum temperature in 2005 and a second peak in 2010. Temperature is strongly structured by year, so the archipelago is uniformly exposed to thermal stress, and this occurred in 2005 and 2010. To a minor extent, during these warm conditions, there may be some greater stress to outer and inner island locations compared to more open exposed locations (i.e. the rock pinnacles and rocky reefs). This suggests the hypothesis that mass bleaching and associated mortality likely happened during 2010, and the surveys here are recording mortality from that event, and subsequent recovery. Further, since temperature does not differ greatly within the archipelago, then any differences in site condition within the archipelago can be hypothesized to be due to some other structuring variable, either unrelated to thermal stress (e.g. fishing, sedimentation), or that alters exposure to thermal stress (e.g. through screening, cooling or acclimation; West and Salm, 2003; Obura, 2005).

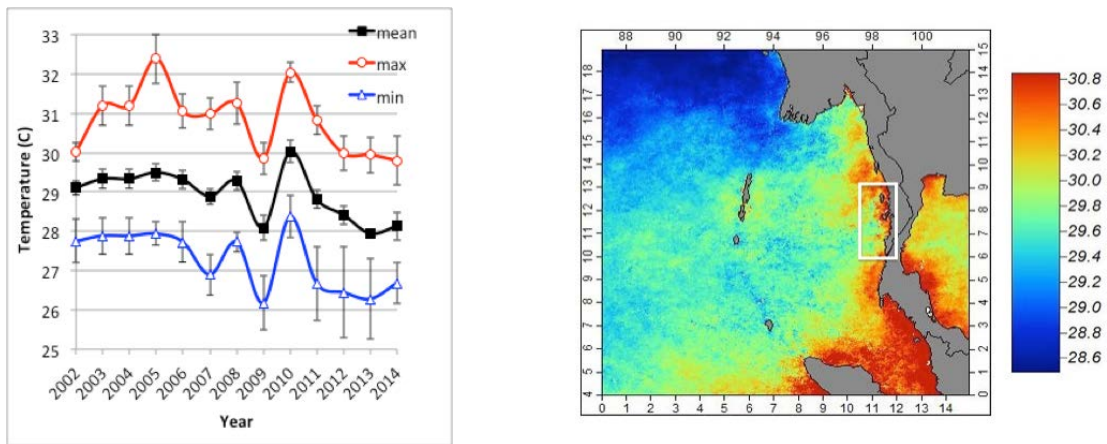


Figure 3 Left: Sea surface temperature in the Myeik archipelago, from 2002 to 2014, using MODIS 4 km resolution data, showing monthly mean, maxima and minima across 24 sampled points. Right: mean monthly temperatures for 2010. The approximate location of the archipelago and survey locations is shown by the white rectangle.

# Chlorophyll

Chlorophyll-a concentration was strongly structured across the archipelago, with highest values at sites Kyet Mi Thar Su (2), Kunn Thee Is (8) and East Sular- S (9), the closest sites to the Tanintharyi River that flows into the waters around the Thayawthadangyi Island. There was a strong peak in chlorophyll levels in 2007, associated with river discharge, most likely due to high rainfall due to La Niña conditions in that year.

# Reef health and resilience

Overall reef resilience was scored at average to below average levels (range 3.1 to 2.6 on a 1 (poor) to 5 (good) scale) Table 2. The higher coral cover and diversity of the inner reefs documented in earlier methods is reflected in their higher resilience scores, with 4 of the top 5 sites being inner reefs. A Pha (32), Chevalier rock (22), Sack (28) and Mee Sein (29) islands topped the list. Bailey Island (17) scored the highest for outer fringing reef sites. Rocky reefs were dispersed broadly throughout the range of resilience scores, while outer fringing reef sites scored the worst, with 9 of the 11 worst sites. Kunn Thee Island (8) and Kabuzya (east side) scored the worst. The average score across all reefs was 2.6, somewhat below a medium score of 3, indicating the degree of impacts to the reefs in general. Mean and range of resilience scores for each reef type revealed inner reefs having a mean of 3.1 versus 2.6 for rock reefs and 2.3 for outer reefs, though none of these were statistically significantly different from one another.

Some sites, particularly those on outer fringing reefs, showed unmistakable evidence of past mortality consistent with the presence of high sea surface temperatures in 2010, likely due to a combination of El Niño and negative Indian Ocean Dipole (IOD) phases. Inner reefs may have been sheltered from thermal stress by high turbidity, and/or the dominance of fast growing *Acropora* resulting in faster recovery from past impacts.

Table 2 Matrix of resilience factors by site, sorted from highest to lowest overall (mean) score. Shading progressively from green through yellow to red.

Sites	Reef type	Mean	SD	1- Coral	2- Algae	3- Inter	4- Subs	6- Screen	7- Imp	9- Recov
32-A Pha Island	inner	3.7	1.2	4.7	4.5	3.0	2.5	2.0	4.0	5.0
22-Chevalier Rock	rock	3.5	1.0	4.7	4.5	2.5	3.0	2.0	4.0	4.0
28-Sack Islandx	inner	3.4	0.6	3.7	3.5	2.5	3.0	4.0	3.0	4.0
29-Mee Sein I.	inner	3.4	1.0	5.0	3.5	3.0	2.5	3.5	2.0	4.0
30-Hlwa Sar Gyi island	inner	3.2	1.0	4.3	3.5	2.5	3.5	1.5	3.0	4.0
17-Bailey Island	outer	3.2	0.8	3.7	4.5	3.5	2.5	2.0	3.0	3.0
13-Prinsep Island (Sular Komouk)	rock	3.1	1.6	2.7	4.0	1.5	1.5	2.0	5.0	5.0
1-Ka Tat Aw	outer	3.0	0.6	3.3	4.0	3.0	2.0	3.0	3.0	3.0
2-Kyet mi thar su	rock	3.0	1.7	3.3	3.5	1.5	1.0	1.5	5.0	5.0
35-Zar del Nge Kyunn	inner	2.9	0.9	4.0	3.0	1.5	3.5	3.5	2.0	3.0
27-Thayawthadangyi Island	inner	2.8	0.7	4.0	3.0	2.5	2.0	3.0	2.0	3.0
20-Metcalfe I, W (beach)	outer	2.8	1.3	4.3	4.0	1.5	2.5	1.0	2.0	4.0
19-West Spur	outer	2.7	1.1	3.7	3.0	1.5	3.0	1.0	4.0	3.0
24-North Pinnacle	rock	2.6	0.9	3.0	3.5	2.0	3.0	1.0	3.0	3.0
33-Wa Ale Kyunn	inner	2.5	1.2	4.3	2.5	3.0	3.0	1.0	1.0	3.0
18-Bailey Island, North shore	outer	2.5	1.2	3.0	3.5	2.0	3.0	1.0	1.0	4.0

Sites	Reef type	Mean	SD	1- Coral	2- Algae	3- Inter	4- Subs	6- Screen	7- Imp	9- Recov
14-Double island	rock	2.4	1.4	2.0	5.0	1.5	1.5	1.0	3.0	3.0
11-West Islet	rock	2.4	1.0	3.0	4.0	2.0	1.5	1.0	3.0	2.0
6-W Sular	outer	2.4	0.7	3.0	2.5	2.5	3.0	2.5	1.0	2.0
25-Kabuzya Island, SW	outer	2.3	1.0	3.3	3.0	1.5	3.0	1.0	1.0	3.0
21-Blundell I, W (beach)	outer	2.2	1.2	4.0	3.0	1.0	2.5	1.0	1.0	3.0
7-W Sular	outer	2.2	0.9	2.3	1.5	3.0	3.5	2.0	1.0	2.0
15-Tower Rock	rock	2.2	0.8	2.7	3.0	1.5	2.0	1.0	2.0	3.0
10-E Sular	outer	2.0	1.1	2.7	2.0	2.5	4.0	1.0	1.0	1.0
9-E Sular	outer	2.0	0.8	2.7	3.0	2.0	2.5	2.0	1.0	1.0
34-Bo Ywe island	rock	2.0	0.9	2.0	3.5	1.0	2.5	1.0	2.0	2.0
12-Dana Theik Di island	outer	2.0	0.7	2.3	2.5	1.5	2.0	1.5	1.0	3.0
16-NW Bay, Sular Khamoul i. (Prinsep Island)	outer	1.9	0.8	3.3	2.0	2.0	2.0	1.0	1.0	2.0
8-Kun Theb Is	outer	1.7	0.7	1.7	3.0	1.5	1.5	2.0	1.0	1.0
26-Kabuzya Island, E	outer	1.6	0.7	2.3	1.5	2.0	2.5	1.0	1.0	1.0



## Discussion

Coral communities were clearly structured by three main reef types: a) fringing reefs on relatively exposed boulder slopes of outer islands, from the surface to about 15 m depth where the boulders transitioned into sandy slopes; b) fringing reefs on relatively sheltered slopes of the inner islands with high turbidity and strong currents; and c) steeply sloping/vertical rock walls on small isolated rocks or outer island cliff faces, extending into deeper water over 20-30 m deep. Coral reefs in the survey area showed high levels of hard coral diversity, with 288 species observed, in 68 genera and 17 families. Species accumulation curves predicted a total of 309 species would be obtained with the same method of sampling. Species diversity of corals was highest on inner reefs due to dominance and high diversity of the genus *Acropora*, which paradoxically meant that genus diversity on inner reefs was often lower than on others. Overall, coral communities were dominated by *Porites*, particularly on outer fringing reefs. *Acropora* was visually dominant on inner reefs, and below these two, a broad suite of faviids, *Psammocora* and *Fungia* (mushroom corals) were abundant.

The health of reefs in the region appeared compromised. While some sites had good coral communities, others showed unmistakable evidence of past mortality, shown by the presence of dead coral skeletons and eroding reef/rubble frameworks, and high cover of algal turf (17%). Outer fringing reefs showed the greatest evidence of mortality. Rocky reefs showed low evidence of past mortality, partly due to lower abundance of coral and dominance by other invertebrates, less build-up of reef framework due to steep slopes and community structure, strong currents, and colder conditions. Inner reefs were dominated by fast growing *Acropora*, so may have recovered faster if there had been past impact, but also may be sheltered from impacts by more turbid conditions. There was a general absence of fish and high presence of sea urchins, suggesting high fishing impacts and corroborating past findings (Cox et al., 2013; Tun, 2013; Saw Han Shein, 2013). Though fishing was not directly observed on most sites, there was high evidence of past fishing with nets and fishing lines tangled in corals.

Resilience factors show that coral and algal state of the sites was relatively good, and recovery from past impacts has been good at some sites (at inner and rock reefs) but other factors scored worse (e.g. lack of complex interactions among species and poor substrate quality). This suggests a degree of responsiveness/recovery potential in the coral community. The condition of individual sites varied considerably, but was strongly grouped by reef type (Table 3). Accordingly, prioritization of sites is divided among the three reef types – outer, inner and rock reefs:

Outer fringing reefs - in general, these showed the highest impact of past mortality and poor recovery, with 10 out of the 16 sites showing poor recovery and low resilience scores. Five sites had high coral genus richness scores, and Bailey Island had the highest resilience score for all outer islands.

Inner fringing reefs - these reefs showed the highest diversity levels as well as best condition of coral communities and resilience scores, due to low overall mortality in the past. Because of their higher resilience/better condition, combined with their proximity to villages and human settlements in the inner islands and mainland, they are among the most important reefs for subsistence and commercial resource use.

Rock/wall reefs – these sites are not classic reef habitats, with co-dominance of soft corals and other heterotrophic invertebrates alongside hard corals. They are more similar to colder/high nutrient rocky reef habitats. As a result, the condition of the benthic community was generally good, but resilience scores focused on coral reef health were not average to poor.

Table 3 Summary of sites characteristics for management recommendations, based on coral diversity and resilience results (above) and observations). Good characteristics are shown in green text, bad characteristics in red text, neutral in black. Sites without characteristic patterns are excluded from the table.

Site	Site name	Coral diversity	Resilience factors	Observations
Outer fringing reefs				
1	Katat Aw			Good condition, intermediate between outer & inner reefs
6	West Sular	High genus	poor recovery/high impact	
7	West Sular	High genus	poor recovery/high impact	
8	Kunn Thee Is	Low genus/species	Poor scores throughout	
9	East Sular (S)	High genus	poor recovery/high impact	
10	East Sular (N)		poor recovery/high impact	Good topography for recovery
12	Dana Theik Di island		Poor scores throughout	
16	NW Bay, Sular Khamouk		Poor scores throughout	Local impacts from boats/settlement on island
17	Bailey Island	Low genus diversity		Un-impacted staghorn Acropora
18	Bailey Island, North			Recruitment seeded from 17
19	West Spur		Coral good, other factors bad	
20	Metcalf I, (beach)		Coral good, other factors bad	Unusual Porites community, good topography for recovery
21	Blundell I, W (beach)	High genus	poor recovery/high impact	Good topography for recovery
25	Kabuzya Island, SW		poor recovery/high impact	
26	Kabuzya Island, E	High genus	Lowest scores overall	
Inner fringing reefs				
27	Sharr Aw, Thayawthadangi		Coral good, other factors bad	
28	Sack Island	Low genus	Coral, algae, recovery good	
29	Mee Sein I.	High genus/high species	Coral, algae, recovery good	Good reef structure and depth profile
30	Hlwa Sar Gyi island		Coral, algae, recovery good	

31	Khin Pyi Son (I.)	High species		Good depth profile, but close to village/high impacts
32	A Pha Island		Highest scores, recovery good	Good reef structure and depth profile
33	Wa Ale Kyunn	High species		
35	Zar Det Nge Kyunn	High genus/species	Coral good, other factors bad	
Rock walls				
2	Kyet Mi Thar Su		Recovery strong	
4	Black Rock	Low species		Spectacular dive
11	West Islet		Very poor recovery	
13	Sular Khamouk		Recovery v. strong	Spectacular dive
14	Double island	Lowest genus		Spectacular dive
15	Tower Rock			Spectacular dive
22	Chevalier Rock	High species	Coral, algae, recovery good	Top rocky reef, all values, Spectacular dive
34	Bo Ywe island		Poor scores throughout	

# SECTION 2

## CORAL DISEASE AND RECRUITMENT

Dr Joleah Lamb

### Introduction

Global deterioration of coral reef ecosystems is of critical conservation concern, not only for numerous reef-associated species, but also for one-eighth of the world's populations who reside within 100 km of a coral reef and benefit from the essential ecosystem services they provide (Moberg and Folke, 1999; Bellwood et al., 2004; Burke et al., 2011). Over the last 30 years, coral cover has decreased, on average, by 50% on Indo-Pacific reefs and 80% on Caribbean reefs (Gardener et al., 2003; Bruno & Selig, 2007). While a number of factors have contributed to these declines, including water pollution, habitat destruction, overfishing, invasive species, and global climate change (Pandolfi et al., 2003; Bellwood et al., 2004; Hoegh-Guldberg et al., 2007; De'ath and Fabricius, 2010), outbreaks of disease have recently emerged as a significant driver of global coral reef degradation and a major threat to reef sustainability (Harvell et al., 2007). The destructive potential of coral disease is most clearly exemplified in the Caribbean, where successive disease outbreaks from 1986 to 1993 decreased populations of two significant reef-building acroporid corals by 95% and contributed substantially to observed ecological phase shifts from coral to algal-dominated reefs (Aronson and Precht, 2001; Sutherland et al., 2004; Weil et al., 2006). The overarching goal of this study is to begin to establish baseline levels of coral health and disease levels in the Myeik Archipelago of Myanmar and associate these levels with anthropogenic influences.

### Methods

Data collection and site selection: surveys were conducted at 38 sites in the Myeik Archipelago of Myanmar during December 2014 and March 2016 (Figure 4). Included in the 38 sites selected were sites located adjacent to small fishing villages, sites with recent signs of craters characteristic of dynamite fishing and corresponding low levels of site complexity, and sites serving as controls sites (no recent signs of dynamite fishing).

Coral health surveys: At each reef site, three 20 m x 1 m belt transects were laid haphazardly along reef contours at 2 - 4 m in depth and approximately 5 m apart, consistent with standardised protocols developed by the Global Environment Facility (GEF) and World Bank Coral Disease Working Group (Beeden et al., 2008), which allow the data from this study to be directly compared to other coral disease datasets collected globally. Specifically, within each 20 m<sup>2</sup> belt transect, every scleractinian coral over 5 cm in diameter was identified to genus and further classified as either diseased (i.e. affected by one or more of the following disease classes recorded in the Indo-Pacific region (Figure 5): white syndromes, skeletal eroding band, black band disease (including other cyanobacterial infections), brown band disease, atramentous necrosis, yellow band disease, and/or growth anomalies); showing other signs of compromised health (i.e., affected by one or more of the following: tissue necrosis due to sediment, bleaching, non-normal pigmentation of tissue, overgrowth by sponges, red or green algae, and cuts and scars from predation by crown-of-thorns starfish and corallivorous marine snails); physically damaged (recently exposed skeleton from breakage or severe abrasions); or healthy (i.e., no visible signs of disease lesions, other

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For full report see: Lamb, J.B., Wenger, A. S. and Karr, K. 2016. Preliminary Report Examining coral reef and fisheries health in Myanmar, March Cruise 2016. Cornell University, James Cook University, Environmental Defense Fund and Fauna & Flora International.

#	Name
<b>2014</b>	
124	Hnget Khar Island
125	Tharn Kyunn Nge
126	Tharn Kyunn
127	Nyaung Oo Phee Is
128	Kho Yinn Khwa Is
129	Narr Kho Is
130	Ja Lann Kyunn
131	Ja Lann Kyunn Village
133	Kan Za Gyi
136	Hlaing Island
137	Saw Mon Hia Is
138	East Sular (E side, S of bay)
139	East Sular (E side, N of bay)
143	Bailey Is (E side)
144	Kyei Laik Island
145	Pyin Sa Bu Is. (W, N bay)
146	Pyin Sa Bu Is. (W, S bay)
148	Khin Pyi Son Is (village)
149	Khin Pyi Son Is (north bay)
150	Wa Ale Kyunn
<b>2016</b>	
2	Nge Khin Nyo Gye (Boulder Bay)
3	Nge Khin Nyo Gye (SW Bay)
4	Jar Lann Kyunn Nth Is. SW Bay
6	Jar Lann Kyunn Nth Is. NE Bay
7	Lampi (Nth W bay)
9	Langann (Khin Pyi Son Is.)
10	Langann (Channel N side) (Hlaing Is)
11	Ma Thee Aw (N side) (Hlaing Is)
12	Mwe Me Neik Is (SE Bay)
13	Saw Mon Hia (Small Rock Is)
15	Pyin Sa Bu Is (Khu Gyan Aw, NW Bay)
16	Mee Sein Is.
17	Lyll Is (SE point)
18	Mee Sein Is. (NE Bay)
19	Pyin Sa Bu Nge (NE Point)
20	Pyin Sa Bu Nge (Opposite Doris Rk)
21	A Pha (East side)
27	Lampi (NW of MaGyone Galet)
28	Nyaung Wee Is. (E side)

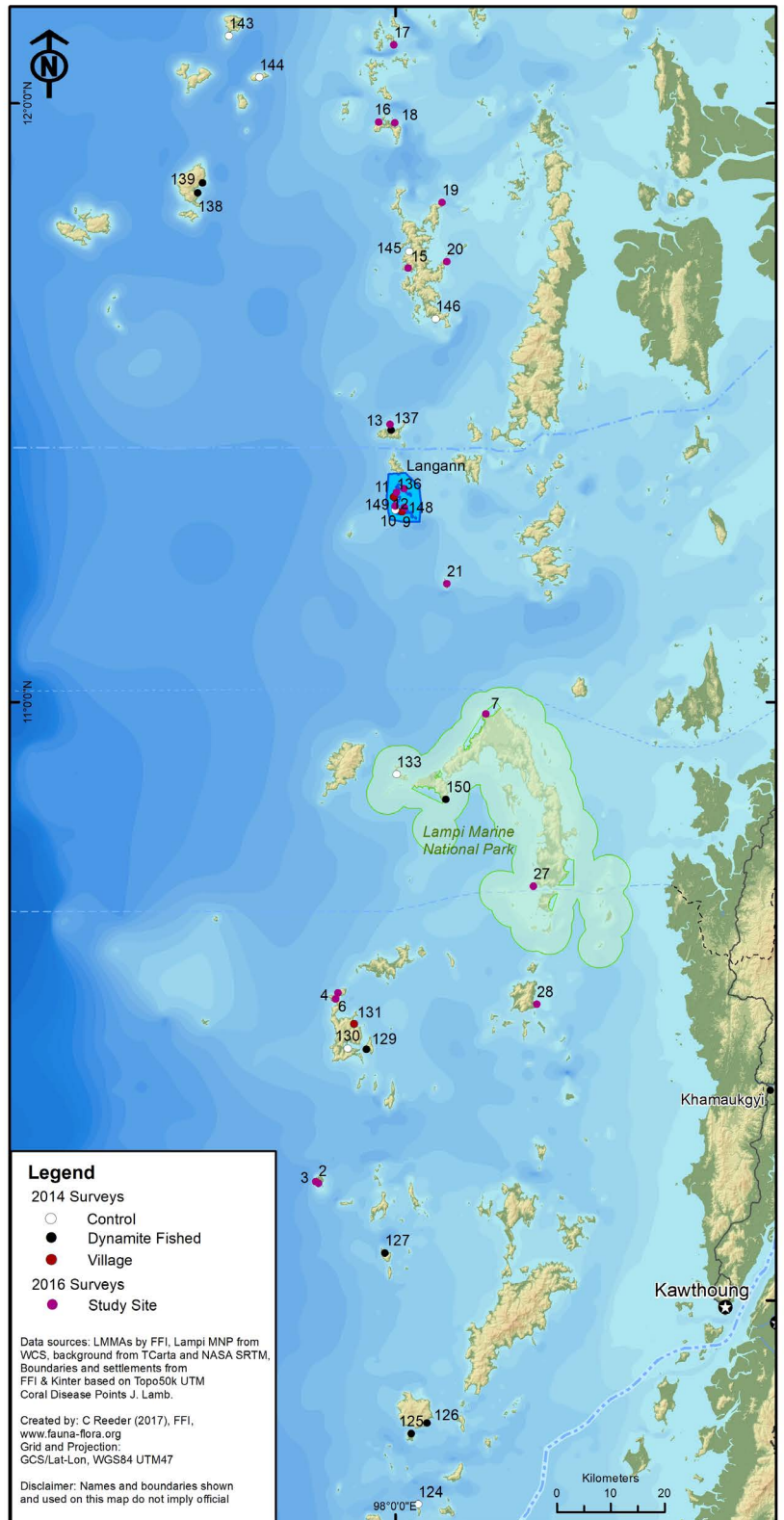


Figure 4 Map of 19 sites surveyed in the Myeik Archipelago in March 2016 (purple circles). The map also indicates the locations of 20 survey sites from surveys conducted in December 2014 (red, white and black circles). (For full map legend see Figure 1)

compromised health indicators or physical damage) (Willis et al., 2004; Lamb and Willis, 2011; Lamb et al., 2014).

Corals smaller than 5 cm in diameter were counted as recruits and identified according to coral family. Standard line-intercept surveys were used to determine coral cover and community composition by estimating the linear extent of each coral to the nearest centimetre along the central line of each 20 m transect. In situ water quality measures in addition to coral health and disease surveys, in situ levels of water quality (n = 3 replicates) were measured at each site using an EXO2 Multiparameter sonde (Xylem, USA, [www.exowater.com](http://www.exowater.com)). Water quality variables included chlorophyll-a, blue-green algae, dissolved oxygen, pH, conductivity, total dissolved solids, turbidity, salinity, depth, and temperature. The data collected from these water quality parameters are still being analysed and therefore not available in this report except for turbidity.

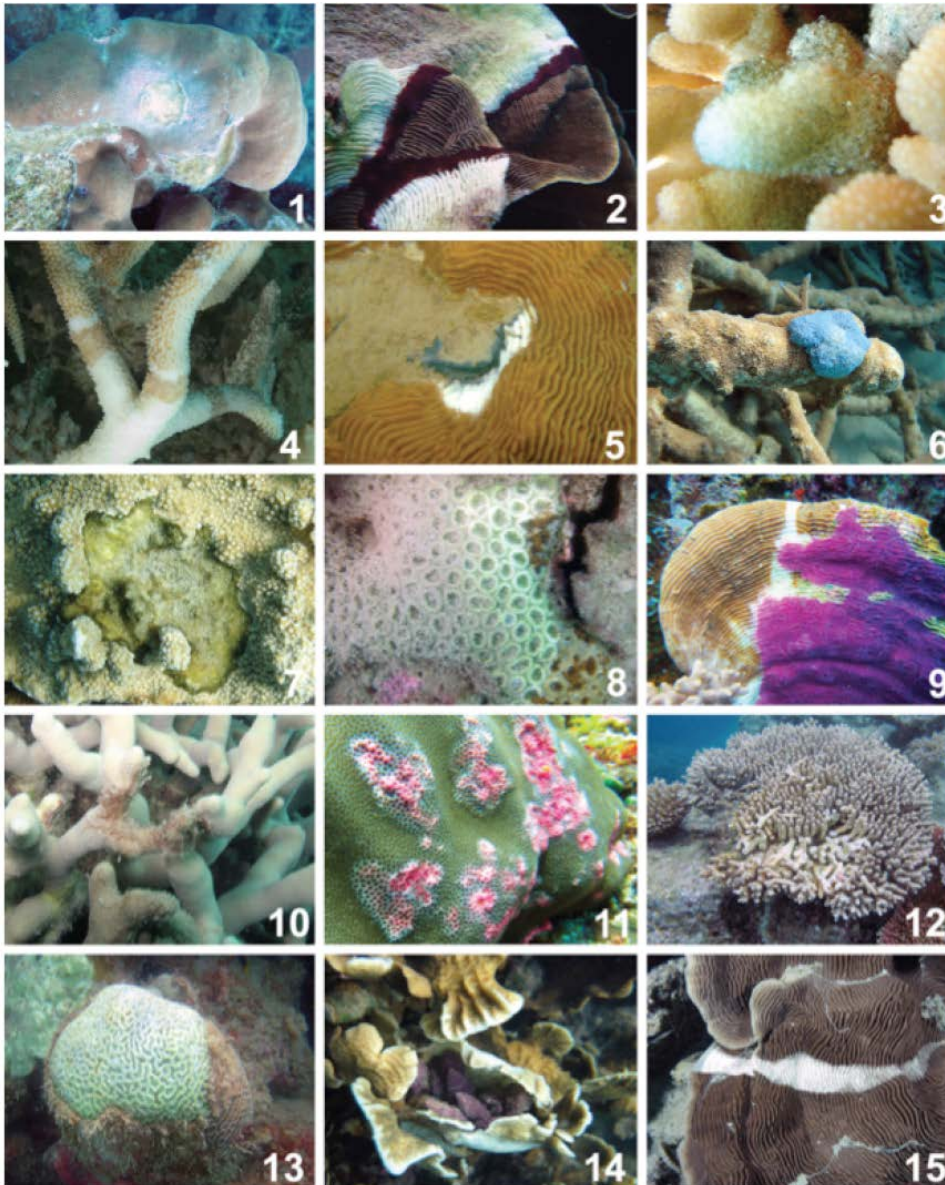


Figure 5 Field photographs exhibiting signs of coral disease and other indicators of compromised health frequently observed affecting scleractinian corals in the Indo-Pacific. Coral diseases: (1) white syndrome, (2) black band disease, (3) skeletal eroding band disease, (4) brown band disease, (5) atramentous necrosis (6) growth anomaly, (7) other cyanobacteria overgrowth. Other indicators of compromised coral health: (8) sediment necrosis, (9) sponge overgrowth, (10) red algae overgrowth, (11) pigmentation response, (12) physical damage, (13) bleaching, (14) predation from *Drupella* spp., (15) unusual bleaching. Standardised signs of disease and compromised coral health as per Beeden et al. (2008), an output of the Global Environment Facility and World Bank Coral Disease Working Group. Figure from Lamb (2013).

# Results

Data in this study were derived from examining 15,471 individual adult hard (scleractinian) coral colonies and 547 juvenile coral colonies across 38 sites (N = 11,216 corals surveyed in December 2014; N = 4,255 corals surveyed in March 2016; 3 replicate transects were surveyed at each site; reef area surveyed at each site = 45m<sup>2</sup>). Coral disease prevalence ranged from 0% to 15% across all sites surveyed, with a mean disease level of 4.9%. Levels of compromised coral health very high across the archipelago, with a mean level of 23.3%.

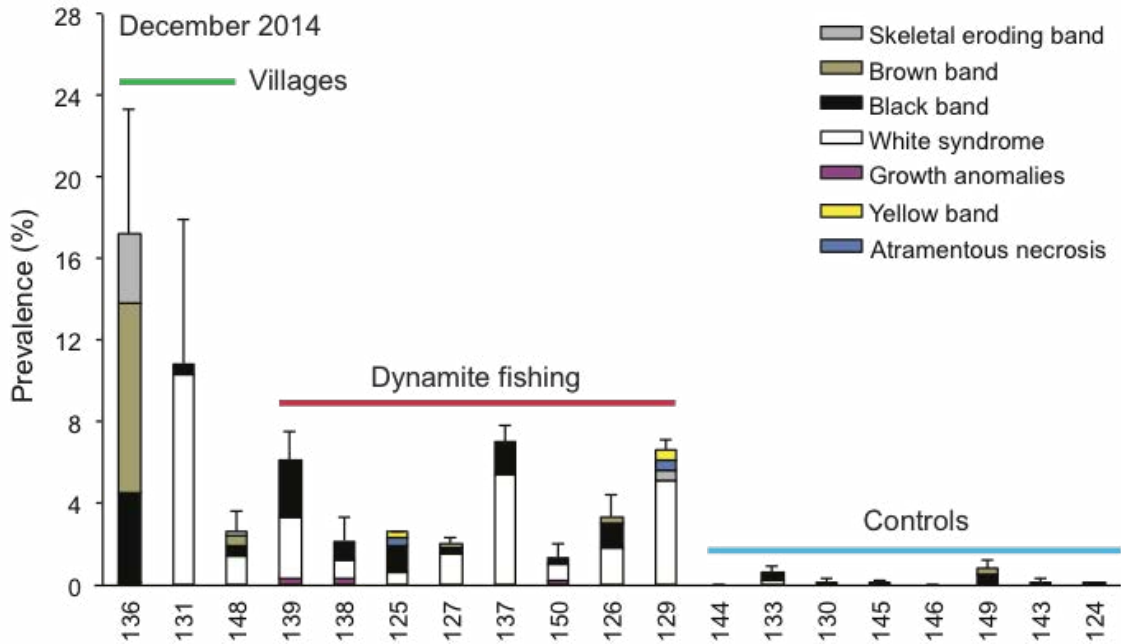


Figure 6a Mean prevalence ( $\pm$  SE) of seven coral diseases at 19 sites surveyed during December 2014 in the Myeik Archipelago, Myanmar. Green line = coral disease prevalence from surveys at sites located near small villages, Red line = coral disease prevalence from surveys at sites with craters characteristic of dynamite fishing and low site complexity. Blue line = coral disease prevalence from surveys at sites without signs of dynamite fishing (control sites).

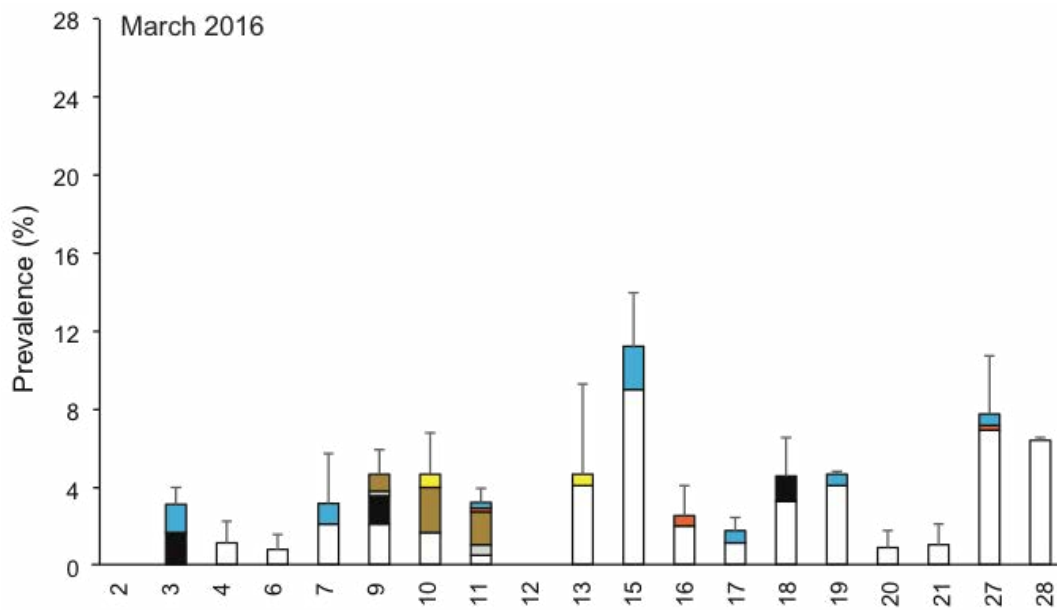


Figure 6b. Mean prevalence ( $\pm$  SE) of seven coral diseases at 19 sites surveyed during March 2016 in the Myeik Archipelago, Myanmar. These sites correspond to the water quality gradient presented in Figure 7.

We observed a strong association between sites with adult corals suffering from increases in visual signs of acute tissue necrosis as a result of sediment accumulation, seawater turbidity and recruitment of juvenile scleractinian corals (Figure 7). This suggests that potential 'sink' populations of coral recruits may coincide with poor levels of water quality. Coral recruits varied greatly across sites with a maximum of 1 ( $\pm 1.4$ ) m<sup>2</sup> at site 27 within Lampi MNP and minimum of 0 at sites 3, 9, 11 and 12 (Figure 7).

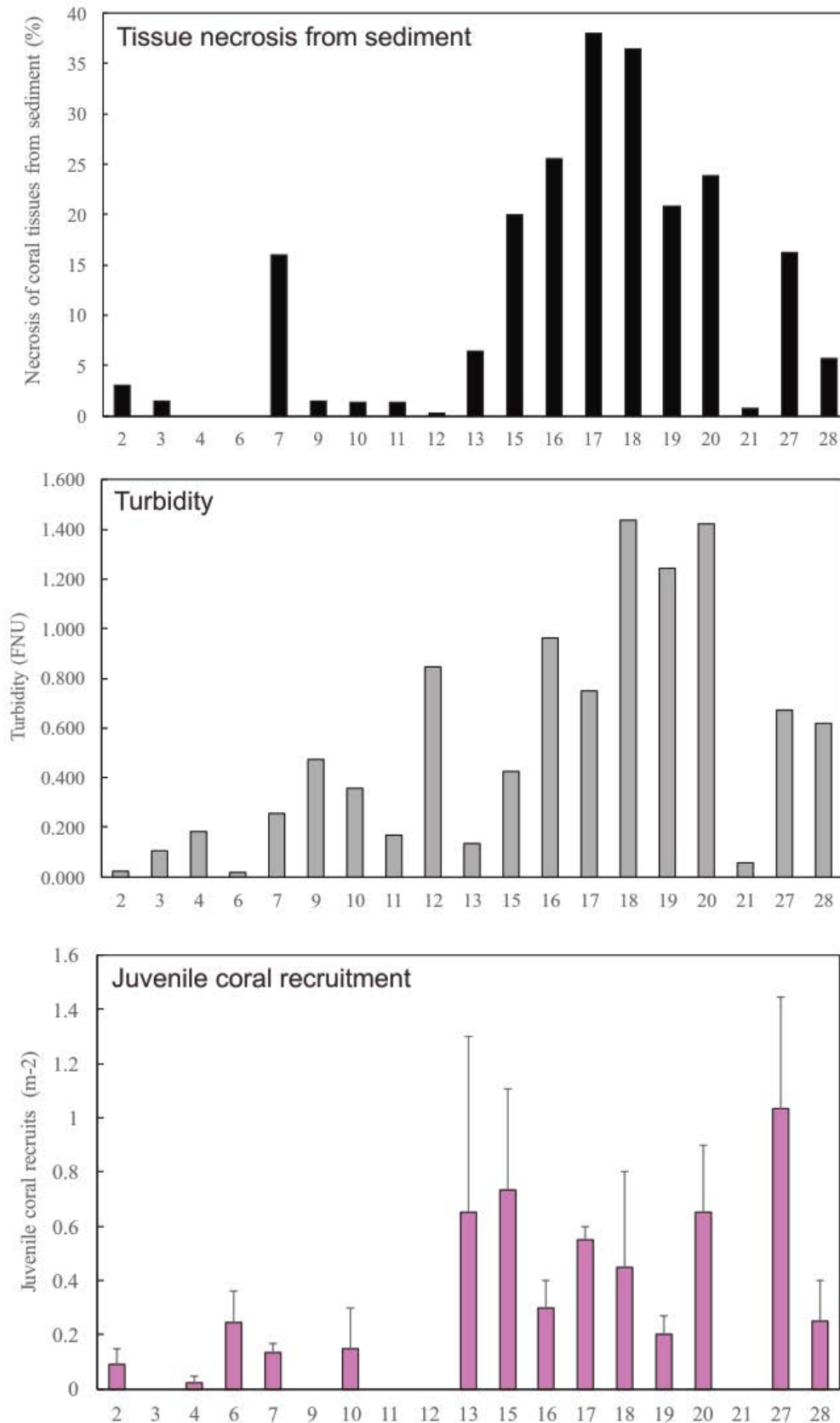


Figure 7 (Top) Mean prevalence of adult corals with tissue necrosis from sediment, (Middle), mean seawater turbidity levels (RFUs) taken at the reef level for each site, and mean ( $\pm$  SE) number of juvenile coral recruits (size range = 1- 5cm diameter) at 19 sites surveyed in the Myeik Archipelago, Myanmar during March 2016. n = 3 replicate measurements per site. Site numbers correspond to Figure 4.



## Discussion

The 2014 and 2016 surveys of coral disease prevalence in the Myeik Archipelago show levels of disease to be similar overall (at 4.9%) compared to the other locations in Asia-Pacific. Lamb et al. (2018) estimates a 'normal' baseline for coral disease in Asia-Pacific to be around 4%. Compared to other parts of the world the archipelago on average could be considered on the lower end with the Caribbean recording up to 47% in the Florida Keys and Great Barrier Reef in Australia between 7.2 and 10.7% (Haapkylä et al., 2007). However, at certain sites level prevalence was found to be extremely high, notably at: coral reefs adjacent to the villages, coral reefs with past dynamite fishing, and reefs closest to the Tanintharyi River Catchment.

For those reefs closest to villages the high prevalence of disease can be attributed to the almost non-existence in waste management in these communities with untreated or unfiltered sewer pipes directed at the marine environment which is known to increase the susceptibility of coral to diseases (Kaczmarek et al., 2005; Redding et al., 2013). The dumping of plastic waste directly into the water, as has been observed in these villages also attributes to higher than usual disease prevalence as noted in Lamb et al. (in press) where coral coming into contact with plastic were found to increase prevalence from 4% to 89%. For reefs that had been dynamited, corals have been shown to be more susceptible to disease when broken or 'injured' such as from a hurricanes or diver contact (Hughes and Connell, 1999; Lamb et al., 2014); with dynamite causing similar physical damage. Corals that have been physically injured by divers have been shown to be four times as susceptible to disease compared to uninjured corals as a result of reduced immune function of the colony caused by such stresses (Lamb et al., 2014). If dynamite fishing is allowed to continue in the archipelago then the damage caused will be catastrophic for the reefs as the physical damage caused could be compounded by higher prevalence of disease. The increased availability of organic matter and nutrients from the Tanintharyi River, notably during the wet season from terrestrial runoff explains the higher prevalence of disease on those reefs close to the catchment. Haapkylä et al. (2011) attributes such an increase in disease from runoff to the potential reduction in "host fitness or by increasing pathogen virulence". Such results show the impact this catchment can have on the whole archipelago (disease, recruitment, smothering, toxins, plastics) if land-use upstream is not managed. Coral reefs with low impacts from human activities indicate that managing these impacts will improve reef health and human livelihoods in Myanmar.

In regards to coral recruitment it is difficult without several years of data to make conclusions as to the recruitment success within the archipelago as coral recruits densities have been shown to be quite variable over seasons (Wallace, 1985; Dunstan and Johnson, 1998). Likewise comparing to other reefs in the region without long-term data may not reveal the whole picture. However, taking a one-time snap shot of coral recruitment in the archipelago compared to others shows recruitment to be quite low. On Palk Bay reef, between India and Sri Lanka coral recruits varied between 1.4–6.2m<sup>2</sup> (Manikandan et al., 2017) while in the Gulf of Thailand recruitment varied between 1.1 to 8.3 colonies/m<sup>2</sup> (Yeemin et al., 2009). These reefs, and Myanmar pale in comparison to more undisturbed ecosystems, notably Chagos Archipelago with 6 to 28 m<sup>2</sup> (Sheppard et al., 2008) and Palmyra Atoll with 0 to 59.5 m<sup>2</sup> (Roth and Knowlton 2009). Interestingly however in the Myeik Archipelago it was the more disturbed reefs i.e. those in the more 'water quality impacted' locations near the degraded Tanintharyi River Catchment which showed higher recruitment. This may be due to water circulation patterns in that area, substrate availability, competition etc. Luter et al. (2016) notes that understanding what drives coral recruitment is complex and varies greatly both spatially and temporally. As such further investigations over time and space would be need to elucidate recruitment patterns in the archipelago.

# SECTION 3

## CORAL COVER

Robert Howard, U Zau Lunn, Antt Maung, Salai Mon Nyi Nyi, Soe Tint Aung and Soe Thiha

### Introduction

Prior to 2013 very few studies had been undertaken on the extent and health of coral reefs throughout the Myeik Archipelago, with most surveys on corals covering diversity (Holmes et al., 2013). The archipelago however had been known for its coral reef ecosystems with liveboard dive boats from Thailand and Myanmar traversing the south of the archipelago from the late 1990s (Roberts, 2013). It was perceived that because Myanmar had been closed off for so many decades the reefs would be in pristine condition given the country's isolation. However, even surveys of Lampi Marine National Park from 2006-2008 showed dynamite fishing over coral reefs was a common practice (BANCA and Oikos, 2011) and dive operators talking of a system that was heavily overfished and bombed (Roberts, 2013).

These issues were also coupled with the problem that in Myanmar Marine Protected Areas were, and still remain, extremely under represented with only six protected areas existing which have marine components (Moscov Island, Thamihla Kyun Wildlife Sanctuary, Lampi Marine National Park and two Shark Protected Areas) (BANCA & Oikos, 2011). In addition, institutions responsible for the management of these areas lack the resources and capacity for their implementation and as such, besides Lampi most remain as paper parks. This is further compounded by the fact that these institutions are lacking temporally and spatially reliable and relevant data on marine ecosystems, species, population dynamics, threats etc. in order to support the design and implementation of conservation measures such as a marine protected area network.

With this information in mind there was a clear need to elucidate the status of reefs in the archipelago and identify management interventions to ensure the reefs' protection. This was not only from an environmental standpoint but also from a social perspective given Myanmar's reliance on marine capture fisheries (FAO, 2010). Therefore, since 2013 till the start of 2017 a team of Myanmar marine biologists, trained in scuba diving and marine survey techniques, undertook broadscale surveys of the coral reefs within Myeik Archipelago using a revised Reef Check method to 1) ascertain the status of coral reefs within the archipelago; and 2) identify key biodiverse areas suitable for marine protected area designation. This section provides the results of coral cover surveys from this work while Chapters 3, 4 and 7 provide the results of fish, invertebrate and threat indicators covered in these Reef Check surveys.

### Methods

To undertake the surveys Reef Check (Hodgson et al., 2006) methodology was employed which is a worldwide monitoring tool used to assess coral reef health and designed for the use by scientists and non-scientists including local community groups. For the purpose of these surveys Reef Check was used to provide a baseline of quantitative data on the archipelago's coral reefs and for the identification of key biodiverse areas. Standard Reef Check methodology involves the use of four 20m transects (replicates) at each site at two depths of 2-6m and 6-12m. Given the scarcity of corals across different depth ranges in the archipelago the survey methodology was revised to carry out five 20m replicates at each site along one depth contour with a minimum five metre gap between each replicate (Figure 8 & 9). All transects ran parallel to the shoreline and depths averaged 6.8m (range 1.0-30.0m).

For substrate composition Point intercept transect (PIT) method was employed in which the type of substrate (see Appendix B) at 0.50 m intervals along each replicate transect line was recorded. Reefs are divided into the three types as described by Obura et al. (2014) and summarized in this report in section 1 above with one addition the Moscos Islands (Figure 1) not surveyed by Obura et al. (2014). These islands are separated from the main archipelago by approximately 100km which includes the discharge from the Dawei River. The reefs are essentially inner reefs but are treated separately below given their geographical separation from the main archipelago.

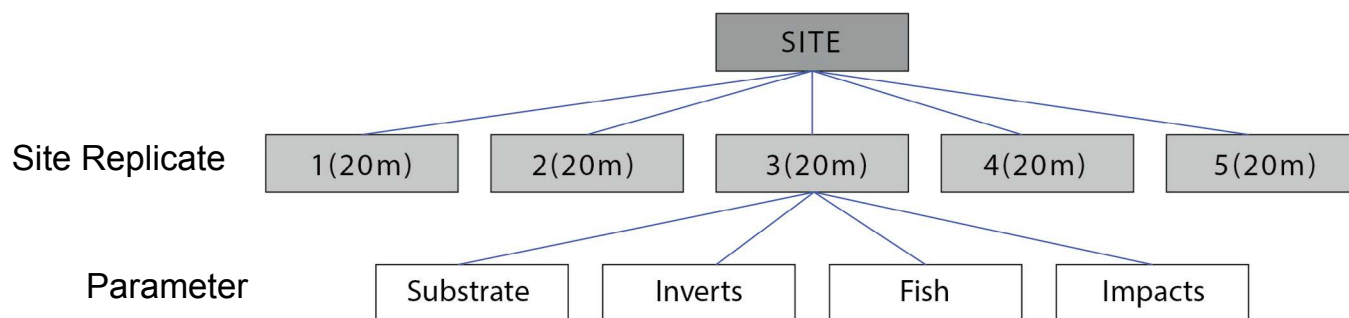


Figure 8 Sampling design for each Reef Check survey.

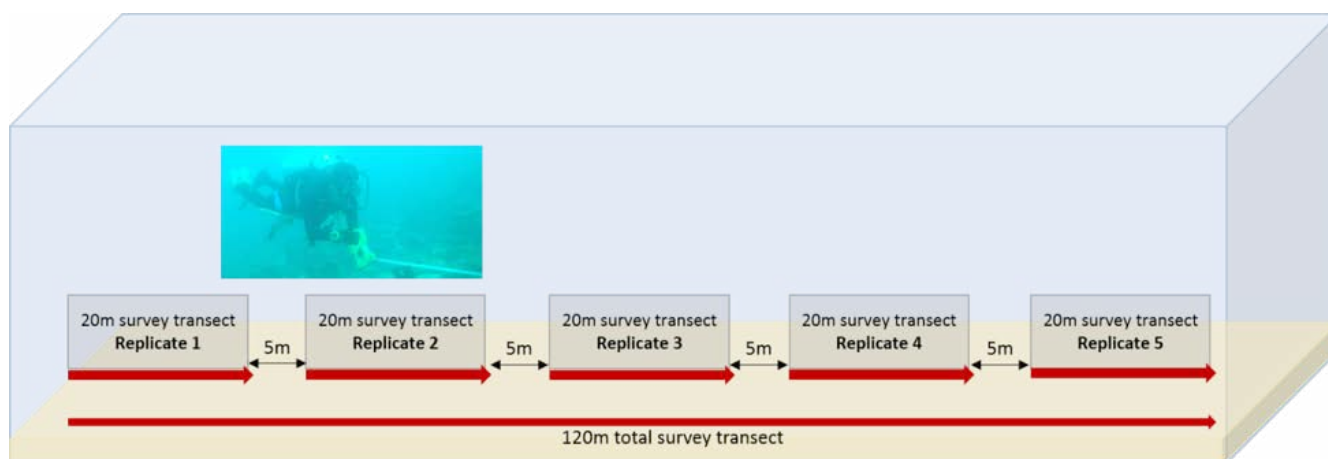


Figure 9 Reef Check methodology used. Five 20 m transects (replicates) surveyed at each site. Each replicate is spatially separated from the next by 5 m.

## Data analysis

The data for each transect was imported into individual Reef Check Excel spreadsheet templates and then into a master spreadsheet containing all sites in which the five replicates per transect could be averaged for analysis. Coral cover was classed as per Habibi et al. (2007) with: Poor (0-25%), Average (26-50%), Good (51-75%) and Very Good (76-100%). Given that sites were not sampled randomly, statistical analysis was not performed on the data. Despite this, some useful conclusions can still be drawn using pivot tables and charts.

## Results

Across 262 surveyed sites hard coral cover dominated with a mean percentage of 48.9% ( $\pm 1.5$ ), with a range of 0% at Blundell (site 89) (which was dominated by soft coral) to 92% at That Pan Nyo (site 38) and Zar Dat Ngal (site 110) (Figure 10) (refer to Figure 13 map series for site locations). The second highest recorded substrate was dead coral with 20.9% ( $\pm 0.9$ ) followed by rubble at 10.2% ( $\pm 0.9$ ). The remaining substrates were all under 7%, the lowest being sponges at 0.4% ( $\pm 0.1$ ).

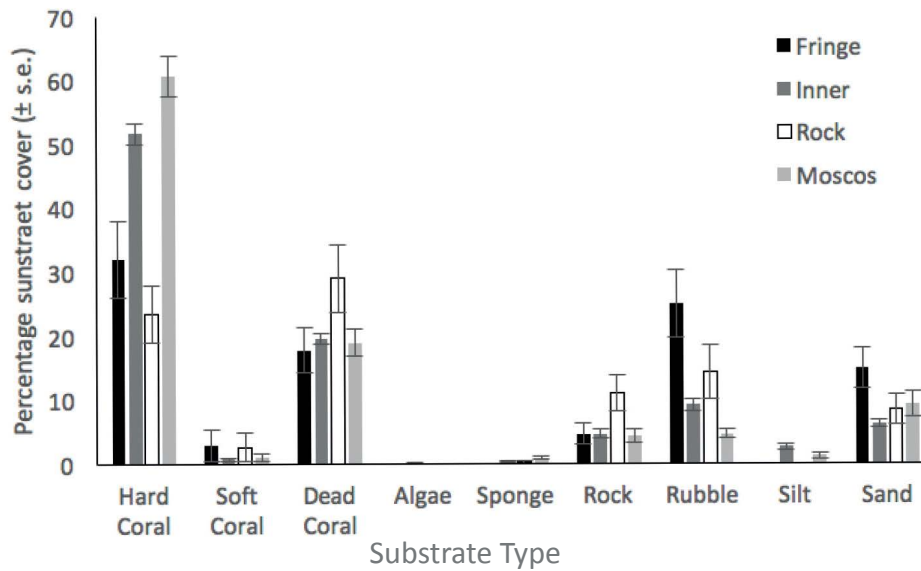


Figure 10. Mean percentage cover of nine categories of substrate ( $\pm$ S.E.) across Myeik Archipelago and Moscos Islands.

