February 2009
TNC Pacific Island Countries
Report No 1/09

Rapid Ecological Assessment

Northern Bismarck Sea

Papua New Guinea

Technical report of survey conducted August 13 to September 7, 2006

Edited by:
Richard Hamilton, Alison Green and Jeanine Almany

Supported by:

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Foreword

Manus and New Ireland provinces lie north of the Papua New Guinea mainland in the Bismarck Archipelago. More than half of the local communities in our provinces are coastal inhabitants, who for thousands of years have depended on marine resources for their livelihood. For coastal communities survival and prosperity is integrally linked to healthy marine ecosystems. Many of our ancestors' recognised the need to manage our marine resources and developed intricate customs and traditional management practices that are still practised today.

But in these modern times we are faced with new pressures and threats. Population growth, access to more efficient fishing technologies and the influence of the cash economy have dramatically increased pressure on our natural resources. We must also deal with recent threats such as climate change, a global challenge that could undermine one of the fundamental cornerstones of our livelihoods, our coral reefs. Today, more then ever, we the people of Manus and New Ireland must make informed decisions on how to conserve our marine environment, so to ensure that our children can enjoy the cultural, social and economic treasures that have defined our people for millennium.

In Manus and New Ireland, The Nature Conservancy (TNC) has been supporting community-based conservation initiatives since 2004, and in 2006 The Nature Conservancy and partners conducted a marine assessment in the waters of the North Bismarck Sea. The area covered included the Tigak Islands, New Hanover and Djaul in New Ireland and around the main island of Manus. The survey provides an assessment of the biodiversity and status of corals and reef fish in waters surrounding these provinces and provides recommendations for their conservation and management. We hope that that this report will encourage us to be aware of our marine environment and in turn be more responsible in how we use the resources within it. On behalf of the people of New Ireland and Manus we would like to thank all of those involved in completing this project. In many ways the completion of this report is the beginning of the hard work not the end. As the Governors of New Ireland and Manus we urge all of us to continue to work in partnerships to sustain the future of our provinces.

Rt Honourable Sir Julius Chan
Governor
New Ireland province

Honourable Michael Sapau
Governor
Manus province

Acknowledgements

The survey was led by The Nature Conservancy and supported by the National Fisheries Authority of Papua New Guinea, Manus Provincial Government, New Ireland Provincial Government, The National Fisheries College, World Wide Fund for Nature, Wildlife Conservation Society, Gillett Preston Associate (Coastal Fisheries Management and Development Project, CFMDP), Ailan Awareness, Lissenung Dive Resort, Mansava Resort and Dive Manus.

We express our sincere thanks to key individuals who assisted with community liaison work prior to and during this survey. In New Ireland we thank; Mr. Joel Opnai (late), Gillette Preston Associates, Ms. Sandra Marahang, New Ireland Province Provincial Fisheries, Mr. Satarek Taput, New Ireland Province Provincial Fisheries, Mr. John Aini, Ailan Awareness, Mr. Tatek Buraik, National Fisheries College, Manoua Karo, Wildlife Conservation Society and Mr. Samol Kanawi, National Fisheries College.

In Manus we thank; Mr. Obed Otto, Manus Province Policy and Planning Division, Mrs. Ipau Apas, Manager at Harborside Hotel, Mr. John Malai, Manus Province Culture and Tourism Division, Mr. Pomat Powayai, Manus Province Fisheries Division, Mr. Selan Kaluwin, CBO, Mr. Bernard Menly, NBC Publication Officer and Mr Mr. Robert Siwer, LLG member.

We would also like to thank the the survey team members, Litau Pomat NFA, Kavieng, Lawrence Litau, The Nature Conservancy, Kavieng, Miro Logai, New Ireland Provincial Fisheries, Jerry Pokiap, The Nature Conservancy Manus and Mr. Pomat Kaluwin, Kavieng. We also thank Nate Peterson from the TNC Brisbane Office for producing all of the maps presented in this report.

The success of this survey hinged on the support and interest of tribal chiefs, church leaders, elders, men, women and children of the communities that we visited and we thank you all. Your kind assistance in helping us carry out this survey on your reefs has been instrumental to its success. It is hoped that the results of the marine assessment will be used to help ensure the sustainability of the marine resources of the Northern Bismarck Sea, while also raising global awareness of the uniqueness and importance of the Bismarck Sea, one of the last great places on earth.

Contents

Executive Summary

The Northern Bismarck Sea marine assessment was conducted in New Ireland and Manus Provinces between August 13th to September 7th, 2006. In New Ireland the survey covered the Tigak Islands, New Hanover and Djaul Island, while in Manus the survey was conducted predominantly around the main island of Manus. The survey team was comprised of international and local scientists, conservationists and Papua New Guinea fisheries' officers. The survey provided an assessment of the biodiversity and status of corals and reef fish in the Northern Bismarck Sea, with recommendations for their conservation and management.