This pattern of hard coral dominating was similar across the main reef types with in Moscos (60.61%  $\pm$ 3.10), Inner Reefs (51.67%  $\pm$ 1.63) and Fringing Reef (31.95%  $\pm$ 6.0). On the more exposed Rock Reefs Dead Coral dominated over Hard Coral with 29% ( $\pm$ 5.31) and 23%.45 ( $\pm$ 4.53) respectively. Dead coral coverage on the whole didn't vary much across reef types (between 17-29%) while rubble, rock and sand, the next dominant substrates varied between sites but generally under 15% (Figure 10). On all reef types soft coral cover was low with the highest on the Fringe Reefs with 2.94% ( $\pm$ 2.36) along with algae which was under 1% across all reef types.

When hard coral is broken down into the various morphological types Massive Coral clearly dominates in the Moscos and Inner Reefs with 31.58% ( $\pm$ 2.8) and 21.56% ( $\pm$ 1.3) respectively, more than double the coverage of two next dominant coral types of branching *Acropora* and encrusting corals (Figure 11). On the Rock reefs Massive Corals again dominated with 12.18% ( $\pm$ 3.8) however this was similar to encrusting corals with 8.90% with all other coral types showing less than 2% cover. On the Fringing Reefs the main coral types of Massive, branching *Acropora* and encrusting corals varied little in coverage ranging from 7.07-9.28%. The remaining categories are sparsely represented with less than 6% cover for each at any site.

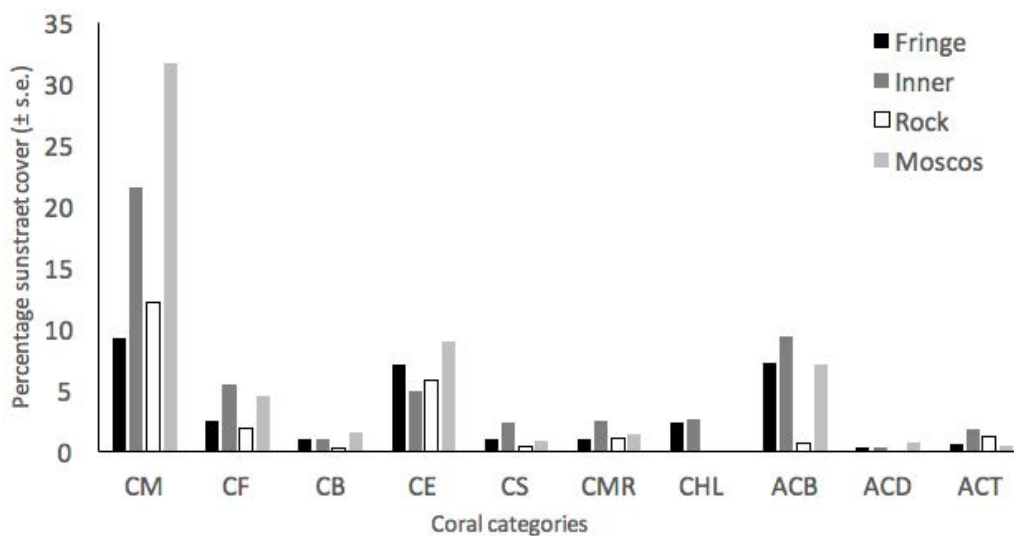
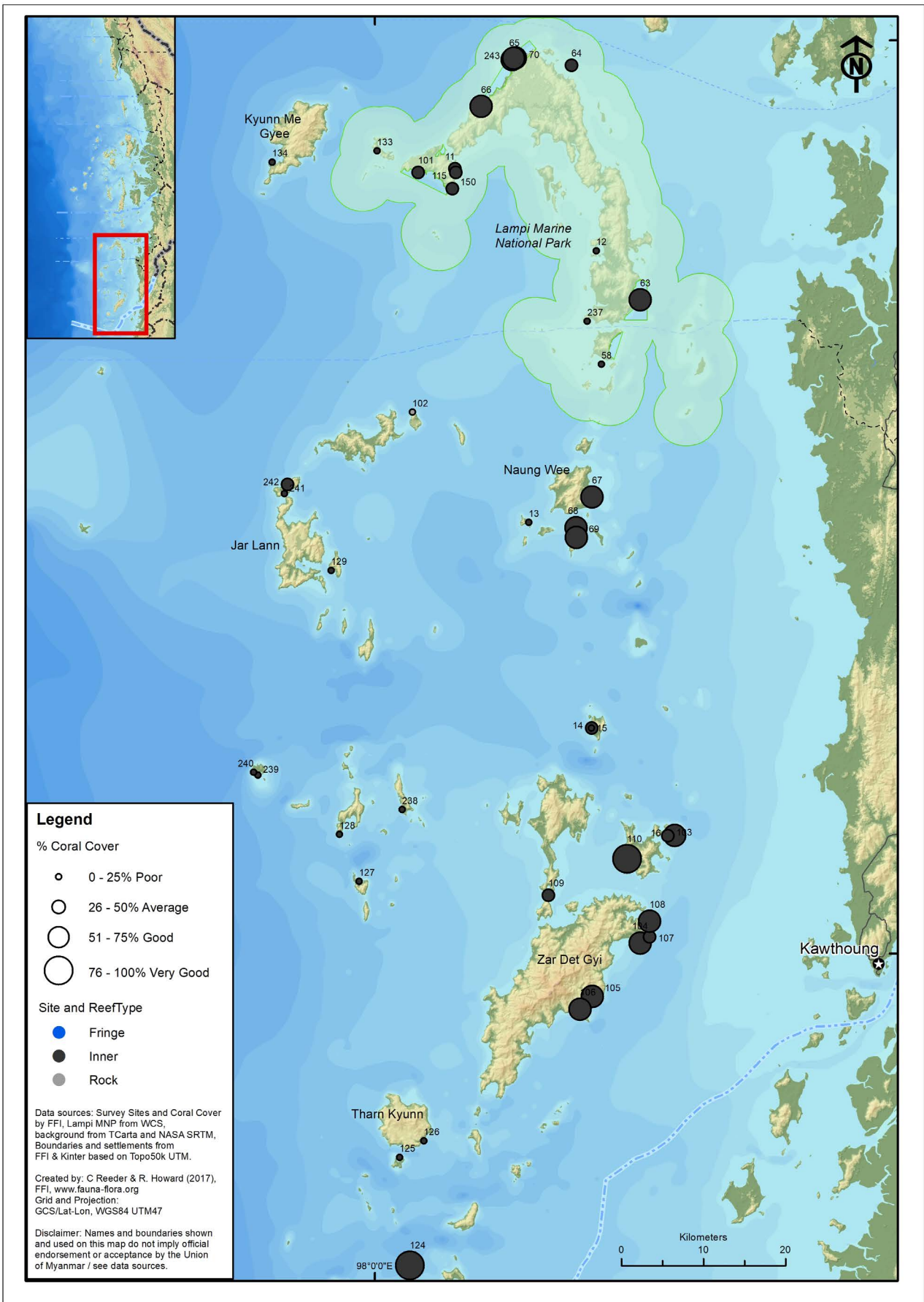
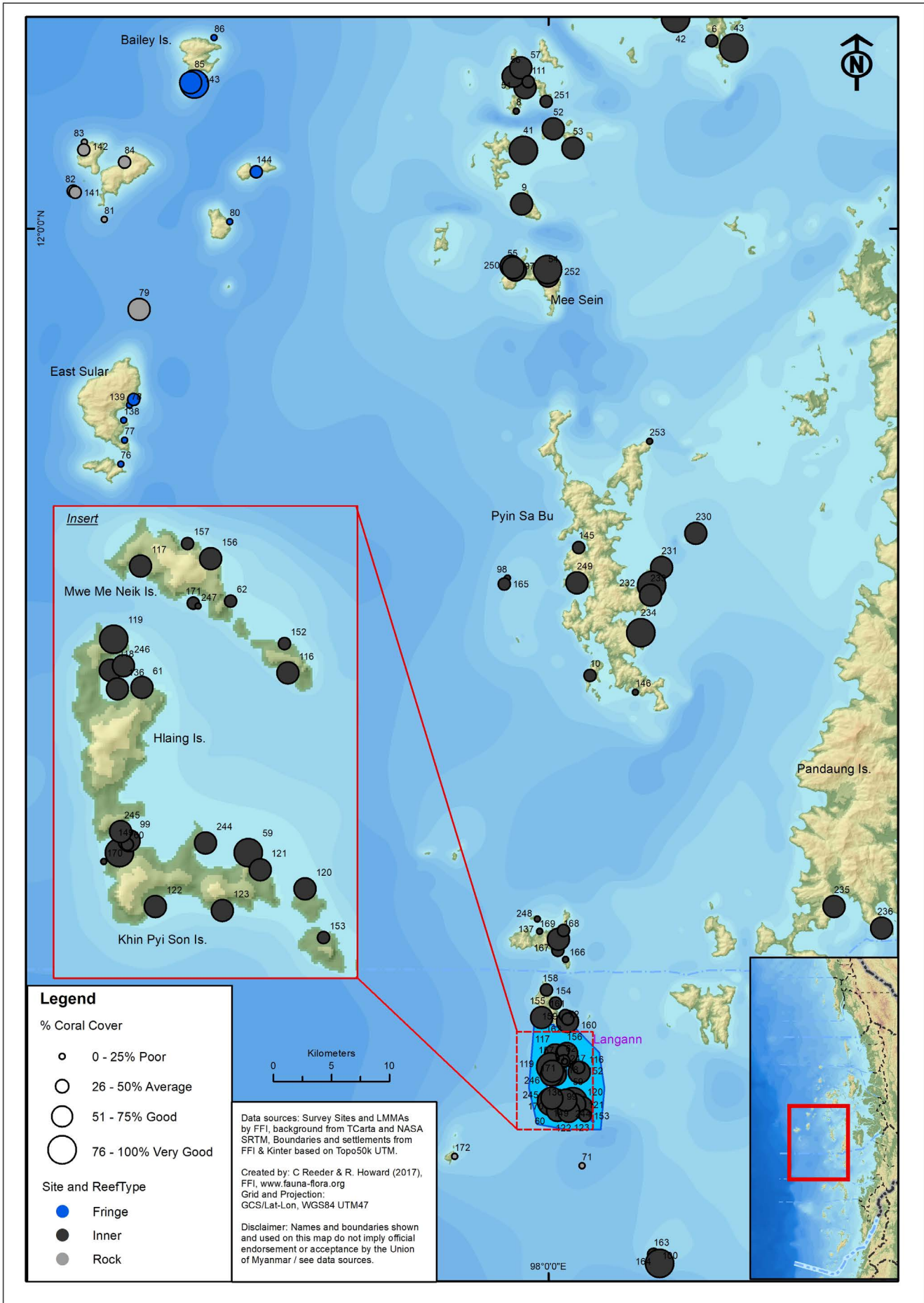
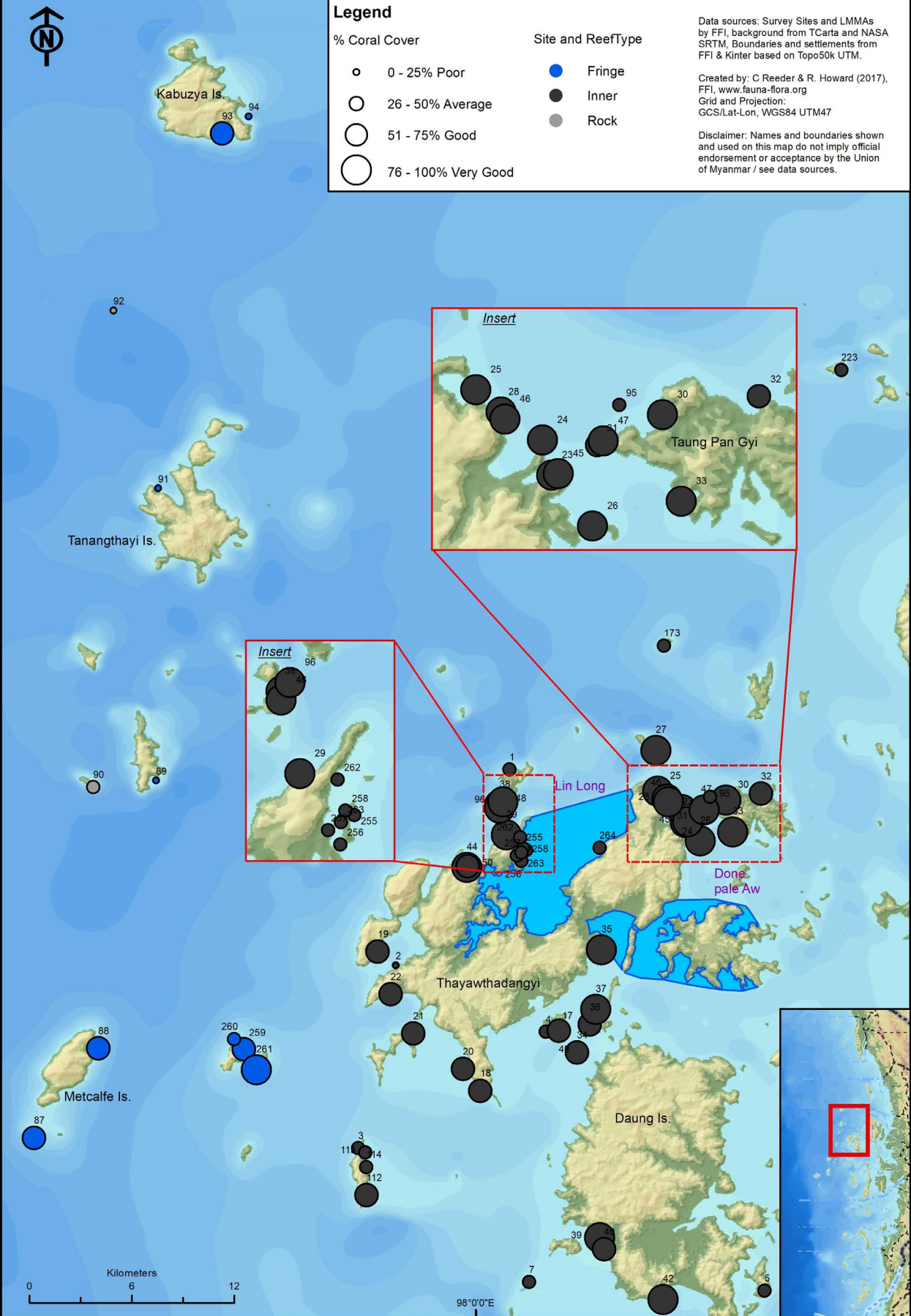


Figure 11 Mean percentage cover of 14 coral categories ( $\pm$ S.E.) across Myeik Archipelago (n = 262). (Codes: CM- Coral Massive; CF- Coral Foliose, CB- Coral Branching; CE- Coral Encrusting; CS- Coral Sub-massive; CMR- Mushroom Coral; CHL- Heliopora; ACB- Acropora Branching; ACD- Acropora Digitata; and ACT- Acropora Tabulate)

Within the three reef types and Moscos, substrates varied across sites and hard coral cover ranged from under 10% to over 90% in some locations (Figure 12). On the Inner reefs (including Moscos) hard coral cover varied from 1.5 to 95% (n= 227); on fringing from 0 to 80% (n= 21); and Rock Reefs 8.1 to 30% (n=14). (See Appendix C for all site coordinates and mean coral cover).







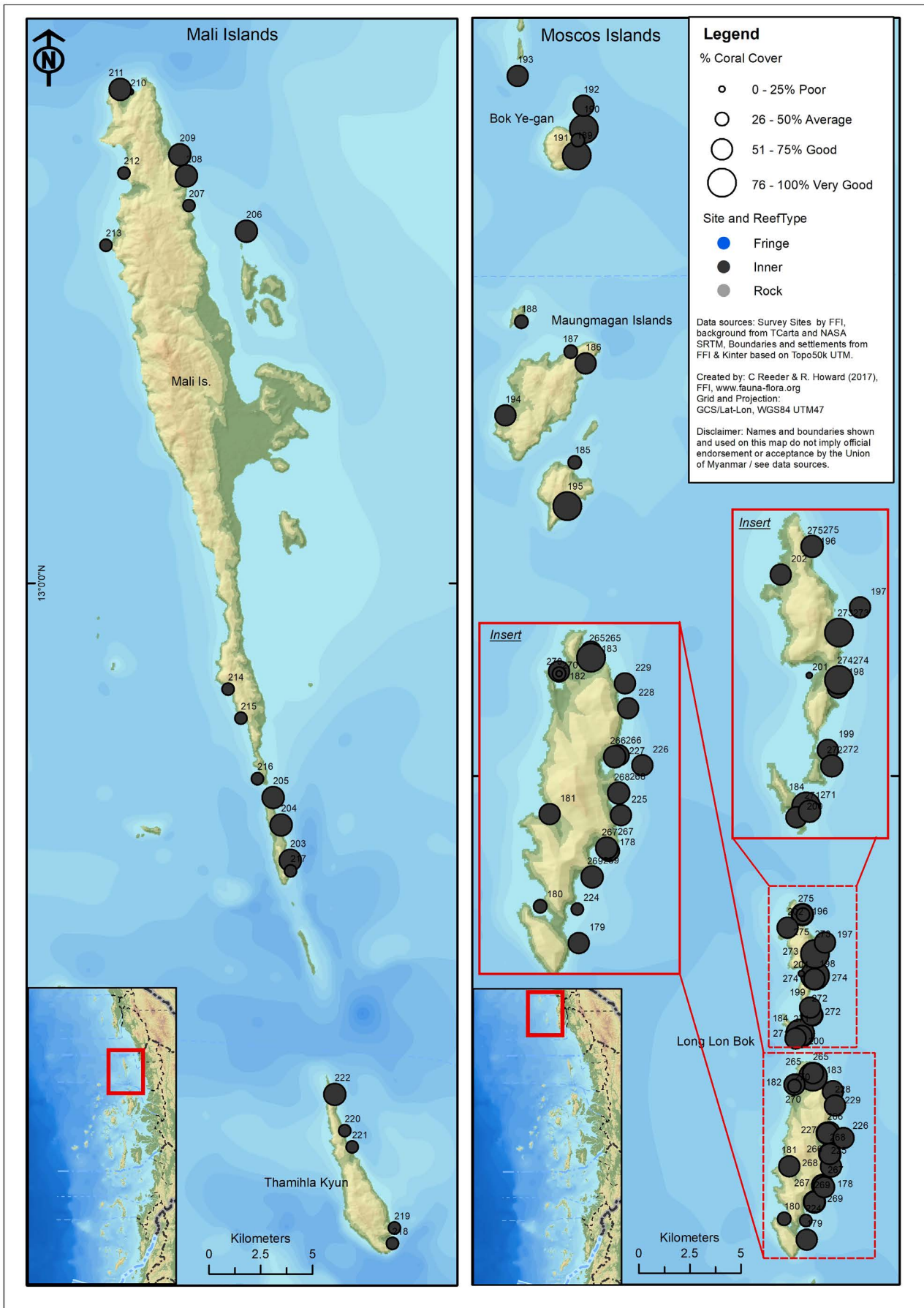


Figure 12. Mean percentage cover of Hard Coral by Reef Types (Inner, Fringe and Rock) and geographical area of the Myeik archipelago, a. Southern, b. Middle, c. Northern, d. Mali and Moscos Islands.



## Discussion

The status of hard coral cover varies greatly across the archipelago from 0% to 92% and although the Reef Check surveys show an average of 48.9% using Habibi et al. (2007) scale this puts the archipelago just inside the Average range (26-50%). It must be noted that the methodology does include a level of bias with surveys sites being selected on the basis that they contain coral reefs and so are not randomly selected. Obura et al. (2014) using qualitative observations came to a similar estimate of average with 33% hard coral cover. For comparison, Reef Check data from the region has Indonesia (surveys from 1997-2006, Habibi et al. (2007)), Australia (surveys 2011-2013, Bauer (2013)), and Malaysia (surveys in 2012, Yewdall (2013)) all considered Average (26-50%). Although Hard Coral dominated in many of the sites, Dead Coral and Coral Rubble was recorded frequently indicating both past and current impacts on the reefs. Thermal stress in 2010 is considered to be a leading contributing factor to coral degradation in the past (Section 1) with more recent impacts by more direct anthropogenic threats including dynamite fishing and boat anchor damage (discussed in Chapter 7). Encouragingly however 97 of the 262 reefs surveyed were within the Good Range (51-75%) for hard coral cover and 40 sites in the Very Good range (76-100%). These sites have formed the foundation of marine protected area plan for the archipelago discussed in more detail in Chapter 8.

In terms of coral morphology the archipelago is clearly dominated by massive corals most notably in the Moscos Islands with these forms almost three times that of branching and foliose corals. Life traits of corals morphology, growth rate and reproductive mode have been used to describe coral community structure as it relates to disturbance. For example, Darling et al. (2012) defined massive/large, slow growing colonies classed as 'stress-tolerant' and able to withstand variable environments and branching/plating forms as 'competitive-corals' which are quick growing, although susceptible to breakage and mortality from storms and high temperature variances i.e. sensitive to environmental change. In addition, Williams et al. (2013) notes that in the absence of regular disturbance or stressors a climax community develops and in their research found slow-growing *Porites sp.* dominating such a community. For the Moscos Islands the reefs, almost exclusively observed on the leeward side of the islands were clearly dominated by very large *Porites sp.* (Figure 13) and given their size potentially several hundred years old. Given the fact that these reefs recorded relatively low scores for most of the threats documented (Chapter 7) it is possible that the Moscos Islands have reached climax and signify a low disturbance ecosystem and one worthy of protection.

In most other Inner reefs in the archipelago proper massive corals also dominated over branching/foliose forms but only by approximately 6% more cover. These reefs therefore have a mix of 'stress-tolerant' and 'competitive-corals' and as such have possibly suffered from some recent disturbance in which the relatively fast growing branching corals are colonising quickly after the perturbation. This is in line with the studies in Section 1 where the authors note that these reefs may have suffered from the 2010 coral bleaching event and are now in recovery although these reefs may have been buffered from high temperatures by high turbidity when compared to Fringe reefs (Section 1). The latter had relatively equal massive and branching coral coverage but the highest amount of rubble and as described in Section 1 these reefs suffered the greatest from the 2010 bleaching event with these reefs less accustomed to large temperature changes. For Rock reefs which had similar Hard and Dead coral coverage, but dominated by massive and encrusting corals are not considered true coral reefs but rather corals on rock. The strong currents which surround these 'reefs' and steep slopes most likely prevent a true reef from forming.

Results of the surveys show that the archipelago shows clear signs of degradation but has a number of sites where the coral habitat is still intact providing a chance of recovery for the ecosystem as a whole. These findings concur with reef resilience studies in Section 1 in which the overall picture for the archipelago was found to be average to below average levels, but for a number of key sites in a state of recovery.



Figure 13. *Porites* sp. corals observed at Moscos Island during Reef Check surveys in November 2015. Photo: Robert Howard/FFI.

## Species of conservation concern

Tabulation of the IUCN Red List status of each coral species (Table 4) shows that three species are classified as Endangered (*Parasimplastrea sheppardi* and *Acropora roseni* and *A. rudis*), and 45 as Vulnerable. For the full list see Appendix A.

Table 4. Number of observed species in each IUCN Red List category

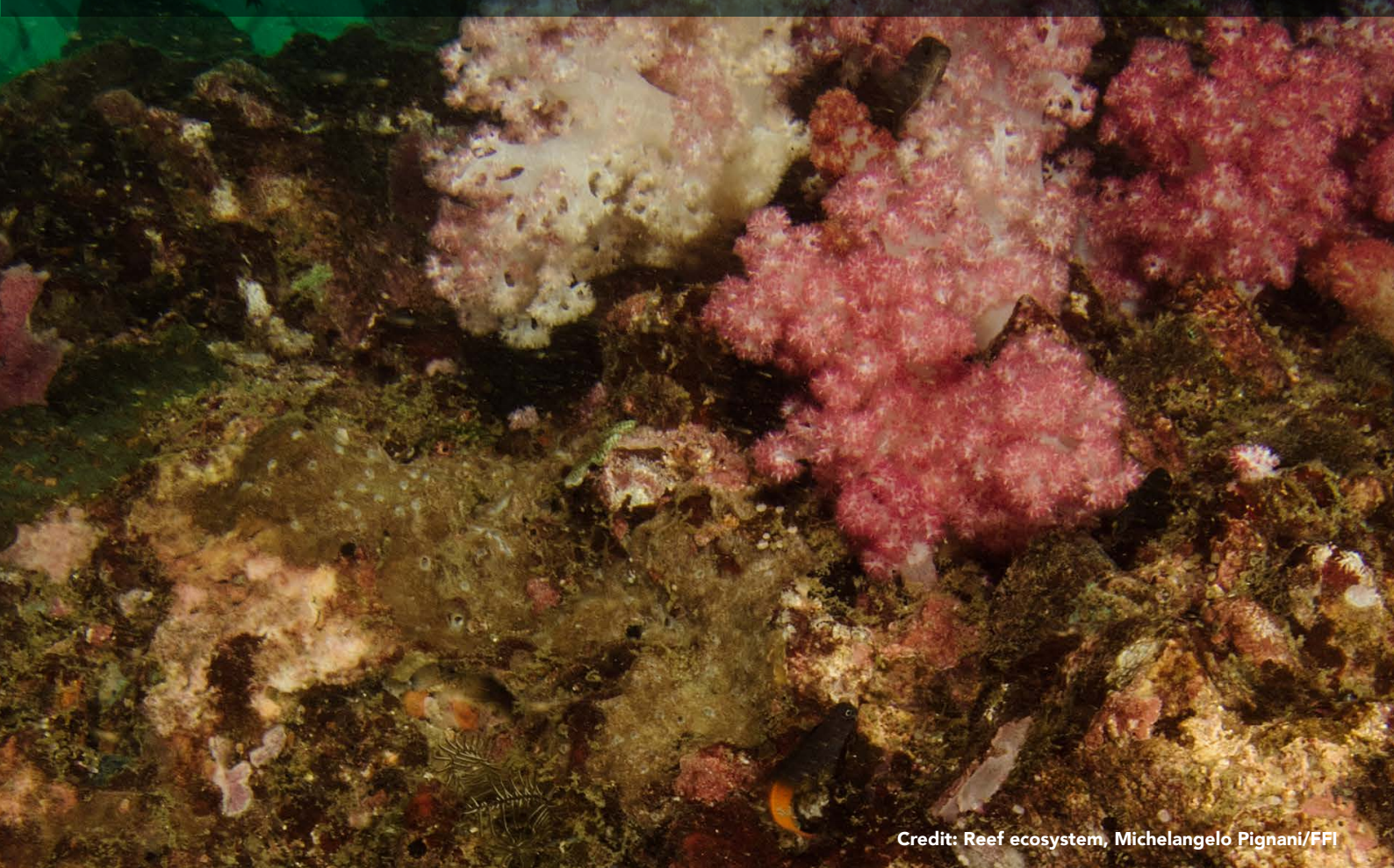
Red List category	# species
Least Concern (LC)	139
Near Threatened (NT)	85
Vulnerable (VU)	45
Endangered (EN)	3
Data Deficient (DD)	4
Not Evaluated (NE)	6
Genus level only	6
<b>Total</b>	<b>288</b>

## Recommendations for Conservation

- Undertake comprehensive land-use planning for the terrestrial landscape adjacent to the archipelago and institutionalise land-use practices which minimize runoff, erosion and the use of chemicals used in agriculture and mining.
- Reef communities were clearly differentiated into three classes – inner fringing reefs, outer fringing reefs and rocky reefs, and management decisions for these reef types should be made independently.
  - Inner reefs are the most diverse and in the best condition due to protection from bleaching impacts, but also the most vulnerable to fishing pressure and of highest immediate value for food security.
  - Outer reefs were intermediate in diversity and in the worst condition due to impacts from past bleaching events (likely in 2010), but with lower impacts from fishing, and will become of increasing value for food security with increasing human population growth and expansion of fishing in the future. As a result of past impacts, key sites can be identified to prevent losses to the best sites, and promote recovery of the most impacted sites with highest recovery potential. Management for recovery and maintaining resilience should be a top priority.
  - Rocky reefs have the lowest diversity and least-typical coral reefs, have low vulnerability to bleaching impacts and also to fishing – but have a particularly vulnerability to entanglement of gear from fisheries in adjacent open waters. They have among the highest value for dive tourism due to their spectacular topography and potential for large fish.
- Direct threats to reefs to the coral reefs of the Myeik archipelago are already high, and clearly differentiated into two types:
  - Fishing imposes an immediate threat in multiple ways across all island types, and to the banks/pelagic zones between the islands. Management and monitoring of fishing effort are two of the strongest tools for reducing impacts to coral reefs and other habitats, and establishment of nuanced monitoring, in partnership between fisheries authorities, all relevant fishery sectors and the conservation/management community is essential. Alongside this establishment of regulations to protect sensitive sites to replenish fished ones, for protection of biodiversity and for other users (e.g. tourism) is necessary. An archipelago-wide spatial management approach is necessary to address this sufficiently, and projecting forwards 20 or more years to expected population levels on the coastline/islands and in the fishery sector is essential.
  - Coral bleaching as a result of thermal stress has already impacted the outer islands, and the threat will increase to all three classes of islands. The spatial management system established for fishery management should also include vulnerability to future thermal stress and its impacts on the reefs, both for general reef resilience and recovery dynamics, as well as for impacts to fishery replenishment and recovery potential.



# 3 FISH FAUNA



Taxonomy: Dr Barry Russell

Biomass: Dr Kendra Karr

Indicator Fish: Robert Howard, U Zau Lunn, Antt Maung,  
Salai Mon Nyi Nyi, Soe Tint Aung and Soe Thiha

## INTRODUCTION

### Taxonomy

The east Andaman Sea region as a whole has a rich and diverse fish fauna. Knowledge of the fishes of the east Andaman region derives mainly from work undertaken in Thailand, largely as a result of the establishment of the Phuket Marine Biological Centre (PMBC) in 1974, and has steadily increased over the past few decades. G. Allen and J. Randall, from the Western Australian and Bishop museums, visited PMBC in 1979. They made a few collections and photographed fishes around Phuket and at the Similan Islands. However, the most important collections for the area were made in 1993 by Ukkrit Satapoomin of PMBC and Richard Winterbottom from the Royal Ontario Museum (ROM). Their collections, now deposited at PMBC and ROM, contain several thousand specimens and more than 500 species (Satapoomin, 2011). Satapoomin (1993) compiled the first comprehensive checklist of coral reef fishes of the west coast of Thailand by assembling information from both available literature (dated back to 1950) and results of surveys carried out during 1990–1992. The list revealed a total of 597 species belonging to 66 families of reef fishes in the area. Allen et al. (2005) undertook visual surveys at 31 sites off the Andaman Sea coast of Thailand including the Surin, Similan and Phi Islands, and two sites at Patong Bay, Phuket Island and recorded 565 species, bringing the total number of coral reef fishes for the region to 764 species in 70 families.

Including non-reef fishes, Satapoomin (2007) reported the number of fishes known from the Andaman Sea coast of Thailand as 888 species in 85 families. In a field guide to the Fishes of the Andaman Sea, Kimura et al. (2009) included 778 species of marine fishes in 106 families, and in the most recent comprehensive checklist, Satapoomin (2011) recorded a total of 1,746 species in 198 families of fishes for the Andaman Sea coast of Thailand. A further study by Vilasri et al. (2015) of fish market landings at Phuket and Ranong recorded two additional species not previously known from the Andaman Sea, bringing the total number of species known from the East Andaman Sea region to 1,748 species in 198 families.

The only previous quantitative reef fish survey work was a partial preliminary ichthyological assessment survey at Lampi Marine National Park, which recorded a total of 42 fish species belonging to 22 families (MOECA and Oikos, 2015). Therefore surveys of the fish fauna of the islands of the Myeik Archipelago, off the Andaman Sea coast of Myanmar, were undertaken in December 2014 and March 2016. The main goal was to provide a comprehensive inventory of shallow coral reef fishes inhabiting the Myeik Archipelago, and to compare this with the fish fauna of the East Andaman Sea region. It therefore excluded deep water fishes, offshore pelagic species such as flying fishes, tunas, and billfishes, and most estuarine forms.

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For full reports see: Russell, B.C. (2015). Survey of coral reef fishes of the Myeik Archipelago, Myanmar. Report No. 13 of the Tanintharyi Conservation Programme, a joint initiative of Fauna and Flora International (FFI) and the Myanmar Forest Department. FFI, Yangon.

Russell, B.C. (2016). 2016 Survey of coral reef fishes of the Myeik Archipelago, Myanmar. Report No. 38 of the Tanintharyi Conservation Programme, a joint initiative of Fauna & Flora International (FFI) and the Myanmar Forest and Fisheries Departments. FFI, Yangon

## Indicator Fish and Biomass

There is a desperate struggle to catch more fish from an ever-dwindling supply in our oceans – leading to widespread overfishing and ecosystem degradation. If the ‘race to fish’ doesn’t change, 80% of global fisheries could collapse by 2030, affecting over 3 billion people worldwide (FAO, 2014). Myanmar is one of 12 governments that account for 62% of the global catch, with the fastest increases in fishing production of any large fishing nation (FAO, 2014). When fishing is sustainable, oceans can flourish. This is especially critical for Myanmar and the estimated 275 million people that live within 30 km of coral reefs and draw extensively on them for employment, coastal protection, tourism income, and cultural significance (Burke et al., 2011). More than 90% of coastal communities in Myanmar rely on reef fish and the productivity of the nearshore fishery for well-being (FAO, 2014). There is a tremendous opportunity to support sustainable fisheries yields, healthy coral reefs and economic prosperity across Myanmar. However, there are currently little protection measures for coral reefs in the country – leaving many communities at risk to overfishing and ecosystem collapse.

In 1978-1980 surveys of Myanmar’s fishable resources was undertaken by the research vessel Dr Fridtjof Nansen (Strømme et al., 1979) and then again in 2013 (Krakstad et al., 2014). Surveys found that the 2013 estimates were less the 10% of the 1978-80 standing stock for pelagic fish. There were however some differences in methodologies such as the number of surveys and aimed trawls verse random trawls. However, the authors noted “there is a shift in standing stock biomass away from long lived and highly valuable species towards smaller fish with shorter life spans and of lower commercial value....reflect[s] a picture of a fishery that may suffer both from growth and recruitment overfishing”.

These surveys however did not cover shallow reef ecosystems due to the boat size. As such from 2013-2017 surveys on the abundance of a set of readily identifiable indicator fish species were undertaken to gauge the health of a coral reef ecosystem and develop a baseline (as of the 2013-2017 period) on shallow water (<30m) coral reef fish. These surveys were complimented by surveys to estimate the biomass of select group of species and a baseline and for comparisons across the region in 2016.

## METHODS

### Taxonomy

Taxonomic surveys of fish fauna were undertaken during two liveaboard research expeditions in December 2014 and March 2016 throughout the archipelago (Figure 14). Surveys were carried out using high definition underwater video (Sony Action Cam) to record fish species at each site. The technique usually involved rapid descent to 20-30 m, then a slow, meandering ascent back to the shallows. Most time was spent in the 2-15 m depth zone, which consistently harbours the largest number of species. Each dive included a representative sample of all major bottom types and habitat situations, for example rocky shallows, reef flat, steep drop-offs, caves, rubble and sand patches, coral areas and “bommies”. Videos were later analysed using slow motion playback and freeze-frame to identify individual species, and to compile species lists for each site. Underwater still photographs taken at the same survey sites by other team members supplemented the video records.

In addition, selected species were collected by spearing for genetic samples and taxonomic study. Similarly, rapid fish market surveys in Ranong were undertaken on two consecutive days using a digital camera to photograph landed fishes, with selective collection of some species for taxonomic/genetic study. Collected specimens have been deposited in the Northern Territory Museum, Darwin and are awaiting identification.

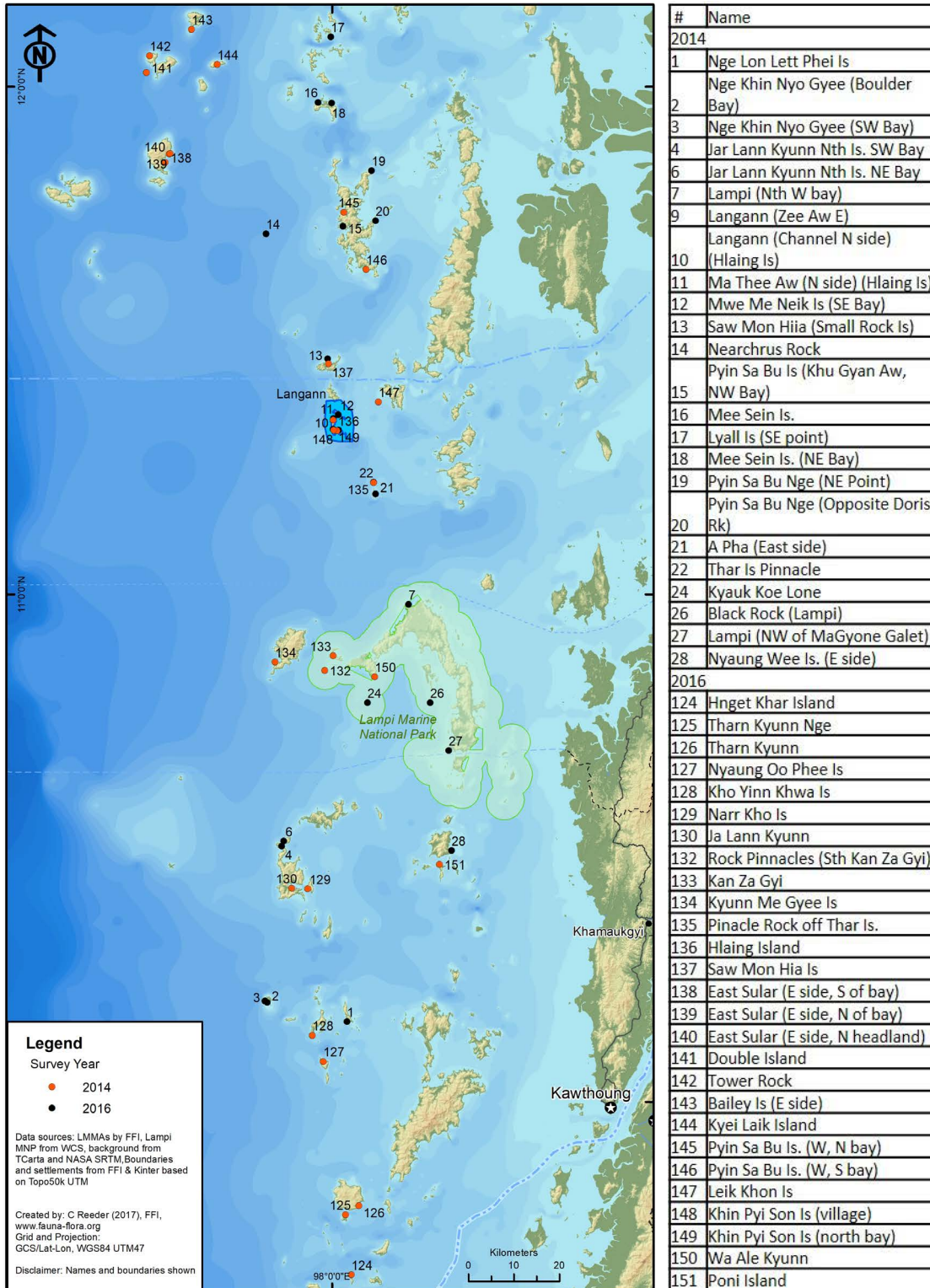


Figure 15. Taxonomic fish survey sites (and island names in table) in the Myeik Archipelago. (For full map legend see Figure 1).

## Indicator Fish and Biomass

The majority of Indicator Fish surveys were undertaken by FFI from locally hired fishing boats during Myanmar's dry season from October-May, 2013-2017 throughout the archipelago, and supplemented by additional surveys from three of FFI's liveaboard research expeditions in March 2014, December 2014 and March 2016. To undertake indicator fish surveys Reef Check (Hodgson et al., 2006) methodology was employed (see Chapter 2 section 3 for details on Reef Check transect method). Specifically for indicator fish (Table 5) abundance estimates along the belt transects are recorded with surveyors estimating the total number of indicator species seen within an imaginary area measuring 10 m wide x 5 m high along each 20 m transect line. Fish size was estimated for Groupers only, e.g. *Epinephelus spp.*

Table 5. Indicator fish groups recorded during reef check surveys.

Common Name	Scientific Name
Butterflyfish	Chaetodontidae ( <i>Chaetodon spp.</i> )
Sweetlip	Haemulidae
Snapper	Lutjanidae
Barramundi Cod	<i>Cromileptes altivelis</i>
Humphead wrasse	<i>Cheilinus undulatus</i>
Bumphead Parrotfish	<i>Bolbometopon muricatum</i>
Parrotfish (other)	Scaridae
Moray eel	Muraenidae
Grouper 30- 40 cm	Serranidae
Grouper 40- 50 cm	Serranidae
Grouper 50- 60 cm	Serranidae
Grouper > 60 cm	Serranidae
Sharks	Elasmobranchii

Biomass surveys were undertaken during FFI's March 2016 liveaboard research expedition. For these surveys (undertaken at sites 2, 3, 4, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 24, 25 and 27 in Figure 14) at each reef site, five 20 m x 5 m belt transects were laid randomly along reef contours at 2- 4 m in depth and approximately 5 m apart, consistent with standardized protocols used by Reef Check, which allow the data to be used by FFI's Reef Check team. A total of 160 transects were surveyed for fish, using the targeted underwater visual survey method across 18 sites. A standardized target fish list of fishable and ecological relevant targets was developed – providing a relatively consistent search image that facilitates accurate species identifications and minimizes “observer overload”. Moreover, line-of-sight issues, which are especially acute in high-rugosity habitats, and errors beyond a diver's focal range in estimating fish sizes or the location of the belt boundary, are minimized by constraining both the number of assessed species and the transect width (Sale and Sharp, 1983; Floeter et al., 2005.). An inherent limitation of narrow transects, however, is their bias against large schooling, or highly mobile, fishes (Floeter et al., 2005). Within each 200 m<sup>2</sup> belt transect, every fish encountered that is fishable, over 10cm and targeted (e.g. fished within the region and known contributor to coral reef reef) was identified to species and measure for total length to the nearest centimetre, also resulting in a relative estimate of abundance per transect (Table 6).



Table 6. Fishable and ecological relevant fish surveyed for biomass.

Species Name	Species Name	Species Name
<i>Abudefduf bengalensis</i>	<i>Epinephelus chlorostigma</i>	<i>Plectorhinchus polytaenia</i>
<i>Abudefduf notatus</i>	<i>Epinephelus corallicola</i>	<i>Plectorhinchus vittatus</i>
<i>Acanthurus leucocheilus</i>	<i>Epinephelus fuscoguttatus</i>	<i>Plectropomus areolatus</i>
<i>Acanthurus tristis</i>	<i>Epinephelus longispinis</i>	<i>Plectropomus laevis</i>
<i>Arothron stellatus</i>	<i>Epinephelus merra</i>	<i>Pomacanthus annularis</i>
<i>Aulostomus chinensis</i>	<i>Forcipiger flavissimus</i>	<i>Pomacanthus imperator</i>
<i>Bodianus mesothorax</i>	<i>Gracila albomarginata</i>	<i>Pomacanthus xanthometopon</i>
<i>Bodianus neilli</i>	<i>Halichoeres hortulanus</i>	<i>Pterocaesio chrysozona</i>
<i>Caesio caerulea</i>	<i>Halichoeres trimaculatus</i>	<i>Pterocaesio marri</i>
<i>Caesio cuning</i>	<i>Hemiglyphidodon plagiometopon</i>	<i>Pygoplites diacanthus</i>
<i>Caesio varilineata</i>	<i>Hemigymnus melapterus</i>	<i>Scarus caudofasciatus</i>
<i>Caesio xanthonota</i>	<i>Heniochus acuminatus</i>	<i>Scarus flavipectoralis</i>
<i>Calotomus carolinus</i>	<i>Heniochus singularis</i>	<i>Scarus frenatus</i>
<i>Cephalopholis argus</i>	<i>Hipposcarus harid</i>	<i>Scarus globiceps</i>
<i>Cephalopholis boenak</i>	<i>Labroides bicolor</i>	<i>Scarus niger</i>
<i>Cephalopholis formosa</i>	<i>Lethrinus erythropterus</i>	<i>Scarus quoyi</i>
<i>Cephalopholis leopardus</i>	<i>Lethrinus obsoletus</i>	<i>Scarus rivulatus</i>
<i>Cephalopholis microprion</i>	<i>Lutjanus argentimaculatus</i>	<i>Scarus rubroviolaceus</i>
<i>Cephalopholis miniata</i>	<i>Lutjanus biguttatus</i>	<i>Scarus schlegeli</i>
<i>Cephalopholis polleni</i>	<i>Lutjanus bohar</i>	<i>Scarus tricolor</i>
<i>Cephalopholis polypspila</i>	<i>Lutjanus decussatus</i>	<i>Scolopsis bilineata</i>
<i>Chaetodon adiergastos</i>	<i>Lutjanus ehrenbergii</i>	<i>Scolopsis trilineata</i>
<i>Chaetodon andamanensis</i>	<i>Lutjanus gibbus</i>	<i>Siganus canaliculatus</i>
<i>Chaetodon collare</i>	<i>Lutjanus lemniscatus</i>	<i>Siganus corallinus</i>
<i>Chaetodon decussatus</i>	<i>Lutjanus madras</i>	<i>Siganus guttatus</i>
<i>Chaetodon trifascialis</i>	<i>Lutjanus monostigma</i>	<i>Siganus javus</i>
<i>Cheilinus trilobatus</i>	<i>Lutjanus rivulatus</i>	<i>Siganus magnificus</i>
<i>Chlorurus bleekeri</i>	<i>Lutjanus rufolineatus</i>	<i>Siganus margaritiferus</i>
<i>Chlorurus capistratoides</i>	<i>Lutjanus sebae</i>	<i>Siganus punctatus</i>
<i>Chlorurus sordidus</i>	<i>Lutjanus timorensis</i>	<i>Siganus stellatus</i>
<i>Chromis viridis</i>	<i>Neoglyphidodon bonang</i>	<i>Sphyraena flavicauda</i>
<i>Cirrhilabrus cyanopleura</i>	<i>Pempheris adusta</i>	<i>Symphorichthys spilurus</i>

Species Name	Species Name	Species Name
<i>Coris aygula</i>	<i>Pempheris vanicolensis</i>	<i>Synodus dermatogenys</i>
<i>Cromoleptes altivelis</i>	<i>Plectorhinchus chaetodonoides</i>	<i>Thalassoma amblycephalus</i>
<i>Ctenochaetus truncatus</i>	<i>Plectorhinchus chrysotaenia</i>	<i>Thalassoma hardwicke</i>
<i>Elagatis bipinnulata</i>	<i>Plectorhinchus lessonii</i>	<i>Upeneus vittatus</i>
<i>Epinephelus bleekeri</i>	<i>Plectorhinchus lineatus</i>	

## RESULTS

### Taxonomy

The total reef fish fauna of the Islands of the Myeik Archipelago of Myanmar as reported herein consists of 495 species belonging to 62 families. This total is based on 409 species recorded during the 2014 survey and 360 species recorded during the 2016 survey (Appendix D) of which 69 species had not previously been recorded. Both the 2014 and 2016 surveys were limited in time and extent, and offshore oceanic reefs were under-represented. The inclusion of these additional habitat types is likely to increase the number of species recorded for the Myeik Archipelago. Plots of cumulative number of species against number of sites for the 2014 survey (26 sites, 409 total species) and 2016 survey (24 sites, 360 total species) show neither set of samples alone reaching an asymptote. However, combining the results of the 2014 and 2016 surveys (50 sites, 495 species) provide a more comprehensive picture of the fish species diversity of the Myeik Archipelago, with the total number of species (495) approaching a predicted 618 species by the Coral Fish Diversity Index (CFDI).

The majority of fishes of the Myeik Archipelago were typical coral and rocky reef-associated species. The most abundant families in order of ranking by numbers of species are gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), cardinalfishes (Apogonidae), groupers (Serranidae), butterflyfishes (Chaetodontidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), parrotfishes (Scaridae), and Scorpionfishes (Scorpaenidae). These 10 families collectively account for 313 species or about 63 percent of the total reef fauna.

The relative species richness of fish families in the Myeik Archipelago is similar to that of the East Andaman Sea, Thailand, although the ranking of individual families is variable. For example, the family Scorpaenidae ranked in the first 10 most speciose families in the Myeik Archipelago, but was much more poorly represented in the East Andaman Sea, Thailand, where it ranked 24th. Some 25 species from 16 families recorded from the Myeik Archipelago during this survey are new records for the East Andaman Sea region.

The most speciose sites for fishes for the combined 2014 and 2016 data are shown in Table 6. The maximum number of fish species recorded at any site in the Myeik Archipelago was 123 (Pyin Sa Bu Is- Khu Gyan Aw, NW Bay), and a maximum of 100 or more species was recorded at seven other sites (Table 7).

The maximum number of species (123 species) recorded at any site in the Myeik Archipelago (2014 and 2016 surveys) is relatively low compared to areas in the Coral Triangle region where more than 200 species is generally the benchmark for high fish diversity, and where up to 284 species from a single site have been recorded (Wambong Bay, Kofiau Island in the Raja Ampat Islands, off the western end of new Guinea- McKenna et al. (2002)).

Table 7. Myeik Archipelago sites (2014 and 2016 surveys) with greatest fish diversity (=>100 species)

Site No.	Year	Location	Total species
15	2016	Pyin Sa Bu Island (Khu Gyan Aw, NW Bay)	123
6	2016	Jar Lann Kyunn Nth Island.NE Bay	119
128	2014	Kho Yinn Khwa Island	117
139	2014	East Sular (E side, N of bay)	112
137	2014	Saw Mon Hia Island	110
129	2014	Narr Kho Island	102
21	2016	A Pha (East side)	102
125	2014	Tharn Kyunn Nge	100

The richest sites for fishes in the Myeik Archipelago tended to be those reefs furthest offshore and with greatest range of habitats and structural diversity. For example, the highest diversity (123 species) was recorded at Site 15 (Pyin Sa Bu Island), a sandy bottom bay about 10m deep, with diverse coral habitats including *Porites* bommies, scattered fungiid corals, *Goniopora*, *Mussidae*, *Diploastrea*, *Astreapora* (in very large bommie/plate form), faviid corals, *Acropora*, *Pocillopora*, and sparse patches of padina algae and corallimorph matting in shallow water.

In contrast, the poorest site for fish diversity, Site 149 (Khin Pyi Son Island- North Bay) was within a small bay with a gentle sloping reef to about 7m, dominated by staghorn *Acropora* cover. Lower diversity also appears to be related to anthropogenic impact: the second lowest diversity (39 species) was recorded at Site 148 (2014 survey- Khin Pyi Son Island), a reef slope close to a village with high siltation, and subject to sewage disposal and high volume boat traffic.

The Ranong Fish Market survey recorded 127 species, including an additional 108 species not previously reported, bringing the total known species for the Ranong Fish Market to 169 species (Appendix E). Of these, 41 were coral reef fish species recorded also during the 2014/2016 underwater surveys.

# Indicator Fish and Biomass

The mean number of fish for all 9 categories across all surveyed sites were found to be low. Snapper numbers were highest, with an average of 12.02 ( $\pm 2.1$ ) fish across the 202 transects surveyed (Figure 15). This was followed by butterflyfish (4.86 ( $\pm 0.4$ )), parrotfish (7.85 ( $\pm 0.7$ )) and grouper (2.24 ( $\pm 0.3$ )). The remaining fish were found to have less than one fish per transect for all surveyed sites. For the groupers, the 30-40cm size class dominated with 78.7% of the total groupers recorded, 4.5 times the next highest category 40-50cm with only 17.2% of the total. Both the 50-60cm and >60cm categories recorded 3.5% and 0.6% respectively. No sharks, rays or sea turtles were recorded on any transects

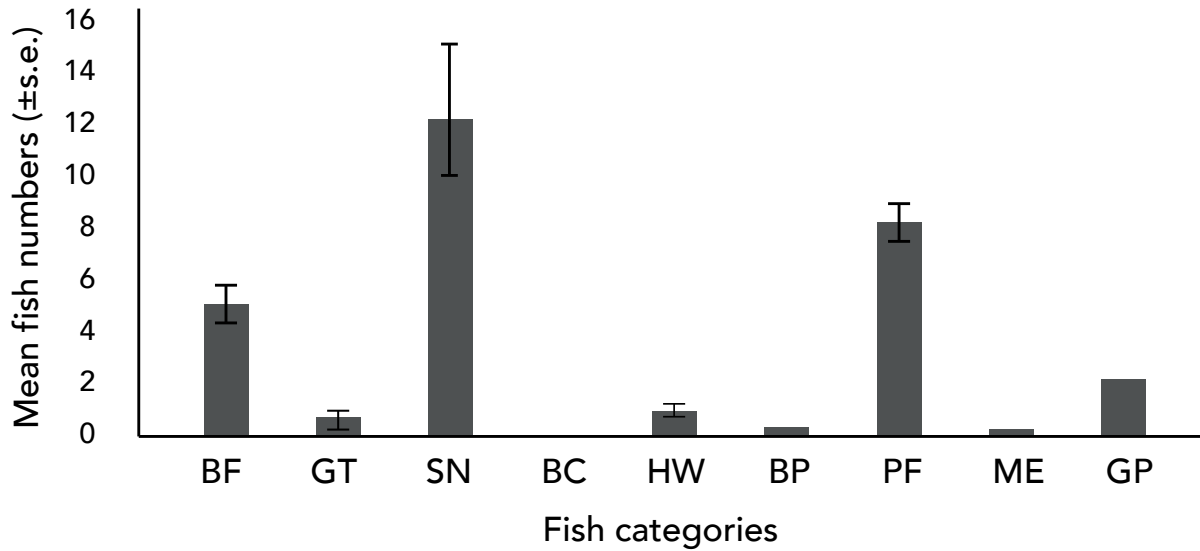


Figure 15 Mean fish numbers for 9 fish categories ( $\pm$ S.E.) per transect at 202 sites across Myeik Archipelago. (BF- Butterflyfish, GT- Haemulidae, Sweetlip, SN- Snapper, BC- Barramundi Cod, HW- Humphead Wrasse, BP- Bumphead Parrotfish, ME- Moray Eel and GP- Grouper).

The mean number of fish per transect did, however, vary at the reef type level, but again butterflyfish, snapper, parrotfish and groupers dominated at all reef types with the other categories recording very low numbers (Figure 16). When comparing the four main fish groups noted above Fringe reefs showed the highest abundance for most of these categories followed by Rock, Moscos and Inner reefs (Table 8). Figure 17 a-d provide spatial results of this data. (See Appendix C for all fish surveyed, site locations and mean abundances for Butterflyfish, Parrotfish, Snapper and Grouper).

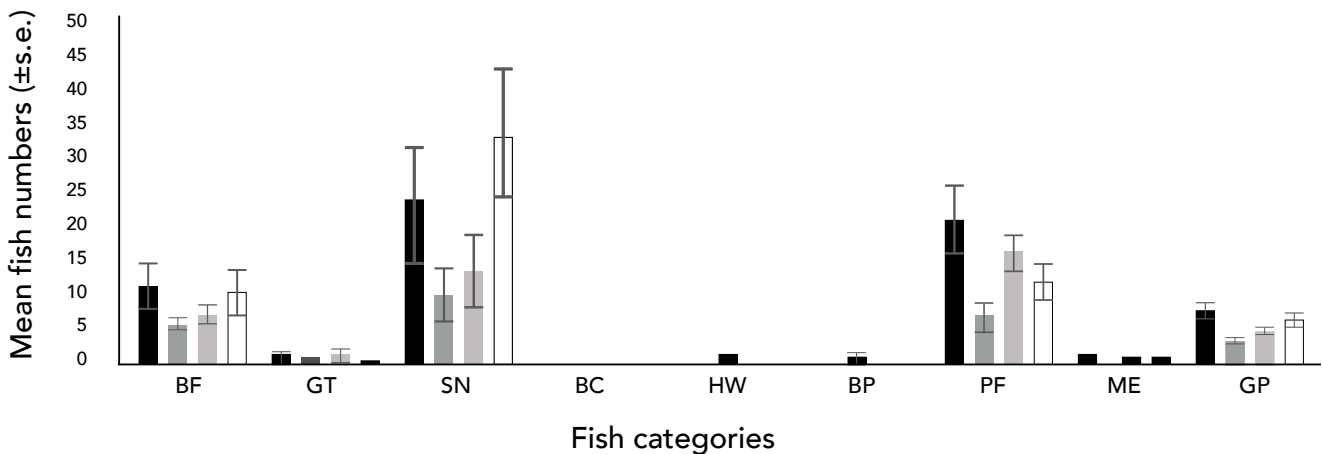
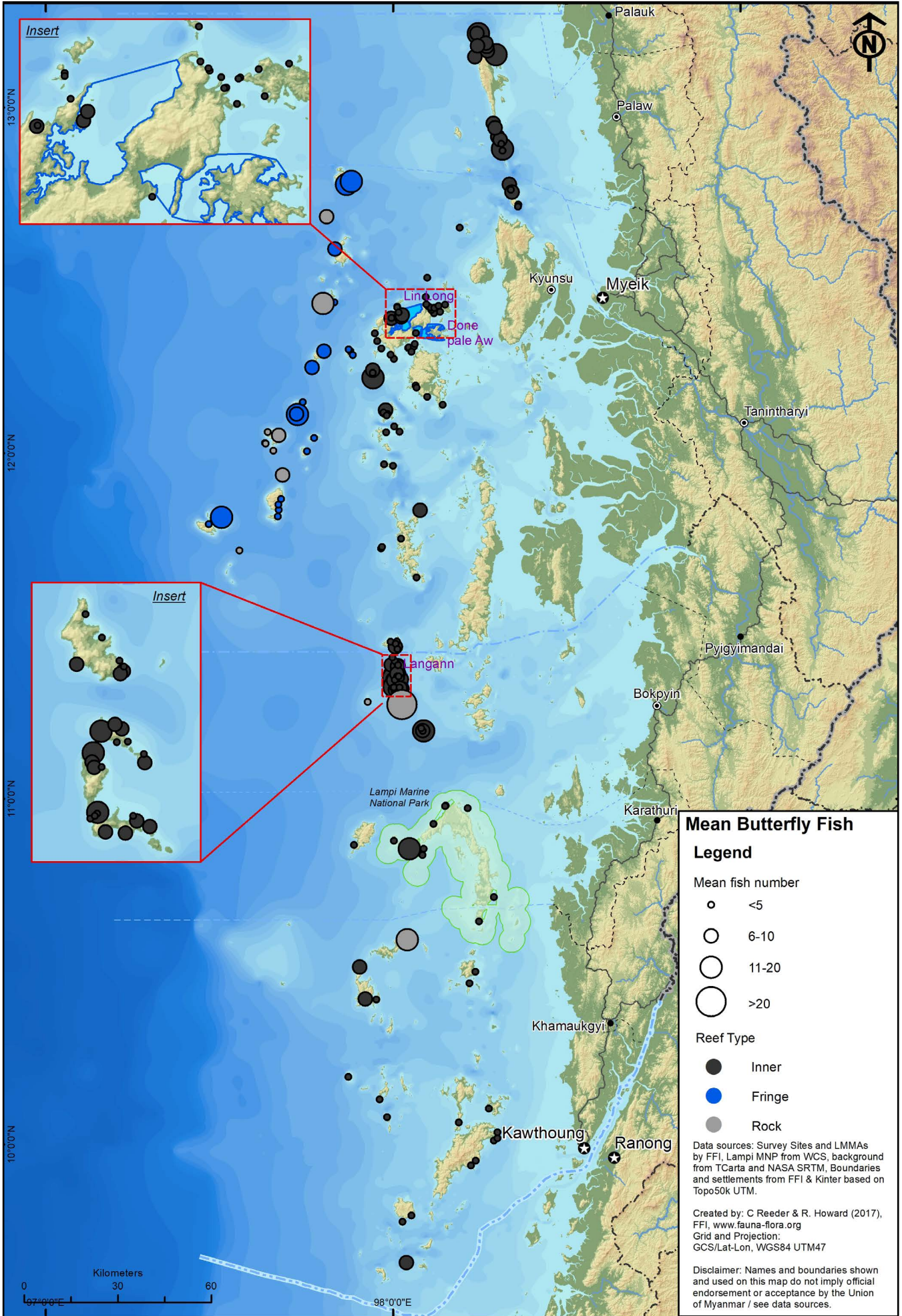
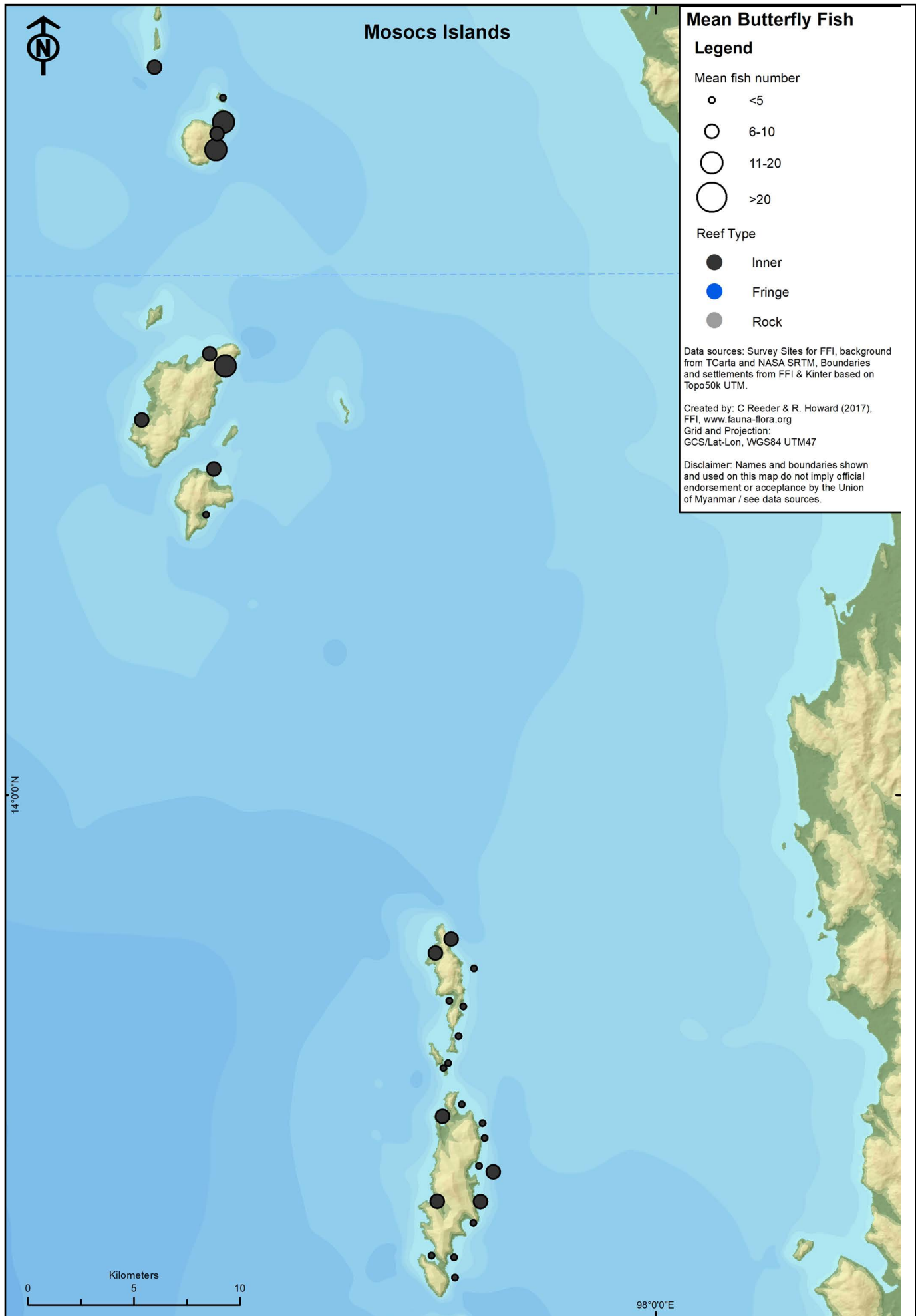


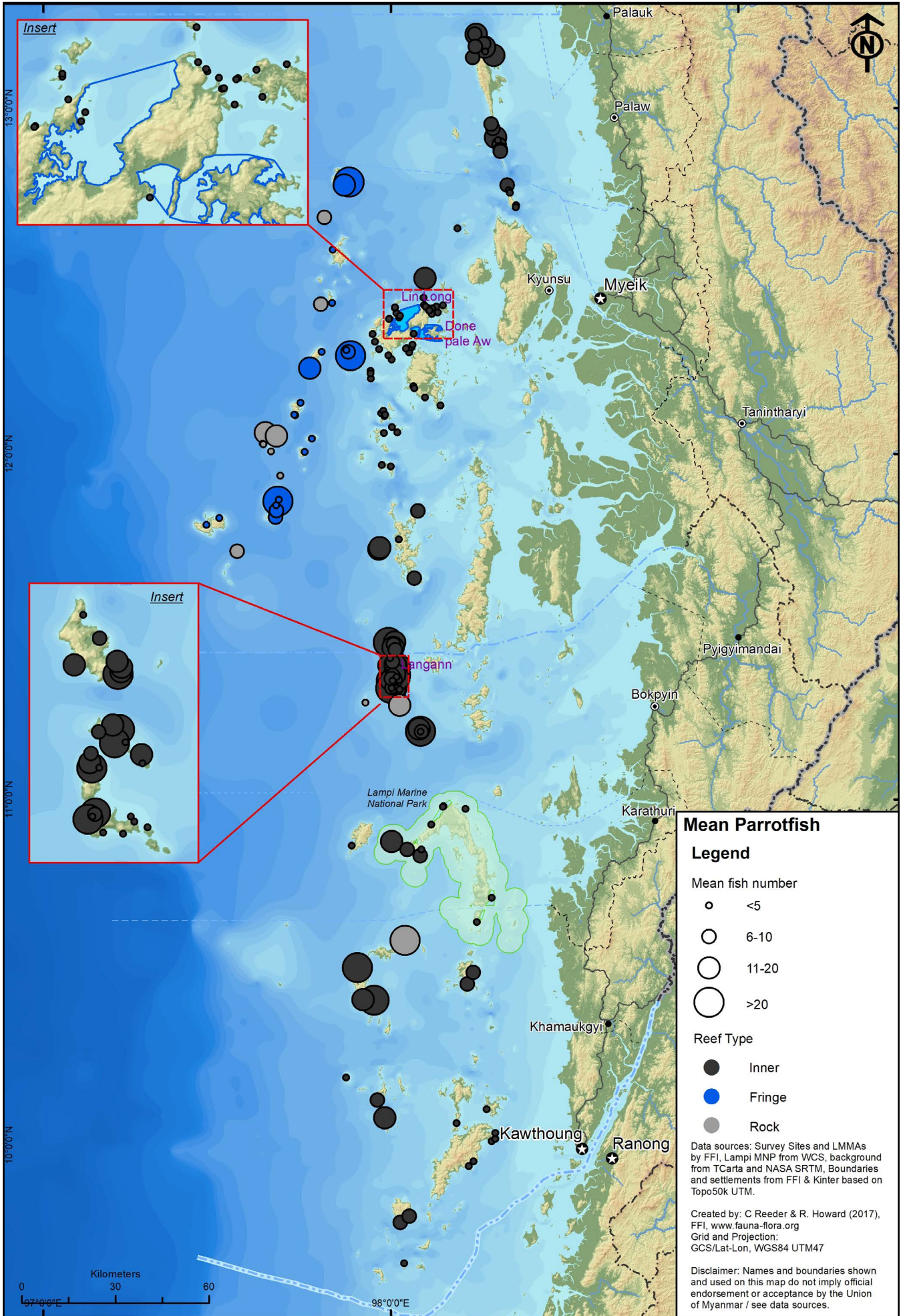
Figure 16 Mean fish numbers for 9 fish categories ( $\pm$ S.E.) per transect by reef type: Fringe (n=21), Inner (n=140), Rock (n=12), and Moscos (n=29). (BF- Butterflyfish, GT- Haemulidae, Sweetlip, SN- Snapper, BC- Barramundi Cod, HW- Humphead Wrasse, BP- Bumphead Parrotfish, ME- Moray Eel and GP- Grouper).

Table 8 mean fish numbers for the four dominant fish categories ( $\pm$ S.E.) per transect by reef type: Fringe (n=21), Inner (n=140), Rock (n=12), and Moscos (n=29). \* Denotes highest value for each fish category and ‡ the lowest.

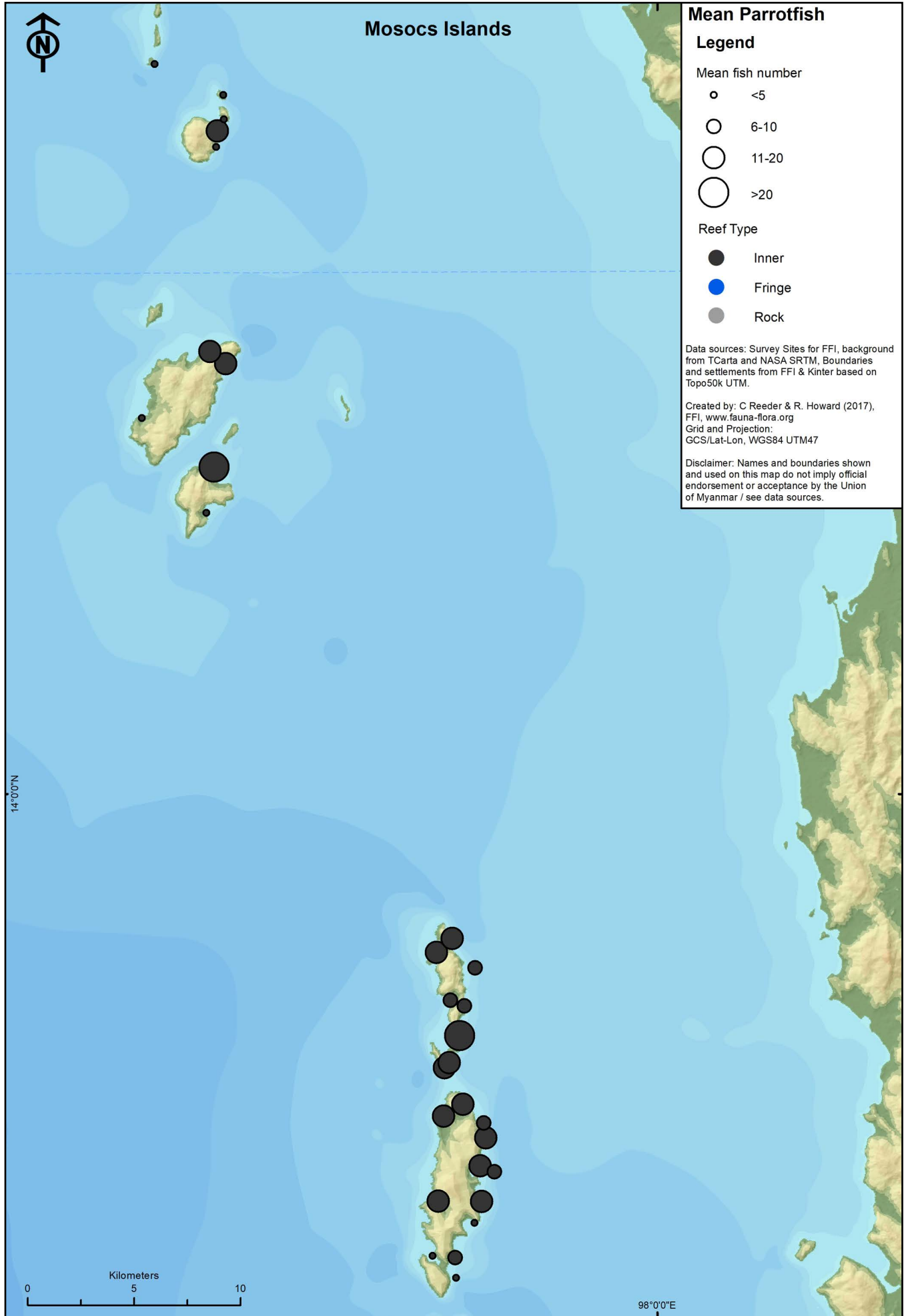
	Butterfly fish	Snapper	Parrotfish	Grouper
Fringe	9.7( $\pm$ 2.5)*	22.6( $\pm$ 9.5)	14.8( $\pm$ 3.7)*	6.6( $\pm$ 1.1)*
Inner	3.8( $\pm$ 0.3) ‡	8.7( $\pm$ 2.3)‡	6.1( $\pm$ 0.7)‡	1.4( $\pm$ 0.3)‡
Rock	8.1( $\pm$ 2.4)	33.4( $\pm$ 3.2)*	9.1( $\pm$ 1.9)	4.7( $\pm$ 1.4)
Moscos	5.6( $\pm$ 0.6)	13.4( $\pm$ 3.2)	11.5( $\pm$ 1.7)	2.2( $\pm$ 0.3)

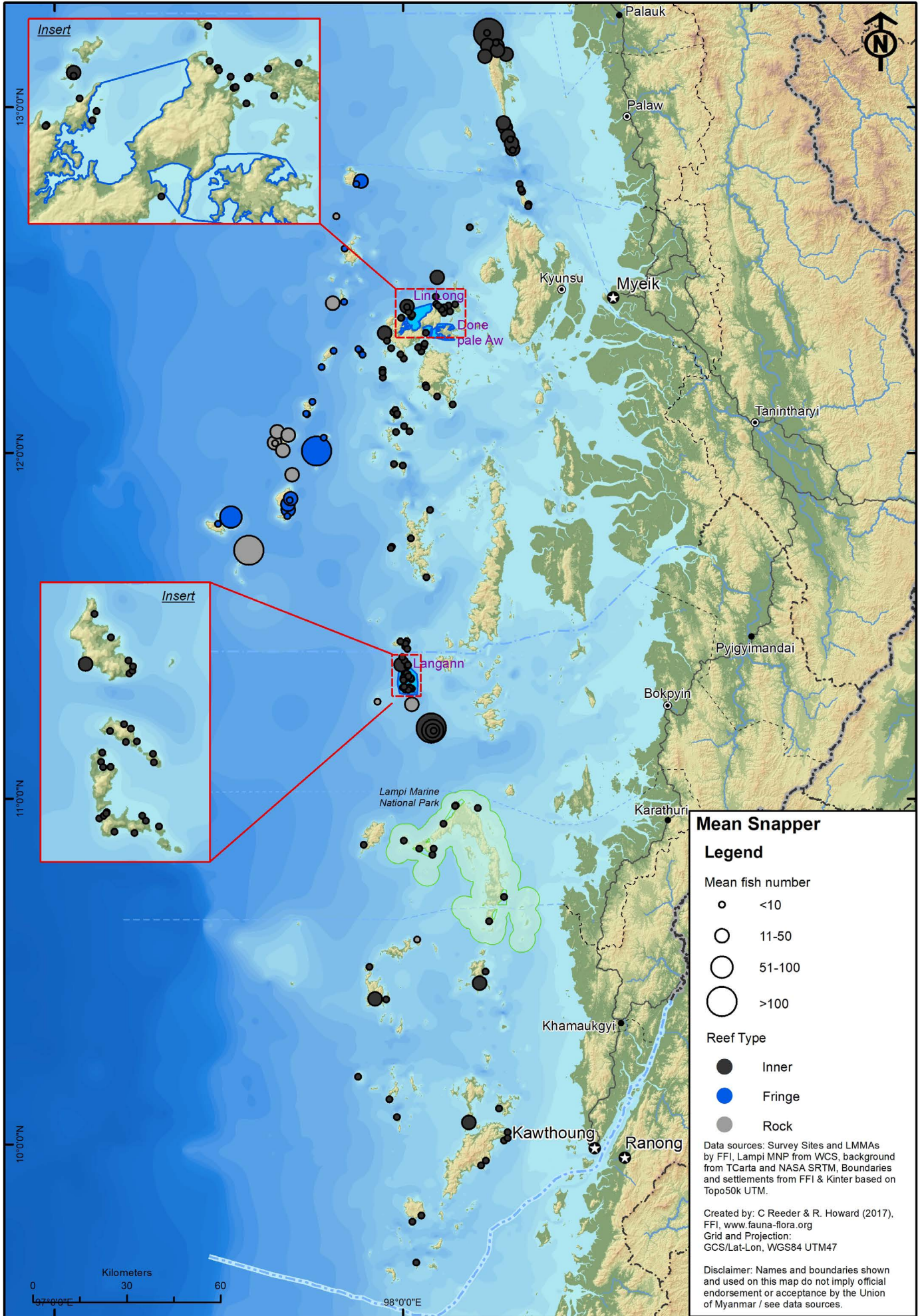


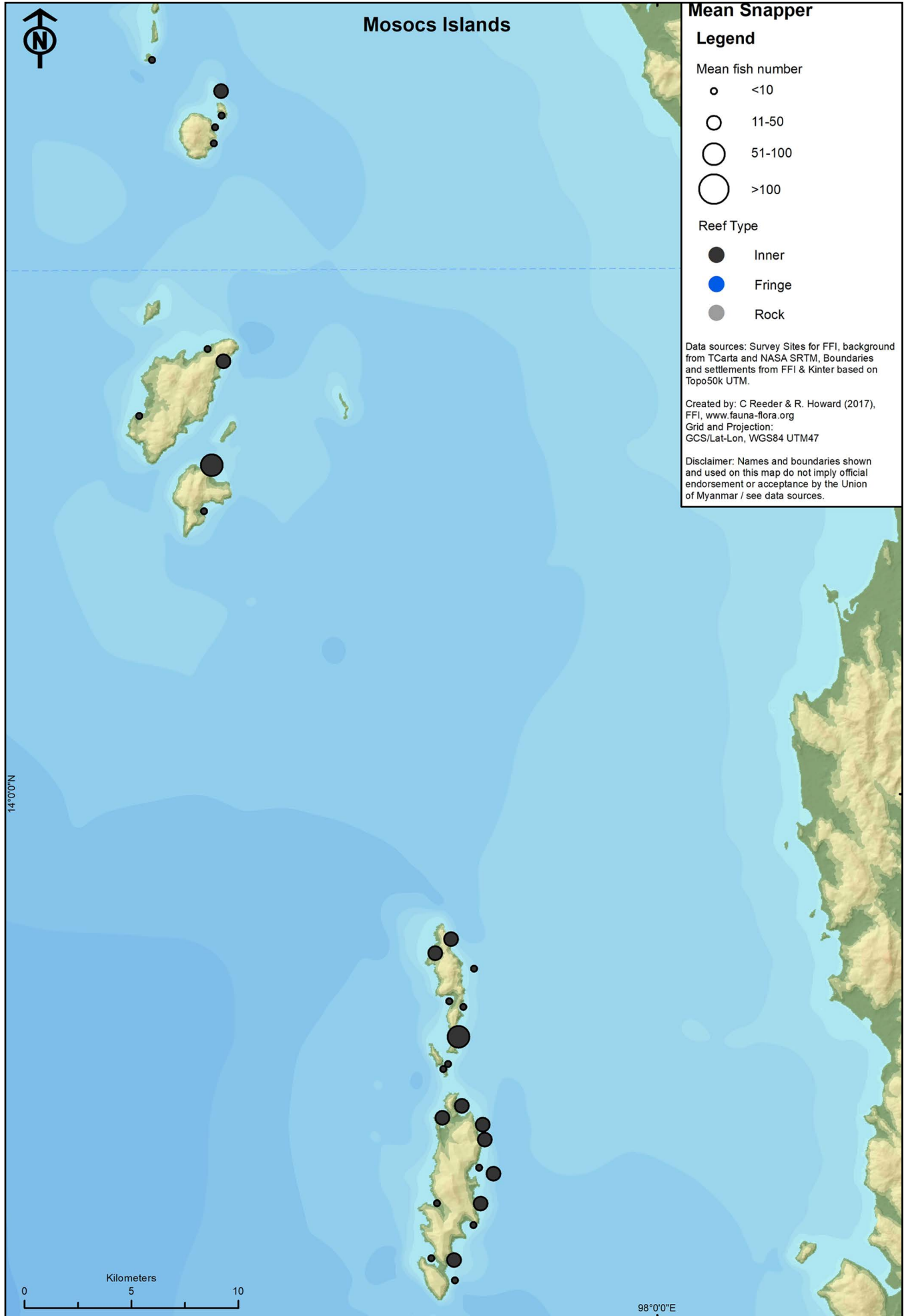


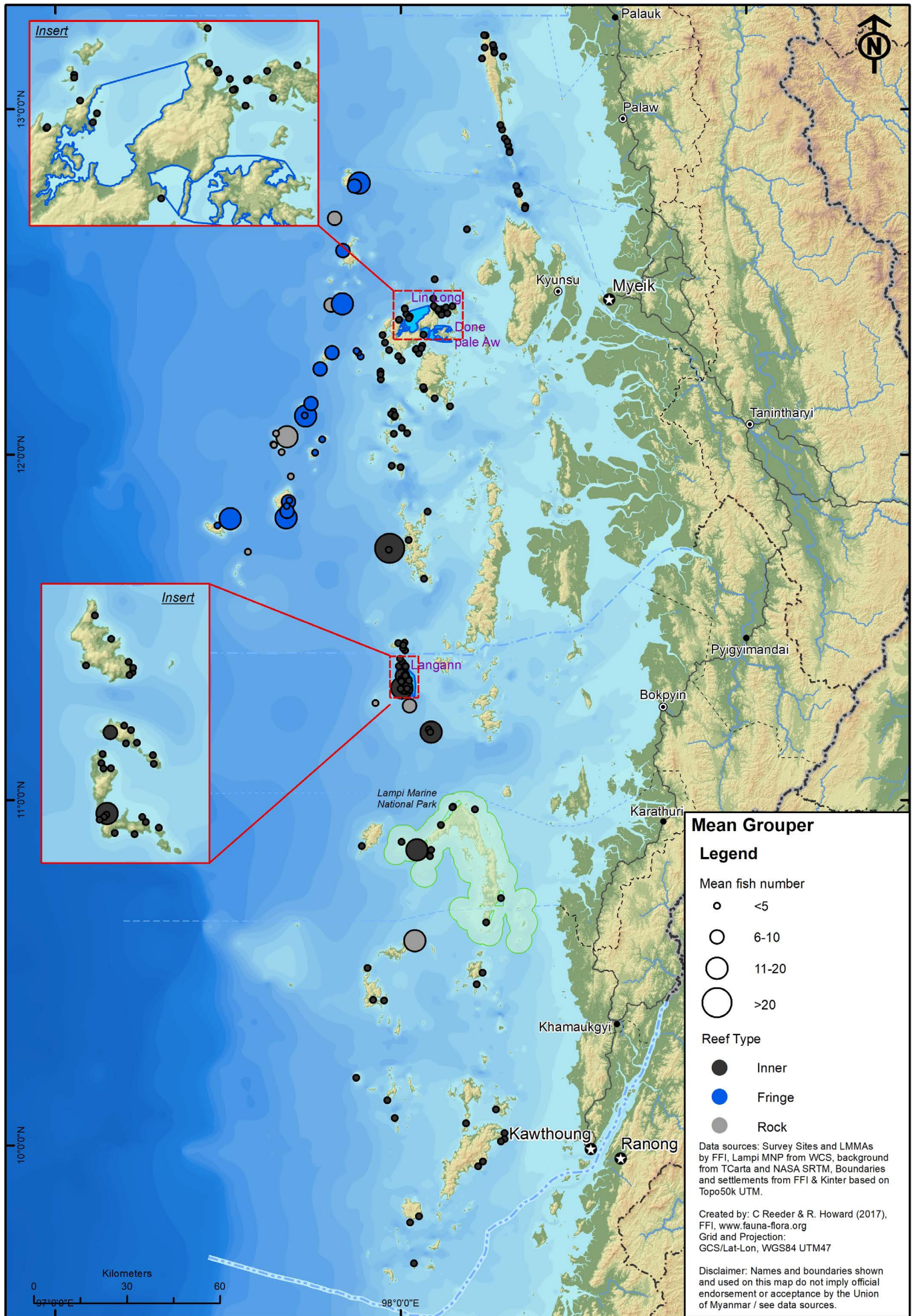












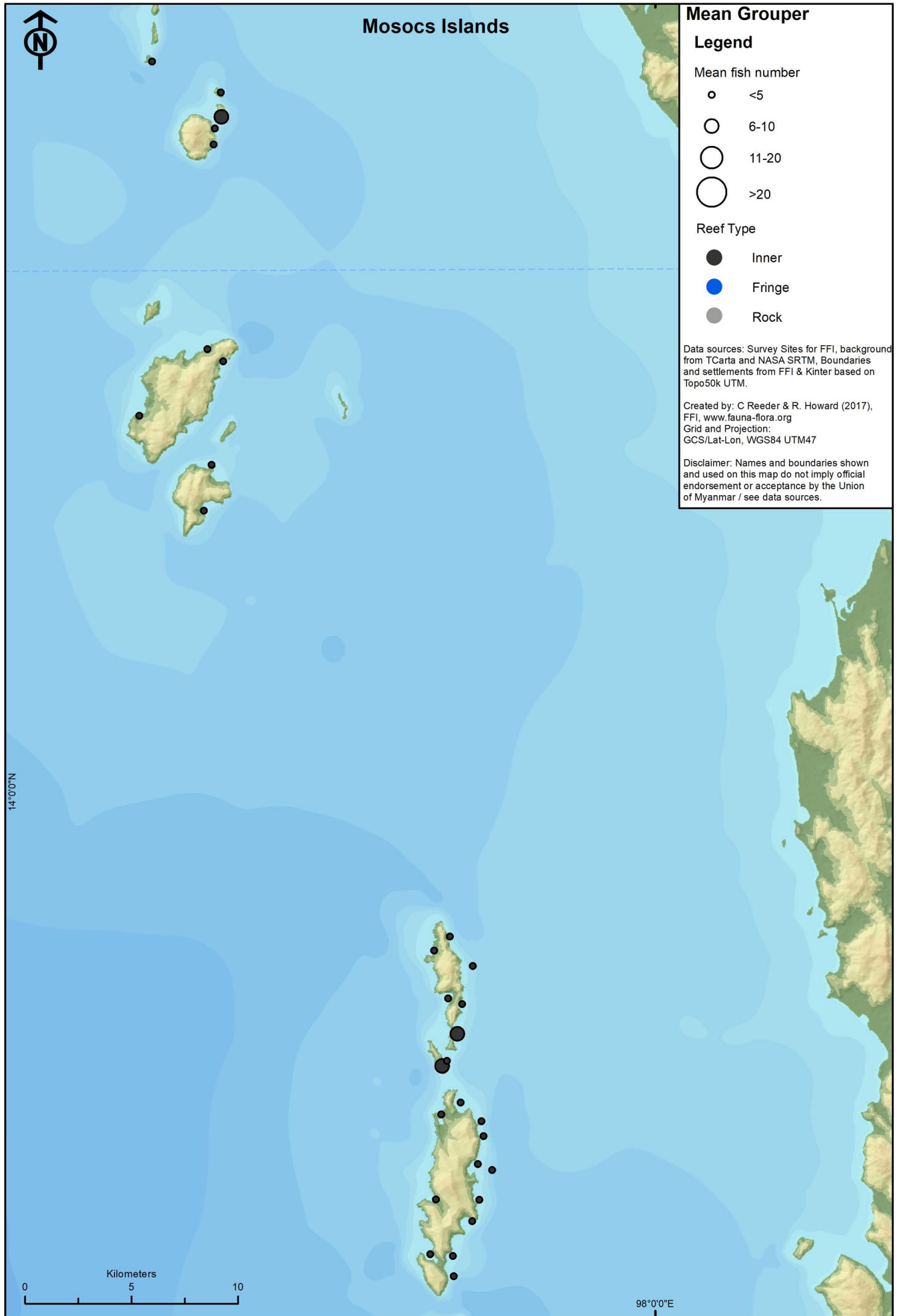


Figure 17. Mean fish numbers per site for the four dominant fish categories: a. Butterflyfish; b. Parrotfish; c. Snapper; and d. Grouper, within Myeik Archipelago. Note the different numbering classes used on each map

For detailed biomass studies, across all transects, 20,234 individual fish were observed, measured to the nearest centimetre (total length) and identified to species during the cruise. For sites 15 & 27, two belt transects depths (five 20m x 5m) at shallow and deeper water depths were carried and averaged for this preliminary analysis, additionally site 21 represents an average of site 21 and 23, sites 15 and 27 were carried out twice and averaged.

The species with the highest relative frequency of observance across all transects is a school forming species, *Caesio cuning* (20%). Followed by several other school forming targets: *Scarus flavipectoralis*, *Lutjanus rufolineatus*, *Lutjanus biguttatus*, *Pempheris vanicolensis*, *Pterocaesio chrysozona*, *Scarus schlegeli*, *Caesio varilineata*, *Scarus globiceps*, *Pterocaesio marri*, representing 80% of the observed species. When assessing mean biomass of species, the major contributor to fishable biomass along the transect are *Lutjanus biguttatus* (77%) and *Cephalopholis polyspila* (8%) of the fishable biomass observed throughout the archipelago, respectively.

Of the 21 families recorded, twelve families represent 90% of the observed species richness; Serranidae (18), Scaridae (15), Lutjanidae (14), Labridae (10), Pomacentridae (10), Chaetodontidae (8), Siganidae (8), Caesionidae (6), Haemulidae (6), Acanthuridae (3), Lethrinidae (2), Nemipteridae (2), respectively. Lutjanidae contributes the most for the archipelago estimate of a mean biomass, followed by Caesionidae, Serranidae, Sphyraenidae, Carangidae, among the others. The observed mean total fishable biomass for the Myeik Archipelago is  $56.96 \pm 20.57$  (g/m<sup>2</sup>). The eighteen fish sites spanned from the southern waters of the Andaman Sea into the north of Pyin Sa Bu. Three sites (four, with averages of the sites that were duplicated) were surveyed in the marine national park, Lampi (24, 25, 27a & b) and Locally Managed Marine Area (LMMA) sites (Langann Island, Done Pale and Lin Lon/ Pa-Raw-Wah; 8, 9, 10, 11 and 12, Figure 1). A few sites (3, 21 and 27) surveyed, surpassed the archipelago mean of  $8.22 \pm 2.45$  individuals / m<sup>2</sup> – several fell below the mean density estimate and the lower limit of the standard error of the mean (sites 2, 4, 11, 12, 16, 17, 18 and 20) – but within the estimated 95% confidence intervals (3.13 and 13.13) of the mean (Table 2). Similar patterns emerged when assessing biomass at the site level – the same sites (3, 21, 24, 27 and 28) were all above the mean archipelago biomass estimate, with site 21 having the highest species richness.

## DISCUSSION

### Taxonomy

Allen (1998) devised a convenient method for assessing and comparing overall reef fish diversity. The technique essentially involves an inventory of six key families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. The number of species in these families is totalled to obtain the Coral Fish Diversity Index (CFDI) for a single dive site, relatively restricted geographic areas or countries and large regions (e.g. Solomon Islands). Based on the 2014 and 2016 surveys, the CFDI obtained for the Myeik Archipelago was 173, and the appropriate regression formula predicted an approximate total of 618 species, indicating that at least 123 more species could be expected by more extensive surveys. In comparison with other regions of the Indo-Pacific, the fish fauna of the Myeik Archipelago ranks at the lower end in terms of species diversity and is less than the East Andaman Sea, Thailand (estimated total 843 species).

Sharks and large rays were notably absent during both the 2014 and 2016 surveys: no shark species were observed at any of the sites visited, and only a few small rays were seen. Larger individuals of predatory species such as groupers (*Epinephelus*, *Plectropomus*), snappers (*Lutjanus*) and emperors (*Lethrinus*) also were present only in relatively small numbers. The general absence of larger species may be evidence of consistent heavy fishing. Large numbers of fishing boats (trawlers, gill-netters, purse-seine, long-line, and squid jig) were observed near all sites and there was evidence of fouled nets on many of the reefs surveyed. In addition, there was evidence of widespread dynamite fishing, with recent fresh fish kills on the surface at several sites, especially fusiliers (Caesionidae), which occurred often in large schools close to reefs. Judging from the large numbers of fishing boats that were present throughout the survey, fishing pressure is enormous.

From the Ranong Fish Market surveys although only 8.2% of the total species observed were recorded in the underwater surveys, these coral reef fishes constituted about 24% of the landed species, indicating industrial fishing

may be impacting significantly on reef fish species, particularly coral reef representatives of the families Serranidae, Lutjanidae, Caesionidae, Haemulidae, Lethrinidae, Nemipteridae, Mullidae, Kyphosidae and Siganidae, which together comprised about 18% of landed fish species. There were few sharks and rays on sale in the government fish market in Ranong. Notwithstanding, there appears to be a thriving private market for elasmobranchs in Thailand and large numbers of sharks and rays were observed in several 'closed' and securely guarded landing warehouses close to the main Ranong Market.

## Indicator Fish and Biomass

Results for the nine fish categories within the archipelago indicate an ecosystem heavily impacted by overfishing and the use of destructive fishing methods. For the butterflyfish, closely associated with coral reefs, only a mean of 4.86 individuals per site were recorded. This result is comparable to data from Malaysia (Yewdall, 2012) but below the 30 plus butterflyfish observed in Indonesia for 2006, which included data from 1997-2006 across 19 provinces (Habibi et al., 2007). For all other fish however the results of this survey appear similar to the low numbers recorded in both Indonesia and Malaysia where overfishing is blamed for reduced fish populations. For example, schooling snapper and sweetlips (e.g. *Lutjanus bengalensis* and *Plectorhincus lineatus*), were rarely seen in large groups, with only 109 of the 969 replicates recording numbers over 20 individuals for snapper and only 14 of the 969 replicates recording numbers over four individuals for sweetlips. Likewise for parrotfish only 109 of the 969 replicates showed groups over 20. Parrotfish play an important functional role on coral reefs keeping algae levels low allowing coral recruits to settle and flourish (Feitosa and Ferreira 2014). Taking these fish out of the system could lead to a phase shift within the archipelago where reefs could become algae dominated (Hughes et al., 1999; Hughes et al., 2007). However, *Diadema* urchins could be potentially filling this roles, for now given the high numbers of these species found on the reefs throughout the archipelago (see Section 4).

For groupers, although not known for large aggregations on reefs, were found to be clearly dominated, albeit in low numbers, by those in the 30-40cm size class which maybe in part due to the finfish fishery within the archipelago where juvenile groupers are wild-caught and reared in cages (Holmes et al., 2013). This a concern for those species of grouper which only become sexually mature above this size range and take several years to reach reproductive age e.g. *Epinephelus coioides* which reaches maturity at 43.5 cm (Grandcourt et al., 2005) and a species targeted by Myanmar fishers (Holmes et al., 2013). This situation is similar to that recorded in the Maldives where 85% of groupers recorded were under 40cm and a need for reviewing landing sizes and protection of spawning sites has been advocated (Solandt, 2014). The remaining surveyed fish, barramundi cod (VU), humphead wrasse (EN), bumphead parrot fish (VU) and moray eels, like in Malaysia and Indonesia were recorded in very low numbers. Along with moray eels, these species are a draw for scuba divers and loss of these species is a conservation concern and could be detrimental to any tourism ventures. Likewise, no sharks, marine turtles or manta rays were recorded at any of the survey sites, the loss of such marine species would be detrimental to the ecosystem. For example, sharks well known for their role as apex predators, have the potential to influence marine communities at both large temporal and spatial scales (Ferretti et al., 2010).

Within the reef type's butterflyfish, snapper, parrotfish and grouper, were generally recorded in the highest mean numbers on the Fringe and Rock reefs, this is surprising giving that these reefs had the lowest coral cover. The distance of these islands from the mainland may be a factor with potentially less fishing activity, although given the amount of dynamite damage encountered here this trend may not last long. Outside of these reefs the highest recording for all of these four fish groups was Moscos. Like Fringe and Rock reefs its remoteness from the main fishing cities, Myeik and Kawthaung may mean less fishing pressure compared to the Inner reefs, and the low observation of dynamite fishing compared to Inner reefs may also play a role with fish habitat remaining intact (see Section 7 Threats). The reefs with the lowest fish records were the Inner reefs which maybe a result of its closeness to Myeik and the high level of anchor damage and discarded fishing netts here compared to the other sites may reflect a greater fishing effort around these islands (see Section 7 Threats). Interestingly, however, these reefs have some of the highest coral cover which means that with a well-managed fishery the fish populations in this area could recover given the habitat is still relatively intact.

For the detailed biomass surveys, as noted many sites have relatively low estimates of fishable biomass (< 3 g/m<sup>2</sup> or 300 kg/ha; with the lower CI of mean at 13.3. g/m<sup>2</sup>). Global estimates of coral reef BMMSY (biomass of multi-species maximum sustainable yield) estimates that between 30-60 g/m<sup>2</sup> is a BMMSY for nearshore multi-species coral reef fisheries, below 30 g/m<sup>2</sup> present unhealthy and unsustainable fishing states (McClanahan et al., 2011; Karr et al., 2015). Only 7 of the 18 sites fall within the BMMSY management window of 30-60 g/m<sup>2</sup> (Site 3, 12, 17, 21, 24, 27 and 28). Of note, all of the sites associated with the recently established (at time of survey) LMMAs (sites 10, 11 and 12) have low fishable biomass, individual/ m<sup>2</sup> and species richness – giving room for reform. The data collected in these sites can serve as a baseline for management success and as estimates of local no-take areas for fished to unfished (restricted fishing) assessments.

## Species of conservation concern

The conservation status of all fish species recorded from the Myeik Archipelago was checked against the IUCN Red List of Threatened Species (IUCN 2017). Red List assessments for fishes, however, are far from complete, and only 174 species (35 % of total species recorded) that occur in the Myeik Archipelago are currently included in the IUCN Red List of Threatened Species (Appendix D). Of these, only three species (Common Seahorse, *Hippocampus kuda*, Humpback Grouper, *Cromileptes altivelus*, and Squaretail Leopard Grouper, *Plectropomus areolatus*), are considered threatened (Vulnerable – VU). An additional species of Grouper (*Epinephelus coioides*) and a Butterflyfish (*Chaetodon trifascialis*) are listed as Near Threatened (NT), with the remainder listed as Least Concern (LC) or Data Deficient (DD). Most of the species recorded from the Myeik Archipelago (65%), however, have not yet been evaluated against the IUCN Criteria and remain Not Evaluated (NE).

## Recommendations for conservation

- Offshore oceanic reefs remain unsampled and would be expected to increase the total number of species of the region.
- The conservation status of fishes in the Myeik Archipelago is known for only about 35% of species, and it is strongly recommended that FFI Myanmar, in partnership with the IUCN Global Marine Species Assessment (GMSA) Project, conduct a Regional Red List workshop to train FFI staff in IUCN Red List assessment methodology and to assess the extinction threat to all species in the region.
- A brief survey of the main government fish landing market in Ranong, Thailand, reported here indicates there is little overlap in species observed on reefs in the Myeik archipelago and those landed by commercial fishing boats, at least in Ranong. A similar survey, however, has not been undertaken in the port of Myeik where much of the commercial catch from the region also is believed to be sold. It is recommended that a survey of fish landings in Myeik be undertaken during both wet and dry seasons.
- There is a need for a network of effective Marine Protected Areas to be established in the Myeik Archipelago for the protection and recovery of larger fishes such as the Napoleon Wrasse, groupers, and snappers, which presently are rare or absent from most sites. Potential MPAs might include the five richest sites for fish diversity that were encountered during the 2014 and 2016 surveys: Pyin Sa Bu Island, Jar Lann Kyunn Nth Island, Kho Yinn Khwa Island, East Sular (E side, N of bay), Saw Mon Hia Island, Narr Kho Island, A Pha (East side), Tharn Kyunn Nge Island, as well as Pyin Sa Bu Is. (W, S bay) and Leik Khon Is where high numbers of juvenile Snappers (Lutjanidae) were observed in 2014 and which appeared to be important nursery areas for these fishes.
- There is also a need to stop all forms of Illegal fishing, particularly the use of dynamite and targeting of sharks and rays, which appear to have been severely impacted in the Myeik Archipelago. It is recommended that FFI Myanmar undertake studies to assess the extent of Illegal, Unreported and Unregulated Fishing (IUU) in the Myeik Archipelago, with a view to advising the Government of Myanmar ways to reduce the impacts of illegal fishing. Set limit on sizes and bags limits for commercial species such as snappers and groupers to ensure juveniles are allowed to mature.
- The marine fishes of Myanmar have been little studied and are poorly represented in museum collections. It is recommended that a reference collection be established within the Department of Fisheries that will enable future study of the fishes and assist with the identification of species and resolution of the taxonomy and nomenclature of the Myanmar fish fauna.





# 4 MARINE INVERTEBRATE FAUNA

## INTRODUCTION

Aside from corals, other marine invertebrate taxa have been shown to provide crucial services to the functioning of coral reef ecosystems (Przeslawski et al., 2008; Glynn and Enochs, 2011). This includes improving the health of reef fish, including stress via cleaning services removing ectoparasites (Bshary et al., 2007); as major contributors to coral reef trophic structure (Kramer et al., 2014) and influencing the overall community structure of reefs such as improving coral recruitment and growth (Idjadi et al. 2010). Furthermore reef invertebrates, such as sea cucumbers and spiny lobsters provide important livelihoods and food sources to millions of people worldwide (Phillips and Kittaka, 2008; Anthony et al., 2011).

In addition, from a coral reef management perspective Hopkins (2009) notes that some marine invertebrates can be used as indicators of a reefs health with their abundance being used to monitor changes in the ecology of a coral reef environment. For example, sea urchins can be used as an indicator of overfishing of fish, as a spike in urchin numbers is often attributed to a loss of their predators from high fishing pressure. In addition, crown of thorns starfish (*Acanthaster planci*), which can have devastating impacts on coral reefs have also been used as an indicator of poorly managed land-use practices, namely agriculture with the larval stages of this starfish thriving on the increase nutrients for terrestrial runoff.

Understanding the diversity and abundance of marine invertebrates within a coral reef ecosystem is therefore of high importance given the services they provide and their use as indicators of a systems health. In Myanmar a number of taxonomic studies have been undertaken on marine invertebrates as reported by Holmes et al. (2013) although many of these have focused on commercially important species such as lobsters, *Scylla* crabs, shrimps and sea cucumbers and those in nearshore environments such as mudflat areas. Less work however appears to have been done on the diversity of invertebrates on coral reefs, excluding corals themselves. Likewise little baseline data exists on the abundance of these species or groups (except for some fisheries data) and the overall health of the coral reefs in Myanmar from an invertebrate perspective.

Surveys were therefore undertaken to add to the current knowledge of the taxonomic diversity of coral reefs in the Myeik archipelago. In addition, surveys on the abundance indicator invertebrate groups were also undertaken to gain an understanding of reef health and to develop a baseline for long-term monitoring of the status of the reefs. This chapter provides the results of these surveys while Chapter 5 details a specific study on the taxonomy of sponges within the archipelago.

## METHODS

### Taxonomy

In 2014 explorations of the Myeik Archipelago conducted by the Smithsonian Institution and Fauna & Flora International from the 10-22 of March. The cruise pursued a rigorous itinerary, covering almost 500 miles and visiting 35 different dive sites in 11 days. The vast majority of these sites had never been surveyed by a scientific team. The

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McKeon, S. (2014). Reef Invertebrates of Myanmar. Smithsonian Marine Station at Ft. Pierce, Ft. Pierce, FL.

McKeon, S. and Jones, S. (2014). Notes from the FFI/SI Myeik Archipelago Expedition. Smithsonian Institute and Fauna & Flora International.

Smithsonian team collected 230 invertebrate specimens representing seven phyla, which were processed and are currently housed by the Smithsonian's National Museum of Natural History.

## Indicator Invertebrates

To undertake indicator invertebrate surveys Reef Check (Hodgson et al. 2006) methodology was employed (see Chapter 2 section 3 for details on Reef Check transect method). Specifically for indicator invertebrates (Table 9) abundance estimates along the belt transects are recorded with surveyors estimating the total number of indicator species seen within an imaginary area measuring 10 m wide along each 20 m transect line. Invertebrate size was estimated for giant clams only.

Table 9. Indicator invertebrate groups recorded during reef check surveys.

Common Name	Scientific Name
Banded Coral Shrimp	<i>Stenopus hispidus</i>
Long spined sea urchin	<i>Diadema sp.</i>
Pencil Urchin	<i>Phyllacanthus sp.</i>
Collector Urchin	<i>Mespilia sp.</i>
Sea Cucumber	Holothuroidea
Crown of Thorns	<i>Acanthaster sp.</i>
Triton	<i>Charonia sp.</i>
Spiny Lobster	<i>Panulirus versicolor</i>
Giant Clam (<10cm; 10-20cm; 20-30cm; 30-40cm; 40-50cm; >50cm)	<i>Tridacna sp.</i>

## RESULTS

### Taxonomy

The total reef invertebrate fauna of the Islands of the Myeik Archipelago of Myanmar as reported herein consists of approximately 258 specimens and of these only 127 could be identified to species level. The majority of the 258 invertebrates observed were decapods with 103 specimens and gastropods with 55. A complete list is found in Appendix F with a photo guide to all specimens in McKeon (2014).

### Indicator Invertebrates

Diadema were the most common of all the invertebrates recorded with 52.01 ( $\pm 5.8$ ) individuals per transect (Figure 18). Mean invertebrate numbers per transect were generally very low with all but banded coral shrimp ( $6.47 \pm 2.2$ ), collector urchin ( $1.13 \pm 0.6$ ) and Diadema recording means under one. The crown of thorns starfish (COT) was found in very low numbers with a mean of only 0.07 ( $\pm < 0.0$ ) and the maximum number recorded at any one site was six individuals on an inner reef (site 244, Langann Zee Pin Aw). For giant clams, with a

mean of only 0.43 ( $\pm 0.2$ ) individuals per transect, records were dominated by those in the smallest size class, length <10cm, with means decreasing with each size class increase (<10cm= 0.19 ( $\pm 0.1$ ), 10-20cm=0.11 ( $\pm 0.0$ ), 20-30cm=0.09( $\pm 0.0$ ), 30-40cm=0.02 ( $\pm 0.0$ ), 40-50cm= 0.02 ( $\pm 0.0$ ) and >50cm=0.01 ( $\pm 0.0$ )).

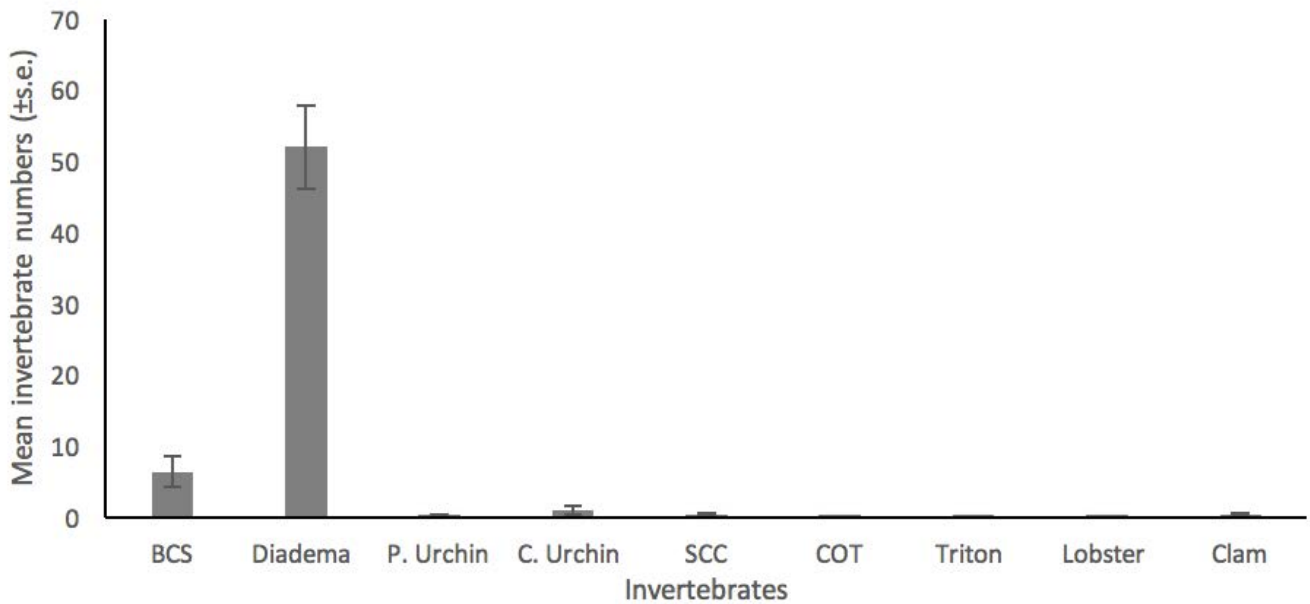


Figure 18 Mean invertebrate numbers for 9 categories ( $\pm$ S.E.) per transect at 225 sites across Myeik Archipelago. (Codes: BCS- Banded Coral Shrimp; P. Urchin- Pencil Urchin; C.Urchin- Collector Urchin; SC- Sea Cucumber; COT- Crown of Thorns; G. Clam- Giant Clam)

Given such low numbers of invertebrates, only Diadema data were analysed at the reef type level. Across the reef types mean Diadema numbers per transect were highest on Rock reefs (164.4 $\pm$ 40.3) followed by Fringe (79.9 $\pm$ 24.1), Moscos (66.3 $\pm$ 17.3) and Inner reefs (37.2 $\pm$  5.3) (Figure 19). Figure 20 provides spatial results of this data at the site level. (See Appendix C for all invertebrate surveyed site locations and mean abundances for Diadema).

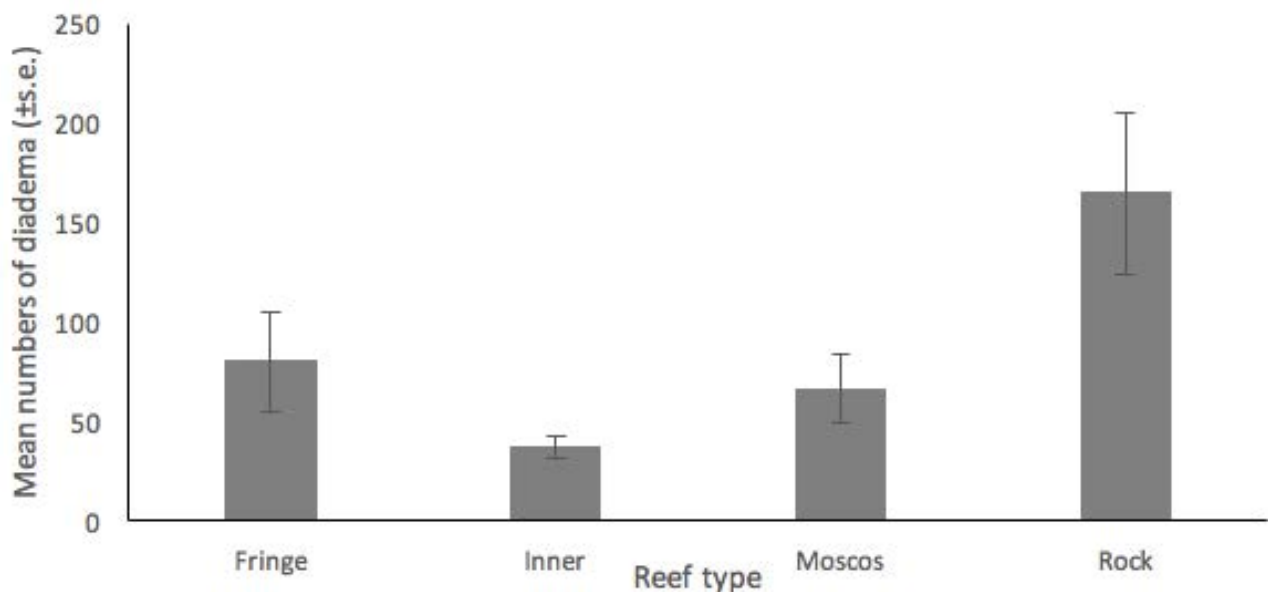
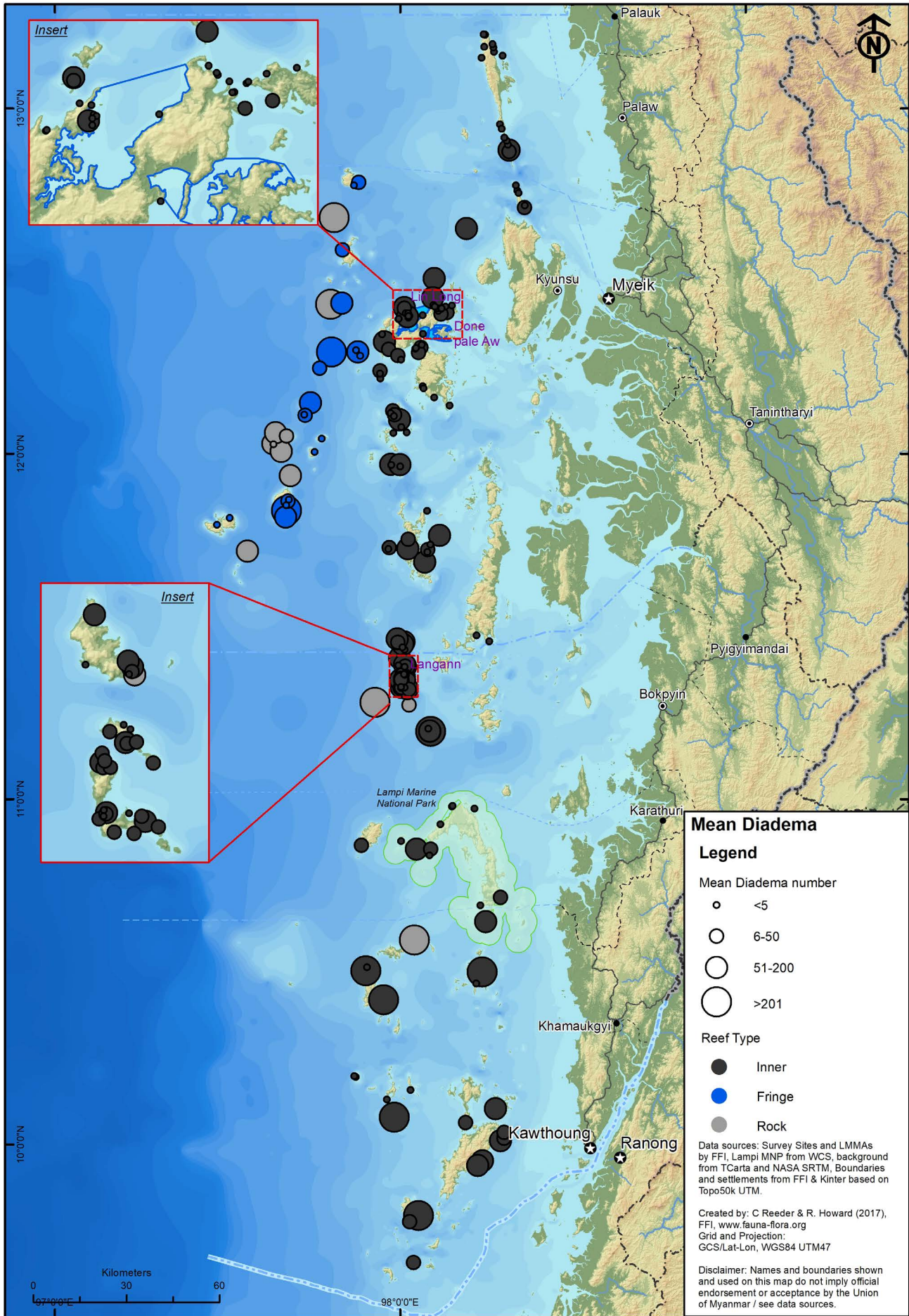


Figure 19 Mean number of Diadema individuals by Reef type.



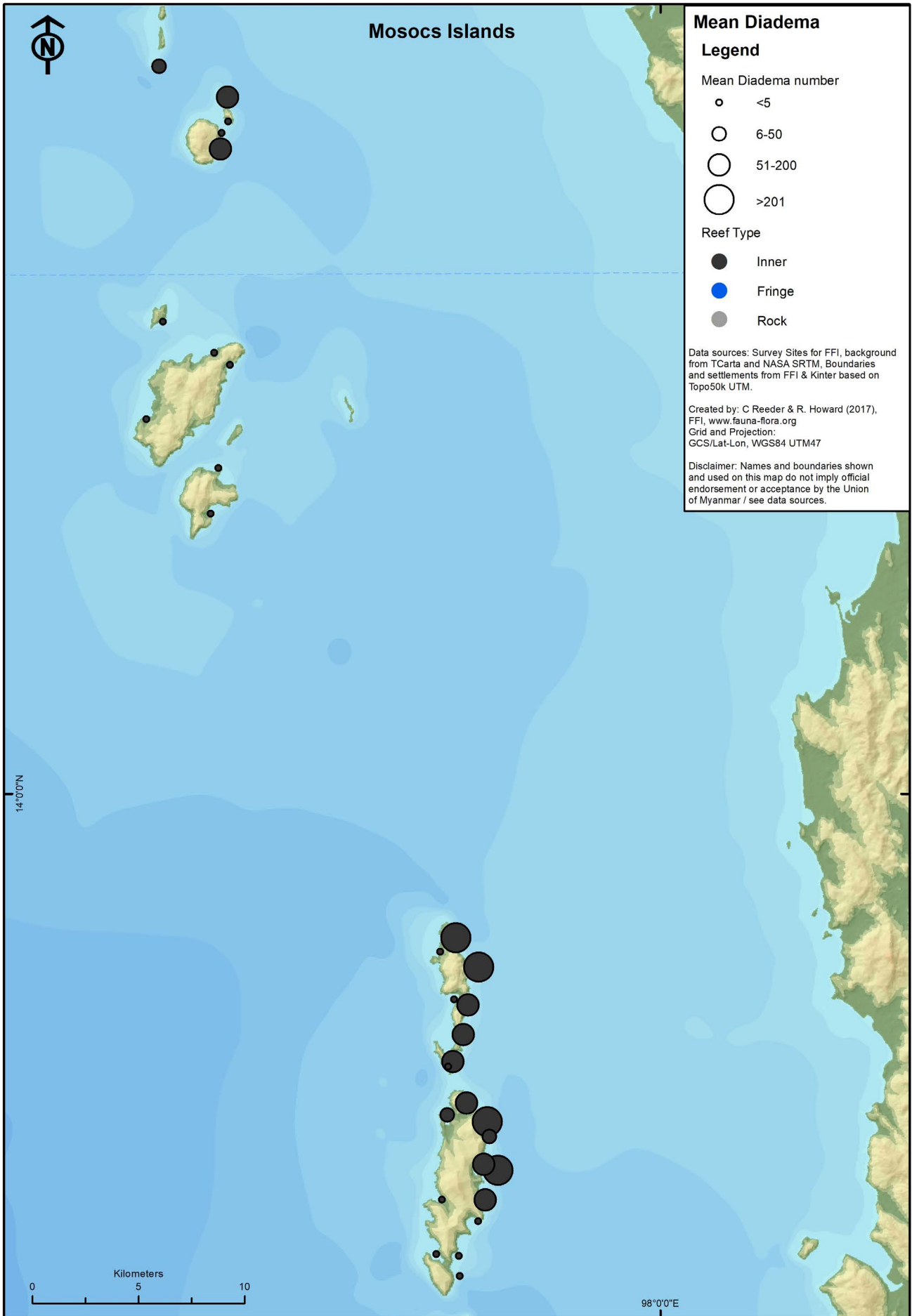


Figure 20 Mean number of Diadema individuals per site by Reef Type

# DISCUSSION

## Taxonomy

Reef diversity appears to be in keeping with regional expectations- though this is very difficult to assess at our most basic level of sampling. Of the 230 specimens collected several of the commensal decapods are undescribed species, but this is not unusual for any reef system. Questions of genetic connectivity with species currently thought to have a broad Indo-West Pacific range might be a tractable first approach to studying regional diversity barring full biodiversity collections.

Many of the species observed are thought to have broad ranges across the Indo-West Pacific (IWP). Previous detailed work on the genetic connectivity and endemism of particular taxa by Meyer and Paulay (2000), has suggested that the Andaman region is has a genetic signal, and some degree of isolation from the rest of the IWP. Ironically, many of the taxa most able to reveal these patterns due to abbreviated larval development (chitons, limpets, turbinids, etc.) are harvested on a commercial scale- and quite difficult to find. Targeted collections with the intent of studying connectivity could work very well to wed ongoing studies of biodiversity in the region to fisheries, and highlight the importance of collections based science to the successful management of the Myeik Archipelago.

## Indicator Invertebrates

The results from the invertebrate surveys showed a landscape dominated by long spined sea urchins and depauperate in the other invertebrates. These results are similar to Malaysia and Indonesia where only *Diadema* were recorded in high numbers whereas the other urchins, sea cucumbers, triton shells, lobsters and giant clams were rarely observed more than once per transect (Habibi et al., 2007; Yewdall, 2013). Low numbers of these species have been blamed on overfishing for both the aquarium trade and as a food source. For the archipelago this was clearly observed by the survey team in Myeik town where a live lobster operation collects wild caught lobsters for export to Thailand, with many of the individuals observed adolescents. One operator from such ventures did however note the need for protection of spawning sites (pers. comm. U Maung Gyi). The trade in sea cucumbers to China is also prevalent within the archipelago and although this is a recent shift in target species as a result of fish populations declining, sea cucumber divers are already reporting reduced catches (Saw Han Shein, 2013). Encouragingly, the surveys recorded low numbers of COTS, a species known for population outbreaks leading to heavily degraded coral reefs (Brodie et al., 2012). These echinoderms occur naturally on coral reefs and so the occasional observation of these starfish in the archipelago is not a cause for concern. Whether Myanmar reefs have ever been affected by large population booms of COTS is unknown due to the lack of underwater surveys in the area, therefore these surveys will provide a useful baseline to monitor against.

For *Diadema* species their abundance is often influenced by fishing pressure on their predators (McClanahan, 2014). For example, McClanahan and Shafir (1990) in comparing closed to open reefs, found that urchin densities were negatively correlated with exploited predatory triggerfish, noting that numbers of urchin decreased as triggerfish abundance increased in closed areas and vice versa for open reefs. Although the surveys did not record specific urchin predators, humphead wrasse are known to feed on these echinoderms (Guardians, 2012) and their low numbers in the archipelago may be one factor affecting urchin abundance. The high numbers of urchins recorded may also be why little algae was recorded during the substrate surveys when herbivorous parrotfish were in such low numbers. If the urchin numbers however are not kept in check their prevalence can lead to urchin barrens in which they remove large amounts of calcium carbonate from living coral and can also feed on coral recruits (Norström et al., 2009). Although *Diadema* were recorded in high numbers on most reef types, on Inner reefs the numbers were very low, along with overall fish numbers. Potentially, given their closeness to the mainland the collection of urchins for consumption maybe higher on Inner reefs than the other sites.

## **Species of conservation concern**

None of the 127 invertebrates identified to species level are listed as above Least Concern as per the IUCN Redlist (Appendix F). This being said there is grave concern for both sea cucumbers, lobsters and giant clams given the dearth of these groups recorded during surveys.

## **Recommendations for conservation**

- Investigate the larval dispersal of commercially targeted invertebrate species to identify and protect source reefs and through genetic studies gain a greater understanding of how reefs are connected.
- Undertake taxonomic studies of the Moscos reefs to elucidate their biodiversity value and to understand the relationship between these reefs and the greater archipelago.
- Ban compressor fishing given its impact on sea cucumber and lobster populations.
- Investigate sustainable mariculture techniques/programmes for sea cucumber farming for small fishing communities.
- Set limit on sizes and bags limits for targeted invertebrates such as lobsters and sea cucumbers.





# 5 SPONGID FAUNA

## INTRODUCTION

There are approximately 8,000 species of sponges currently named in the world, with an estimated 7,000 yet undescribed species from under sampled geographic areas and habitats. Sponges are dominant members of hard and soft bottom habitats worldwide, with distributions in polar, temperate, and tropical climates. Sponges play an important structural role in these ecosystems as habitat for small invertebrates and fish. As prolific filter feeders, sponges can remove phytoplankton, bacteria, and other organic matter from the water column at rates of more than one liter per hour. Many sponges also host diverse and abundant communities of microbial symbionts that, like in corals, are capable of photosynthesis and other complex metabolic pathways. These symbionts allow sponges to remove and recycle nutrients from the water, providing their hosts with food required for survival and playing important roles in reef nutrient cycling. Although sponge abundance is increasing in some parts of the world as coral cover is declining, sponge community structure is also impacted by overfishing, human development, and stressors related to climate change.

Furthermore, because marine sponges feed predominantly by filtering bacteria and other small particles from the water column, their elemental composition reflects local sources of C (Carbon) and N (Nitrogen) that can be impacted by numerous factors (for instance, source C and N values can vary with proximity to land and/or human development). By studying the elemental composition of sponge tissue, we can determine the dominant source of C and N utilized by a sponge species at a given site and, by assessing the elemental composition of the same sponge species from across diverse sites, it is possible to investigate how local sources of C and N vary over large and small geographic distance.

## METHODS

Sponge samples were collected during FFI's December 2014 research expedition in Myeik archipelago which involved swimming transects at each site and collections of a species when present. In addition to these surveys for species diversity, replicate (5-10) individuals of common sponge species were collected at each site. Samples were initially preserved in 95% ethanol for future taxonomic identification based on histological methods. At the Smithsonian Marine Station in Fort Pierce, Florida, USA, small sections of each putative species were placed in 10% bleach to remove organic matter and the remaining silica spicules (sponge skeletal elements) were sequentially rinsed in water and 95 % ethanol and fixed to glass slides (Figure 21a). To catalogue sponge skeletal arrangement, small (<1mm) sections were taken from frozen samples, dried with ethanol and fixed to glass slides (Figure 21b, 16c). Identifications were carried out via dissecting and compound microscopy (Figure 22a-d). These collections are also for future analysis of the elemental composition (via the stable isotope ratios of C and N) and the abundance of cyanobacterial symbionts (via chlorophyll- a- analyses) of sponge tissue.

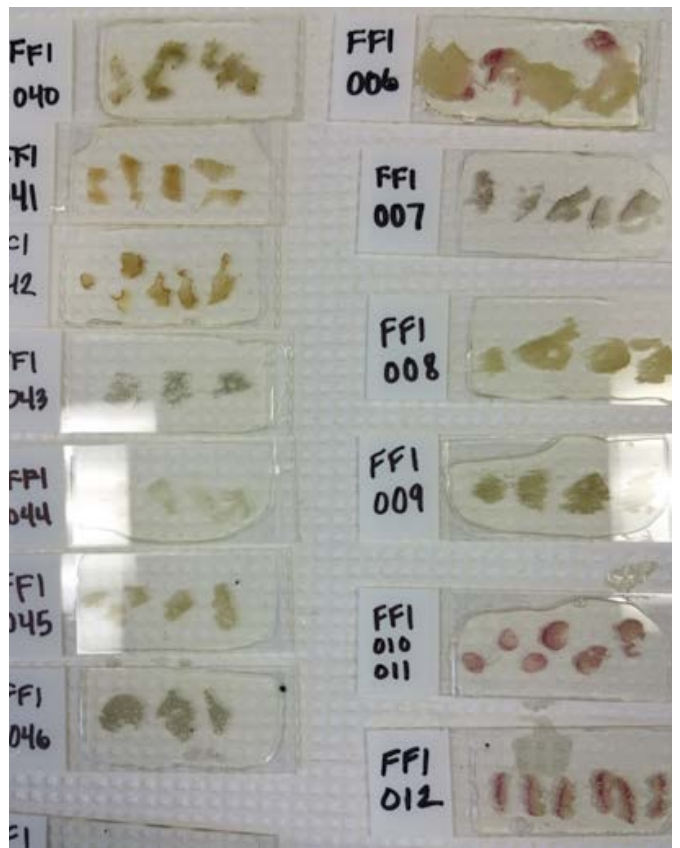
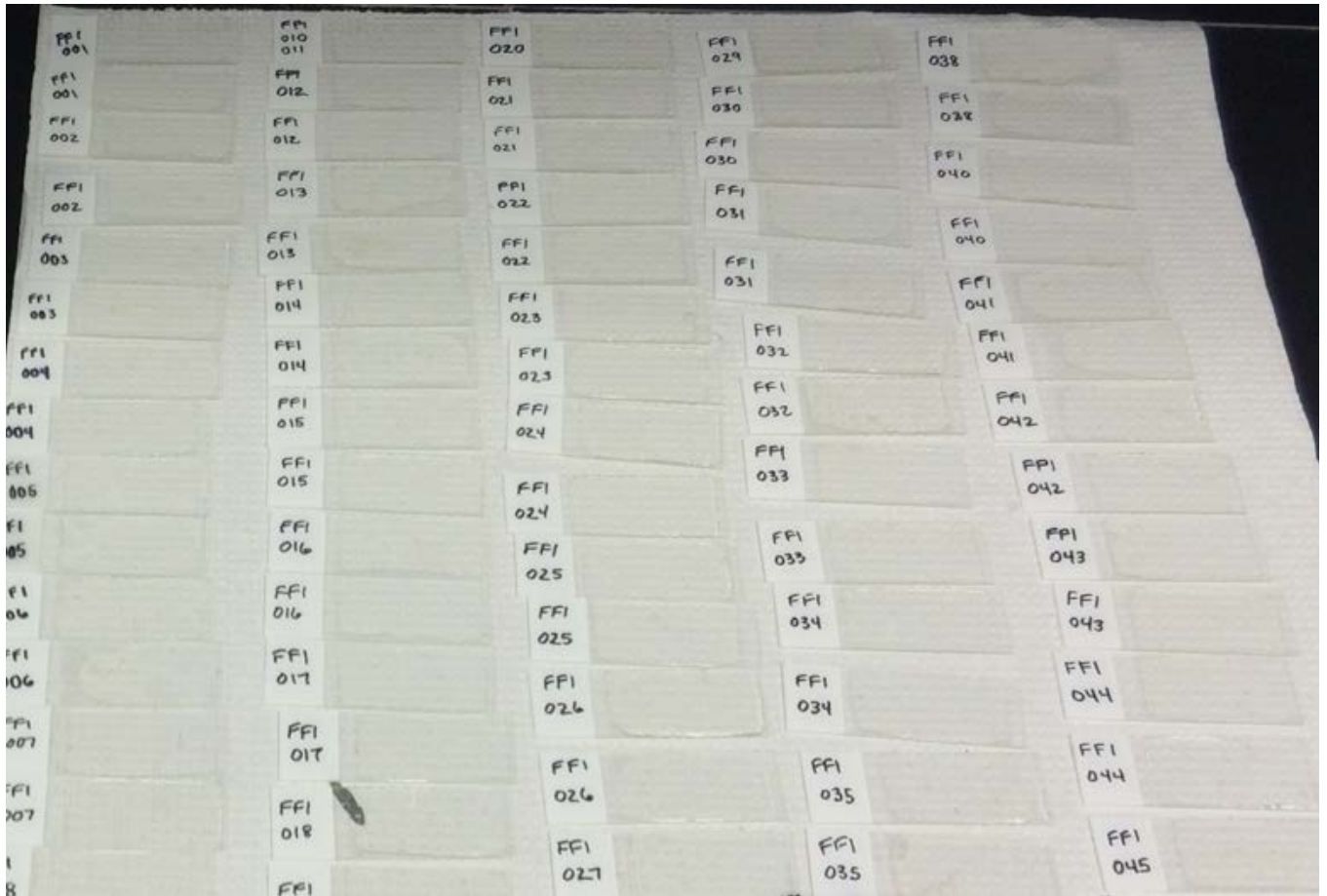


Figure 21. (a: top photo) sponge spicule slides, (b: bottom left) frozen sponge samples, and (c: bottom right) skeletal sections for species identification.

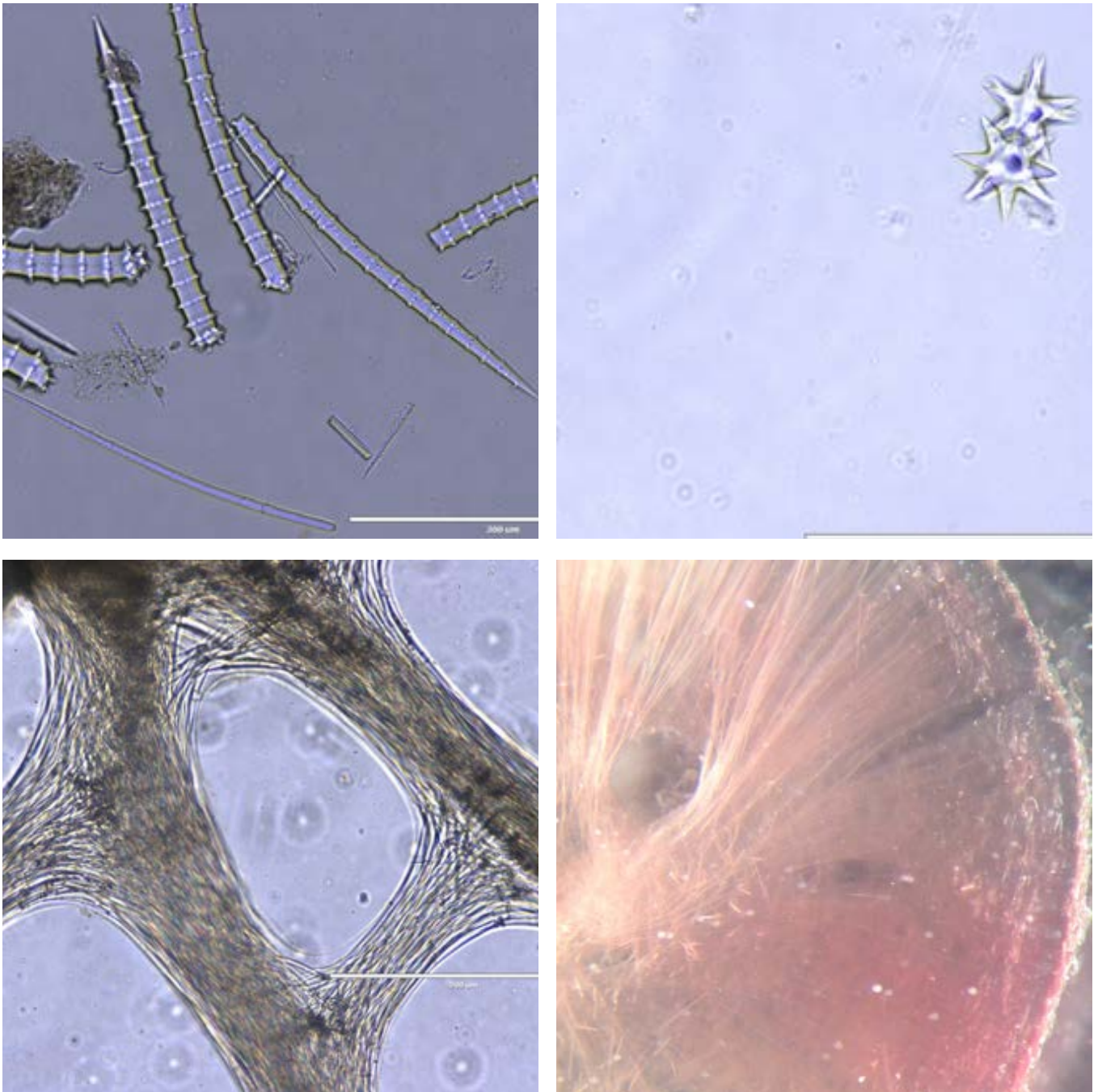


Figure 22 (a,b: top photos) examples of sponge spicules and (c,d: bottom photos) skeletal configurations used for species identification.

## Results

We estimate that 36 unique species were collected during this expedition (Figure 23), with representatives from at least nine orders. To date, four sponges have been identified to species (*Xestospongia testudinaria*, *Neopetrosia exigua*, *Stelletta clavosa* and *Stylissa massa*), with nine more being grouped into a genus and the rest being identified to either family or order. Twelve species are currently listed as to be defined (TBD) due to difficulty in identification and will likely have to be identified using a combination of DNA barcoding and morphological characteristics via scanning electron microscopy.

The resulting data will be analysed using advanced statistical packages to investigate how different species process C and N and how this varies across sites. Samples for chlorophyll-a analysis will be processed and analysed at the Smithsonian Marine Station in Fort Pierce, Florida. These values will be compared to data from stable isotope analysis.

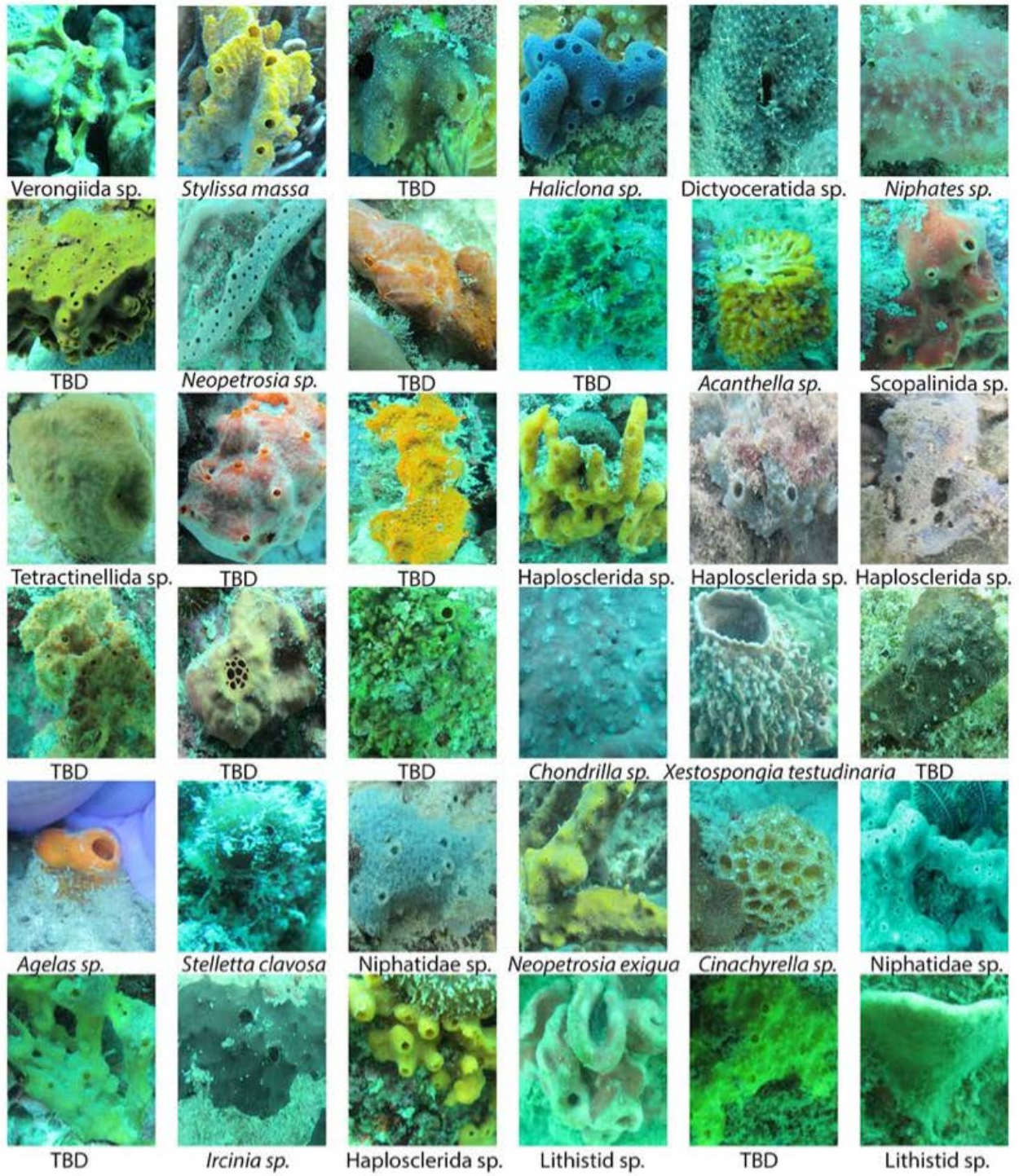


Figure 23. Putative sponge species (with current lowest taxonomic identification) from the Myeik Archipelago

## DISCUSSION

Some of the putative species are rare, representing new records for this area of the Andaman Sea (including the Andaman and Nicobar Islands), where overall sponge diversity has previously been estimated to be between 20 and approximately 90 species. With unique skeletal morphologies and novel spicule types, some of these species are likely to be new records for science, increasing estimates of sponge biodiversity in the eastern Indian Ocean (where current estimates are well over 200 species). Additional taxonomic work will continue to resolve these species. Species richness varied across sites, ranging from zero to seven species per site, but sponge percent cover was relatively low at most sites. Percent cover was highest at more exposed sites, presumably due to increased water flow that provides high levels of particulate food for these filter feeders and reduces sedimentation that can clog sponge canals and feeding structures. Although the giant barrel sponge (*Xestospongia testudinaria*) was found at several sites across the archipelago, it was particularly abundant at these high flow sites, with sizes well over 1 m tall. These species are able to filter large volumes of water and are likely an ecologically important species in the archipelago. Smaller sponges in other, less exposed bay sites may be influenced by lower flow rates and increased sediment load at these locations. These data provide initial evidence that local environmental conditions are driving sponge abundance and community structure in this archipelago and that changes to these ecosystems (caused by increased river discharge or human development) may impact these important benthic organisms. By providing an initial assessment of the common sponge species present at diverse sites off the coast of Myanmar, these data increase our understanding of the overall biodiversity in this region.

### Species of conservation concern

None of the 36 species collected during this expedition are listed as above Least Concern as per the IUCN Redlist.

### Recommendations for conservation

- Isotope and chlorophyll-a data may allow us to understand how local sources of C and N vary within this region, and whether some of these sites are impacted by nutrients derived from human development.
- Because sponges are present at almost all sites, these organisms are a natural integrator of local nutrient sources across sites. Repetitive collections of these species, especially following development within this region, may thus allow researchers to monitor changes in nutrient inputs to these ecosystems.
- Data from stable isotope and chlorophyll-a analyses will be used in a publication outlining resource use and the trophic structure of common sponge species off the coast of Myanmar.



# 6 SEAGRASS ECOSYSTEMS

## INTRODUCTION

### Taxonomy and extent

The ecological importance of seagrass beds has been well documented and includes the provision of sheltered habitats and crucial feeding, spawning and nursery grounds for economically important species of marine invertebrates and fish species (Dawes, 1981; Zieman et al., 1989; Dawes et al., 2004; Adulyanukosol et al., 2006; Nakanishi et al., 2006). Furthermore, they are key primary producers, involved in epibenthic and benthic production; provide important nutrients and contaminant filtration, producers of oxygen, and recyclers of nutrients (Orth et al., 2006). However, since 1980 about 60% of seagrass populations globally have seen a reduction in their distribution due to habitat destruction and marine pollution (Green and Short 2003; Short et al., 2007). Seagrasses occur all along three coastal regions of Myanmar, namely Rakhine, Ayeyarwady Delta and the Gulf of Mottama (Martaban) and Tanintharyi. Eleven species of seagrasses has been described in Myanmar. Given their importance, both ecologically and economically, and the global decline in seagrass beds, the protection of seagrasses within Myanmar is seen as paramount. Studies were therefore undertaken to provide updated information on the current status, distribution and coverage of seagrasses at select sites within the Tanintharyi coastal region of Myanmar.

### Seagrass associates

Understanding habitat links to fisheries is critical for the consideration of short-term fisheries management but is also important for understanding the vulnerability of marine systems to climate change and their future resilience (Folke, 2006; McClanahan et al., 2009). Given the need to understand the role that different habitat types have in supporting tropical marine fisheries, the limited literature and knowledge on seagrass biodiversity in the Indo-Pacific, and the growing evidence of the role of seagrass meadows in supporting Indo-Pacific marine fisheries, here we provide a baseline assessment of the seagrass and its associated fish assemblages at four locations in the Myeik Archipelago in southern Myanmar.

## METHOD

### Taxonomy and extent

Surveys were conducted in 2015 between the 6th of March and 4th of April at ten study sites in the Myeik Archipelago (Figure 24). To gain quantitative data on percentage cover the study followed the SeagrassNet protocol (Short et. al 2006), consisting of three fixed, parallel, 50 m cross transects referred to as cross transects A, B and C, with cross transect A closest to shore and C most seaward; B, midpoint of these cross transects were established on a transect laid out seaward, perpendicular to the shore (Figure 25). Percentage cover of seagrasses was visually estimated within 12 randomly placed 0.25m<sup>2</sup> quadrats along each transect line using a photo guide of percent cover. Positions and areas of seagrass for each study site were recorded by GPS with extent being recorded by walking around the seagrass bed taking GPS points every 10 secs. All specimens were identified using the standard monograph of seagrasses prepared by Den Hartog (1970) and Kuo et al. (2006). This study had followed the classification system used by Fortes (1993). All voucher specimens were deposited at the Herbarium of Department of Marine Science, Mawlymine University, Mawlymine, Myanmar.



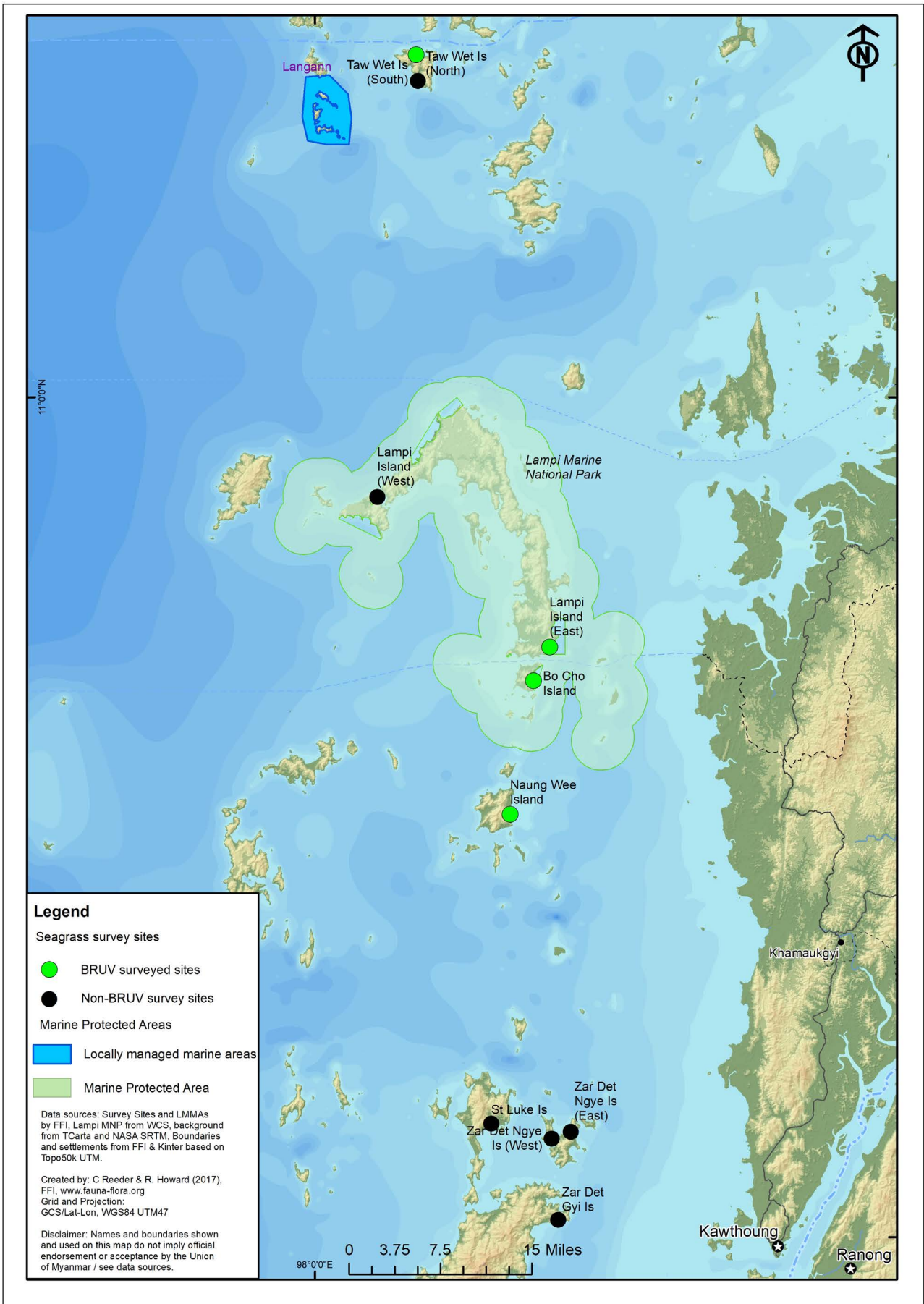


Figure 24. Seagrass and BRUV survey sites in the Myeik Archipelago, in the Tanintharyi Coastal Region.

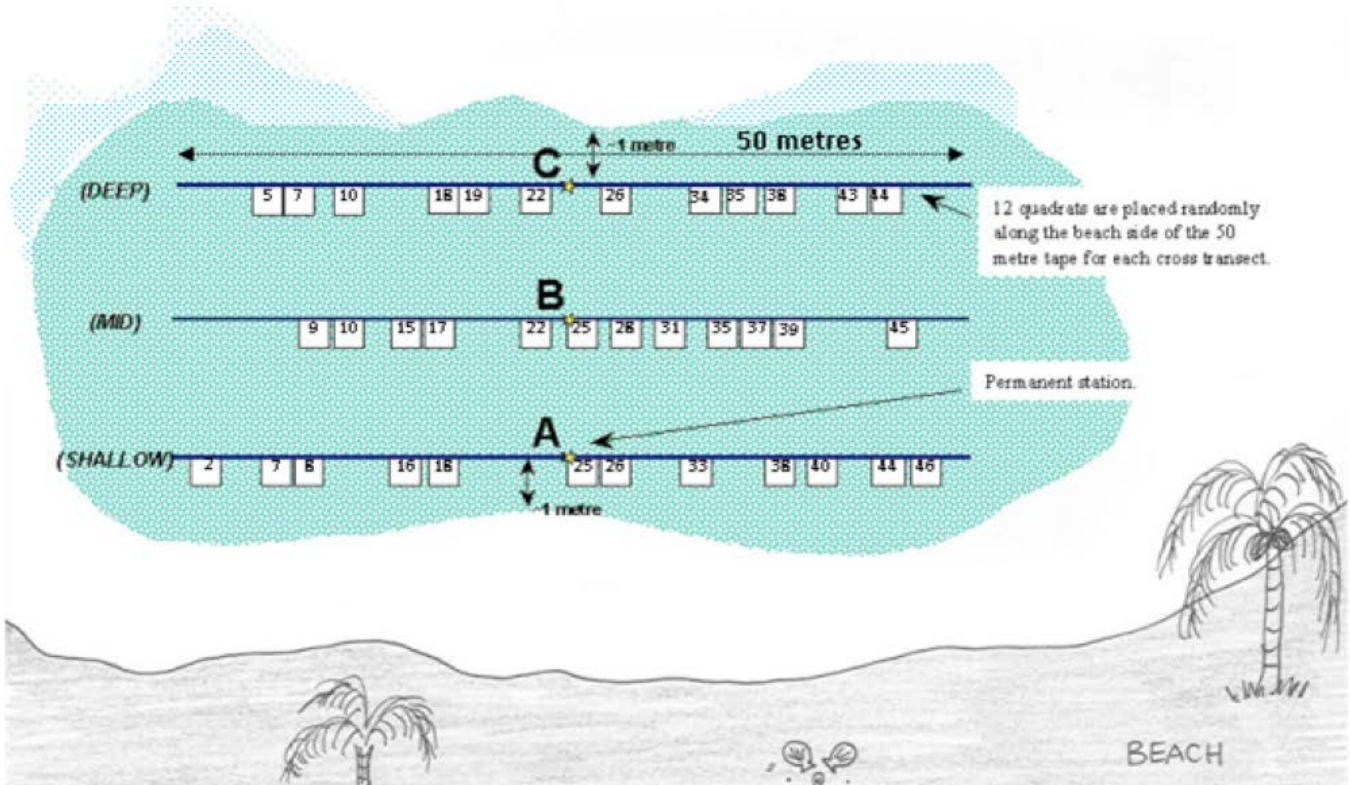


Figure 25. The layout of the monitoring cross-transsects, A, B and C, with 12 quadrats at the interval of pre-selected random distance along the vertically established transects approximately perpendicular (at right angles) to the water's edge (Source: Modified from Short et al. (2006)).

## Seagrass Associates

The relative abundance and diversity of fish assemblages were assessed at the species level at the four seagrass meadows using mono-camera Baited Remote Underwater Video systems (BRUVs) during April and May 2016. These mono-BRUV systems were constructed based on designs by Cappo et al. (2004), using a stainless-steel tripod-style frame constructed as a mount for a GoPro Hero 4. A bait arm (20 mm stainless steel conduit) extending 1 m from the base plant of the camera supported a plastic bait container, containing standardised bait (ground goatfish and sardine – sourced locally), which was replenished prior to every deployment (Figure 26).



Figure 26 Baited remote underwater system deployed in seagrass. (Photo: Benjamin Jones)

Five sets of three deployments, spaced 50m apart (15 samples) were conducted at Taw Wet North and four sets of three deployments, again spaced 50 m apart (12 samples) were conducted at Lampi East, Bo Cho and Nyaung Wee (Figure 24). The deployment duration used in this investigation was 30 minutes. This amount of time has proved suitable in previous studies for assessing the fish assemblage and remaining cost effective (Haggitt et al., 2014; Kelaher et al., 2014; Malcolm et al., 2015; Wraith et al., 2013; Wraith, 2007). While deployment length can vary (Unsworth et al., 2014a), short sampling duration enables a higher number of samples to be collected, achieving a great spatial representation of the variability of the fish assemblages. All deployments were in a depth range of between 0.5 and 1.5m and deployed on an incoming tide in sets of 3. All BRUV system sampling was conducted during daylight hours. No sampling was conducted at night.

Video footage was assessed in order to determine the MaxN of each individual fish species in each video sample. MaxN is a metric commonly used for the quantification of the relative abundance of fish observed on underwater video (Cappo et al., 2004; Unsworth et al., 2014b). It counts the maximum number of fish recorded at any one time (single video frame) and therefore removes the concerns associated to potentially double counting individual fish (Priede et al., 1994). All footage was analysed using the specialised SeaGIS software EventMeasure v.3.51. In order to analyse the footage, the MaxN of each species was determined in every video frame throughout the 30 minutes of footage and an overall MaxN then calculated at the end of each 30 minutes.

One-way ANOVA was used to test for differences in the key seagrass morphometrics across sites with Bonferroni post-hoc tests for differences between sites using the software SPSS v.23. Analysis of differences in the structure of fish assemblage between locations was conducted using multivariate non-metric multidimensional scaling ordination (nMDS) using the software PRIMER v.6.1.5 and a 2-way analysis of similarities (ANOSIM) was used to investigate differences identified from MDS (Clarke and Warwick, 1994). All summary data are presented as means  $\pm$  standard deviation.

## RESULTS

### Taxonomy and extent

In the present study a total of 7 species of seagrasses were identified including: 1. *Cymodocea serrulata*; 2. *Cymodocea rotundata*; 3. *Halodule uninervis*; 4. *Halodule pinifolia*; 5. *Enhalus acoroides*; 6. *Thalassia hemprichii*; and 7. *Halophila ovalis* (Table 10). Of the 7 species of seagrasses collected in this study, *Halophila pinifolia* was the most commonly observed species and the only one to be distributed across all study sites. *Thalassia hemprichii* was not recorded on the transects and only occasionally observed during the survey and considered low in abundance. In terms of species diversity among the 10 study sites Zar Det Ngye I. (East) and Pa Law Kar Kyan I. contained 7 species each. Highest percentage cover of seagrass meadows was observed at Lampi I. (East) with 64.57% (Table 10).

Table 10. The percentage cover and frequency of the occurrence of seagrasses encountered along 3 cross-transects in 10 study sites in the Tanintharyi Coastal Region of Myanmar.

LOCALITY	POSITION	COVER %	SPECIES							Total
			Cr	Cs	Hu	Hp	Ho	Ea	Th	
Zar Det Gyi Is	10.02003; 98.28963	44.72	*	*	*	*	*		*	7
Zar Det Ngye Is (West)	10.11687; 98.28199	25.75	*	*	*	*	*		*	7
Zar Det Ngye Is (East)	10.12510; 98.30450	55.77	*	*	*	*	*	*	*	8
St Luke Is (Pa Law Kar Kyan)	10.13461; 98.21011	38.14	*	*	*	*	*	*	*	8
Naung Wee Island	10.50319; 98.23227	59.72	*	*	*	*	*		*	7
Bo Cho Island	10.66216; 98.26000	20.89	*	*	*	*	*		*	7
Lampi Island (East)	10.70202; 98.27948	64.57	*	*		*	*		*	6
Lampi Island (West)	10.88089; 98.07436	18.75	*			*				3
Taw Wet Is (South)	11.37642; 98.12234	33.75			*	*	*			4
Taw Wet Is (North)	11.40776; 98.12032	40.5	*	*		*	*		*	6

Abbreviations: Cr-Cymodocea rotundata, Cs-Cymodocea serrulata, Hu-Halodule univervis, Hp-Halodule pinifolia, Ho-Halophila ovalis, Ea-Enhalus acoroides, Th-Thalassia hemprichii.

## Seagrass Associates

A total of 85 individuals (based on MaxN) from 12 different taxa were recorded, of which 1 was a Cephalopod. Certain individuals could not be identified to species level so were given a family name only (e.g. Gobiidae and Lutjanidae). Total relative faunal abundance (MaxN) per sample ranged from 17 individuals at Bo Cho to 0 individuals (at all sites). The average relative fish abundance (MaxN) across all sites and samples was  $1.7 \pm 3.7$  (SD). In Taw Wet North this was  $0.3 \pm 0.6$ , in Lampi East  $3.0 \pm 4.6$ , in Bo Cho  $2.9 \pm 5.6$  and in Nyaung Wee was  $0.8 \pm 1.4$  (Figure 27).

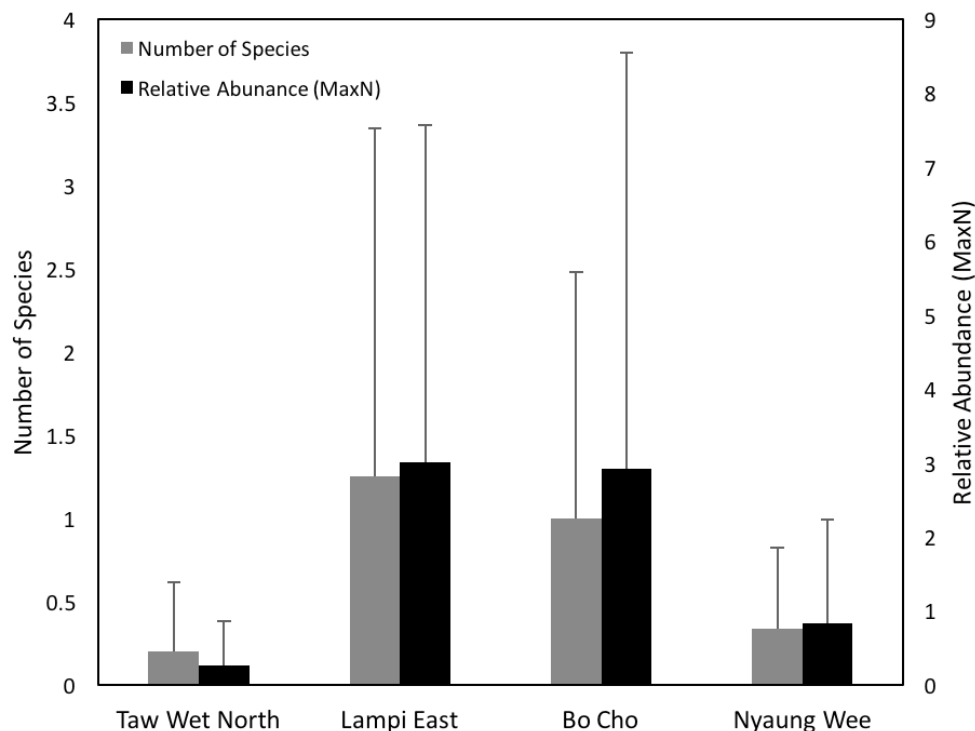


Figure 27. Mean ( $\pm$  SD) abundance and number of species of motile fauna recorded within four seagrass meadows across the Myeik Archipelago, Myanmar during April and May 2016 using mono Baited Remote Underwater Video systems.

Average number of species was highest at Lampi East, with  $1.3 \pm 2.1$  per sample. At Bo Cho this was  $1.0 \pm 1.5$  and at Nyaung Wee this was  $0.3 \pm 0.5$ . Average number of species was lowest at Taw Wet North, with  $0.2 \pm 0.4$ . Average sample diversity (Shannon Wiener H') was again highest at Lampi East ( $0.3 \pm 0.5$ ) and Bo Cho ( $0.2 \pm 0.4$ ). There was no sample diversity at Nyaung Wee or Taw Wet North ( $0.0 \pm 0.0$ ) (Figure 27).

The most abundant species were the northern whiting (*Shillago siamma*) ( $7.0 \pm 4.5$ ), the common silver-biddy (*Gerres oyena*) ( $3.1 \pm 1.6$ ) and the pearly-spotted wrasse (*Halichoeres bicolor*) ( $2.0 \pm 1.2$ ). While 7 individuals of the seagrass wrasse (*Novaculoides macrolepidotus*) were recorded, these were observed in only one sample. *G. oyena* was most frequent across all sites, occurring in 14 % of samples, followed by *H. bicolor* (10 %), fish from the Gobiidae family (10 %) and *S. siamma* (8 %). In total, only 2 taxa were recorded at the Taw Wet North and Nyaung Wee, with 9 at Lampi East and 7 at Bo Cho. The most frequently sampled fish in Taw Wet North were *S. siamma*, which were present in 13 % of the samples. *G. oyena* (25 %), fish from the Gobiidae family (25 %) and *H. bicolor* (17 %) were the most frequently sampled in Lampi East. *H. bicolor* (17 %), thumbprint emperor (*Lethrinus harak*) (25%) and *S. siamma* (17%) were the most frequently sampled fish in Bo Cho and *G. oyena* (25%) in Nyaung Wee (Table 11).

Table 11. Presence of individual species of fish recorded in samples using mono Baited Remote Underwater Video systems from four sites across the Myeik Archipelago, as a percentage of the total number of samples from each site.

FAMILY	SPECIES	COMMON NAME	TAW WET NORTH	LAMPI EAST	BO CHO	NYAUNG WEE
Gerreidae	<i>Gerres oyena</i>	Common silver biddy	-	25	8	25
Gobiidae		Goby	-	25	8	8
Labridae	<i>Halichoeres bicolor</i>	Pearly-spotted wrasse	-	17	25	-
Labridae	<i>Novaculoides macrolepidotus</i>	Seagrass wrasse	-	8	-	-
Lethrinidae	<i>Lethrinus harak</i>	Thumbprint emperor	-	-	25	-
Lethrinidae	<i>Lethrinus variegatus</i>	Slender emperor	13	-	-	-
Lutjanidae			-	8	-	-
Mugilidae	<i>Chelon spp.</i>	Mullet	-	8	-	-
Mullidae	<i>Parupeneus barberinus</i>	Dash-and-dot goatfish	-	8	8	-
Pomacentridae	<i>Pomacentrus spp.</i>	Dameslfishes	-	8	-	-
Siganidae	<i>Siganus canaliculatus</i>	White-spotted spinefoot	-	8	-	-
Sillaginidae	<i>Shillago siamma</i>	Northern whiting	7	8	17	-
Tetraodontidae	<i>Arothron hispidus</i>	White-spotted puffer	-	-	8	-

The faunal species assemblages within the four seagrass meadows were not significantly different from each other (ANOSIM,  $R = 0.04$ ,  $P = 0.067$ ), however pairwise tests confirmed individual inter-site differences between Taw Wet North and Lampi East ( $R = 0.09$ ,  $P < 0.05$ ). No grouping existed for samples from the four sites, indicating some over-lapping species assemblage, which was to be expected given the low number of species observed across samples (Figure 28).

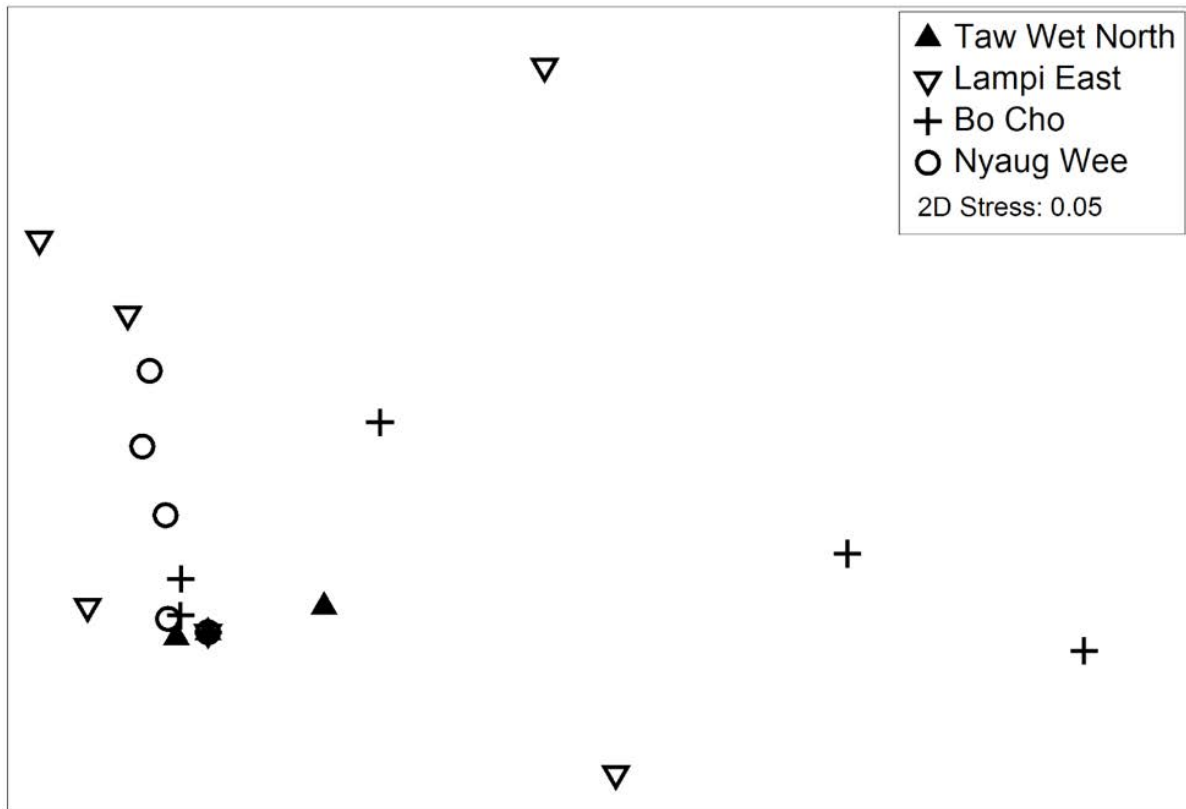


Figure 28. Two-dimensional non-metric MDS scaling configuration for comparisons between motile faunal assemblages recorded within seagrass meadows at four locations during April and May 2016 the Myeik Archipelago, Myanmar using mono Baited Remote Underwater Video

## DISCUSSION

### Taxonomy and extent

The current study was able to develop an easily replicable baseline for 10 seagrass sites within Myeik Archipelago to allow for long-term monitoring of seagrass beds and provide the ability to quantitatively measure the impact of management interventions aimed at seagrass conservation. Of the 10 sites surveyed only four had been previously studied using the same methodology (Novak et al., 2009), and so comparisons can be made. Of the four only one, Lampi East showed an increase in percentage cover with 64.57% recorded in the current survey compared to 45% in the Novak et al. (2009) 2007 surveys. A number of reasons may be responsible for this increase such as a decrease in shrimp and fish catch in the area leading trawlers to search elsewhere for catch or from the increase in presence of Department of Forestry staff at the Lampi Island Marine National Park headquarters opposite the seagrass bed, resulting in greater support by the NGO community to the MPAs management. Two of the other sites, Taw Wet North and Nyaung Wee, did show a decrease in percentage cover but only by 9% and ~11% respectively, with such a result potentially down to transect placement. These sites will however need to be monitored to ensure that it's only a statistical error causing this decrease and not anthropogenic impacts such as bottom trawling. The final site, which had previously been surveyed in 2007, was Lampi West and this seagrass bed has seen an extensive loss in percentage cover with 18.75% recorded in this survey compared to 80% cover in 2007. Boat activity in this area was observed to be quite high during the surveys with this part of Lampi Island providing protection for many boats during periods of high winds and as such could be targeted by trawlers when conditions away from the island are unfavourable. These seagrass beds were noted to have a high cover of sand sediments smothering their stems. The current support being provided to manage this Marine National Park by organisations such as the Italian NGO Istituto Oikos may help to ensure these seagrass beds protection and long term conservation. In

terms of species diversity seven species of seagrasses were found. In the present study, however, unlike Kress et al. (2003) no specimens of *Zostera marina* were recorded. This species normally occurs in temperate waters and is known to extend into the higher latitudes of Myanmar waters and has previously been found in all three coastal regions of Myanmar. Further surveys are therefore needed to elucidate the status of this species within the country.

Although Soe-Htun et al. (2002) reported there were no stresses in the meadows of seagrasses in coastal areas of Myanmar, with these ecosystems showing pristine, climax conditions, they are now facing the problems such as smothering by sand. Such issues can arise from trawlers stirring up sediments or from land-slides where forest areas have been cleared such as those observed on Zar Det Gyi I. In general seagrass beds in Myanmar are exposed to a number of threats including runoff from cities and towns and hazardous wastes and oil dispersals released from industrial zones located in the upper areas of natural seagrass beds are seen as serious threats to these habitats. Bottom trawlers also operate directly through seagrass beds targeting shrimps and other marine species destroying these habitats.

## Seagrass Associates

Despite historic reports of productive and abundant seagrass meadows in Myanmar by Soe-Htun et al. (2002), the present study provides irrefutable evidence that the fisheries resources of seagrass meadows within the Myeik area of Myanmar are in a poor and potentially perilous state. This adds to a growing literature suggesting the nation's marine habitats are in decline (Russell, 2015). Across the sites surveyed within this study, only 12 taxa of motile fauna were recorded. Relative to other regional and global studies this is extremely low (Unsworth et al., 2014b). Across the Indo-Pacific, the number of seagrass associated (known to utilise seagrass during at least some stage of its life cycle) fish species is high. Nearly 700 species of fish are reported to have been observed in seagrass meadows, the most common being *Lethrinus harak*, *Siganus canaliculatus* and *Gerres oyena*, all of whom are common fishery species that were sparse within the current study (Unsworth et al., 2014b).

Multiple studies from the Indo-Pacific region suggest that many recognised and important reef dwellers utilise multiple habitat types, for example *Lethrinus spp.* and *Siganus spp.*, yet these were sparse in the seagrass meadows. One *Siganus canaliculatus* individual was observed at Lampi East,  $1.0 \pm 0.0$  *Lethrinus variagatus* individual was observed at Taw Wet North and  $1.3 \pm 0.6$  *Lethrinus harak* individuals were observed at Bo Cho. Whilst some seagrass dependant (species whom spend their whole life in seagrass) species such as *Gerres oyena* were present, (Berkstrom et al., 2013; Dorenbosch et al., 2005; Unsworth et al., 2008), their low abundance was not characteristic of the Indo-Pacific region. Multiple habitat usage by marine fauna is largely related to foraging migrations (as adults) or ontogenetic dietary shifts (as juveniles) (Nagelkerken, 2009). Thus, reliance on multiple habitats underlines the importance connectivity for maintaining fish assemblages.

Although dynamite fishing continues in the Myeik archipelago, enforcement measures for this activity have come into force in recent years (MOECF and Oikos, 2015). Coral reef habitats within the archipelago are of average condition (see Chapter 2 Section 3), and mangrove communities, although minor in terms of extension (notably within Lampi MNP), are in almost intact condition with high ecological value (BANCA and Oikos, 2011). This suggests that in time, these habitats may recover but true enforcement is sorely needed.

Seagrass meadows are well known to fishers in Myanmar as an important gleaning area (Schneider et al., 2014), additionally with local people calling seagrasses *Leik-Sar-Phat-Myet*, meaning the food of marine turtles (Soe-Htun et al., 2015; Soe-Htun et al., 2002). But evidence suggests that seagrasses and associated habitats within the Myeik Archipelago, although far from populations, are facing the common problems associated with extensive overfishing seen across the Indo-Pacific region in previous decades (McManus, 1997). Barrier Net fishing, with nets that close off entire bays are common and trawlers operate close to shore targeting shrimps and other fish species (Soe-Htun et al., 2015). Anecdotal on-site observations confirm this, revealing the removal of top predators, such as sharks, from habitats within the archipelago despite enforcement on the activity. A distressing finding of the present study, and others on associated habitats is a lack of top predatory fish (see Chapter 3), likely a result of the practices mentioned above. While we appreciate all samples were collected during the day, and lower abundances

of predatory fish can be expected due to diel differences in feeding activity (Unsworth et al., 2007), there were no fish from predatory fish families such as Carangidae, Serranidae or Lutjanidae recorded within samples. Even in low abundance, these predatory fish are generally much more receptive when using baited cameras. This lack of predatory species is symptomatic of a highly exploited fishery, which even at a small-scale can be excessive.

While the present study provides the first concerning abundance and diversity baseline for seagrass meadows within the Myeik Archipelago, it also offers some optimism for the future. Sites with the highest fish abundance and diversity (Lampi East and Bo Cho) are within Myanmar's only Marine National Park (MOECAP and Oikos, 2015). It is possible that the recent development of a 5-year management plan and on ground support to ranger patrols by the international NGO Instituto Oikos is having a positive impact on the marine environment. While low diversity can likely be influenced disproportionately by a lack of night time sampling (Unsworth et al., 2007), the absence of healthy adjacent migratory habitats suggests that limited migration occurs to utilise available resources effectively.

## **Species of conservation concern**

All species of seagrass identified during the survey are listed as Least Concern under the IUCN Redlist.

## **Recommendations for conservation**

- Designation of key seagrass areas as marine protected areas (MPAs) linked with wider spatial planning exercises for Myeik Archipelago.
- Provide financial and technical support to various Myanmar institutions such as government departments and universities, including capacity development for community-based biodiversity conservation efforts.
- Improve public knowledge and recognition of the importance of seagrass habitats through nationwide education and awareness programmes targeting policy and decision makers, fishers and local communities and those involved in activities which impact seagrass beds.
- Ensure seagrass conservation is included in any coastal development projects and in all regional/state development plans.
- Undertake further detailed research on seagrass habitats including surveys of the ecosystem services provided by seagrass beds with a special focus on their importance to fisheries;
- Regularly monitor the status of seagrass ecosystems along the coast of Myanmar including on ground surveys and satellite remote sensing analysis.
- Long-term monitoring of fish assemblages through more stratified sampling approach that incorporates greater consideration of environmental cycles (diel, tidal and lunar).





# 7 THREATS

## INTRODUCTION

The importance of coral reefs to fisheries have shown that healthy reefs are estimated to produce, per km<sup>2</sup> per year 0.2- 40 tons of seafood, with a mean of around 5 tons of seafood/km<sup>2</sup>/year (Nature Conservancy, 2017). For Myanmar the proportion of marine catch that comes directly from coral reefs is unknown although surveys of the Ranong market in Thailand in which many Myanmar boats land their catch reported 24% of the landed species being coral reef fishes (Russell, 2016; see Chapter 3). Myanmar relies heavily on marine fish for its economy and local livelihoods with 3036.42 metric tonnes being landed in the 2016-17 period alone (DoF, 2017). Therefore reports of the country's marine ecosystems being under increasing pressure from unregulated fishing, destructive fishing techniques, sedimentation, pollution, increasing coastal populations and climate change is a cause for alarm (BANCA and Oikos, 2011; Rao et al., 2013). Damage from dynamite and anchor scars can have long lasting affects is on the corals, the foundation of reefs, with recovery from dynamite even after 40 years found to be minimal (Guard and Masaiganah, 1997).

To compliment research on status of the coral reefs of Myeik Archipelago through Reef Check surveys (as detailed in Chapters 2 (Section 3), 3 and 4) studies to quantify some of the threats noted above were undertaken across the archipelago between 2013 and 2017. These surveys were aimed at understanding what anthropogenic threats were affecting the reefs most through a set of indicator threats observed commonly in the region. These surveys were also designed to guide enforcement efforts of government agencies to crack down on illegal fishing methods, namely dynamite fishing. The threats recorded were certainly not an exhaustive list of reef threats but certainly some of the most direct.

## METHOD

Surveys of anthropogenic impacts on the reefs were undertaken using the Reef Check (Hodgson et al., 2006) methodology (see Chapter 2 section 3 for details on Reef Check transect method). Impacts (Table 12) and severity of were recorded along belt transects with surveyors estimating anthropogenic damage within the 5m x 20m belt transect area. Damage was categorised in terms of severity within a 0-3 scale, with: 0 = no damage; 1 = low damage, 1 instance; 2 = medium damage, 2-4 instances; 3 = high damage, > 5 instances.

Table 12. Anthropogenic impacts recorded during reef check surveys

Impact	Description
Boat Anchor	Damage- boat or anchor
Dynamite	Damage- dynamite
ALDFG	Trash- Abandoned, Lost or otherwise discarded fishing gear
Litter	Trash- litter
Other	Damage- other

# RESULTS

Of the five categories of anthropogenic impacts assessed no one impact dominated, with a mean impact score of approximately one (low damage) for each (Figure 29). This level of damage was similar when comparing reef types with the highest levels of damage of just under 1.55 for fishing nets on Moscos (Figure 30). At the site level however impacts varied from scores of 0 to those with 3, the highest level of damage, Figure 31 provides a spatial view of these results.

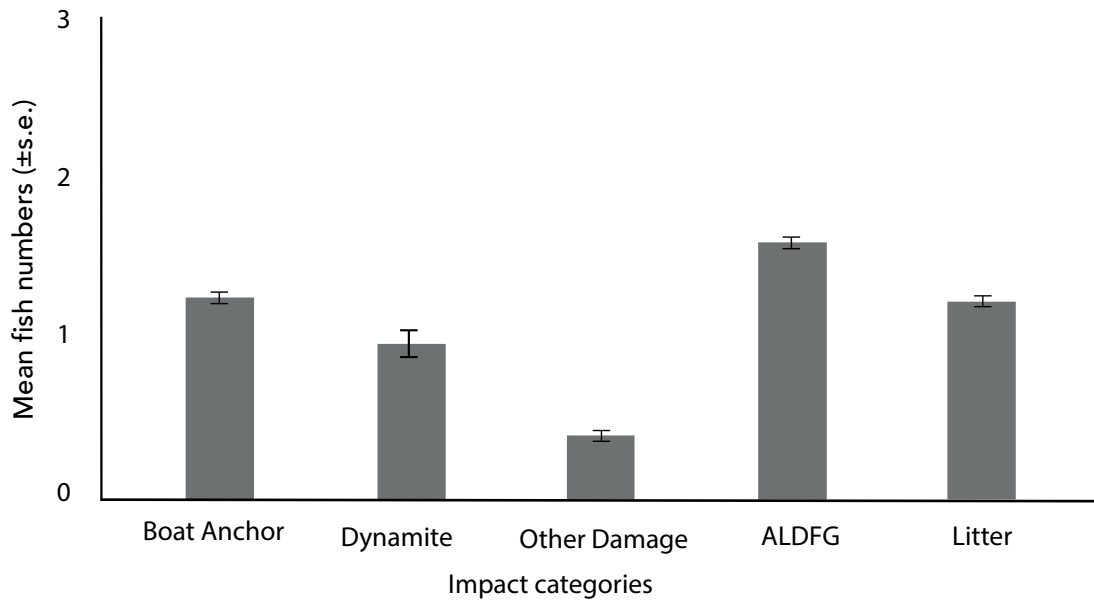


Figure 29. Impact score (0 no damage, 3 highest damage) for the five anthropogenic impacts assessed across 212 sites. (ALDFG- Abandoned, Lost or otherwise discarded fishing gear).

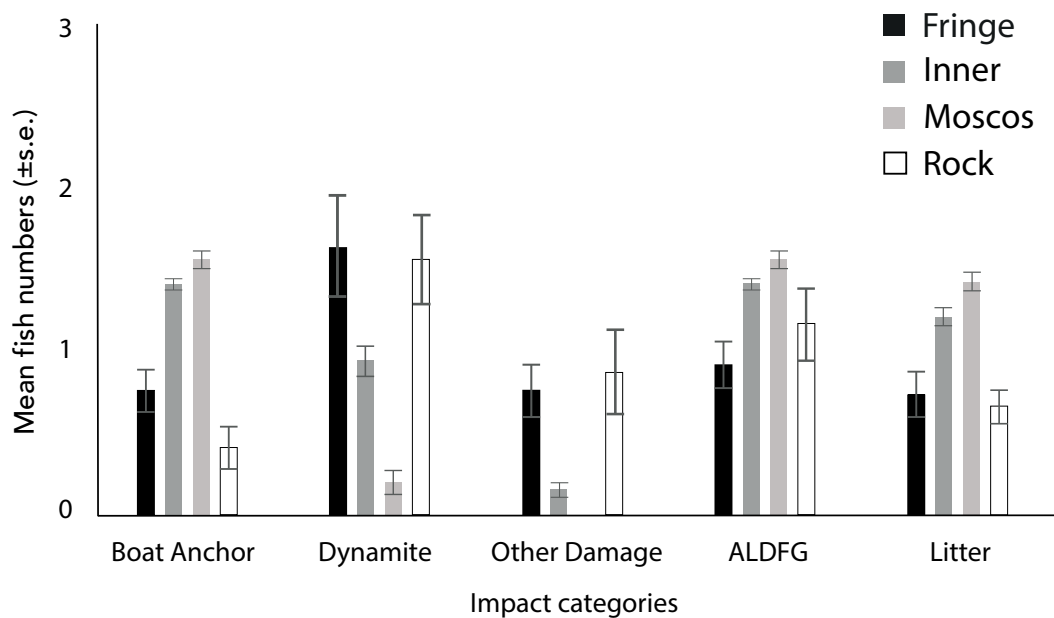
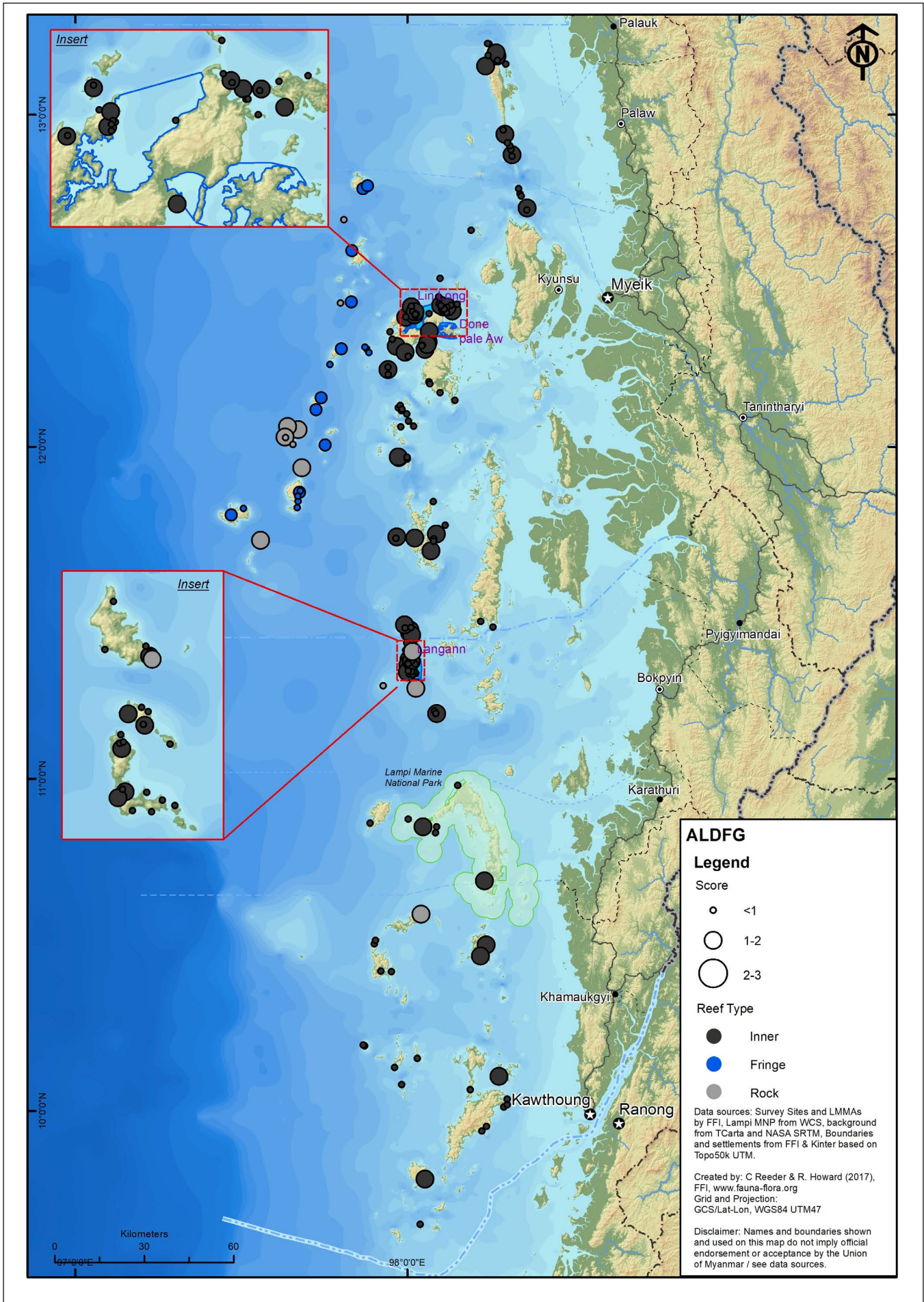
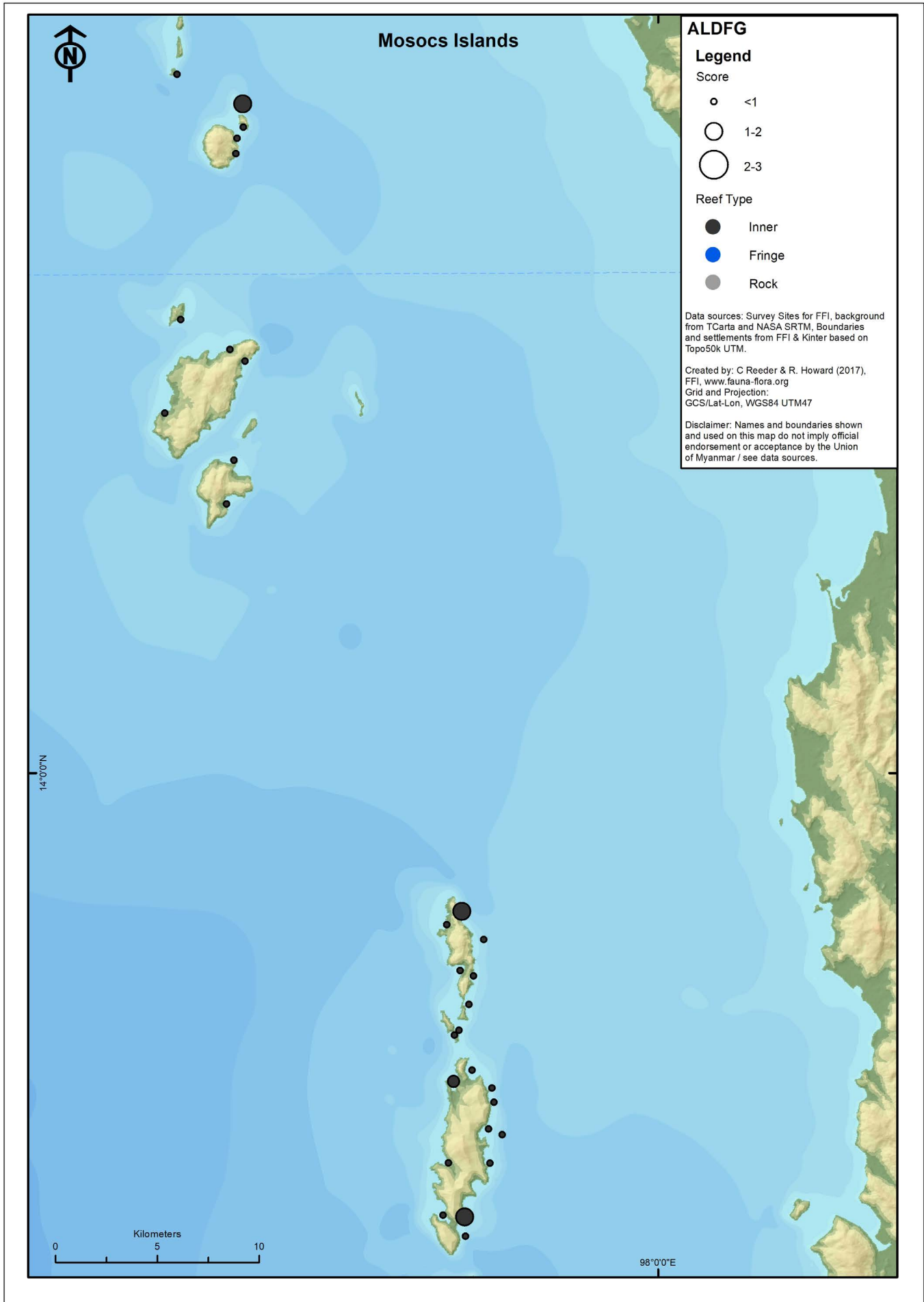
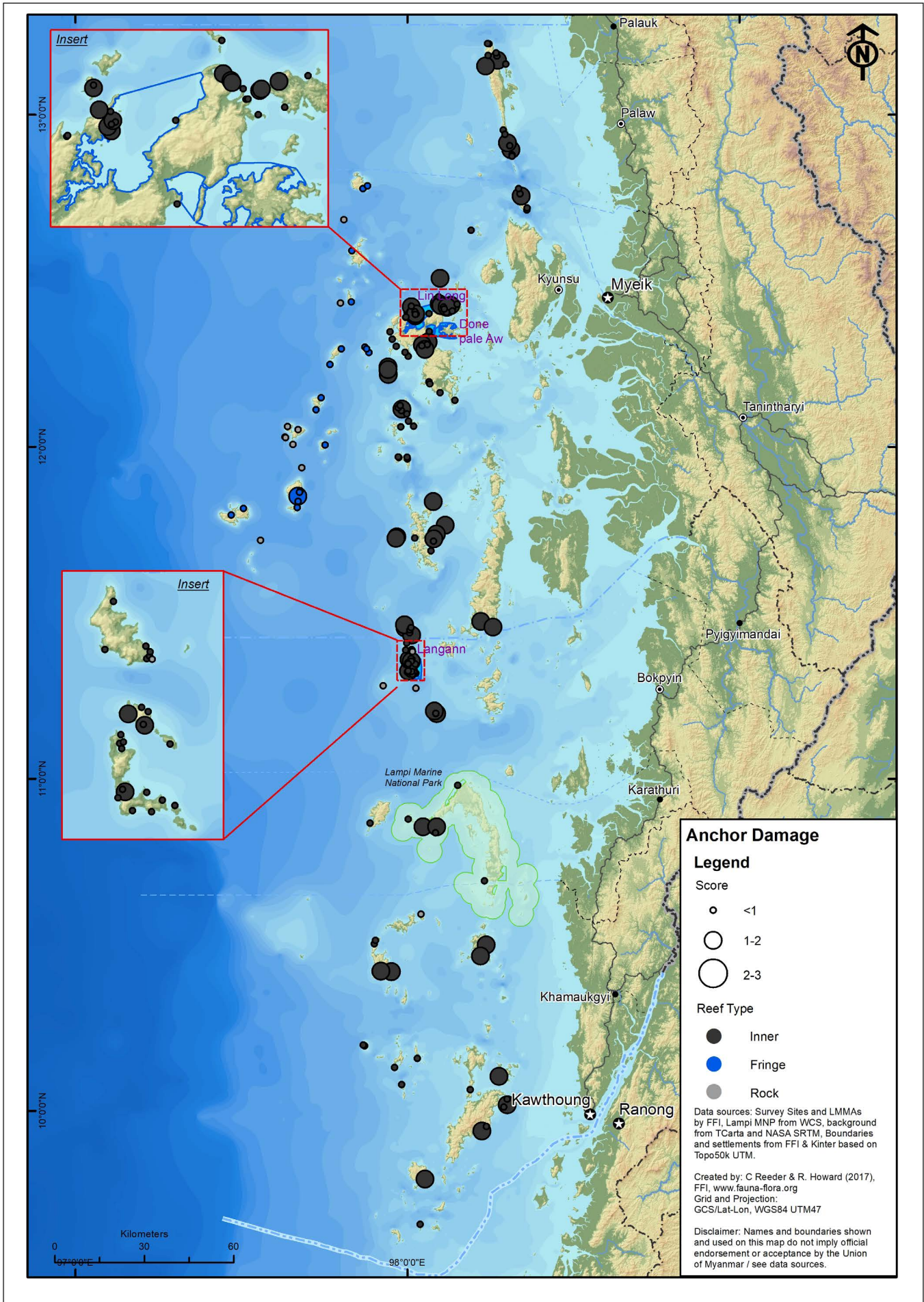
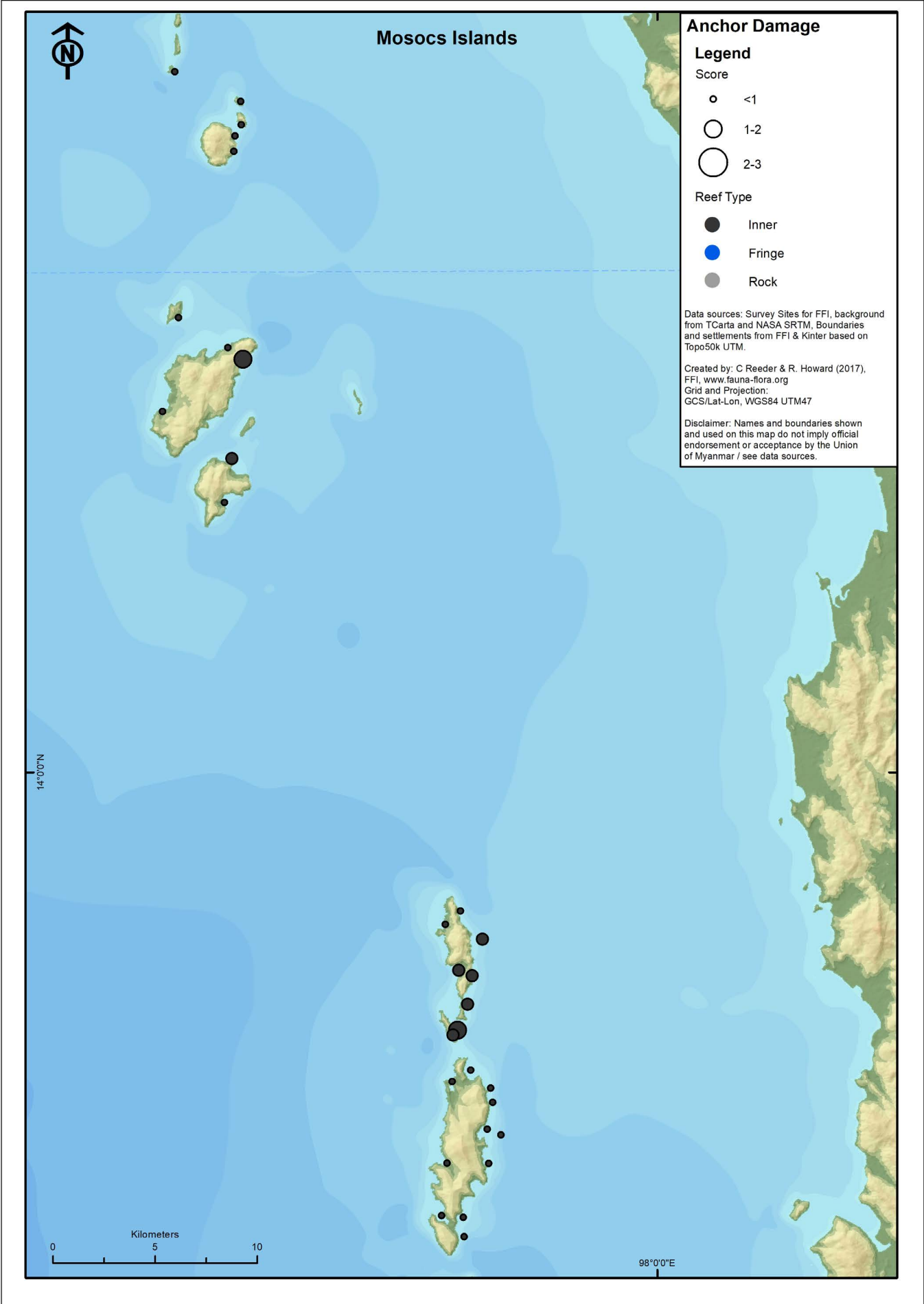


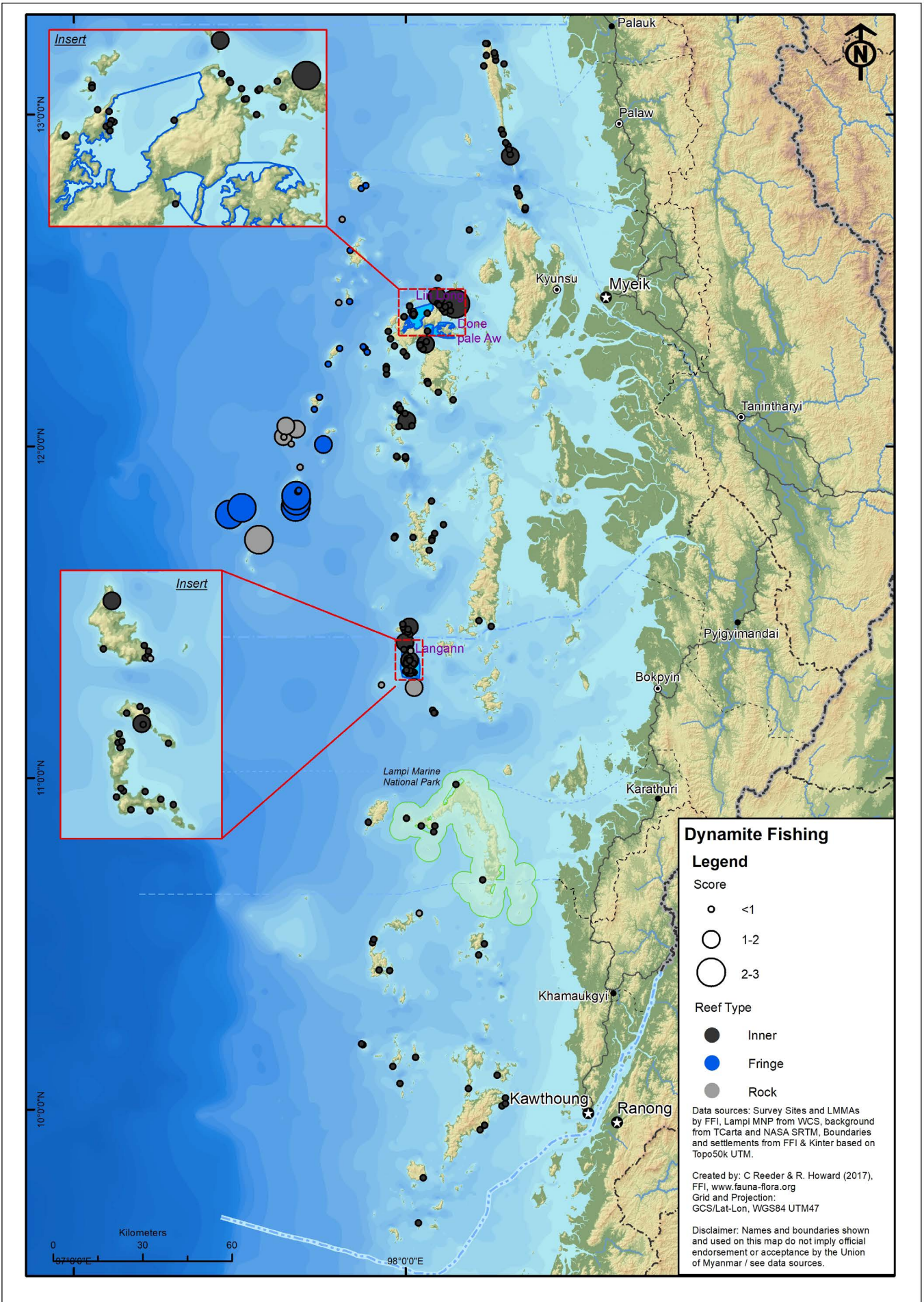
Figure 30. Impact score (0 no damage, 3 highest damage) for the five anthropogenic impacts assessed by geographical area: Fringe (n=19); Inner (n=150), Moscos (n=30); and Rock (n=13). (ALDFG- Abandoned, Lost or otherwise discarded fishing gear).



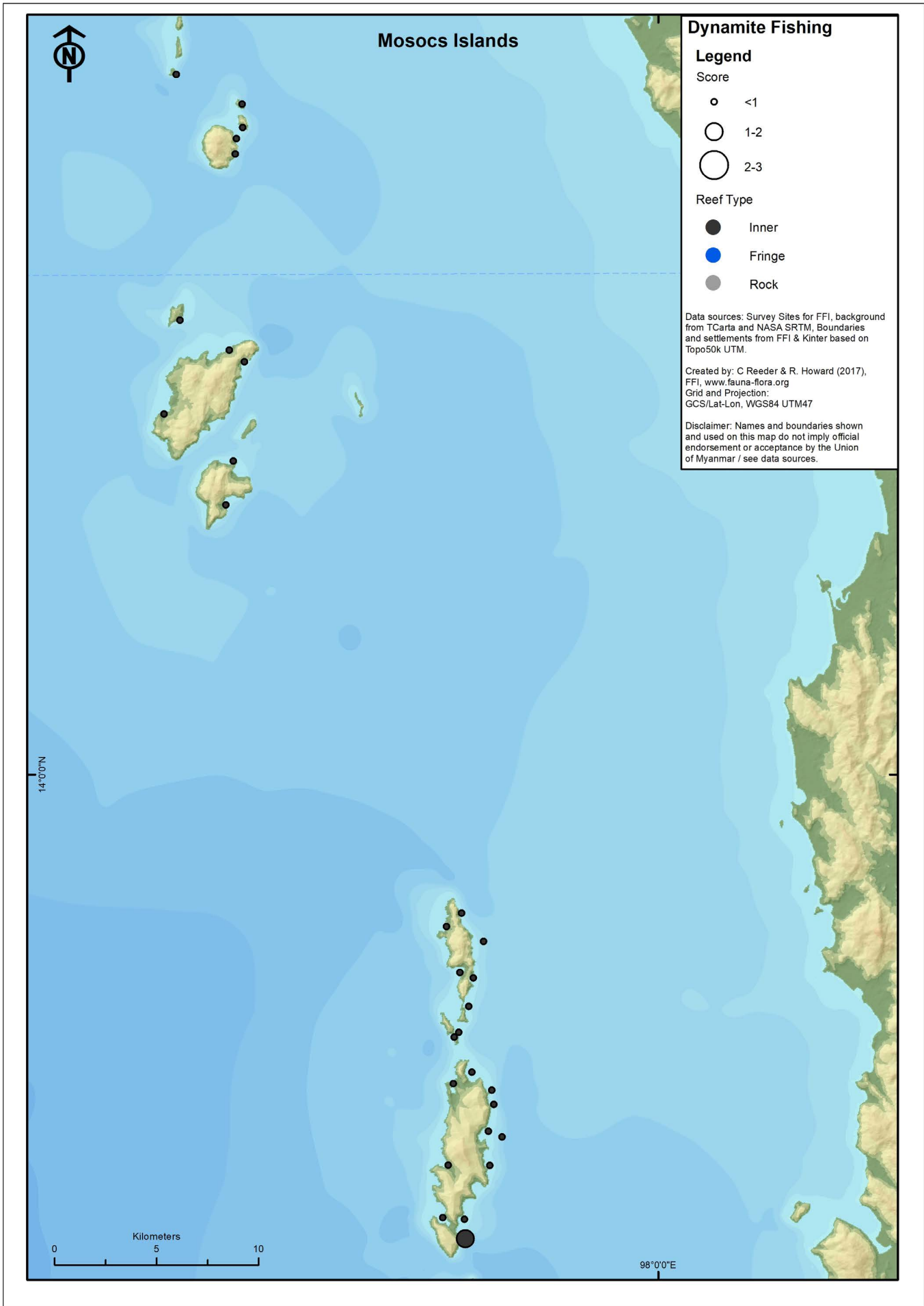


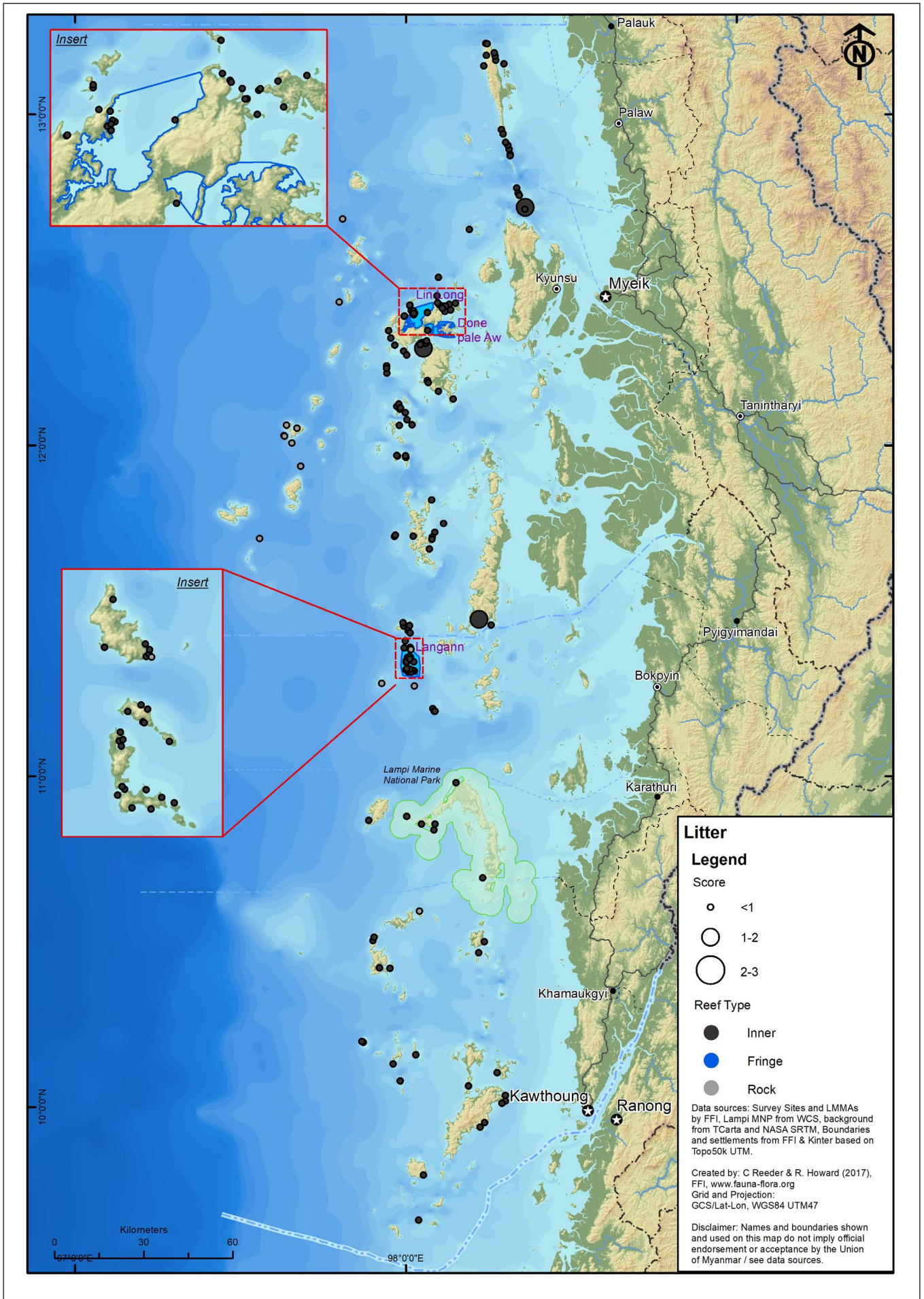


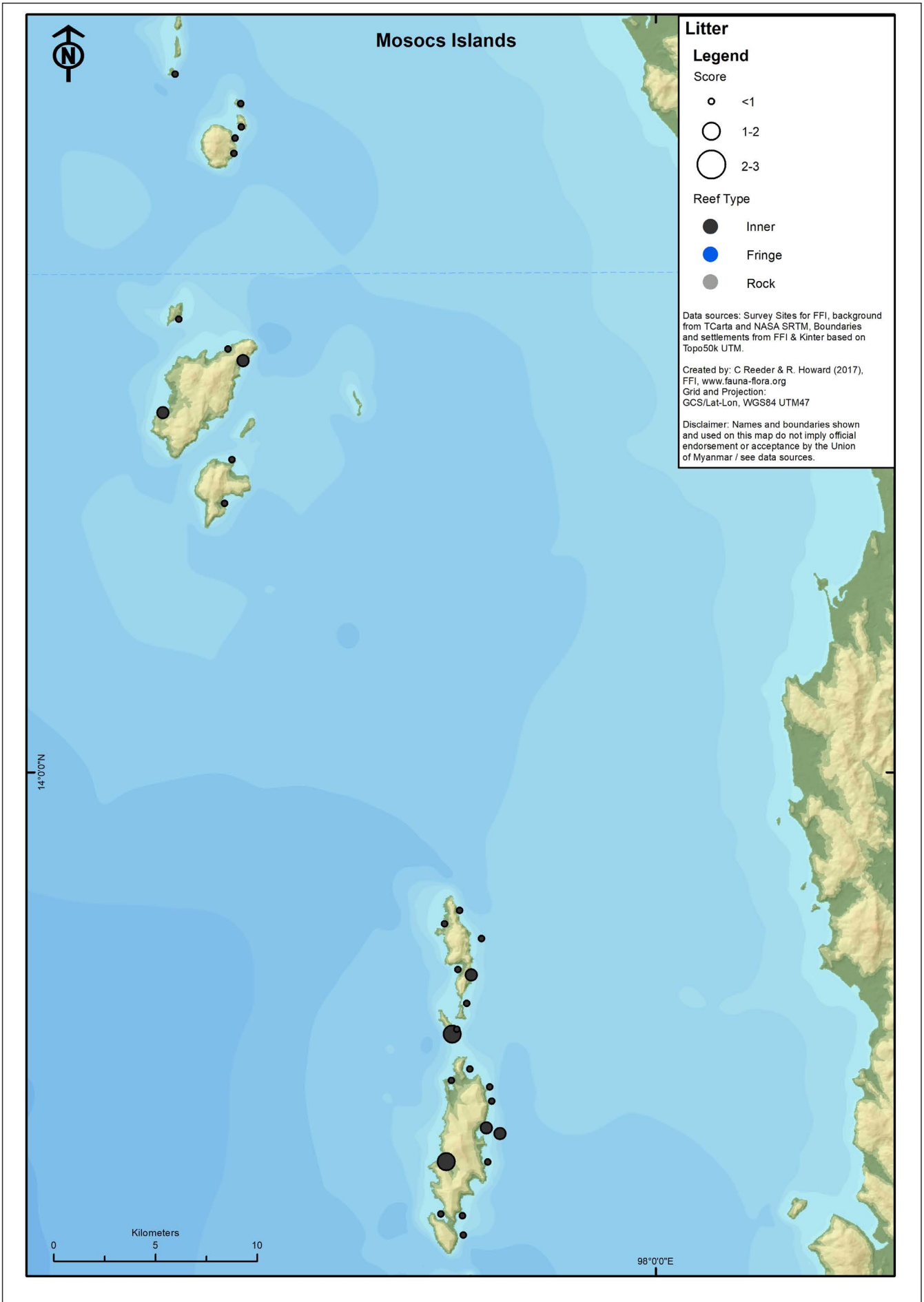


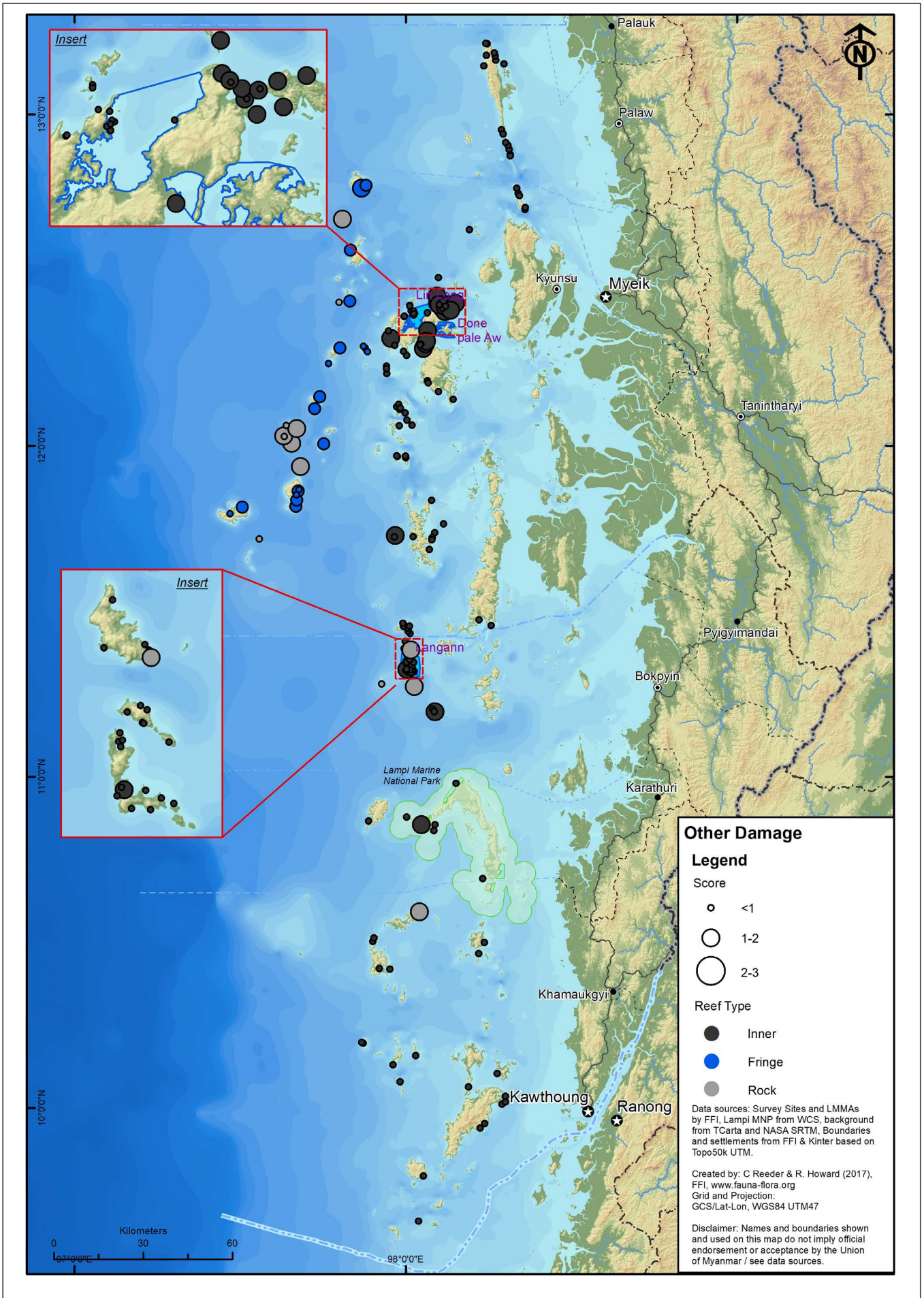












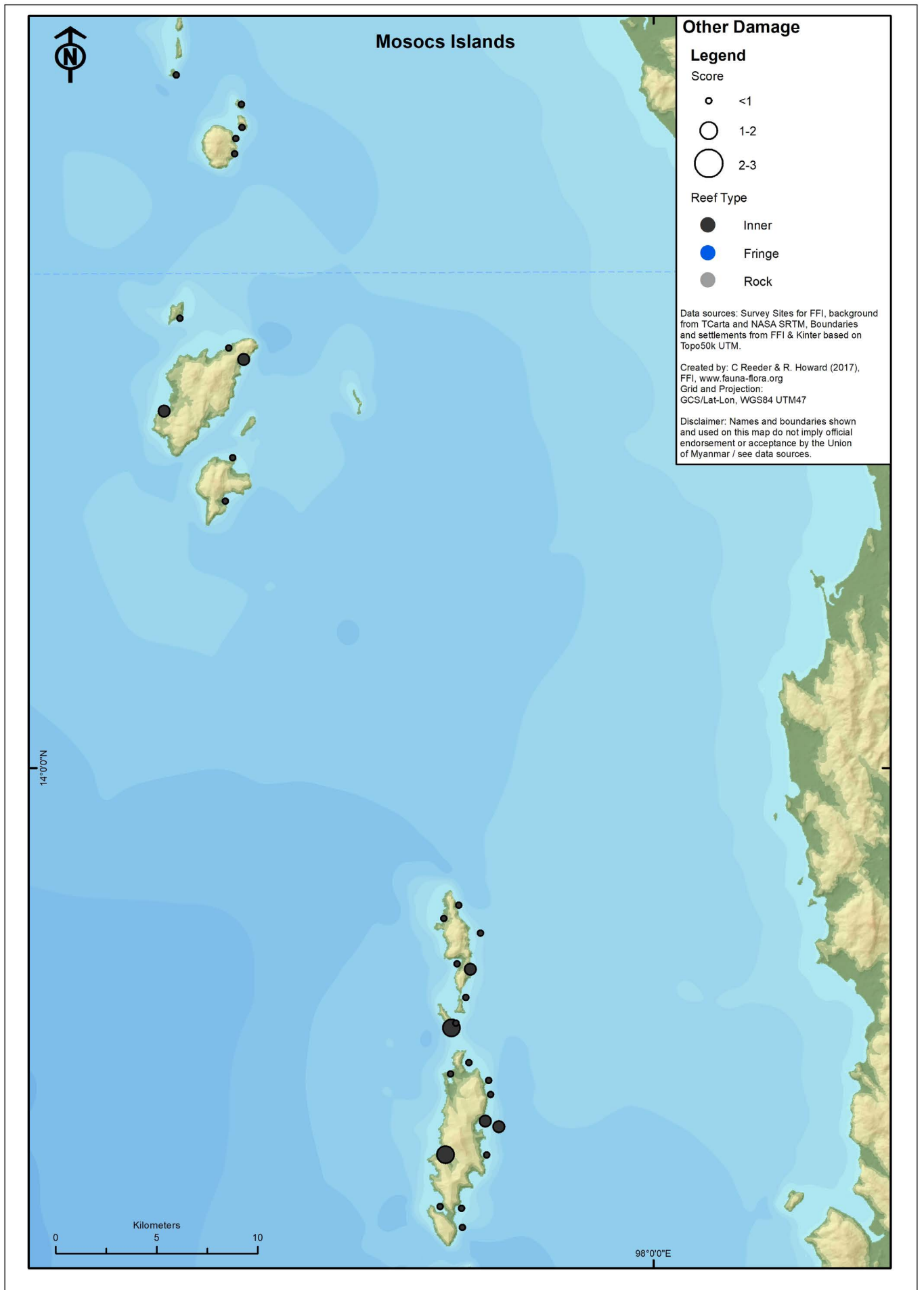


Figure 31. Impact score (0 no damage, 3 highest damage) for the five anthropogenic impacts assessed a. ALDGF b. Boat Anchor; b. Dynamite; c. Litter; d. Other. (ALDGF- Abandoned, Lost or otherwise discarded fishing gear).

## DISCUSSION

Although the overall impact score for the archipelago for each variable was in the low damage category, most sites recorded some level of damage and 71 of the 212 sites surveyed for impacts by Reef Check recording medium to high impacts (i.e. 2 to 3 score). In comparisons to surveys from Malaysia, Myanmar reefs show higher incidences of damage especially in terms of dynamite fishing and discarded fishing nets but show similar impact scores across all categories with reefs in Indonesia (Habibi et al., 2007; Yewdall, 2013). What is most concerning for the reefs in Myanmar is the continued use of dynamite fishing across the archipelago. This form of fishing, not only negatively effects the fish populations which the users are targeting but also smaller non target fish, invertebrates and can lead to declines in demersal plankton (Guard and Masaiganah, 1997). Application of the law banning the use of this method needs to be strongly enforced to ensure recovery of the habitat on which so many species rely.

Like dynamite, casting of boat anchors onto the coral reefs is also having a damaging impact within the archipelago and this is most prevalent in Inner and Moscos reefs. In the Inner reefs this result may be due to these reefs close proximity to a large fishing centres, and therefore more boat traffic passing through these islands. While in Moscos, which showed less fishing pressure (see Chapter 3) these islands are the only refuge for boats in poor weather and are regularly used to shelter. The islands around these two reef types are of great importance to the archipelago given the high coral cover observed here and therefore management interventions such as no anchoring areas or public moorings need to be established to ensure these reefs stay intact. As for the discarded fishing nets, it's unknown if these nets were used for trawling directly adjacent or above the reefs or whether they drifted onto the reefs once lost. Either way the mere presence of these nets over the reefs could have negative effects on coral growth and recruitment as many of them were observed covered in algae and smothering the substrate. Stopping these nets from being entangled in the reef will require both rigorous application of the law pertaining to trawling grounds and clean up divers removing the nets from the reef which could be done community groups involved in marine conservation.

## Recommendations for conservation

- The Myanmar Marine Fisheries Law of 1990 prohibits the use of explosives for fishing. Although the amount of dynamite fishing has apparently reduced in the past few years its use is still wide spread. Stricter punishments need to be given to those flaunting the well-known law and source of the explosives identified so that action can be taken to deal with the trade.
- The impact of discarded fishing nets not only effects the reef but also floating ghosts nets still catch fish and other marine life as well as being a nuisance for boat propellers. Education programs need to target this very issue and draw attention to the threat it has on the marine environment. This should be coupled with ghost net clean-ups using volunteer divers which has already started in 2017 (pers. comm. Thanda Ko Gyi)
- Given the number of fishing boats and the ever increasing numbers of tourism boats, the latter which gravitate to coral reefs, anchor damage will only increase if measures are not put in place to reduce the impact. This should start with an awareness campaign targeting boat skippers about the importance of the reefs to the fishery and to tourists and followed by the installation of mooring buoys in sensitive areas with high boat traffic. Lessons could be learnt from neighbouring countries such as Thailand reading materials to use and how to avoid theft or vandalism to the structures.
- General waste notably plastics is an issue across the region and any management interventions need to start with the city centers, in this case Myeik, Dawei and Kawthaung. This will require the support of large funding bodies to support the large infrastructure to handle the vast amount of waste being accumulated. Steps have been made by the local government in Myeik in recent years with street rubbish bins and collections becoming more common. This however does not deal the issue of people still throwing plastic bags, wrappers, bottles etc. on the ground or into the water. Like many other countries before this was tackled with nationwide 'clean-up' campaigns teaching people of the issue of waste and dispose of rubbish responsibly.



# 8 CONSERVATION RECOMMENDATIONS

As the preceding chapters have shown the Myeik Archipelago is a biologically rich and diverse seascape abound with unique, rare and threatened flora and fauna. Myanmar as a whole is a place of exceptional significance for its potential contribution to marine biodiversity and ecosystem service conservation. However, over recent times, impacts from human activities such as overfishing, dynamite fishing, land conversion, and pollution have had rapid and widespread negative impacts on marine ecosystems. This is especially true in the Archipelago, where more than 800 islands are recognized as a Key Biodiversity Area of global importance. There is urgent need to curtail these threats and at the same time move quickly to protect sites of high ecological value (see Figure 32 & 33 for recommended priority sites for protection and MPA Network establishment as identified from the data presented in this report). Establishing an ecosystem-based approach to fisheries management and developing a network of marine protected areas (MPAs) are critical management tools in this regard.

In 2016 a report was commissioned to provide a synthesis of progress made to date, identify remaining data gaps, evaluate the legal, policy, and institutional context, and suggest a road map to guide future activities for conservation management with a focus on establishing a network of MPAs in Myanmar with special reference to the Myeik Archipelago. The below is a summary of the report and the 49 recommendations for moving forward. A full description of each recommendation can be found in Dearden (2016) .

The legislative and policy environment for protected area (PA) development in Myanmar does not demonstrate international best practice. Ideally, the PA legislation should be rewritten. If this is not possible at this time, then existing legislation can be used to establish new Wildlife Sanctuaries, Marine National Parks, and Locally Managed Marine Areas (LMMAs).

There is a strong need to develop an MPA policy for Myanmar that will provide guidance to the necessary practices and principles for network development. Such a policy would complement the National Biodiversity Strategic Action Plan and the Ecotourism Policy and Management Strategy for Protected Areas, provide guidance for subsequent legislative amendments, and determine administrative arrangements necessary to implement an MPA network. Several different configurations of governance arrangements are discussed in Dearden (2016), but final determination of the optimal structure should involve widespread consultation.

Over the past few years, efforts have been made to collect available and new data on both the biophysical and socio-economic conditions of the Myeik Archipelago. Although data collection in all areas is incomplete, there exists enough information in some areas that areal designation can move forward with a degree of confidence. These areas would include, for example, seagrass, avifauna, and coral reefs. Areas that are particularly data deficient include sharks, marine mammals, as well as lesser-known species and habitats such as upwellings, species aggregations, connectivity routes, and terrestrial mammals.

In addition to data availability, it is important to assess the degree of threat, and some habitats, such as mangroves and reefs, are under more imminent threat than others, such as seagrass. The same is true in species, with sharks,

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Dearden, P. (2016). Blueprint for a network of Marine Protected Areas in the Myeik Archipelago, Myanmar. Report No.39 of the Tanintharyi Conservation Programme, a joint initiative of Fauna & Flora International (FFI), Myanmar Department of Fisheries and the Myanmar Forest Department. FFI, Yangon.



for example, being under severe threat. This assessment of data adequacy and threat provides a means to identify future data collection efforts, as well as priorities for establishment of protective status. Overall, the mangrove/mudflat/avifauna habitat comes out as being of very high priority due to its still remarkable diversity and international conservation significance, the high degree of threat currently being experienced, and the relatively high level of knowledge regarding location of potential conservation sites. Mangrove habitats also have very high levels of ecosystem service provision, and this is an area where investigation in the Myeik Archipelago has just begun.

It is globally recognized that the success of MPAs is highly related to the degree of support from local communities. This will be especially so in the Myeik Archipelago, where there is virtually no enforcement capability. Communities have to see it as being in their own long term best interest if they are to become positively involved with conservation initiatives. Consultations in the Archipelago suggest a strong concern over the declining catches that are being experienced, and a keen interest in improved fisheries management and conservation amongst a wide range of stakeholders. It is critical that any proposed conservation measures do not have a disproportionately negative impact on the poorer sectors of society.

Some conservation sites have already been established in the Myeik Archipelago, such as Moscos Wildlife Sanctuary and Lampi Marine National Park. These have been ineffectual as conservation sites due to a lack of management inputs. Lampi now has a new management plan, and every effort is being made by Instituto Oikos to support the plan achieving its goals. Establishing a strong conservation presence at Lampi provides a cornerstone for conservation throughout the Archipelago. Moscos needs further examination, and development and implementation of a management plan to improve its effectiveness, particularly with regard to marine protection.

The MPA policy suggested above will outline various principles for guiding MPA network establishment in more detail, but a community-based approach, an ecosystem-based approach, and a phased, adaptive, pre-cautionary approach are identified as key elements to guide network establishment. Various methodological approaches are available for network design, including computer algorithms such as Marxan. Exploration of the advantages and disadvantages of various approaches leads to recommendation for an expert and community-driven “multi-objective hotspot with complementary sites” approach that will suit the level of data availability and the need for strong community representation.

Several models are considered for network configuration, including a system of nature reserves, a system of Locally Managed Marine Areas (LMMA), a system based on marine national parks (MNPs), and an integrated regional system as represented by a biosphere reserve type of approach. These approaches are not mutually exclusive, but decisions need to be made about the optimal configuration for Myanmar. An integrated designation that treats the Myeik Archipelago as a unit for planning would yield the most satisfactory results from a technical point of view. Such a planning authority would also be able to engage readily with Thai counterparts on planning for a connected trans-boundary conservation initiative.

Myanmar is at the beginning of the journey in establishing an effective MPA network. Much needs to be done and an overview is provided of the main steps that need to be taken. Although these are presented in sequential order, it is preferable that several of these be undertaken simultaneously to speed up the process of protection. Acquiring sufficient funding to be able to undertake the necessary steps in an efficient and timely manner is also a major concern. There is very high potential for a network of MPAs in the Myeik Archipelago to become financially self-sufficient over the long term. However, funding is needed to implement critical planning, management, research, enforcement, capacity raising, and sustainable livelihood development activities in the near future. The international donor community should be invited to contribute to these tasks.

#### RECOMMENDATION 1: NATIONAL AND LOCAL CONTEXT IS PARAMOUNT.

Tailor the MPA network to the national, regional and local contexts being considered for the initiative to maximize chance of successful outcomes

#### RECOMMENDATION 2: FORMATION OF PRELIMINARY SCRUTINY BODY

The Minister should implement section 8e of the Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law (1994) and form a Public Scrutiny Body to examine the affected rights of the public from the formation of protected areas.

#### RECOMMENDATION 3: NEW PROTECTED AREA LEGISLATION FOR MYANMAR

Draft new protected area legislation for Myanmar based upon current international best practice that includes a chapter specifically devoted to MPA network establishment and management.

#### RECOMMENDATION 4: NEW MPA LEGISLATION FOR MYANMAR

If recommendation 1 cannot be implemented then separate MPA legislation should be enacted taking into account the current amendments to the Fisheries Act to permit LMMA establishments

#### RECOMMENDATION 5: REVISE EXISTING LEGISLATION.

If recommendations 1 and 2 cannot be implemented then a thorough revision of the “Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law” (1994) should be drafted paying particular attention to the items of international best practice noted above as well as the many subsequent details that will follow the policy document to be recommended in the next section.

#### RECOMMENDATION 6. MAINTAIN THE LMMA CATEGORY OF MPA UNDER THE FISHERIES ACT.

The way in which legislation works varies from country to country and what works well in one country may not do so in another. For that reason it is advisable to supplement technical advice with political advice from each country.

#### RECOMMENDATION 7: ENGAGE THE SPECIAL TASK FORCE ON ENVIRONMENTAL POLICY, LAW AND PROCEDURES

Request the Special Task Force on Environmental Policy, Law and Procedures under the Environmental Conservation Committee to review and make recommendations on PA legislation in general and MPA legislation in particular.

#### RECOMMENDATION 8: VISION FOR MPA NETWORK IN MYANMAR

Establish a vision for an MPA network in Myanmar to guide policy development.

#### RECOMMENDATION 9: DEVELOP A MPA POLICY FOR MYANMAR

Develop, through a stakeholder-driven process, an MPA policy for Myanmar that provides a platform for legislative reform and guidelines for network and site implementation to meet national goals and international commitments.

#### RECOMMENDATION 10: DEVELOP AN ACTION PLAN FOR MPA DEVELOPMENT IN MYANMAR.

Making full use of existing policies and action plans develop an Action Plan for MPA Development in Myanmar that accelerates the speed of development envisioned in other plans, broadens their recommendations to explicitly include the marine environment and develops stand-alone recommendations, timelines and responsibilities that will lead to establishment of an effective MPA network in Myanmar.

#### RECOMMENDATION 11: SUPPORT IMPLEMENTATION OF 15% REEF PROTECTION

Assist the Myanmar government to meet their stated goal of protecting 15% of Myanmar reefs by 2020.

#### RECOMMENDATION 12: ENGAGE THE SPECIAL TASK FORCE ON ENVIRONMENTAL POLICY, LAW AND PROCEDURES

Request the Special Task Force on Environmental Policy, Law and Procedures under the Environmental Conservation Committee to review and make recommendations on optimal institutional arrangements for effective development of the MPA network in Myanmar.

#### RECOMMENDATION 13: ESTABLISH A HIGH LEVEL WORKING GROUP ON INSTITUTIONAL ARRANGEMENTS.

Failing the willingness or ability of the Task Force to assist in the determination of an optimal institutional MPA model then a small working group should be established composed of Union and regional government representatives

ALONG WITH OTHER STAKEHOLDERS AS RELEVANT TO UNDERTAKE THE TASK.

#### RECOMMENDATION 14: IDENTIFY CONSERVATION TARGETS AT THE NATIONAL, REGIONAL AND SITE LEVELS.

Identify key biodiversity features and targets for their protection within the Myanmar MPA network.

#### RECOMMENDATION 15: PROTECT 15% OF REEFS NOW

Given the official Myanmar target of protecting 15% of the country's reefs, immediate steps should be taken to translate this goal into a specific areal target, identify priority candidates and design and implement a protective strategy immediately.

#### RECOMMENDATION 16: USE INTERIM MEASURES FOR REEF PROTECTION.

The small sites already identified as potential no-take zones in the Myeik Archipelago should be protected in the short term through a fisheries notification while the longer time scale details of MPA network design and management are established

#### RECOMMENDATION 17: SEAGRASS PROTECTION

Seagrass is an important habitat for both diversity and ecosystem services, the information for the Myeik Archipelago appears to be relatively complete and identified sites should be included in MPA network design at the first opportunity.

#### RECOMMENDATION 18: MANGROVE PROTECTION

As a matter of urgency collect the necessary outstanding information to identify the most effective sites for mangrove conservation, determine the necessary boundaries and work with local communities to develop effective protection regimes.

#### RECOMMENDATION 19: PAYMENT FOR ECOSYSTEM SERVICES (PES) PROTECTION

Undertake a preliminary analysis of the potential for funding for mangrove protection in the Myeik Archipelago to be derived from PES and the specific steps that would be necessary to access such funding.

#### RECOMMENDATION 20: PROTECTION OF OTHER HABITATS.

Identify main gaps in information base on other significant habitats in the Myeik Archipelago that have yet to be addressed and prioritise future data collection.

#### RECOMMENDATION 21: SHARK POPULATIONS

Establish a Baited Remote Underwater Video field programme to document remaining population distributions.

#### RECOMMENDATION 22: SHARK PROTECTION.

Cancel the ineffective shark no-take zones, maintain and strengthen the national ban on shark fishing and establish total no-take fishing zones at reef sites.

#### RECOMMENDATION 23: RAY PROTECTION.

Undertake further research to document ray distributions and designate important aggregation sites as protected with a fisheries notification

#### RECOMMENDATION 24: TURTLE PROTECTION

Enforce regulations at existing conservation sites and undertake further research to identify additional sites where turtle protection should be a priority.

#### RECOMMENDATION 25: MARINE MAMMAL PROTECTION

Marine mammal distributions and numbers are very poorly known and a major effort should be made to rectify this situation and identify potential critical habitats for protection.

#### RECOMMENDATION 26: AVIFAUNA PROTECTION

The Myeik Archipelago has globally significant bird populations and the habitats required to protect these populations have been largely identified and should be protected as per recommendations 18 and 19 above and include upland and island forests.

#### RECOMMENDATION 27: OTHER SPECIES

The lack of knowledge regarding the status and distribution of other species, such as island and coastal mammals, should be addressed immediately to inform better conservation decisions.

#### RECOMMENDATION 28: ECOSYSTEM SERVICES

Identify and map main sources of ecosystem service provision in the Myeik Archipelago, determine potential conservation protection designations and explore possibilities of developing PES agreements

#### RECOMMENDATION 29: SOCIO-ECONOMIC DATA ADEQUACY

There needs to be additional socio-economic surveys that will encompass the entire Myeik Archipelago and also provide greater depth of understanding on issues identified in existing studies.

#### RECOMMENDATION 30: SOCIETAL HETEROGENEITY AND EQUITY.

Given the societal heterogeneity present in the Myeik Archipelago, it is essential that any conservation initiatives do not disproportionately disadvantage any groups without full measures taken to redress the situation.

#### RECOMMENDATION 31: COMPRESSOR FISHING

Ban compressor fishing and undertake extensive outreach to explain to fishers why such a step is necessary

#### RECOMMENDATION 32: SUSTAINABLE LIVELIHOODS AND CAPACITY BUILDING.

Design, resource and implement an effective sustainable alternative livelihoods programme, including capacity building, in consultation with communities

#### RECOMMENDATION 33: STRATEGIC ECOTOURISM PLAN

Design and implement a strategic tourism plan for the Myeik Archipelago that seeks to optimize conservation and community benefits (see for Figure 34 for map developed to guide the plan).

#### RECOMMENDATION 34: RELATIVE PRIORITIES FOR FUTURE DATA COLLECTION

The synthesis suggests that highest priorities for future data collection efforts should be: mangroves, sharks, ecosystem services and socio-economic data.

#### RECOMMENDATION 35: RELATIVE BIOPHYSICAL PRIORITIES FOR ESTABLISHING PROTECTION.

The synthesis suggests that the highest priorities for immediate protection should be: mangroves (avifauna) and coral.

#### RECOMMENDATION 36: LAMPI MARINE NATIONAL PARK

Establishing a strong conservation presence at Lampi is a cornerstone for improved conservation throughout the Myeik Archipelago. Every effort should be made to support plan implementation and make Lampi a successful model for conservation efforts throughout the Myeik Archipelago.

#### RECOMMENDATION 37: MOSCOS ISLAND WILDLIFE SANCTUARY

Further effort needs to be invested in Moscos to determine its current and potential future contribution to conservation efforts, determine a suitable management structure in accord with the overall Myeik Archipelago conservation plan and establish a management plan and necessary management activities.

#### RECOMMENDATION 38: LMMAS

Continue planning and implementation of the three existing LMMAs and await decision on overall MPA system

design to ascertain most favourable sites for future expansion.

#### RECOMMENDATION 39: A COMMUNITY-BASED STRATEGIC ECOTOURISM PLAN.

Design and implement a community-based strategic ecotourism plan for the Myeik Archipelago that will provide alternative livelihoods to communities.

#### RECOMMENDATION 40: A COMMUNITY-BASED APPROACH

Adopt a community-based approach to all aspects of MPA network design and implementation in the Myeik Archipelago and ensure that conservation measures do not have a disproportionate impact on the poorer sectors of society

#### RECOMMENDATION 41: AN ECOSYSTEM-BASED APPROACH

Adopt an ecosystem-based approach to MPA network establishment in the Myeik Archipelago that pays full attention to environmental issues and concerns arising outside the borders of protected areas.

#### RECOMMENDATION 42: FISHERIES PATROLS

Seek to improve adherence to existing fisheries regulations and enforce future protective measures by instigating a patrol system that could include communities, the Department of Fisheries, the Marine Police, the Navy and other potential partners.

#### RECOMMENDATION 43: A PHASED, ADAPTIVE APPROACH

Establish the MPA network in a phased, precautionary approach that reflects conservation priorities and feasibility and develop an adaptive approach to management.

#### RECOMMENDATION 44: MONITORING

Establishment of an effective monitoring system (biophysical and socio-economic) from the outset is a necessary tool to implement effective adaptive management

#### RECOMMENDATION 45: A MULTI-OBJECTIVE HOTSPOT WITH COMPLEMENTARY SITES APPROACH.

Take a “multi-hotspot with complementary sites” approach to site selection based on the best available knowledge and community consultations.

#### RECOMMENDATION 46: SITES THAT DEMONSTRATE SUCCESS

Include the ability for a site to demonstrate success over a relatively short time period as one of the criteria for site selection.

#### RECOMMENDATION 47: MODEL FOR MPA ESTABLISHMENT

Establish a small working group composed of senior officials for relevant union and regional governments to examine the potential models for MPA network configuration and hold a small workshop to decide the optimal strategy to be presented to the relevant Ministers.

#### RECOMMENDATION 48: TRANSBOUNDARY MPAS

Initiate discussions with Thailand regarding the possibility of developing transboundary MPA network linkages across the international boundary.

#### RECOMMENDATION 49: FUNDING

Approach the international donor community to provide funding to support the further design and implementation of an effective network of MPAs in the Myeik Archipelago.

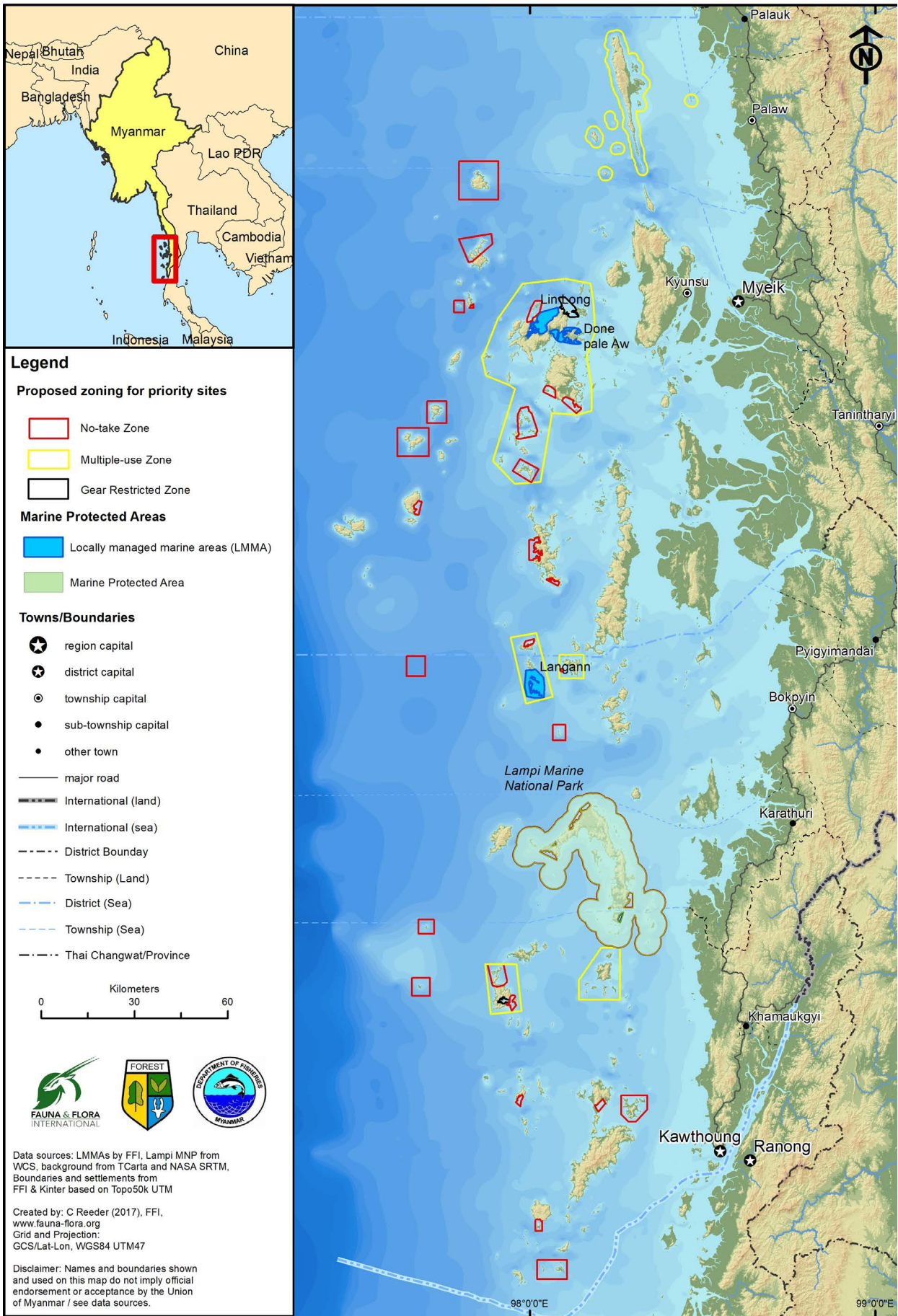


Figure 32. Myeik Archipelago priority sites for protection and MPA network establishment as identified from the data presented in this report. Map FFI.

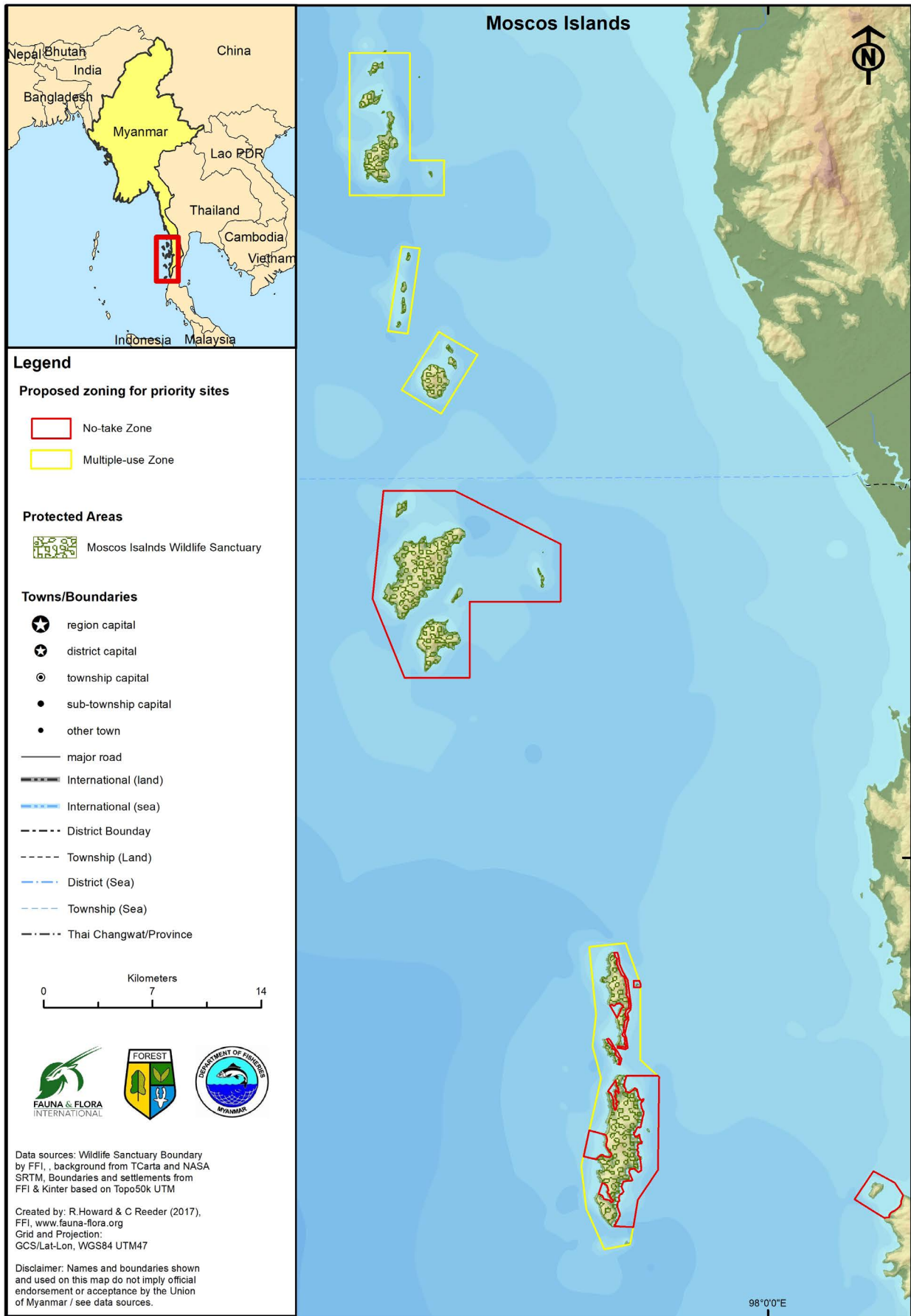


Figure 33 Moscos Islands priority sites for protection and MPA network establishment as identified from the data presented in this report. Map FFI.

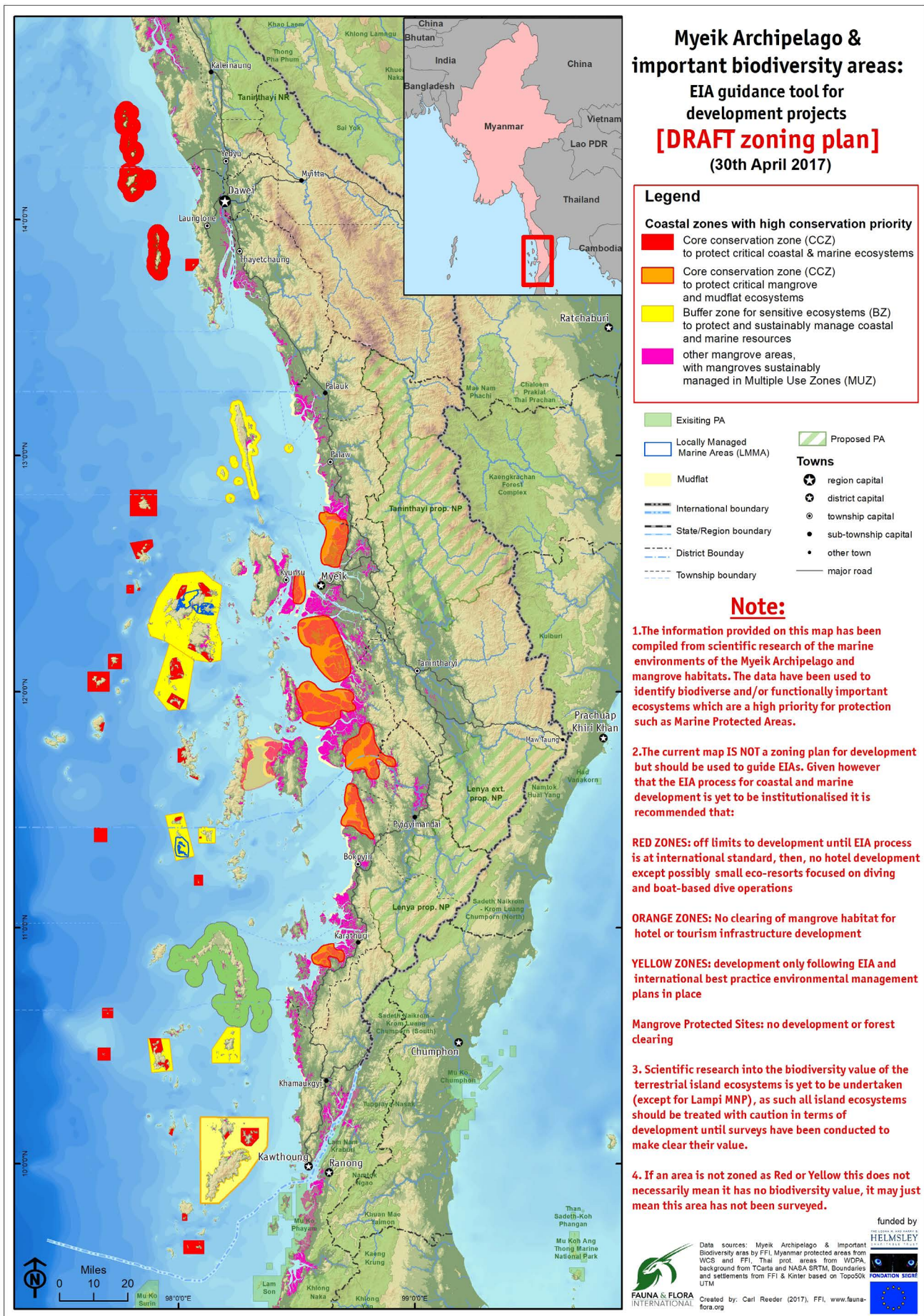


Figure 34. Map submitted to the Myanmar government in May 2017 highlighting critical and core ecosystem areas and other sensitive areas in the Myeik Archipelago and surrounding coastline designed to guide a strategic tourism plan and any tourism development (FFI).



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# 10. APPENDIX

## APPENDIX A CORAL SPECIES LIST

Dr David Obura

Genus	Species	RL
<b>Family: Acroporidae</b>		
<i>Acropora</i>	<i>acuminata</i>	VU
<i>Acropora</i>	<i>appressa</i>	NT
<i>Acropora</i>	<i>aspera</i>	VU
<i>Acropora</i>	<i>austera</i>	NT
<i>Acropora</i>	<i>bifurcata</i>	DD
<i>Acropora</i>	<i>cerealis</i>	LC
<i>Acropora</i>	<i>clathrata</i>	LC
<i>Acropora</i>	<i>cytherea</i>	LC
<i>Acropora</i>	<i>digitifera</i>	NT
<i>Acropora</i>	<i>divaricata</i>	NT
<i>Acropora</i>	<i>echinata</i>	VU
<i>Acropora</i>	<i>gemmifera</i>	LC
<i>Acropora</i>	<i>granulosa</i>	NT
<i>Acropora</i>	<i>horrida</i>	VU
<i>Acropora</i>	<i>humilis</i>	NT
<i>Acropora</i>	<i>hyacinthus</i>	NT
<i>Acropora</i>	<i>inermis</i>	DD
<i>Acropora</i>	<i>intermedia</i>	LC
<i>Acropora</i>	<i>kosurini</i>	VU
<i>Acropora</i>	<i>latistella</i>	LC
<i>Acropora</i>	<i>loripes</i>	NT
<i>Acropora</i>	<i>lutkeni</i>	NT
<i>Acropora</i>	<i>macrostoma</i>	DD
<i>Acropora</i>	<i>microphthalma</i>	LC
<i>Acropora</i>	<i>muricata</i>	NT
<i>Acropora</i>	<i>nana</i>	NT
<i>Acropora</i>	<i>nasuta</i>	NT
<i>Acropora</i>	<i>retusa</i>	VU
<i>Acropora</i>	<i>robusta</i>	LC
<i>Acropora</i>	<i>roseni</i>	EN
<i>Acropora</i>	<i>rudis</i>	EN
<i>Acropora</i>	<i>samoensis</i>	LC

<i>Acropora</i>	<i>secale</i>	NT
<i>Acropora</i>	<i>selago</i>	NT
<i>Acropora</i>	<i>spicifera</i>	VU
<i>Acropora</i>	<i>subulata</i>	LC
<i>Acropora</i>	<i>tenuis</i>	NT
<i>Acropora</i>	<i>valida</i>	LC
<i>Acropora</i>	<i>zp1</i>	-
<i>Alveopora</i>	<i>tizardi</i>	LC
<i>Astreopora</i>	<i>expansa</i>	NT
<i>Astreopora</i>	<i>gracilis</i>	LC
<i>Astreopora</i>	<i>incrustans</i>	VU
<i>Astreopora</i>	<i>listeri</i>	LC
<i>Astreopora</i>	<i>myriophthalma</i>	LC
<i>Astreopora</i>	<i>ocellata</i>	LC
<i>Isopora</i>	<i>palifera</i>	NT
<i>Montipora</i>	<i>aequituberculata</i>	LC
<i>Montipora</i>	<i>calcareo</i>	VU
<i>Montipora</i>	<i>confusa</i>	VU
<i>Montipora</i>	<i>cryptus</i>	NT
<i>Montipora</i>	<i>digitata</i>	LC
<i>Montipora</i>	<i>efflorescens</i>	NT
<i>Montipora</i>	<i>effusa</i>	NT
<i>Montipora</i>	<i>floweri</i>	LC
<i>Montipora</i>	<i>foveolata</i>	NT
<i>Montipora</i>	<i>hispida</i>	LC
<i>Montipora</i>	<i>informis</i>	LC
<i>Montipora</i>	<i>monasteriata</i>	LC
<i>Montipora</i>	<i>nodosa</i>	NT
<i>Montipora</i>	<i>spongodes</i>	LC
<i>Montipora</i>	<i>stilosa</i>	VU
<i>Montipora</i>	<i>tuberculosa</i>	LC
<i>Montipora</i>	<i>undata</i>	NT
<i>Montipora</i>	<i>verrucosa</i>	LC

Family: Agariciidae		
<i>Coeloseris</i>	<i>mayeri</i>	LC
<i>Gardineroseris</i>	<i>planulata</i>	LC
<i>Leptoseris</i>	<i>amitoriensis</i>	NT
<i>Leptoseris</i>	<i>foliosa</i>	LC
<i>Leptoseris</i>	<i>glabra</i>	LC
<i>Leptoseris</i>	<i>incrustans</i>	VU
<i>Leptoseris</i>	<i>mycetoseroides</i>	LC
<i>Leptoseris</i>	<i>scabra</i>	LC
<i>Leptoseris</i>	<i>solida</i>	LC
<i>Pachyseris</i>	<i>rugosa</i>	VU
<i>Pachyseris</i>	<i>speciosa</i>	LC
<i>Pavona</i>	<i>cactus</i>	VU
<i>Pavona</i>	<i>clavus</i>	LC
<i>Pavona</i>	<i>decussata</i>	VU
<i>Pavona</i>	<i>duerdeni</i>	LC
<i>Pavona</i>	<i>explanulata</i>	LC
<i>Pavona</i>	<i>maldivensis</i>	LC
<i>Pavona</i>	<i>varians</i>	LC
<i>Pavona</i>	<i>venosa</i>	VU
Family: Astrocoeniidae		
<i>Stylocoeniella</i>	<i>armata</i>	LC
<i>Stylocoeniella</i>	<i>guentheri</i>	LC
Family: Coscinaraeidae		
<i>Anomastrea</i>	<i>irregularis</i>	VU
<i>Coscinaraea</i>	<i>columna</i>	LC
<i>Coscinaraea</i>	<i>crassa</i>	NT
<i>Coscinaraea</i>	<i>exesa</i>	LC
<i>Coscinaraea</i>	<i>monile</i>	LC
<i>Coscinaraea</i>	<i>wellsi</i>	LC
<i>Coscinaraea</i>	<i>zp1</i>	-
Family: Dendrophylliidae		
<i>Tubastrea</i>	<i>micrantha</i>	NE
<i>Tubastrea</i>	<i>spp</i>	-
<i>Turbinaria</i>	<i>frondens</i>	LC
<i>Turbinaria</i>	<i>irregularis</i>	LC
<i>Turbinaria</i>	<i>mesenterina</i>	VU
<i>Turbinaria</i>	<i>peltata</i>	VU

<i>Turbinaria</i>	<i>stellulata</i>	VU
Family: Euphyllidae		
<i>Euphyllia</i>	<i>ancora</i>	VU
<i>Euphyllia</i>	<i>glabrescens</i>	NT
<i>Physogyra</i>	<i>lichtensteini</i>	VU
<i>Plerogyra</i>	<i>sinuosa</i>	NT
Family: Faviidae		
<i>Barabattoia</i>	<i>amicorum</i>	LC
<i>Caulastrea</i>	<i>connata</i>	VU
<i>Cyphastrea</i>	<i>chalcidicum</i>	LC
<i>Cyphastrea</i>	<i>microphthalma</i>	LC
<i>Cyphastrea</i>	<i>serailia</i>	LC
<i>Diploastrea</i>	<i>heliopora</i>	NT
<i>Echinopora</i>	<i>gemmacea</i>	LC
<i>Echinopora</i>	<i>lamellosa</i>	LC
<i>Echinopora</i>	<i>pacificus</i>	NT
<i>Favia</i>	<i>danae</i>	LC
<i>Favia</i>	<i>favus</i>	LC
<i>Favia</i>	<i>helianthoides</i>	NT
<i>Favia</i>	<i>lizardensis</i>	NT
<i>Favia</i>	<i>maritima</i>	NT
<i>Favia</i>	<i>matthai</i>	NT
<i>Favia</i>	<i>maxima</i>	NT
<i>Favia</i>	<i>pallida</i>	LC
<i>Favia</i>	<i>rosaria</i>	VU
<i>Favia</i>	<i>rotumana</i>	LC
<i>Favia</i>	<i>speciosa</i>	LC
<i>Favia</i>	<i>stelligera</i>	NT
<i>Favia</i>	<i>truncatus</i>	LC
<i>Favia</i>	<i>veroni</i>	NT
<i>Favia</i>	<i>vietnamensis</i>	NT
<i>Favites</i>	<i>abdita</i>	NT
<i>Favites</i>	<i>acuticolis</i>	NT
<i>Favites</i>	<i>bestae</i>	NT
<i>Favites</i>	<i>chinensis</i>	NT
<i>Favites</i>	<i>complanata</i>	NT
<i>Favites</i>	<i>halicora</i>	NT
<i>Favites</i>	<i>pentagona</i>	LC

<i>Favites</i>	<i>russelli</i>	NT
<i>Favites</i>	<i>spinosa</i>	VU
<i>Favites</i>	<i>vasta</i>	NT
<i>Goniastrea</i>	<i>aspera</i>	LC
<i>Goniastrea</i>	<i>australensis</i>	LC
<i>Goniastrea</i>	<i>edwardsi</i>	LC
<i>Goniastrea</i>	<i>minuta</i>	NT
<i>Goniastrea</i>	<i>palauensis</i>	NT
<i>Goniastrea</i>	<i>pectinata</i>	LC
<i>Goniastrea</i>	<i>retiformis</i>	LC
<i>Leptastrea</i>	<i>aequalis</i>	VU
<i>Leptastrea</i>	<i>pruinosa</i>	LC
<i>Leptastrea</i>	<i>purpurea</i>	LC
<i>Leptastrea</i>	<i>transversa</i>	LC
<i>Leptoria</i>	<i>irregularis</i>	VU
<i>Leptoria</i>	<i>phrygia</i>	NT
<i>Montastrea</i>	<i>annuligera</i>	NT
<i>Montastrea</i>	<i>curta</i>	LC
<i>Montastrea</i>	<i>magnistellata</i>	NT
<i>Montastrea</i>	<i>salebrosa</i>	VU
<i>Montastrea</i>	<i>valenciennesi</i>	NT
<i>Oulophyllia</i>	<i>crispa</i>	NT
<i>Oulophyllia</i>	<i>levis</i>	LC
<i>Parasimplastrea</i>	<i>sheppardi</i>	EN
<i>Platygyra</i>	<i>acuta</i>	NT
<i>Platygyra</i>	<i>carosus</i>	NT
<i>Platygyra</i>	<i>daedalea</i>	LC
<i>Platygyra</i>	<i>lamellina</i>	NT
<i>Platygyra</i>	<i>pini</i>	LC
<i>Platygyra</i>	<i>ryukyuensis</i>	NT
<i>Platygyra</i>	<i>sinensis</i>	LC
<i>Platygyra</i>	<i>verweyi</i>	NT
<i>Platygyra</i>	<i>yaeyamaensis</i>	VU
<i>Plesiastrea</i>	<i>versipora</i>	LC
<i>Plesiastrea</i>	<i>zp1</i>	-
<b>Family: Fungiidae</b>		
<i>Ctenactis</i>	<i>echinata</i>	LC
<i>Cycloseris</i>	<i>costulata</i>	LC

<i>Cycloseris</i>	<i>erosa</i>	LC
<i>Cycloseris</i>	<i>patelliformis</i>	LC
<i>Cycloseris</i>	<i>somervillei</i>	LC
<i>Fungia</i>	<i>concina</i>	LC
<i>Fungia</i>	<i>corona</i>	LC
<i>Fungia</i>	<i>danaei</i>	LC
<i>Fungia</i>	<i>fungites</i>	NT
<i>Fungia</i>	<i>granulosa</i>	LC
<i>Fungia</i>	<i>moluccensis</i>	LC
<i>Fungia</i>	<i>paumotensis</i>	LC
<i>Fungia</i>	<i>repanda</i>	LC
<i>Fungia</i>	<i>scabra</i>	LC
<i>Fungia</i>	<i>scruposa</i>	LC
<i>Fungia</i>	<i>scutaria</i>	LC
<i>Fungia</i>	<i>seychellensis</i>	VU
<i>Herpolitha</i>	<i>limax</i>	LC
<i>Herpolitha</i>	<i>weberi</i>	LC
<i>Lithophyllon</i>	<i>undulatum</i>	NT
<i>Podabacia</i>	<i>crustacea</i>	LC
<i>Podabacia</i>	<i>lankaensis</i>	NE
<i>Polyphillia</i>	<i>novaehiberniae</i>	NE
<i>Polyphillia</i>	<i>talpina</i>	LC
<i>Sandalolitha</i>	<i>dentata</i>	LC
<i>Sandalolitha</i>	<i>robusta</i>	LC
<b>Family: Hydrozoa</b>		
<i>Heliopora</i>	<i>coerulea</i>	VU
<i>Millepora</i>	<i>exesa</i>	LC
<i>Millepora</i>	<i>platyphylla</i>	LC
<i>Millepora</i>	<i>tenaera</i>	NE
<b>Family: Merulinidae</b>		
<i>Hydnophora</i>	<i>exesa</i>	NT
<i>Hydnophora</i>	<i>microconos</i>	NT
<i>Hydnophora</i>	<i>rigida</i>	LC
<i>Merulina</i>	<i>ampliata</i>	LC
<i>Scapophyllia</i>	<i>cylindrica</i>	LC
<b>Family: Mussidae</b>		
<i>Acanthastrea</i>	<i>brevis</i>	VU
<i>Acanthastrea</i>	<i>echinata</i>	LC

<i>Acanthastrea</i>	<i>hemprichii</i>	VU
<i>Acanthastrea</i>	<i>regularis</i>	VU
<i>Acanthastrea</i>	<i>rotundoflora</i>	NT
<i>Acanthastrea</i>	<i>subechinata</i>	NT
<i>Australomussa</i>	<i>rowleyensis</i>	NT
<i>Blastomussa</i>	<i>merletti</i>	LC
<i>Cynarina</i>	<i>lachrymalis</i>	NT
<i>Lobophyllia</i>	<i>corymbosa</i>	LC
<i>Lobophyllia</i>	<i>flabelliformis</i>	VU
<i>Lobophyllia</i>	<i>hataii</i>	LC
<i>Lobophyllia</i>	<i>hemprichii</i>	LC
<i>Lobophyllia</i>	<i>pachysepta</i>	NT
<i>Lobophyllia</i>	<i>robusta</i>	LC
<i>Micromussa</i>	<i>amakusensis</i>	NT
<i>Scolymia</i>	<i>australis</i>	LC
<i>Symphyllia</i>	<i>agaricia</i>	LC
<i>Symphyllia</i>	<i>radians</i>	LC
<i>Symphyllia</i>	<i>recta</i>	LC
<i>Symphyllia</i>	<i>valenciennesi</i>	LC

#### Family: Oculinidae

<i>Galaxea</i>	<i>fasicularis</i>	NT
<i>Galaxea</i>	<i>paucisepta</i>	NT
Family: Pectiniidae		
<i>Echinomorpha</i>	<i>nishihira</i>	NE
<i>Echinophyllia</i>	<i>aspera</i>	LC
<i>Echinophyllia</i>	<i>echinata</i>	LC
<i>Echinophyllia</i>	<i>echinoporoides</i>	LC
<i>Echinophyllia</i>	<i>patula</i>	LC
<i>Echinophyllia</i>	<i>taylorae</i>	NT
<i>Mycedium</i>	<i>elephantotus</i>	LC
<i>Mycedium</i>	<i>robokaki</i>	LC
<i>Oxypora</i>	<i>crassispinosa</i>	LC
<i>Oxypora</i>	<i>lacera</i>	LC
<i>Pectinia</i>	<i>africana</i>	VU
<i>Pectinia</i>	<i>alcicornis</i>	VU
<i>Pectinia</i>	<i>lactuca</i>	VU
<i>Pectinia</i>	<i>paeonia</i>	NT

#### Family: Pocilloporidae

<i>Madracis</i>	<i>kirbyi</i>	LC
<i>Pocillopora</i>	<i>damicornis</i>	LC
<i>Pocillopora</i>	<i>danai</i>	VU
<i>Pocillopora</i>	<i>eydouxii</i>	NT
<i>Pocillopora</i>	<i>indiana</i>	VU
<i>Pocillopora</i>	<i>ligulata</i>	LC
<i>Pocillopora</i>	<i>verrucosa</i>	LC
<i>Pocillopora</i>	<i>woodjonesii</i>	LC
<i>Pocillopora</i>	<i>zelli</i>	LC

#### Family: Poritidae

<i>Goniopora</i>	<i>albiconus</i>	VU
<i>Goniopora</i>	<i>columna</i>	NT
<i>Goniopora</i>	<i>djiboutiensis</i>	LC
<i>Goniopora</i>	<i>lobata</i>	NT
<i>Goniopora</i>	<i>minor</i>	NT
<i>Goniopora</i>	<i>pendulus</i>	LC
<i>Goniopora</i>	<i>planulata</i>	VU
<i>Goniopora</i>	<i>somaliensis</i>	LC
<i>Goniopora</i>	<i>stokesi</i>	NT
<i>Goniopora</i>	<i>stutchburyi</i>	LC
<i>Goniopora</i>	<i>zp.</i>	-
<i>Porites</i>	<i>annae</i>	NT
<i>Porites</i>	<i>aranetai</i>	VU
<i>Porites</i>	<i>australensis</i>	LC
<i>Porites</i>	<i>cylindrica</i>	NT
<i>Porites</i>	<i>deformis</i>	NT
<i>Porites</i>	<i>horizontalata</i>	VU
<i>Porites</i>	<i>lichen</i>	LC
<i>Porites</i>	<i>lobata</i>	NT
<i>Porites</i>	<i>lutea</i>	LC
<i>Porites</i>	<i>monticulosa</i>	LC
<i>Porites</i>	<i>nigrescens</i>	VU
<i>Porites</i>	<i>profundus</i>	LC
<i>Porites</i>	<i>rus</i>	LC
<i>Porites</i>	<i>silimaniana</i>	NE
<i>Porites</i>	<i>solida</i>	LC
<i>Porites</i>	<i>stephensoni</i>	NT

<b>Family: Siderastreidae</b>		
<i>Psammocora</i>	<i>albopicta</i>	DD
<i>Psammocora</i>	<i>digitata</i>	NT
<i>Psammocora</i>	<i>explanulata</i>	LC
<i>Psammocora</i>	<i>niestraazi</i>	LC
<i>Psammocora</i>	<i>obtusangula</i>	NT
<i>Psammocora</i>	<i>profundacella</i>	LC
<i>Pseudosiderastrea</i>	<i>tayami</i>	NT
<i>Pseudosiderastrea</i>	<i>zp1 (cf. formosa)</i>	-
<i>Siderastrea</i>	<i>savignyana</i>	LC
<b>Family: Trachyphylliidae</b>		
<i>Trachyphyllia</i>	<i>geoffroyi</i>	NT

RL = IUCN Redlist category

Totals= 288 species, 68 genera, 17 families.

## APPENDIX B REEF CHECK SUBSTRATE TYPES

Substrate	Code	Description
Acropora coral	ACB	Acropora Branching – coral colonies that have a tree-like formation, corals arranged in a series of fused horizontal branches. ACB shows 2nd branching with axial polyps. Their colour can vary bright to pale blue to brown.
Acropora coral	ACD	Acropora Digitata – coral colonies in the digitate category. These corals have thick, dome-shaped axial corallites. It has a solid base and branches that grow upright. They have many colours, but the most common are brown, cream, blue and purple.
Acropora coral	ACE	Acropora Encrusting – coral that are formed by thick ridges, branches, columns or encrusting plates. These colonies are generally upright but can have irregular shape (depending upon wave action), very large and have distinct Acropora polyps. They have smooth, exert and rounded corallites, generally there are no axial corallites. The colour varies from brown to pale cream.
Acropora coral	ACS	Acropora Submassive – coral with irregular shape, encrusting base with columnar branches that show distinct acropora polyps. Their central branches are thick and conical whether prostrate branches are thinner with upturned. Their colour can vary from cream to bright green to yellow-brown.
Acropora coral	ACT	Acropora Tabulate – corals colonies that have flat table-like plate formation or aggregation of small plates. The base may be formed by a fused solid mass, branchlets have an upward projection. On the margin of the table profile ACT has axial polyps, radial corallites from a rosette and are cup-shaped. Their colour varies from grey or green to brown and cream.
Non-Acropora Coral	CB	Branching coral – corals that show uniform upright branches; 2nd branching with no axial polyps. Branches are compact and thick when found and wave-exposed environments; but when found in protected areas they have more open and thinner branches. This category is for all species that show branching excluding Acropora corals.
Non-Acropora Coral	CE	Encrusting coral – species that attach itself to the hard substrate below taking the profile and shape of the substrate. Its margins are very thin and it can form plate like colonies. Their colour can vary from mottled brown or brown to white. During the day their white tentacles may be extended.
Non-Acropora Coral	CF	Foliose coral – coral colonies can be encrusting or laminar. Also called foliose corals, they often are plate like colonies with small polyps. The plate can be horizontal or vertical and the tentacles are normally only extended at night. They are usually are green, grey, brown or pink but sometimes they may have white, green or red oral discs. Some colonies may show a distinctive colour margin.

Non-Acropora Coral	CM	Massive coral – coral colonies that are very large, boulder or mound shapes. Those colonies have thick margin; septa are widely spaced and irregular. Even if their septa size varies, they all appear very similar in all dimensions. They show a wide colour variation, but mottled with pale calices is often shown.
Non-Acropora Coral	CMR	Mushroom coral- includes all members of the Fungiidae family, also called mushroom corals. These colonies are solitary marine organism that are not attached to the reef and are capable of benthic locomotion. Those are free-living organisms have solitary polyp which they extend to feed at night.
Non-Acropora Coral	CS	Sub-massive coral – indeterminate colonies that have various growth forms, often showing nodular surface, columns, hillocky, flat, thickened branches or massive rounded colonies. They can be several meters across and they tend to have green or brown colours.
Non-Acropora Coral	CHL	Heliopora – deep brown, smooth surface, blue on the inside and white fluffy polyps when extended.
Non-Acropora Coral	CME	Fire coral – all species belonging to the Millepora family. These corals have smooth surface but when the polyps are extended they have a fuzzy appearance; normally mustard yellow/brown in colour.
Non-Acropora Coral	CTU	Tubipora corals – unique coral family also called organ pipe coral. This coral have a hard calcium carbonate skeleton that has many stacked organ pipe-like tubes. Each tube contains the coral polyps. The skeleton is bright red, but often hidden by the polyps which are grey or green in colour.
Dead Coral	DC	Dead coral – include recently dead corals. Dead coral colonies may have a visible yellow or white skeleton with no algae. Their corallite walls, holes and growth forms holes will still be recognizable; the smaller structures could be eroded and there may be a very thin.
Dead Coral	DCA	Dead coral algae – includes corals that have been dead for a large period of time. Those colonies are covered with thick fleshy algae. The substrate close to those dead corals is normally covered with microscopic turf algae. The majority of those dead corals retain their coral structure.
Algae	AA	Algae – non-distinct algal mass usually made up of different types of algae. Their size is bigger than turf algae, but smaller than macro algae usually <5cm.
Algae	CA	Coralline algae – calcified coralline algae. Their colour can range from pink to dark burgundy; often encrusting but sometimes they appear like leaves.
Algae	HA	Halimeda – genus of green micro algae. This organism has a triangle-shaped, segmented, calcified stacked green body. Most herbivores do not eat these algae due to its calcareous skeleton.

Algae	MA	Macroalgae – non-district algae that are >5m in height. Generally, those do not have complex anatomical forms; their bodies are often erected. These can be brown, green and red in colour.
Algae	TA	Turf algae – multi-specific, but often those are uniform, short filamentous or mat of algae. Their size vary between >1cm & <5cm. This categories has a high diversity, including 30-50 species commonly occurring.
Other fauna	SC	Soft coral – this category includes all species of soft or leathery coral. Their colour range from dark shades of brown to very bright and colourful.
Other fauna	SP	Sponge – this category includes all animals from the Porifera Phylum. Sponges vary in shape, size and colour. These multicellular organisms have prominent openings and rough surface texture.
Other fauna	ZO	Zoanthids – those belong to a cnidarian order that is commonly found in coral reefs. Those are sea anemones that live in small colonies. These organisms usually have polyps joined together with two rings tentacles.
Other fauna	OT	Other – this category is for any other organism like gorgonians, anemones, sea squirt and sea grass.
Abiotic	S	Sand – normally composed by fine grains, their size range between >63mm and <2mm. When stirred it settles immediately.
Abiotic	SI	Silt – is normally composed by fine particles that when stirred, form a cloud where the particles remain suspended and settles very slowly.
Abiotic	RU	Rubble – broken unconsolidated pieces of coral; those can be dead or alive. Their size vary but generally <15cm in size.
Abiotic	WA	Water – in this category is included any crevice, crack or fissure deeper than 50cm.
Abiotic	RCK	Rock – hard substrate of non-carbonate origin. It can be made of stone or granites. Hard substrates that are covered by barnacles, oysters, encrusting turf or coralline algae also fall into this category.
Abiotic	DB	Debris – both natural (unconsolidated material) and manmade (marine litter, abandoned fishing gear etc.) When exposed to the marine environment, debris can be colonized by algae and sessile organisms (oysters, mussels, barnacles etc.)



# APPENDIX C REEF CHECK SURVEY SITES AND SUMMARY DATA

SITE	LatDD	LongDD	SiteName	Reef Type	% Hard Coral	Fish				Diadema
						Butterfly Fish	Parrot Fish	Snapper	Grouper	
1	12.442028	98.017694	Thayawthadangyi	Inner	35.0	ns	ns	ns	ns	ns
2	12.339000	97.957778	Thayawthadangyi	Inner	13.0	ns	ns	ns	ns	ns
3	12.242667	97.938139	Thayawthadangyi	Inner	42.5	ns	ns	ns	ns	ns
4	12.303972	98.036833	Ba Gyee Kyunn	Inner	30.0	ns	ns	ns	ns	ns
5	12.167528	98.152056	Wadi Kyunn (Helper Is.)	Inner	33.1	ns	ns	ns	ns	ns
6	12.145417	98.126722	Daung Kyunn	Inner	36.5	ns	ns	ns	ns	ns
7	12.172111	98.028028	Ao Lei Kyunn	Inner	25.6	ns	ns	ns	ns	ns
8	12.090972	97.975056	Taung Kyun Pone (Street Is.)	Inner	6.0	ns	ns	ns	ns	ns
9	12.018889	97.979222	Kyet Paung Is.	Inner	53.0	ns	ns	ns	ns	ns
10	11.653056	98.032333	Pyin Sa Bu (SW)	Inner	49.0	ns	ns	ns	ns	ns
11	10.859306	98.087639	Wa Ale Is.	Inner	31.5	ns	ns	ns	ns	ns
12	10.769417	98.242472	Lampi Is.	Inner	11.0	ns	ns	ns	ns	ns
13	10.472083	98.168250	Nyaung Wee Is. (115)	Inner	17.5	ns	ns	ns	ns	ns
14	10.246972	98.237472	Shwe Kyunn Gyi	Inner	43.0	ns	ns	ns	ns	ns
15	10.247028	98.237000	Shwe Kyunn Gyi	Inner	20.0	ns	ns	ns	ns	ns
16	10.129389	98.328111	Thay Yae Kyunn	Inner	50.5	ns	ns	ns	ns	ns
17	12.305778	98.045444	Za Latt	Inner	35.0	0.4	0	1	0.4	2.4
18	12.272861	98.002417	Pearl farm	Inner	53.0	1.2	0.2	4.4	2.4	0
19	12.346083	97.948333	Phalar Aw	Inner	53.5	1	3	40	0.4	0
20	12.284389	97.993250	Thayawthadangyi	Inner	59.5	0	0	3.4	0	41
21	12.303083	97.967139	Thit Lat Tan Aw	Inner	60.0	0	0	0	0	43.2
22	12.323694	97.955111	Thayawthadangyi	Inner	74.0	0.8	0	0	0	73.8
23	12.414250	98.110389	Tit Ti Tu Aw	Inner	90.5	0.2	0	0	0	0
24	12.421000	98.108639	Shar Aw	Inner	88.0	0.2	0	0	0	0
25	12.430667	98.095833	Palu Palal Aw	Inner	88.0	0	0	0	0.4	0
26	12.404472	98.118222	Sas Tit Aw	Inner	82.0	0.6	0	0	0	5.2
27	12.452194	98.094833	Burne Is.	Inner	77.5	0.6	0.8	0	0	91
28	12.426389	98.100694	Shar Aw	Inner	81.5	1.6	0	2	0.8	0
29	12.407583	98.016111	Thayawthadangyi	Inner	80.5	0.6	2	0	2.6	0
30	12.425889	98.131667	Taung Pan Gyi (MacLeod Is.)	Inner	81.5	0	0	0	0	0
31	12.420028	98.119139	Taung Pan Gyi (MacLeod Is.)	Inner	74.5	0.2	0	0	0.4	0

32	12.429389	98.150194	Taung Pan Gyi (MacLeod Is.)	Inner	56.0	0.2	0	0	0.4	0
33	12.409222	98.135297	Taung Pan Gyi (MacLeod Is.)	Inner	88.0	0.4	0	0	0	5.8
34	12.293056	98.053361	Thayawthadangyi	Inner	68.0	0	0	0	0.6	7.4
35	12.347083	98.066194	Zalwal	Inner	78.0	2	0	0	0.2	0
36	12.307694	98.060000	Thayawthadangyi	Inner	71.5	0.2	0	0	0.4	18
37	12.315694	98.063139	Thayawthadangyi	Inner	79.5	0	0	0	1	0
38	12.423417	98.012528	Sack Is.	Inner	92.0	4.2	0.4	26.6	1.8	94.4
39	12.195500	98.065167	Nyaung Hmine	Inner	91.5	1.8	0	0	0	0
40	12.189417	98.067500	Nyaung Hmine	Inner	72.0	1.4	0	0	0.2	0
41	12.060528	97.980500	Mee Thway Is.	Inner	88.0	0	0	0	0	0
42	12.162944	98.098639	Dahaw	Inner	79.0	1.2	0	0	0.2	0.8
43	12.139972	98.143722	Dahaw	Inner	87.0	1.6	0	0	0.2	0
44	12.390500	97.995278	Taung Pan Gyi (MacLeod Is.)	Inner	85.0	7	0	0	1.2	0.8
45	12.414528	98.111667	Tit Ti Tu Aw	Inner	79.5	1.8	0	0	0.2	0.2
46	12.425000	98.101417	Shar aw	Inner	84.0	2.8	0.8	0	2.4	1.2
47	12.420833	98.120306	Taung Pan Gyi (MacLeod Is.)	Inner	79.5	3.6	0.8	4	1	0
48	12.421667	98.012500	Sack Is.	Inner	87.0	3.4	0.6	0	0.4	24
49	12.304472	98.043750	Ba Gyee Kyunn	Inner	61.0	0.6	0	0	2	3.4
50	12.391139	97.995833	Aw Wine	Inner	67.5	2	0.2	0.6	1	0.6
51	12.109111	97.981833	Lyll Is.	Inner	62.0	2.8	0.4	0	0.2	1.4
52	12.077278	98.003833	Nat Thamee Yay Twinn	Inner	73.0	1	0.2	0	1.2	0
53	12.062111	98.019056	Nat Thamee Yay Twinn	Inner	57.0	1.6	0	0	1.4	0
54	11.963056	97.999861	Mee Sein Is.	Inner	70.5	0.4	0	0	0.4	0.4
55	11.967583	97.974417	Mee Sein Is.	Inner	56.5	2	0	0	1	0
56	12.117889	97.972583	Howe Is.	Inner	63.0	3.4	0.4	0	0.4	2.8
57	12.124556	97.978639	Clyde Is.	Inner	72.5	6	0.4	0	0.6	9.2
58	10.645167	98.247944	Bo Cho Is.	Inner	11.5	0	0	0	0	140
59	11.322417	98.018889	Khin Pyi Son Is. (Zee Pin Aw)	Inner	86.0	0.2	2.4	0	0	30.4
60	11.322389	98.002528	Khin Pyi Son Is.	Inner	84.5	0.8	1.2	0	0.2	0
61	11.343417	98.005361	Hlaing Is.	Inner	72.5	2.8	1.4	0	0.4	16.8
62	11.354389	98.016639	Mwe Meneik Is.	Inner	49.0	1.6	2	0	0.6	25.6
63	10.715556	98.290500	Lampi Is.	Inner	52.0	2.8	0.4	1.4	0	18.4
64	10.972417	98.215167	Than Lwin Is.	Inner	30.5	1	0	0	0.8	4.2
65	10.978500	98.150278	Lampi Is.	Inner	71.0	0.6	0	0.2	0.8	2.8
66	10.927389	98.116361	Lagyan Aw (Lampi Is.)	Inner	51.5	1.8	0	0.8	0.4	4
67	10.499778	98.237750	Nyaung Wee Is.	Inner	60.5	1.4	7	3.2	0	248
68	10.466306	98.220083	Poni Is.	Inner	65.5	2	8	22	0	0
69	10.455667	98.220611	Poni Is.	Inner	51.5	ns	ns	ns	ns	ns
70	10.980611	98.153889	Lampi Is.	Inner	67.5	ns	ns	ns	ns	ns
71	11.272694	98.026139	Kyat Mi Thar Su Is.	Rock	22.5	30	15	50	7	15

SITE	LatDD	LongDD	SiteName	Reef Type	% Hard Coral	Fish				Diadema
						Butterfly Fish	Parrot Fish	Snapper	Grouper	
72	11.383333	98.015806	Saw Pu Is.	Rock	25.0	ns	ns	ns	ns	140
73	11.718306	97.558444	Sular Nge Is.	Rock	7.5	0	6	106	2	70
74	11.794611	97.469528	West Sular Is.	Fringe	2.5	2	4	5	1	5
75	11.814139	97.506667	West Sular Is.	Fringe	10.0	11	3	59	11	5
76	11.817194	97.668556	Kunn Thee Is.	Fringe	5.0	5	10	9	12	60
77	11.835750	97.671444	East Sular	Fringe	5.0	1	6	50	6	340
78	11.862750	97.675111	East Sular	Fringe	17.5	54	55	10	10	30
79	11.937028	97.682528	West Islet	Rock	65.0	7	1	15	1	160
80	12.005194	97.752972	Dana Theik Di Is.	Fringe	7.5	4	4	200	4	3
81	12.006944	97.655611	Sular Khamouk Islet (S)	Rock	15.0	0	1	12	5	100
82	12.028917	97.631611	Double Island	Rock	27.5	5	0	50	1	140
83	12.066917	97.640278	Tower Rock	Rock	2.5	ns	ns	ns	ns	ns
84	12.051250	97.671250	Sular Khamouk	Rock	27.5	8	14	14	11	12
85	12.111917	97.725417	Bailey Is.	Fringe	80.0	12	1	0	11	16
86	12.147917	97.740861	Bailey Is.	Fringe	17.5	5	0	5	9	80
87	12.248083	97.767306	West Spur	Fringe	70.0	6	12	3	9	35
88	12.295194	97.801139	Metcalfe Is.	Fringe	55.0	8	2	3	9	435
89	12.436306	97.831611	Blundell Is.	Fringe	0.0	0	0	0	12	53
90	12.432778	97.798556	Chevalier Rock	Rock	37.5	12	9	17	7	340
91	12.590250	97.832694	Tanangthayi Is.	Fringe	20.0	8	5	9	9	25
92	12.683861	97.809167	North Pinnacle	Rock	12.5	9	8	7	6	358
93	12.777028	97.866500	Kabuzya Is.	Fringe	57.5	17	19	7	9	1
94	12.786056	97.880333	Kunn Thee Is.	Fringe	7.5	12	58	17	17	17
95	12.427722	98.123417	Thayawthadangyi	Inner	48.8	ns	ns	ns	ns	ns
96	12.425083	98.014250	Sack Is.	Inner	80.0	ns	ns	ns	ns	ns
97	11.970778	97.970944	Mee Sein Is.	Inner	62.5	ns	ns	ns	ns	ns
98	11.728639	97.968194	Hlwa Sar Gyi Is.	Inner	21.3	0	11	4	24	50
99	11.323917	98.003750	Khin Pyi Son Is.	Inner	72.5	11	28	5	15	185
100	11.196194	98.088222	A Pha Is.	Inner	18.8	14	6	6	18	450
101	10.855139	98.047333	Wa Ale Is.	Inner	28.8	14	6	6	18	55
102	10.592722	98.041028	Bo Ywe Is	Rock	7.5	17	21	10	16	465
103	10.129056	98.320500	Zar Det Nge	Inner	50.0	ns	ns	ns	ns	ns
104	10.011528	98.290472	Zar Det Kyee	Inner	59.0	2.8	1.6	7	0	60
105	9.952944	98.238111	Zar Det Kyee	Inner	52.0	1.4	0	0.2	1	175
106	9.939167	98.224444	Zar Det Kyee	Inner	51.0	2.2	1	0.6	0.4	150
107	10.018222	98.300778	Zar Det Kyee	Inner	38.0	0	1.6	0	0.2	22.6
108	10.035278	98.300750	Zar Det Kyee	Inner	52.5	1	0.6	1.4	0.4	8
109	10.063944	98.189917	Zar Det Kyee	Inner	49.0	3.2	1	24.6	0.8	10.2

110	10.103722	98.276028	Zar Det Nge	Inner	92.0	0	0	0	0	54.8
111	12.113667	97.984283	Lyll Is.	Inner	33.0	5	0.4	0	0	7
112	12.217933	97.942389	Gedway (Greenlaw) Is.	Inner	66.0	10.4	0.2	0	0.2	3.6
113	12.240417	97.941806	Gedway (Greenlaw) Is.	Inner	45.0	7.6	1.8	0	0	21
114	12.232694	97.942333	Gedway (Greenlaw) Is.	Inner	46.5	0	0	0	0	3
115	10.855028	98.088417	Wa Ale Is.	Inner	45.5	2.6	1	0	0	48
116	11.345270	98.023930	Khin Oo	Inner	59.5	7.6	2.4	7	0.4	24.2
117	11.358830	98.005200	Mwe Meneik Is.	Inner	67.0	13.6	9	4.4	5.4	11.2
118	11.345570	98.001360	Hlaing Is.	Inner	57.5	9.2	10.2	4	3	85.4
119	11.349540	98.001800	Hlaing Is.	Inner	80.5	11.6	5.6	1.8	4	11.2
120	11.317810	98.026080	Po War Is.	Inner	51.5	5.2	2	0.2	0.2	9.6
121	11.320250	98.020420	Khin Pyi Son Is.	Inner	52.0	5.2	2.6	0	3.2	157.2
122	11.315550	98.007080	Khin Pyi Son Is.	Inner	69.5	9.6	2	0.8	0.6	37.8
123	11.315060	98.015590	Khin Pyi Son Is.	Inner	54.5	6	3.8	0	1	12.6
124	9.658720	98.038370	Hnget Khar Is.	Inner	80.0	5.2	4	1.4	1.2	11.2
125	9.776860	98.027240	Tharn Kyunn Nge	Inner	15.0	1.6	6.8	8	0	10
126	9.794950	98.053540	Tharn Kyunn	Inner	16.5	1.2	5.6	4.2	0	215.2
127	10.079080	97.982860	Nyaung Oo Phee Is.	Inner	21.5	4.4	17.2	4.6	0.4	221.8
128	10.130520	97.961240	Kho Yinn Khwa Is	Inner	9.0	0.4	5.4	8.2	0	0
129	10.419430	97.952150	Narr Kho Is.	Inner	20.0	0.8	57	1	0	265.4
130	10.420680	97.920700	Ja Lann Kyunn	Inner	16.5	5.2	13.6	11.6	1.2	ns
133	10.878750	98.002610	Kan Za Gyi	Inner	12.0	0.8	16	5.6	0.4	3.4
134	10.866400	97.887730	Kyunn Me Gyee	Inner	23.0	1.6	0	8.8	1.2	41.6
136	11.343220	98.002270	Hlaing Island	Inner	67.5	6	30.5	0	0	24.75
137	11.454570	97.993090	Saw Mon Hia Is.	Inner	21.9	3	42.25	1.25	0	37
138	11.851040	97.670740	East Sular	Fringe	12.5	2.5	22.5	31	0.5	156.25
139	11.867370	97.678390	East Sular	Fringe	28.1	12.5	39.25	18	0.5	54.5
141	12.027930	97.633130	Double Island	Rock	41.3	1	8.75	95.25	0.25	18.75
142	12.060900	97.639720	Tower Rock	Rock	30.0	4	18	17	0	75
143	12.112970	97.722560	Bailey Is (E side)	Fringe	63.8	6	19.25	10.5	1.25	166.5
144	12.043890	97.773540	Kyei Laik Is.	Fringe	25.6	4	9.25	3.25	1.25	119.75
145	11.752410	98.023380	Pyin Sa Bu Is. (W)	Inner	33.8	2	0	0	0	15.5
146	11.640090	98.067500	Pyin Sa Bu Is. (W, S bay)	Inner	ns	1.5	6.5	0	0.75	ns
149	11.323470	98.003540	Khin Pyi Son Is.	Inner	48.1	4.5	7.75	0	0.25	11.5
150	10.837320	98.084790	Wa Ale Is.	Inner	45.0	1	7.5	2.75	0.25	2.5
152	11.348980	98.023480	Khin Oo	Inner	43.0	3.6	11.8	5.8	0.6	ns
153	11.311620	98.028430	Khin Phone Is.	Inner	38.0	ns	ns	ns	ns	ns
154	11.399040	98.005600	Saw Pu Is.	Inner	43.0	2.8	6.4	2.2	0.8	ns
155	11.387660	97.994670	Saw Pu Is.	Inner	66.5	9.6	14.8	18.4	1	0
156	11.359780	98.014110	Mwe Meneik Is.	Inner	70.0	7.6	27.6	4.4	0.6	2
157	11.361700	98.011180	Mwe Meneik Is.	Inner	38.5	5.6	10.4	3.2	0.8	0.2
158	11.409080	97.998500	Saw Pu Is.	Inner	47.0	0	0	0.4	0	198
159	11.383510	98.013380	Saw Pu Is.	Inner	32.0	6	25.8	6.2	0.4	0
160	11.384690	98.014690	Saw Pu Is.	Inner	62.5	6.8	17.2	4.4	1.8	43.6

SITE	LatDD	LongDD	SiteName	Reef Type	% Hard Coral	Fish				Diadema
						Butterfly Fish	Parrot Fish	Snapper	Groupers	
161	11.389190	98.013100	Saw Pu Is.	Inner	33.5	3.6	11.4	4.6	0.4	86
162	11.386570	98.015030	Saw Pu Is.	Inner	38.5	1.6	13	1.4	0	104
163	11.203940	98.081470	Thar Is.	Inner	50.0	3.6	10.8	280	3.2	5
164	11.196560	98.086280	A Pha Is.	Inner	43.5	4.8	2.2	12.6	0.6	135
165	11.724140	97.965750	Hlwa Sar Gyi Is.	Inner	25.5	3.6	15.2	2	0.4	0
166	11.432850	98.013240	Mya Lay Is.	Inner	16.5	0.8	6	2.2	0.2	2
167	11.439840	98.007350	Saw Mon Hia Is.	Inner	35.0	6.8	12.2	3.8	0	0
168	11.448470	98.007680	Saw Mon Hia Is.	Inner	53.0	1.6	7.6	2.8	0	131
169	11.455420	98.011610	Saw Mon Hia Is.	Inner	32.5	4	12.8	6.2	1	166
170	11.321280	98.000530	Khin Pyi Son Is.	Inner	12.0	2.8	25	3.2	0	16.4
171	11.354140	98.011910	Mwe Meneik Is.	Inner	42.0	4.8	23	7.4	1	150.6
172	11.280060	97.927190	Yan Ywe Is.	Rock	7.0	3.6	7.2	7.6	0	244
173	12.507390	98.099020	Thayawthadangyi	Inner	44.4	3.6	11.6	26.6	2.4	154
178	13.818890	97.922770	Long Lon Bok	Moscoss	62.0	3.6	0	0	1.6	0.6
179	13.795670	97.915080	Long Lon Bok	Moscoss	51.5	4.4	0	0	0	4.8
180	13.804860	97.905150	Long Lon Bok	Moscoss	37.0	2.8	5	4.2	0.6	1
181	13.828060	97.907460	Long Lon Bok	Moscoss	55.0	7.6	18.4	6.8	1.4	2.8
182	13.863950	97.909710	Long Lon Bok	Moscoss	58.5	5.5	14	11.5	4.5	34.4
183	13.868950	97.917870	Long Lon Bok	Moscoss	54.0	3.6	18	11.4	1.6	138
184	13.886480	97.912140	Aek Bok	Moscoss	76.5	2.8	11.2	7.2	1	68
185	14.137910	97.812930	Maungmagan Bok	Moscoss	30.0	5.2	37.4	51	4	0
186	14.181550	97.817730	North Is.	Moscoss	51.5	14.8	17.2	42.8	3.2	0.2
187	14.186740	97.811160	North Is.	Moscoss	46.5	5.2	11.8	5.8	1.4	0.2
188	14.199900	97.789380	Sabyat Kyun	Moscoss	47.5	ns	ns	ns	ns	0.6
189	14.273080	97.813810	Bok Ye-gan	Moscoss	84.5	12	1	1.4	0.8	73
190	14.284730	97.816990	Bok Ye-gan	Moscoss	89.0	12.4	3	3	6.2	0
191	14.279850	97.814280	Bok Ye-gan	Moscoss	29.0	6.4	11.8	6.6	1.8	0.2
192	14.294990	97.816830	Bok Ye-gan	Moscoss	56.5	4.4	3.4	24.4	4.4	56
193	14.308120	97.787820	Lay Lone Tann	Moscoss	62.0	6.4	3.8	3.6	2.6	41
194	14.158640	97.782330	North Is.	Moscoss	53.5	6.8	1.6	2.4	1.8	0.2
195	14.118680	97.809600	Maungmagan Bok	Moscoss	77.5	3.6	4	0	0.8	0.4
196	13.938890	97.913390	Auk Bok	Moscoss	37.0	5.6	13	19.8	1	256
197	13.926550	97.923100	Auk Bok	Moscoss	59.0	3.2	9	1	2.2	320
198	13.910400	97.918540	Auk Bok	Moscoss	74.5	3.2	9	1	0.2	82
199	13.897840	97.916580	Auk Bok	Moscoss	70.0	1.6	38	76.6	6	124
200	13.884290	97.910140	Auk Bok	Moscoss	51.5	4.4	14.4	5.8	6.6	0
201	13.912850	97.912680	Auk Bok	Moscoss	19.5	2.4	6.4	3.4	1	0
202	13.933080	97.906680	Auk Bok	Moscoss	54.5	8	20	28.2	2.6	0
203	12.879430	98.315800	Mali Nge Is.	Inner	51.5	10.8	7.8	16.2	1.6	69

204	12.894810	98.311800	Mali Nge Is.	Inner	69.0	4.4	9.6	12.4	3.2	1.6
205	12.906740	98.308330	Mali Nge Is.	Inner	56.5	5.2	4.6	7.4	2.4	0.4
206	13.153050	98.296690	Mali Is.	Inner	60.0	10.4	13.8	12.2	3.2	0
207	13.164160	98.271670	Mali Is.	Inner	44.5	10	3.2	10.8	1.4	0
208	13.177090	98.270530	Mali Is.	Inner	51.0	9.6	11.6	25.2	3.4	0
209	13.186260	98.267720	Mali Is.	Inner	53.5	5.6	8.2	9.8	1.4	0
210	13.213710	98.246220	Mali Is.	Inner	24.0	13	10.6	185	1.8	0
211	13.214740	98.241820	Mali Is.	Inner	51.0	6	9	9.4	1	0
212	13.178400	98.243360	Mali Is.	Inner	30.0	5.6	7	22.6	1	0
213	13.146990	98.235630	Mali Is.	Inner	43.0	6.8	8.8	10.6	1.8	0
214	12.953870	98.288690	Mali Is.	Inner	32.0	7.2	9.2	15	1.8	0
215	12.941230	98.294330	Mali Is.	Inner	32.0	5.2	10	37.6	2	0
216	12.914960	98.301500	Mali Is.	Inner	48.5	6.4	14.8	35.2	3.6	0
217	12.874860	98.315930	Mali Is.	Inner	50.0	2.8	5.6	8.8	1	42
218	12.712770	98.360220	Thamihla Is.	Inner	49.5	1.6	1.4	4.8	0.8	11
219	12.719490	98.361090	Thamihla Is.	Inner	40.5	4	5	6.4	1.2	2
220	12.761820	98.339500	Thamihla Is.	Inner	47.0	3.2	3.2	5	0.8	0.8
221	12.754730	98.342670	Thamihla Is.	Inner	43.0	5.6	3.2	8.6	1.8	0.8
222	12.777640	98.335110	Thamihla Is.	Inner	50.5	8.4	7	9	2.2	0
223	12.652520	98.192500	Lay Kyun (Gifford Is.)	Inner	47.5	3.6	3	5.4	3.2	124
224	13.804180	97.914690	Thamihla Is.	Inner	46.5	4.4	9.6	18.4	0.6	4.6
225	13.827840	97.925790	Long Lon Bok	Moscoss	64.5	7.6	14	21.2	1.2	122
226	13.840470	97.931250	Long Lon Bok	Moscoss	55.0	5.6	9.6	17	1.4	300
227	13.842940	97.925140	Long Lon Bok	Moscoss	73.5	4.4	15.2	8.2	2	90
228	13.854780	97.927530	Long Lon Bok	Moscoss	56.5	4.4	13.6	13.6	1.2	43
229	13.861010	97.926700	Long Lon Bok	Moscoss	72.0	5	9.75	12	1.25	230
230	11.763360	98.114200	The Phyu Is.	Inner	72.0	ns	ns	ns	ns	84
231	11.736850	98.087710	Pyin Sa Bu Is. (E)	Inner	67.5	ns	ns	ns	ns	1.2
232	11.722940	98.079960	Pyin Sa Bu Is. (E)	Inner	79.5	ns	ns	ns	ns	45
233	11.715530	98.079160	Pyin Sa Bu Is. (E)	Inner	63.5	ns	ns	ns	ns	0
234	11.686350	98.071660	Pyin Sa Bu Is. (E)	Inner	85.5	ns	ns	ns	ns	88
235	11.473820	98.221500	Pandaung Is. (Livock Bay)	Inner	71.0	ns	ns	ns	ns	2.8
236	11.457100	98.258340	Pandaung Is. (Livock Bay)	Inner	64.5	ns	ns	ns	ns	0
237	10.692261	98.232500	Lampi Is.	Inner	11.0	ns	ns	ns	ns	0
238	10.157600	98.029960	Nge Lon Lett Phei Is.	Inner	22.0	ns	ns	ns	ns	2.8
239	10.195490	97.872050	Nga Khin Nyo Gyee Is.	Inner	8.0	2.8	1.6	1.4	2	4.2
240	10.198400	97.867480	Nga Khin Nyo Gyee Is.	Inner	5.0	ns	ns	ns	ns	0
241	10.503610	97.900960	Jar Lann Kyunn	Inner	1.5	ns	ns	ns	ns	310
242	10.513630	97.904610	Jar Lann Kyunn	Inner	35.5	8.8	30.2	8	2.8	0
243	10.980180	98.151740	Lampi Is.	Inner	69.5	2.4	2.8	2.2	2	0
244	11.323640	98.013450	Khin Pyi Son Is. (Zee Pin Aw)	Inner	73.0	ns	ns	ns	ns	0
245	11.325090	98.002660	Hlaing Is.	Inner	72.5	ns	ns	ns	ns	0
246	11.346160	98.003010	Hlaing Is.	Inner	74.5	ns	ns	ns	ns	8
247	11.353750	98.012520	Hlaing Is.	Inner	22.5	ns	ns	ns	ns	32

SITE	LatDD	LongDD	SiteName	Reef Type	% Hard Coral	Fish				Diadema
						Butterfly Fish	Parrot Fish	Snapper	Grouper	
248	11.464170	97.991440	Khin Pyi Son Is.	Inner	16.0	ns	ns	ns	ns	62
249	11.724880	98.022130	Pyin Sa Bu (Is.) Khu Gyan Aw	Inner	51.5	ns	ns	ns	ns	78
250	11.969430	97.972590	Mee Sein Is.	Inner	63.0	ns	ns	ns	ns	88
251	12.098340	97.998180	Lyll Is.	Inner	45.0	ns	ns	ns	ns	81
252	11.968150	97.999420	Mee Sein Is.	Inner	76.5	ns	ns	ns	ns	57.4
253	11.834820	98.078490	Pyin Sa Bu Nge Is.	Inner	12.0	10	9.2	6.4	2.4	0
254	11.196970	98.086270	A Pha Is.	Inner	77.0	10	21.6	67	4.2	134
255	12.399663	98.026560	Thayawthadangyi	Inner	47.5	5.2	1.2	0.6	0.4	0
256	12.394004	98.023918	Thayawthadangyi	Inner	27.5	5.6	3.6	4.4	0.4	2.2
257	12.396719	98.021552	Thayawthadangyi	Inner	49.0	ns	ns	ns	ns	72
258	12.400496	98.024873	Thayawthadangyi	Inner	50.0	ns	ns	ns	ns	1.4
259	12.294790	97.877840	Smart Is.	Fringe	62.5	5.6	6	7.6	1	76
260	12.300070	97.872630	Smart Is.	Fringe	46.5	10.8	10.4	11.6	1.6	0
261	12.283910	97.884510	Smart Is.	Fringe	77.0	17.2	24	14.8	3	0
262	12.406420	98.023360	Thayawthadangyi	Inner	36.0	ns	ns	ns	ns	0
263	12.398300	98.024030	Thayawthadangyi	Inner	50.0	ns	ns	ns	ns	0
264	12.400850	98.065210	Thayawthadangyi	Inner	41.5	ns	ns	ns	ns	0
265	13.867440	97.917880	Long Lon Bok	Moscoss	89.5	ns	ns	ns	ns	ns
266	13.842600	97.924150	Long Lon Bok	Moscoss	65.0	ns	ns	ns	ns	ns
267	13.819570	97.922150	Long Lon Bok	Moscoss	70.0	ns	ns	ns	ns	ns
268	13.833440	97.925230	Long Lon Bok	Moscoss	54.5	ns	ns	ns	ns	ns
269	13.812340	97.918470	Long Lon Bok	Moscoss	65.5	ns	ns	ns	ns	ns
270	13.863360	97.909700	Long Lon Bok	Moscoss	41.0	ns	ns	ns	ns	ns
271	13.885480	97.912830	Long Lon Bok	Moscoss	74.5	ns	ns	ns	ns	ns
272	13.894640	97.917400	Long Lon Bok	Moscoss	74.5	ns	ns	ns	ns	ns
273	13.921490	97.918760	Long Lon Bok	Moscoss	82.5	ns	ns	ns	ns	ns
274	13.911950	97.918790	Long Lon Bok	Moscoss	89.5	ns	ns	ns	ns	ns
275	13.938810	97.913150	Long Lon Bok	Moscoss	69.0	ns	ns	ns	ns	ns
Number of sites surveyed					262	202	202	202	202	225

ns=not surveyed

# APPENDIX D FISH SPECIES LIST

Dr Barry Russell

Species	Genus	RL
Family: Dasyatidae		
<i>Taeniura</i>	<i>lymma</i>	NT
Family: Muraenidae		
<i>Echidna</i>	<i>nebulosa</i>	NE
<i>Gymnothorax</i>	<i>favagineus</i>	NE
<i>Gymnothorax</i>	<i>fimbriatus</i>	NE
<i>Gymnothorax</i>	<i>flavimarginatus</i>	NE
<i>Gymnothorax</i>	<i>herrei?</i>	NE
<i>Gymnothorax</i>	<i>javanicus</i>	NE
<i>Gymnothorax</i>	<i>thyrsoidea</i>	NE
<i>Uropterygius</i>	<i>xanthopterus</i>	NE
Family: Synodontidae		
<i>Saurida</i>	<i>sp.</i>	-
<i>Synodus</i>	<i>dermatogenys</i>	LC
<i>Synodus</i>	<i>jaculum</i>	LC
<i>Synodus</i>	<i>sp.</i>	-
<i>Synodus</i>	<i>variegatus</i>	LC
Family: Clupeidae		
<i>Amblygaster</i>	<i>sp.</i>	-
Family: Holocentridae		
<i>Myripristis</i>	<i>hexagona?</i>	LC
<i>Sargocentron</i>	<i>rubrum</i>	LC
Family: Aulostomidae		
<i>Aulostomus</i>	<i>chinensis</i>	LC
Family: Fistulariidae		
<i>Fistularia</i>	<i>commersonii</i>	LC
Family: Centriscidae		
<i>Centriscus</i>	<i>scutatus</i>	LC
Family: Syngnathidae		
<i>Corythoichthys</i>	<i>benedetto</i>	LC
<i>Corythoichthys</i>	<i>sp.</i>	-
<i>Doryrhamphus</i>	<i>janssi</i>	LC
Family: Scorpaenidae		
<i>Dendrochirus</i>	<i>zebra</i>	LC

<i>Parascorpaena</i>	<i>picta</i>	LC
<i>Pterois</i>	<i>antennata</i>	LC
<i>Pterois</i>	<i>miles</i>	NE
<i>Scorpaenopsis</i>	<i>possi</i>	LC
<i>Scorpaenopsis</i>	<i>ramaraoi</i>	LC
<i>Scorpaenopsis</i>	<i>sp.</i>	-
Family: Playcephalidae		
<i>Onigocia</i>	<i>sp.</i>	-
Family: Serranidae		
<i>Aethaloperca</i>	<i>rogaa</i>	DD
<i>Anyperodon</i>	<i>leucogrammicus</i>	LC
<i>Cephalopholis</i>	<i>argus</i>	LC
<i>Cephalopholis</i>	<i>boenak</i>	LC
<i>Cephalopholis</i>	<i>formosa</i>	LC
<i>Cephalopholis</i>	<i>microprion</i>	LC
<i>Cephalopholis</i>	<i>miniata</i>	LC
<i>Cephalopholis</i>	<i>polyspila</i>	LC
<i>Cromoleptes</i>	<i>altivelis</i>	NE
<i>Diploprion</i>	<i>bifasciatum</i>	LC
<i>Epinephelus</i>	<i>aereolatus</i>	NE
<i>Epinephelus</i>	<i>coeruleopunctatus</i>	LC
<i>Epinephelus</i>	<i>coioides</i>	NT
<i>Epinephelus</i>	<i>erythrurus</i>	DD
<i>Epinephelus</i>	<i>faveatus</i>	DD
<i>Epinephelus</i>	<i>ongus</i>	LC
<i>Epinephelus</i>	<i>quoyanus</i>	LC
<i>Pseudanthias</i>	<i>rubrizonatus</i>	LC
Family: Cirrhitidae		
<i>Cirrhitichthys</i>	<i>aprinus</i>	LC
Family: Atherinidae		
<i>Crenilabrus</i>	<i>crenilabrus?</i>	NE
Family:		
<i>Atherinomorus</i>	<i>sp.</i>	-
Family: Pseudochromidae		
<i>Pseudochromis</i>	<i>andamanensis</i>	NE
<i>Pseudochromis</i>	<i>caudalis</i>	NE



Family: Plesiopidae		
<i>Plesiops</i>	<i>sp.</i>	-
Family: Opistognathidae		
<i>Opistognathus</i>	<i>sp.</i>	-
Family: Plesiopidae		
<i>Priacanthus</i>	<i>hamrur</i>	LC
Family: Apogonidae		
<i>Apogon</i>	<i>sp. (transparent, spot on peduncle)</i>	-
<i>Apogonichthyoides</i>	<i>sialis</i>	NE
<i>Archamia</i>	<i>bleekeri?</i>	NE
<i>Cheilodipterus</i>	<i>artus</i>	NE
<i>Cheilodipterus</i>	<i>macrodon (=lineatus?)</i>	NE
<i>Cheilodipterus</i>	<i>quiquelineatus</i>	NE
<i>Cheilodipterus</i>	<i>sp. X (Kuitier)</i>	-
<i>Nectamia</i>	<i>bandanensis</i>	NE
<i>Ostorhinchus</i>	<i>angustatus</i>	NE
<i>Ostorhinchus</i>	<i>aureus</i>	NE
<i>Ostorhinchus</i>	<i>compressus</i>	LC
<i>Ostorhinchus</i>	<i>cookii</i>	NE
<i>Ostorhinchus</i>	<i>cyanosoma</i>	NE
<i>Ostorhinchus</i>	<i>endekataenia</i>	NE
<i>Ostorhinchus</i>	<i>fleurieu</i>	LC
<i>Ostorhinchus</i>	<i>moluccensis</i>	NE
<i>Ostorhinchus</i>	<i>nanus</i>	NE
<i>Ostorhinchus</i>	<i>nigrofasciatus</i>	NE
<i>Pristiapogon</i>	<i>fraenatus</i>	NE
<i>Rhabdamia</i>	<i>sp.</i>	-
<i>Siphamia</i>	<i>fuscolineata?</i>	NE
<i>Taeniamia</i>	<i>fucata</i>	NE
<i>Taeniamia</i>	<i>macroptera</i>	NE
<i>Zoramia</i>	<i>perlita?</i>	NE
Family: Carangidae		
<i>Atule</i>	<i>mate</i>	NC
<i>Carangoides</i>	<i>ferdau</i>	LC
<i>Carangoides</i>	<i>plagiotaenia</i>	LC
<i>Elagatis</i>	<i>bipinnulata</i>	LC
<i>Gnathanodon</i>	<i>speciosus</i>	LC
<i>Trachinotus</i>	<i>baillonii</i>	LC

<i>Trachinotus</i>	<i>blochii</i>	LC
Family: Lutjanidae		
<i>Aprion</i>	<i>virescens</i>	LC
<i>Lutjanus</i>	<i>argentimaculatus</i>	LC
<i>Lutjanus</i>	<i>biguttatus</i>	LC
<i>Lutjanus</i>	<i>bohar</i>	LC
<i>Lutjanus</i>	<i>decussatus</i>	LC
<i>Lutjanus</i>	<i>fulviflamma</i>	LC
<i>Lutjanus</i>	<i>fulvus</i>	LC
<i>Lutjanus</i>	<i>indicus</i>	NE
<i>Lutjanus</i>	<i>lemniscatus</i>	NE
<i>Lutjanus</i>	<i>lutjanus</i>	LC
<i>Lutjanus</i>	<i>quiquelineatus</i>	LC
<i>Lutjanus</i>	<i>russelli</i>	NE
<i>Lutjanus</i>	<i>sebae</i>	LC
<i>Lutjanus</i>	<i>vitta</i>	LC
<i>Macolor</i>	<i>niger</i>	LC
Family: Caesionidae		
<i>Caesio</i>	<i>caerulaurea</i>	LC
<i>Caesio</i>	<i>cuning</i>	LC
<i>Caesio</i>	<i>teres?</i>	LC
<i>Pterocaesio</i>	<i>lativittata</i>	LC
<i>Pterocaesio</i>	<i>tessellata</i>	LC
<i>Pterocaesio</i>	<i>pisang</i>	LC
<i>Pterocaesio</i>	<i>tile</i>	LC
Family: Haemulidae		
<i>Diagramma</i>	<i>melanra</i>	NE
<i>Diagramma</i>	<i>pictum</i>	NE
<i>Plectorhinchus</i>	<i>chaetodonoides</i>	NE
<i>Plectorhinchus</i>	<i>gibbosus</i>	LC
<i>Plectorhinchus</i>	<i>vittatus</i>	NE
Family: Lethrinidae		
<i>Gymnocranius</i>	<i>griseus</i>	LC
<i>Lethrinus</i>	<i>erythropterus</i>	LC
<i>Lethrinus</i>	<i>nebulosus</i>	LC
Family: Nemipteridae		
<i>Nemipterus</i>	<i>peronii</i>	LC
<i>Scolopsis</i>	<i>affinis</i>	LC
<i>Scolopsis</i>	<i>bilineatus</i>	NE
<i>Scolopsis</i>	<i>ciliatus</i>	NE

<i>Scolopsis</i>	<i>margaritifer</i>	NE
<i>Scolopsis</i>	<i>monogramma</i>	LC
<i>Scolopsis</i>	' <i>torquatus</i> '	-
<i>Scolopsis</i>	<i>vosmeri</i>	NE
<i>Scolopsis</i>	<i>xenochrous</i>	NE
Family: Gerreidae		
<i>Gerres</i>	<i>longirostris?</i>	LC
<i>Gerres</i>	<i>oyena?</i>	LC
Family: Mullidae		
<i>Parupeneus</i>	<i>heptacanthus</i>	LC
<i>Parupeneus</i>	<i>indicus</i>	LC
<i>Parupeneus</i>	<i>macronemus</i>	LC
<i>Upeneus</i>	<i>tragula</i>	LC
Family: Pempheridae		
<i>Pempheris</i>	<i>oualensis</i>	NE
<i>Pempheris</i>	<i>vanicolensis</i>	NE
<i>Pempheris</i>	<i>sp.</i>	-
Family: Kyphosidae		
<i>Kyphosus</i>	<i>vaigensis</i>	NE
Family: Chaetodontidae		
<i>Chaetodon</i>	<i>andamanensis</i>	DD
<i>Chaetodon</i>	<i>auriga</i>	LC
<i>Chaetodon</i>	<i>collare</i>	LC
<i>Chaetodon</i>	<i>decussatus</i>	LC
<i>Chaetodon</i>	<i>lineolatus</i>	LC
<i>Chaetodon</i>	<i>octofasciatus</i>	LC
<i>Chaetodon</i>	<i>rafflesi</i>	LC
<i>Chaetodon</i>	<i>triangulum</i>	LC
<i>Chaetodon</i>	<i>trifascialis</i>	NT
<i>Chaetodon</i>	<i>trifasciatus</i>	LC
<i>Coradion</i>	<i>chrysozonus</i>	LC
<i>Heniochus</i>	<i>diphreutes</i>	LC
<i>Heniochus</i>	<i>pleurotaenia</i>	LC
<i>Heniochus</i>	<i>singularius</i>	LC
Family: Pomacanthidae		
<i>Centropyge</i>	<i>flavipectoralis</i>	LC
<i>Centropyge</i>	<i>multispinis</i>	LC
<i>Pomacanthus</i>	<i>annularis</i>	LC

<i>Pomacanthus</i>	<i>imperator</i>	LC
<i>Pomacanthus</i>	<i>semicirculatus?</i>	LC
Family: Pomacentridae		
<i>Abudefduf</i>	<i>bengalensis</i>	LC
<i>Abudefduf</i>	<i>septemfasciatus</i>	LC
<i>Abudefduf</i>	<i>vaigiensis</i>	LC
<i>Amblyglyphidodon</i>	<i>aureus</i>	LC
<i>Amblyglyphidodon</i>	<i>indicus</i>	LC
<i>Amblyglyphidodon</i>	<i>leucogaster</i>	LC
<i>Amphiprion</i>	<i>akallopisos</i>	LC
<i>Amphiprion</i>	<i>clarkii</i>	NE
<i>Amphiprion</i>	<i>ephippium</i>	LC
<i>Amphiprion</i>	<i>ocellaris</i>	NE
<i>Amphiprion</i>	<i>sebae</i>	NE
<i>Chromis</i>	<i>atripectoralis</i>	NE
<i>Chromis</i>	<i>cinerascens</i>	LC
<i>Chromis</i>	<i>flavipectoralis</i>	LC
<i>Chromis</i>	<i>lepidolepis?</i>	NE
<i>Chromis</i>	<i>opercularis</i>	NE
<i>Chromis</i>	<i>tematensis</i>	NE
<i>Chromis</i>	<i>weberi</i>	NE
<i>Chrysiptera</i>	<i>rollandi</i>	NE
<i>Dascyllus</i>	<i>aruanus</i>	NE
<i>Dascyllus</i>	<i>carneus</i>	NE
<i>Dascyllus</i>	<i>trimaculatus</i>	NE
<i>Dischistodus</i>	<i>perspicillatus</i>	NE
<i>Hemiglyphidodon</i>	<i>plagiometopon</i>	NE
<i>Neoglyphidodon</i>	<i>melas</i>	NE
<i>Neoglyphidodon</i>	<i>nigroris</i>	NE
<i>Neopomacentrus</i>	<i>anabantoides</i>	NE
<i>Neopomacentrus</i>	<i>filamentosus</i>	NE
<i>Neopomacentrus</i>	<i>sororius</i>	NE
<i>Neopomacentrus</i>	<i>cyanomos</i>	NE
<i>Neopomacentrus</i>	<i>violescens?</i>	NE
<i>Plectroglyphidodon</i>	<i>lacrymatus</i>	NE
<i>Pomacentrus</i>	<i>adelus</i>	NE
<i>Pomacentrus</i>	<i>amboinensis</i>	NE
<i>Pomacentrus</i>	<i>bankanensis</i>	NE
<i>Pomacentrus</i>	<i>coelestis</i>	NE
<i>Pomacentrus</i>	<i>lepidogenys</i>	NE
<i>Pomacentrus</i>	<i>moluccensis</i>	NE

<i>Pomacentrus</i>	<i>nagasakiensis</i>	NE
<i>Pomacentrus</i>	<i>pavo</i>	NE
<i>Pomacentrus</i>	<i>philippinus</i>	NE
<i>Pomacentrus</i>	<i>polyspinus?</i>	NE
<i>Pomacentrus</i>	<i>proteus?</i>	NE
<i>Pomacentrus</i>	<i>similis</i>	NE
<i>Pomacentrus</i>	<i>tripunctatus</i>	NE
<i>Stegastes</i>	<i>nigricans?</i>	NE
<i>Stegastes</i>	<i>obreptus</i>	NE
Family: Labridae		
<i>Anampses</i>	<i>caeruleopunctatus</i>	LC
<i>Anampses</i>	<i>lineatus</i>	DD
<i>Anampses</i>	<i>meleagrides</i>	LC
<i>Bodianus</i>	<i>diana</i>	LC
<i>Bodianus</i>	<i>mesothorax</i>	LC
<i>Bodianus</i>	<i>neilli</i>	LC
<i>Cheilinus</i>	<i>chlorourus</i>	LC
<i>Cheilinus</i>	<i>fasciatus</i>	LC
<i>Cheilinus</i>	<i>oxycephalus</i>	LC
<i>Cheilinus</i>	<i>rhodochrous</i>	NE
<i>Cheilinus</i>	<i>trilobatus</i>	LC
<i>Cirrhilabrus</i>	<i>cyanopleura</i>	DD
<i>Coris</i>	<i>batuensis</i>	LC
<i>Coris</i>	<i>gaimard</i>	LC
<i>Diproctacanthus</i>	<i>xanthurus</i>	LC
<i>Epibulus</i>	<i>insidiator</i>	LC
<i>Gomphosus</i>	<i>caeruleus</i>	LC
<i>Halichoeres</i>	<i>juv</i>	-
<i>Halichoeres</i>	<i>bicolor?</i>	LC
<i>Halichoeres</i>	<i>chloropterus</i>	LC
<i>Halichoeres</i>	<i>chrysotaenia</i>	NE
<i>Halichoeres</i>	<i>dussumieri</i> (= <i>nigrescens?</i> )	NE
<i>Halichoeres</i>	<i>hortulanus</i>	LC
<i>Halichoeres</i>	<i>kallochroma</i>	LC
<i>Halichoeres</i>	<i>kneri</i>	NE
<i>Halichoeres</i>	<i>lamarii</i> (prev <i>marginatus?</i> )	NE
<i>Halichoeres</i>	<i>leucoxanthus</i>	LC
<i>Halichoeres</i>	<i>nebulosus</i>	LC
<i>Halichoeres</i>	<i>scapularis</i>	LC

<i>Halichoeres</i>	<i>sp.</i>	-
<i>Halichoeres</i>	<i>timorensis</i>	LC
<i>Halichoeres</i>	<i>zeylonicus</i>	LC
<i>Hemigymnus</i>	<i>fasciatus</i>	LC
<i>Hemigymnus</i>	<i>melapterus</i>	LC
<i>Hologymnosus</i>	<i>annulatus</i>	LC
<i>Labrichthys</i>	<i>unilineatus</i>	LC
<i>Labroides</i>	<i>dimidiatus</i>	LC
<i>Labropsis</i>	<i>manabei</i>	LC
<i>Leptojulius</i>	<i>chrysotaenia</i>	LC
<i>Leptojulius</i>	<i>cyanopleura</i>	LC
<i>Macropharyngodon</i>	<i>ornatus</i>	LC
<i>Oxycheilinus</i>	<i>bimaculatus</i>	LC
<i>Oxycheilinus</i>	<i>digamma</i>	LC
<i>Pseudocheilinus</i>	<i>evanidus</i>	LC
<i>Stegastes</i>	<i>obreptus</i>	NE
<i>Stethojulius</i>	<i>albovittata</i>	LC
<i>Stethojulius</i>	<i>interrupta</i>	LC
<i>Stethojulius</i>	<i>trilineata</i>	LC
<i>Thalassoma</i>	<i>jansenii</i>	LC
<i>Thalassoma</i>	<i>lunare</i>	LC
Family: Scaridae		
<i>Chlorurus</i>	<i>cf bleekeri</i>	NE
<i>Chlorurus</i>	<i>capistratoides</i>	LC
<i>Chlorurus</i>	<i>sordidus</i>	LC
<i>Chlorurus</i>	<i>strongocephalus?</i> ( <i>juv</i> )	NE
<i>Scarus</i>	<i>frenatus</i>	LC
<i>Scarus</i>	<i>ghobban</i>	LC
<i>Scarus</i>	<i>maculipinna</i>	DD
<i>Scarus</i>	<i>niger</i>	LC
<i>Scarus</i>	<i>quoyi</i>	LC
<i>Scarus</i>	<i>rubroviolaceus</i>	LC
<i>Scarus</i>	<i>russelli</i>	LC
<i>Scarus</i>	<i>viridifucatus</i>	LC
Family: Pinguipedidae		
<i>Parapercis</i>	<i>clathrata</i>	NE
<i>Parapercis</i>	<i>hexophthalma</i>	NE
<i>Parapercis</i>	<i>snyderi</i> (=sp. 4 <i>Kuiter</i> )?	NE

<i>Parapercis</i>	<i>sp. 6 (Kuitert)</i>	-
<b>Family: Tripterygiidae</b>		
<i>Helcogramma</i>	<i>sp. 2? Alen &amp; Erdmann</i>	-
<i>Helcogramma</i>	<i>striatum</i>	LC
<i>Helcogramma</i>	<i>sp.</i>	-
<b>Family: Blenniidae</b>		
<i>Aspidontus</i>	<i>taeniatus</i>	LC
<i>Crossosalarius</i>	<i>sp.?</i>	-
<i>Ecsenius</i>	<i>bicolor</i>	LC
<i>Ecsenius</i>	<i>lubbocki</i>	LC
<i>Ecsenius</i>	<i>paroculus</i>	LC
<i>Meiacanthus</i>	<i>smithi</i>	LC
<i>Petroscirtes</i>	<i>mitratus</i>	LC
<i>Plagiotremus</i>	<i>phenax</i>	LC
<i>Plagiotremus</i>	<i>rhinorhynchus</i>	LC
<i>Plagiotremus</i>	<i>tapeinosoma</i>	LC
<i>Salarias</i>	<i>fasciatus</i>	LC
<b>Family: Gobiidae</b>		
<i>Amblyeleotris</i>	<i>diagonalis</i>	NE
<i>Amblyeleotris</i>	<i>downingi</i>	NE
<i>Amblyeleotris</i>	<i>latifasciata</i>	NE
<i>Amblyeleotris</i>	<i>periophthalma</i>	NE
<i>Amblyeleotris</i>	<i>steinitzi</i>	NE
<i>Amblyeleotris</i>	<i>sp. 3 (Kuitert)?</i>	-
<i>Amblyeleotris</i>	<i>wheeleri?</i>	LC
<i>Amblygobius</i>	<i>nocturnus</i>	NE
<i>Amblygobius</i>	<i>hectori</i>	LC
<i>Asterropteryx</i>	<i>semipunctata</i>	NE
<i>Bryaninops</i>	<i>amplus</i>	LC
<i>Bryaninops</i>	<i>loki</i>	LC
<i>Bryaninops</i>	<i>sp.</i>	-
<i>Bryaninops</i>	<i>yongei</i>	LC
<i>Callogobius</i>	<i>sp.?</i>	-
<i>Cryptocentrus</i>	<i>sericus</i>	NE
<i>Cryptocentrus</i>	<i>fasciatus</i>	NE
<i>Cryptocentrus</i>	<i>latifasciata</i>	NE
<i>Cryptocentrus</i>	<i>cf inexplicatus</i>	NE
<i>Cryptocentrus</i>	<i>strigilliceus</i>	LC
<i>Ctenogobiops</i>	<i>pomastictus</i>	NE

<i>Eviota</i>	<i>fasciola?</i>	LC
<i>Eviota</i>	<i>sebreei</i>	NE
<i>Eviota</i>	<i>sp.</i>	-
<i>Eviota</i>	<i>zebrina</i>	LC
<i>Exyrias</i>	<i>belissimus</i>	LC
<i>Exyrias</i>	<i>ferrarisi</i>	LC
<i>Fusigobius</i>	<i>sp.</i>	-
<i>Fusigobius</i>	<i>inframaculatus</i>	NE
<i>Istigobius</i>	<i>goldmani?</i>	NE
<i>Istigobius</i>	<i>decoratus</i>	NE
<i>Istigobius</i>	<i>spence?</i>	LC
<i>Istigobius</i>	<i>sp.</i>	-
<i>Mahidolia</i>	<i>mystacina</i>	NE
<i>Myersina</i>	<i>sp.</i>	-
<i>Pleurosicya</i>	<i>labiata?</i>	LC
<i>Pleurosicya</i>	<i>mossambica</i>	LC
<i>Valenciennea</i>	<i>immaculata?</i>	NE
<i>Valenciennea</i>	<i>muralis</i>	NE
<i>Valenciennea</i>	<i>puellaris</i>	LC
<i>Valenciennea</i>	<i>randalli</i>	NE
<i>Valenciennea</i>	<i>sexguttata</i>	NE
<b>Family: Microdesmidae</b>		
<i>Parioglossus</i>	<i>formosus?</i>	LC
<b>Family: Ptereleotridae</b>		
<i>Ptereleotris</i>	<i>microlepis</i>	NE
<b>Family: Ehippidae</b>		
<i>Platax</i>	<i>teira</i>	NE
<b>Family: Siganiidae</b>		
<i>Siganus</i>	<i>argenteus</i>	LC
<i>Siganus</i>	<i>corallinus</i>	LC
<i>Siganus</i>	<i>guttatus</i>	LC
<i>Siganus</i>	<i>javus</i>	LC
<i>Siganus</i>	<i>virgatus</i>	NE
<b>Family: Zanclidae</b>		
<i>Zanclus</i>	<i>cornutus</i>	LC
<b>Family: Acanthuridae</b>		
<i>Acanthurus</i>	<i>blochii?</i>	LC
<i>Acanthurus</i>	<i>leucocheilus</i>	LC
<i>Acanthurus</i>	<i>lineatus</i>	LC

<i>Acanthurus</i>	<i>mata</i>	LC
<i>Acanthurus</i>	<i>pyroferus</i>	LC
<i>Acanthurus</i>	<i>thompsoni</i>	LC
<i>Acanthurus</i>	<i>tristis</i>	LC
<i>Acanthurus</i>	<i>xanthopterus</i>	LC
<i>Ctenochaetus</i>	<i>binotatus</i>	LC
<i>Ctenochaetus</i>	<i>striatus</i>	LC
<i>Zebrasoma</i>	<i>scopas</i>	LC
Family: Sphyraenidae		
<i>Sphyraena</i>	<i>obtusata?</i>	NE
<i>Sphyraena</i>	<i>putnamae</i>	NE
Family: Balistidae		
<i>Abalistes</i>	<i>stellatus</i>	NE
<i>Balistapus</i>	<i>undulatus</i>	NE
<i>Balistoides</i>	<i>viridescens</i>	NE
<i>Pseudobalistes</i>	<i>flavimarginatus</i>	NE
<i>Pseudobalistes</i>	<i>fuscus</i>	NE
<i>Sufflamen</i>	<i>bursa</i>	NE
<i>Sufflamen</i>	<i>chrysopterus</i>	NE
Family: Ostraciidae		
<i>Ostracion</i>	<i>cubicus</i>	NE
<i>Ostracion</i>	<i>meleagris</i>	NE
<i>Ostracion</i>	<i>rhinorhynchus</i>	NE
Family: Tetraodontidae		
<i>Arothron</i>	<i>manilensis</i> (= <i>immaculatus</i> )?	LC
<i>Arothron</i>	<i>mappa</i>	LC
<i>Arothron</i>	<i>nigropunctatus</i>	LC
<i>Arothron</i>	<i>stellatus</i>	LC
<i>Canthigaster</i>	<i>papua</i>	LC
<i>Canthigaster</i>	<i>petersi</i>	LC
<i>Canthigaster</i>	<i>valentini</i>	LC
Family: Monacanthidae		
<i>Aluterus</i>	<i>scriptus</i>	LC
<i>Cantherhines</i>	<i>pardalis</i>	LC
Family: Diodontidae		
<i>Chilomycterus</i>	<i>reticulatus</i>	LC
<i>Cylichthys</i>	<i>orbicularis</i>	NE
<i>Diodon</i>	<i>hystrix</i>	LC

RL=IUCNRedlistcategory

# APPENDIX E FISH SPECIES LIST FROM RANONG MARKET

Dr Barry Russell

Family/species	Rnong fish market 2016	Myeik Surveys (2014, 2016)
<b>Centropomidae</b>		
<i>Lates calcarifer</i>	X	
<b>Serranidae</b>		
<i>Cephalopholis boenak</i>		
<i>C. formosa</i>	X	X
<i>C. miniata</i>	X	X
<i>Epinephelus aereolatus</i>	X	X
<i>E. amblycephalus</i>	X	X
<i>E. bleekeri</i>	X	
<i>E. chlorostigma</i>	X	
<i>E. coioides</i>	X	X
<i>E. epistictus</i>	X	
<i>E. fuscoguttatus</i>	X	
<i>E. heniochus</i>		
<i>E. malabaricus</i>	X	
<i>E. quoyanus</i>	X	X
<b>Apogonidae</b>		
<i>Apogonichthyoides umbratilis</i>		
<b>Mugilidae</b>		
<i>Crenimugil crenilabrus?</i>	X	X
<i>Liza vaigiensis</i>	X	
<b>Belonidae</b>		
<i>Ablennes hians</i>	X	
<b>Hemiramphidae</b>		
<i>Hemiramphus far</i>	X	
<i>H. sp</i>	X	
<b>Terapontidae</b>		
<i>Terapon jarbua</i>	X	

<b>Priacanthidae</b>		
<i>P. sagittarius</i>	X	
<b>Lactariidae</b>		
<i>Lactarius lactarius</i>	X	
<b>Sillaginidae</b>		
<i>Sillago ciliata</i>	X	
<i>S. sihama</i>	X	
<b>Rachycentridae</b>		
<i>Rachycentron canadum</i>	X	
<b>Carangidae</b>		
<i>Alectis indica</i>	X	
<i>Atule mate</i>		X
<i>Carangoides caeruleopunctatus</i>		
<i>Carangoides malabaricus</i>	X	
<i>C. talamparoides</i>		
<i>Caranx ignobilis</i>	X	
<i>C. lugubris</i>	X	
<i>Elagatis bipinnulata</i>	X	X
<i>Megalaspis cordyla</i>	X	
<i>Parastromateus niger</i>	X	
<i>Scomberoides commersonianus</i>	X	
<i>S. tol</i>	X	
<i>Selar crumenophthalmus</i>		
<i>Selaroides leptolepis</i>	X	
<i>Uraspis uraspis</i>		
<b>Leiognathidae</b>		
<i>Equulites stercorarius</i>		
<i>Leignathus equulus</i>	X	
<i>Nuchequula blochii</i>		

Lutjanidae		
<i>Lutjanus argentimaculatus</i>	X	X
<i>L. bohar</i>	X	X
<i>L. erythropterus</i>	X	
<i>L. indicus</i>	X	X
<i>L. lemniscatus</i>	X	X
<i>L. lutjanus</i>	X	X
<i>L. malabaricus</i>	X	
<i>L. quinquelineatus</i>	X	X
<i>L. sebae</i>	X	X
<i>L. vitta</i>	X	X
<i>Pristipomoides multidens</i>	X	
<i>P. typus</i>		
Caesionidae		
<i>Caesio cuning</i>	X	X
<i>Pterocaesio tessellata</i>	X	X
Gerreidae		
<i>Gerres filamentosus</i>		
<i>G. oblongus</i>		
Lobotidae		
<i>Lobotes surinamensis</i>	X	
Haemulidae		
<i>Diagramma pictum</i>	X	X
<i>Plectorhinchus flavomaculatus</i>	X	X
<i>Pomadasys furcatum</i>	X	
<i>P. kaakan</i>	X	
<i>P. maculatus</i>		
Sparidae		
<i>Acanthopagrus berda</i>	X	
Lethrinidae		
<i>Gymnocranius elongatus</i>		
<i>G. griseus</i>	X	X
<i>Lethrinus lentjan</i>	X	X
<i>L. microdon</i>	X	
<i>L. nebulosus</i>	X	X
Nemipteridae		
<i>Nemipterus bipunctatus</i>	X	
<i>N. furcosus</i>	X	

<i>N. hexodon</i>	X	
<i>N. japonicus</i>	X	
<i>N. marginatus</i>	X	
<i>N. nemurus</i>	X	
<i>N. peronii</i>	X	X
<i>N. tambuloides</i>	X	
<i>N. zysron</i>	X	
<i>Scolopsis affinis</i>	X	X
<i>S. monogramma</i>	X	X
<i>S. taeniopterus</i>	X	
Sciaenidae		
<i>Johnius borneensis</i>		
<i>J. plagiosoma</i>		
<i>Otolithes ruber</i>	X	
Polynemidae		
<i>Eleutheronema tetradactylum</i>	X	
Gerreidae		
<i>Gerres filamentosus</i>	X	
Mullidae		
<i>Mulloidichthys vanicolensis</i>	X	
<i>Parupeneus heptacanthus</i>	X	X
<i>P. indicus</i>	X	X
<i>Upeneus tragula</i>	X	X
Kyphosidae		
<i>Kyphosus vaigensis</i>	X	X
Drepanidae		
<i>Drepane punctata</i>	X	
Pomacanthidae		
<i>Pomacanthus imperator</i>	X	X
Pomacentridae		
<i>Pomacentrus alpha</i>		
Labridae		
<i>Halichoeres hartzfeldii</i>	X	
<i>Hemigymnus melapterus</i>	X	X
<i>Iniistius bimaculatus</i>	X	
Scaridae		
<i>Chlorurus capistratoides</i>	X	X

<b>Pinguipedidae</b>		
<i>Parapercis albovittata</i>	X	
<i>P. filamentosa</i>		
<i>P. maculata</i>		
<b>Uranoscopidae</b>		
<i>Ichthyoscopus lebeck</i>	X	
<i>Uranoscopus oligolepis</i>		
<b>Ephippidae</b>		
<i>Ephippus orbis</i>		
<b>Acanthuridae</b>		
<i>Acanthurus dussumieri</i>		
<i>A. mata</i>		
<i>A. nigricauda</i>		
<i>Naso unicornis</i>		
<b>Siganidae</b>		
<i>Siganus fuscescens</i>	X	X
<i>S. javus</i>	X	X
<i>S. vermiculatus</i>	X	
<b>Trichiuridae</b>		
<i>Trichiurus lepturus</i>	X	
<b>Scombridae</b>		
<i>Acanthocybium solandri</i>	X	
<i>Auxis thazard</i>	X	
<i>Rastrelliger faughni</i>	X	
<i>R. kanagurta</i>	X	
<i>Scomberomorus commerson</i>	X	
<b>Istiophoridae</b>		
<i>Istiophorus platypterus</i>	X	
<b>Sphyraenidae</b>		
<i>Sphyraena barracuda</i>	X	
<i>S. jello</i>	X	
<i>S. pinguis</i>		
<i>S. putnamae</i>	X	X
<i>S. qenie</i>	X	
<b>Stromateidae</b>		
<i>Pampus argenteus</i>	X	
<b>Cynoglossidae</b>		

<i>Cynoglossus arel</i>	X	
<i>C. brachycephalus</i>	X	
<i>C. cynoglossus</i>		
<i>C. kopsii</i>		
<i>C. quadrilineatus</i>	X	
<b>Psettodidae</b>		
<i>Psettodes erumei</i>	X	
<b>Paralichthyidae</b>		
<i>Pseudorhombus argus</i>		
<b>Bothidae</b>		
<i>Engyprosopon grandisquama</i>		
<b>Soleidae</b>		
<i>Assagerodes satapoomini</i>		
<b>Balistidae</b>		
<i>Abalistes stellatus</i>	X	X
<b>Tetraodontidae</b>		
<i>Lagocephalus spadiceus</i>	X	
<b>Monacanthidae</b>		
<i>Acreichthys tomentosus</i>		
<i>Aluterus monoceros</i>	X	X
<i>A. scriptus</i>	X	
<b>TOTAL</b>	<b>127</b>	<b>41</b>



# APPENDIX F INVERTEBRATE SPECIES LIST

Dr Seabird McKeon and Dr Scott Jones

Genus	Species	RL
Family: Ricordeidae		
<i>Ricordea</i>	<i>sp.</i>	-
Family: Actinodendronidae		
<i>Megalactis</i>	<i>sp.</i>	-
Family: Alcyoniidae		
<i>Sinularia</i>	<i>sp.</i>	-
Family: Antipathidae		
<i>Cirrhopathes</i>	<i>sp.</i>	-
Family: Cerianthida		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
Family: Euphylliidae		
<i>Catalaphyllia</i>	<i>sp.</i>	-
Family: Gorgoniidae		
<i>Rumphella</i>	<i>sp.</i>	-
Family: Melithaeidae?		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
Family: Nephtheidae		
<i>Dendronephthya?</i>	<i>sp.</i>	-
<i>Nephthea</i>	<i>sp.</i>	-
<i>Litophyton</i>	<i>sp.</i>	-
Family: Plexauridae		
<i>Euplexaura?</i>	<i>sp.</i>	-
Family: Sphenopidae		
<i>Protopalythoa</i>	<i>sp.</i>	-
Family: Stichodactylidae		
<i>Heteractis</i>	<i>magnifica</i>	NE
<i>Stichodactyla</i>	<i>mertensii</i>	NE
Family: Subergorgiidae		
<i>Anella?</i>	<i>sp.</i>	-
Family: Veretillidae		

<i>Cavernularia</i>	<i>sp.</i>	-
Family: Xenidae		
<i>Anthelia</i>	<i>sp.</i>	-
Family: Zoanthidea		
<i>Undescr.</i>		-
Class: Anthozoa		
<i>Undescr.</i>		-
Family: Ascidiidae		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
Family: Crinoidea		
<i>Atrium</i>	<i>robustum?</i>	NE
Family: Didemnidae		
<i>Undescr.</i>		-
Family: Acanthasteridae		
<i>Acanthaster</i>	<i>sp.</i>	-
Family: Asterinidae		
<i>Asteropsis</i>	<i>carinifera</i>	NE
Family: Goniasteridae		
<i>Fromia</i>	<i>cf. monilis</i>	NE
Family: Mithrodiidae		
<i>Thromidia</i>	<i>sp.</i>	-
Family: Ophiasteridae		
<i>Linckia</i>	<i>sp.</i>	-
<i>Linckia</i>	<i>multifora</i>	NE
Family: Oreasteridae		
<i>Choriaster</i>	<i>granulatus</i>	NE
<i>Culcita</i>	<i>schmideliana</i>	NE
<i>Pentaceraster</i>	<i>alveolatus</i>	NE
<i>Protoreaster</i>	<i>sp.</i>	-
Family: Cardiidae		
<i>Tridacna</i>	<i>crocea</i>	LC
<i>Tridacna</i>	<i>squamosa</i>	NE

Class: Bivalvia (Class)		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
Family: Malleidae		
<i>Malleus</i>	<i>malleus</i>	NE
Family: Pectinidae		
<i>Pedum</i>	<i>sp.</i>	-
Family: Pinnidae		
<i>Atrina</i>	<i>vexillum?</i>	NE
Family: Pteriidae		
<i>Pteria</i>	<i>sp.</i>	-
<i>Pinctada</i>	<i>sp.</i>	-
<i>Pinctada</i>	<i>margaritifera</i>	NE
Family: Loliginidae		
<i>Sepioteuthis</i>	<i>sp.</i>	-
Family: Idiosepiidae		
<i>Idiosepius</i>	<i>sp.</i>	-
Family: Sepiidae		
<i>Sepia</i>	<i>sp.</i>	-
Family: Comasteridae		
<i>Oxycomanthus</i>		-
<i>Class: Crinoidea</i>		
<i>Undescr.</i>		-
Family: Phloeodictyidae		
<i>Oceanapia</i>	<i>sp.</i>	-
Family: Cidaridae		
<i>Phyllacanthus</i>	<i>imperialis</i>	-
Family: Diadematidae		
<i>Diadema</i>	<i>setosum</i>	NE
<i>Echinothrix</i>	<i>calamaris</i>	NE
Family: Temnopleuridae		
<i>Mespilia</i>	<i>globulus</i>	NE
Family: Toxopneustidae		
<i>Toxopneustes</i>	<i>pileolus</i>	NE
Family: Amphinomidae		

<i>Chloeia</i>	<i>parva</i>	NE
Family: Aglajidae		
<i>Chelidonura</i>	<i>hirundini</i>	NE
Family: Bornellidae		
<i>Bornella</i>	<i>anguilla</i>	NE
Family: Cassidae		
<i>Cassis</i>	<i>sp.</i>	-
Family: Chromodorididae		
<i>Chromodoris</i>	<i>annulata</i>	NE
<i>Chromodoris</i>	<i>hintuanensis</i>	NE
<i>Doriprismatica</i>	<i>atromarginata</i>	NE
<i>Glossodoris</i>	<i>atromarginata</i>	NE
<i>Glossodoris</i>	<i>hikuerensis</i>	NE
<i>Goniobranchus</i>	<i>annulata</i>	NE
<i>Goniobranchus</i>	<i>hintuanensis</i>	NE
<i>Hypselodoris</i>	<i>maridadilus</i>	NE
<i>Hypselodoris</i>	<i>pulchella</i>	NE
<i>Hypselodoris</i>	<i>whitei</i>	NE
<i>Hypselodoris?</i>	<i>sp.</i>	-
Family: Conidae		
<i>Conus</i>	<i>episcopatus</i>	LC
<i>Conus</i>	<i>nussatella</i>	LC
<i>Conus</i>	<i>textile</i>	LC
Family: Cypraeidae		
<i>Cypraea</i>	<i>caurica</i>	NE
<i>Cypraea</i>	<i>talpa</i>	NE
<i>Cypraea</i>	<i>tigris</i>	NE
Family: Cysticidae		
<i>Cystiscus</i>	<i>garretti</i>	NE
Family: Discodorididae		
<i>Carminodoris</i>	<i>estrellyado</i>	NE
<i>Halgerda</i>	<i>stricklandi</i>	NE
<i>Platydorid?</i>	<i>sp.</i>	-
<i>Taringa?</i>	<i>sp.</i>	-
Family: Facelinidae		
<i>Caloria?</i>	<i>sp.</i>	-
<i>Pteraeolidia</i>	<i>ianthina</i>	NE

Family: Fascioliidae		
<i>Latirus</i>	<i>nodatus</i>	NE
<i>Pleuroploca</i>	<i>filamentosa</i>	NE
Family: Fionidae		
<i>Cuthona</i>	<i>sp.</i>	-
Family: Hexabanchidae		
<i>Hexabanchus?</i>	<i>sp.</i>	-
Family: Muricidae		
<i>Quoyula</i>	<i>sp.</i>	-
<i>Undescr.</i>		-
<i>Morula</i>	<i>sp.</i>	-
<i>Chicoreus</i>	<i>palmarosa</i>	NE
<i>Chicoreus</i>	<i>ramosus</i>	NE
Family: Naticidae?		
<i>Undescr.</i>		-
Family: Ovulidae		
<i>Calpurnus</i>	<i>verrucosus</i>	NE
<i>Phenacovolva</i>	<i>rosea</i>	NE
<i>Volva</i>	<i>volva</i>	NE
Family: Phyllidiidae		
<i>Phyllidia</i>	<i>coelestis</i>	NE
<i>Phyllidia</i>	<i>elegans</i>	NE
<i>Phyllidia</i>	<i>multituberculata</i>	NE
<i>Phyllidia</i>	<i>ocellata</i>	NE
<i>Phyllidiella</i>	<i>zeylanica</i>	NE
<i>Phyllidia</i>	<i>ocellata</i>	NE
Family: Elysiidae		
<i>Elysia</i>	<i>ornata</i>	NE
Family: Pleurobranchidae		
<i>Pleurobranchus</i>	<i>forskalii</i>	NE
Family: Polyceridae		
<i>Roboastra</i>	<i>gracilis</i>	NE
<i>Tambja</i>	<i>amakusana</i>	NE
<i>Undescr.</i>		-
ly: Stomatellidae		
<i>Stomatella</i>	<i>sp.</i>	-

Family: Strombidae		
<i>Strombus</i>	<i>sp.</i>	-
Family: Tergipedidae		
<i>Phestilla</i>	<i>minor</i>	NE
Family: Tritonidae		
<i>Tritonopsis</i>	<i>elegans</i>	NE
Family: Turbinellidae		
<i>Vasum</i>	<i>turbinellum</i>	NE
Family: Turbinidae		
<i>Astralium</i>	<i>sp.</i>	-
<i>Astralium</i>	<i>sp.</i>	-
<i>Undescr.</i>		-
Family: Velutinidae		
<i>Coriocella</i>	<i>nigra</i>	NE
<i>Class: Gastropoda</i>		
<i>Undescr.</i>		-
Family: Holothuriidae		
<i>Holothuria</i>	<i>atra</i>	LC
<i>Holothuria</i>	<i>edulis</i>	LC
<i>Holothuria</i>	<i>hilla</i>	LC
<i>Holothuria</i>	<i>pervicax</i>	LC
<i>Pearsonothuria</i>	<i>graeffeii</i>	LC
Family: Phyllophoridae		
<i>Massinium</i>	<i>sp.</i>	-
Family: Synaptidae		
<i>Synapta</i>	<i>maculata</i>	NE
<i>Order: Dendrochirotida</i>		
<i>Undescr.</i>		-
Family: Scyllaridae		
<i>Scyllarus</i>	<i>sp.</i>	-
Family: Alpheidae		
<i>Alpheus</i>	<i>edwardsii</i> <i>cf. sulunensis</i>	NE
<i>Alpheus</i>	<i>lottini</i>	NE
<i>Alpheus</i>	<i>cf. leptochirus</i>	NE
<i>Alpheus</i>	<i>cf. leviusculus</i>	NE

<i>Alpheus</i>	<i>pareuchirus</i>	NE
<i>Alpheus</i>	<i>sp pacificus</i>	NE
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Alpheus</i>	<i>sp.</i>	-
<i>Racilius</i>	<i>compressus</i>	NE
<i>Synalpheus</i>	<i>demani</i>	NE
<i>Synalpheus</i>	<i>sp.</i>	-
<i>Synalpheus</i>	<i>sp.</i>	-
<i>Synalpheus</i>	<i>sp.</i>	-
<i>Synalpheus</i>	<i>sp.</i>	-
<i>Synalpheus</i>	<i>striatus</i>	NE
Family: Axiidae		
<i>Undescr.</i>		-
Family: Coenobitidae		
<i>Coenobita</i>	<i>rugosus</i>	NE
Family: Cryptochiridae		
<i>Hapalocarcinus</i>	<i>sp.</i>	-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Utinomiella</i>	<i>dimorpha</i>	NE
Family: Diogenidae		
<i>Calcinus</i>	<i>gaimardii</i>	NE
<i>Calcinus</i>	<i>haigae</i>	NE
<i>Calcinus</i>	<i>pulcher</i>	NE
<i>Ciliopagurus</i>	<i>strigatu</i>	NE
<i>Dardanus</i>	<i>lagopodes</i>	NE
<i>Dardanus</i>	<i>pedunculat</i>	NE
Family: Epialtidae		
<i>Tylocarcinus</i>	<i>dumerilii</i>	NE

<i>Eriphia</i>	<i>sebana</i>	NE
Family: Galatheidae		
<i>Allogalatea</i>	<i>elegan</i>	NE
<i>Galathea</i>	<i>inflata</i>	NE
Family: Gonodactylidae		
<i>Undescr.</i>		-
Family: Grapsidae		
<i>Grapsus</i>	<i>intermedia?</i>	NE
Family: Hippolytidae		
<i>Lysmata</i>	<i>amboinensis</i>	NE
<i>Saron</i>	<i>sp.</i>	-
<i>Thor</i>	<i>ambonensis</i>	NE
Family: Inachidae		
<i>Camposcia</i>	<i>retusa</i>	NE
Family: Leucosiidae		
<i>Heteronucia?</i>	<i>sp.</i>	-
Family: Majidae		
<i>Schizophrys</i>	<i>aspera</i>	NE
<i>Schizophrys</i>	<i>sp.</i>	-
Family: Ocypodidae		
<i>Ocypode</i>	<i>sp.</i>	-
Family: Odontodactylidae		
<i>Odontodactylus</i>	<i>scyllarus</i>	-
Family: Paguridae		
<i>Paguritta</i>	<i>sp.</i>	-
<i>Paguritta</i>	<i>sp.</i>	-
Family: Palaemonidae		
<i>Ancylomenes</i>	<i>magnificus</i>	NE
<i>Coralliocaris</i>	<i>superba</i>	NE
<i>Cuapetes</i>	<i>sp.</i>	-
<i>Undescr.</i>	<i>(ex crinoid)</i>	-
<i>Coralliocaris</i>	<i>sp.</i>	-
<i>Periclimenes</i>	<i>brevicarpalis</i>	NE
<i>Undescr.</i>		-
<i>Periclimenes</i>	<i>imperator</i>	NE
<i>Periclimenes</i>	<i>soror</i>	NE
<i>Vir</i>	<i>philipinensis</i>	NE

<i>Vir</i>	<i>sp.</i>	-
Family: Palinuridae		
<i>Panulirus</i>	<i>versicolor</i>	LC
Family: Pilumnidae		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
Family: Plagusidae		
<i>Percnon</i>	<i>planissimus</i>	NE
Family: Porcellanidae		
<i>Undescr.</i>		-
<i>Neopetrolisthes</i>	<i>maculatus</i>	NE
<i>Neopetrolisthes</i>	<i>sp.</i>	-
<i>Pachycheles</i>	<i>sp.</i>	-
<i>Petrolisthes</i>	<i>sp.</i>	-
<i>Raphidopus</i>	<i>sp.</i>	-
<i>Raphidopus</i>	<i>sp.</i>	-
Family: Portunidae		
<i>Caphyra</i>	<i>laevis</i>	NE
<i>Charybdis</i>	<i>acutifrons</i>	NE
<i>Charybdis</i>	<i>feriatus</i>	NE
<i>Portunus</i>	<i>sp.</i>	-
<i>Portunus</i>	<i>pelagicus</i>	NE
<i>Portunus</i>	<i>sanguinolentus</i>	NE
<i>Thalamita</i>	<i>admete</i>	NE
<i>Thalamita</i>	<i>mitsienseis</i>	NE
Family: Rhynchocinetidae		
<i>Rhynchocinetes</i>	<i>durbanensis</i>	NE
Family: Stenopodidae		
<i>Stenopus</i>	<i>hispidus</i>	NE
Family: Trapeziidae		
<i>Quadrella</i>	<i>boopsis</i>	NE
<i>Tetralia</i>	<i>sp.</i>	-
<i>Tetralia</i>	<i>nigrolineata</i>	NE
<i>Trapezia</i>	<i>cymodoce</i>	NE
Family: Xanthidae		
<i>Chloridiella</i>	<i>laevissim</i>	NE
<i>Cymo</i>	<i>sp.</i>	-

<i>Etisus</i>	<i>bifrontalis?</i>	NE
<i>Lacnopodus?</i>	<i>sp.</i>	-
<i>Liocarpilodes</i>	<i>integerrimus</i>	NE
<i>Liomera</i>	<i>monticulosa</i>	NE
<i>Liomera</i>	<i>venosa?</i>	NE
<i>Lophozozymus</i>	<i>sp.</i>	-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Neoxanthops</i>	<i>lineatus</i>	NE
<i>Pilodius</i>	<i>pugil</i>	NE
Order: Amphipoda		
<i>Undescr.</i>		-
Order: Isopoda -		
<i>Undescr.</i>		-
Family: Amphiuridae		
<i>Ophiothrix?</i>	<i>sp.</i>	-
Family: Gorgonocephalidae		
<i>Astroboa</i>	<i>sp.</i>	-
Family: Ophiotrichidae		
<i>Macrothrix</i>	<i>sp.</i>	-
<i>Ophidia</i>	<i>sp.</i>	-
<i>Ophiothela</i>	<i>sp.</i>	-
Family: Phascolosomatidae		
<i>Phascolosoma</i>	<i>sp.</i>	-
<i>Phascolosoma</i>	<i>sp.</i>	-
Family: Chaetopteridae		
<i>Chaetopterus</i>	<i>sp.</i>	-
Family: Eunicidae		
<i>Eunice</i>	<i>sp.</i>	-
Family: Sabellidae		
<i>Undescr.</i>		-
<i>Sabellastarte</i>	<i>sp.</i>	-
Family: Serpulidae		
<i>Undescr.</i>		-
<i>Protula</i>	<i>magnifica</i>	NE

<i>Spirobranchus</i>	<i>sp.</i>	-
Family: Catostylidae		
<i>Crambione</i>	<i>sp.</i>	-
Family: Cepheidae		
<i>Cephea</i>	<i>cephea</i>	NE
Family: Ulmaridae		
<i>Aurelia</i>	<i>sp.</i>	-
Family: Pseudocerotidae		
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Undescr.</i>		-
<i>Pseudobiceros</i>	<i>bedfordi</i>	NE
<i>Thysanozoon</i>	<i>sp.</i>	-
<i>Thysanozoon</i>	<i>sp.</i>	-
Family: Porcellanidae		
<i>Petrolisthes</i>	<i>sp.</i>	-

RL=IUCNRedlistcategory

*“With more than three billion people depending on marine and coastal biodiversity for a living, protecting areas like the Myeik Archipelago is critical for our survival. FFI will therefore continue to support research to further our understanding of, and help protect, such environments for our future.”*

Mark Rose, Chief Executive, Fauna & Flora International.