The survey showed that the North Bismarck Sea hosts very high hard coral species richness. A total of 452 species belonging to 70 genera in 15 families were recorded on this survey. The reefs that the team visited around Manus Island were all in good to excellent condition and tended to have higher hard coral diversity than reefs around New Ireland. Although some reefs visited in New Ireland were healthy, many were in poor condition; there were crown of thorns starfish on most reefs with significant coral mortality at some sites within the Tigak Islands.

The survey also confirmed that the Northern Bismarck Sea has a high biodiversity of reef fish. A combination of historical data and 577 new records from the current survey yields a total of 801 species belonging to 76 families and 274 genera for the Northern Bismarck Archipelago. A formula for predicting the total reef fish fauna indicates that at least 945 species can be expected to occur in this region.

The entire Bismarck Sea is expected to support a total of 514 coral species (http://www.coralreefresearch.org/html/crr_cg.htm) and 1493 coral reef fish species (Allen, unpublished data). This survey confirms that the Bismarck Sea is part of the global centre of marine diversity, known as the Coral Triangle (Figure 1), which includes all or part of the Philippines, Indonesia, Malaysia, Timor Leste, Papua New Guinea and the Solomon Islands. The Coral Triangle comprises a staggering 76% of the world's corals and 37% of the world's coral reef fish species in an area that covers less than 2% of the planet's oceans.

Fishing pressure appears to be considerably less than in some areas further west in the Coral Triangle. Fish populations were very healthy in most locations in Manus, with spectacular fish communities and lots of big fish observed at several sites. However, there was some evidence of overexploitation in New Ireland. Reef fish surveys showed that large vulnerable fishes such as sharks, bumphead parrotfish and large species of groupers were present in low abundances in New Ireland where historically commercial fishing pressure has been greater than in Manus. In both provinces the reef health team rarely sighted high value macro invertebrates such as sea cucumbers, trochus and giant clams, indicating that these resources have already been overfished.

Figure 1. The Coral Triangle (Green and Mous, 2008).

Conservation & Management Recommendations

In this section the survey team offers a range or recommendations for the conservation and sustainable use of marine habitats and important marine resources in the Northern Bismarck Sea. These recommendations are based on the survey team's collective experience along with input from community representatives and provincial fisheries departments. They include recommendations for the establishment of networks of community based marine protected areas and management options for some important reef fisheries.

MARINE PROTECTED AREAS

Locally managed Marine Protected Areas[1] (MPAs) can play a critical role in protecting biological diversity and managing marine resources. Several good examples of this are the recent commitments of communities in Manus and New Ireland to protect specific areas on their customary reefs where 1000s of groupers are known to aggregate to spawn at predicable times of the year (Hamilton et al., 2005). By preventing fishing at these critically important areas communities are conserving the biodiversity at these multispecies spawning aggregation sites and exercising a precautionary approach towards managing their grouper fisheries.

This and other efforts by local communities and NGOs are helping to build the socio-political and cultural climate for conservation in the region. However further efforts will be required if Papua New Guinea is to adequately protect the remarkable biological diversity of the Northern Bismarck Sea. One option that would help to conserve the Northern Bismarck Seas marine biodiversity would be to establish a network of locally managed MPAs that include representative examples of the main habitat types (coral reefs, mangroves and seagrasses), with special attention to critical sites such as fish spawning aggregations, nursery areas and turtle nesting beaches. In designing such a network the likely impacts of climate change could also be accounted for.

While it is seldom possible to capture all key targets in a single area, there is plenty of scope to design a network of MPAs that covers the full range of biodiversity that occurs within the Northern Bismarck Sea. In Melanesia, coastal communities have customary ownership over the mangroves, lagoons and reefs in their nearby vicinity, so any efforts to establish MPAs requires support from the customary owners. Consequently, for a MPA network to be successfully implemented in the Northern Bismarck Sea, it will need to be designed so that it incorporates high biodiversity areas that local communities are interested in and capable of conserving.

In general the Northern Bismarck Sea has good potential for reef conservation, based on the results of the current survey. A wide variety of habitats are represented, frequently within relatively confined areas which provide an ideal scenario for establishing MPAs. Some of the areas that the survey team believes would make good choices for inclusion into a MPA network are outlined below by province. These suggestions are made taking into account the very high coral and fish biodiversity of these regions as well as general reef health. In some of the areas of high biodiversity conservation efforts are already underway, and these geographies would be the obvious areas to focus on if attempting to scale up existing conservation efforts.

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[1] In this document we use the definition developed by the International World Conservation Union (IUCN), which defines MPA as: "Any area of intertidal or subtidal terrain, together with its overlaying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment."

New Ireland

Areas that the survey team believes would make good choices for conservation action in New Ireland are shown in Figure 2.

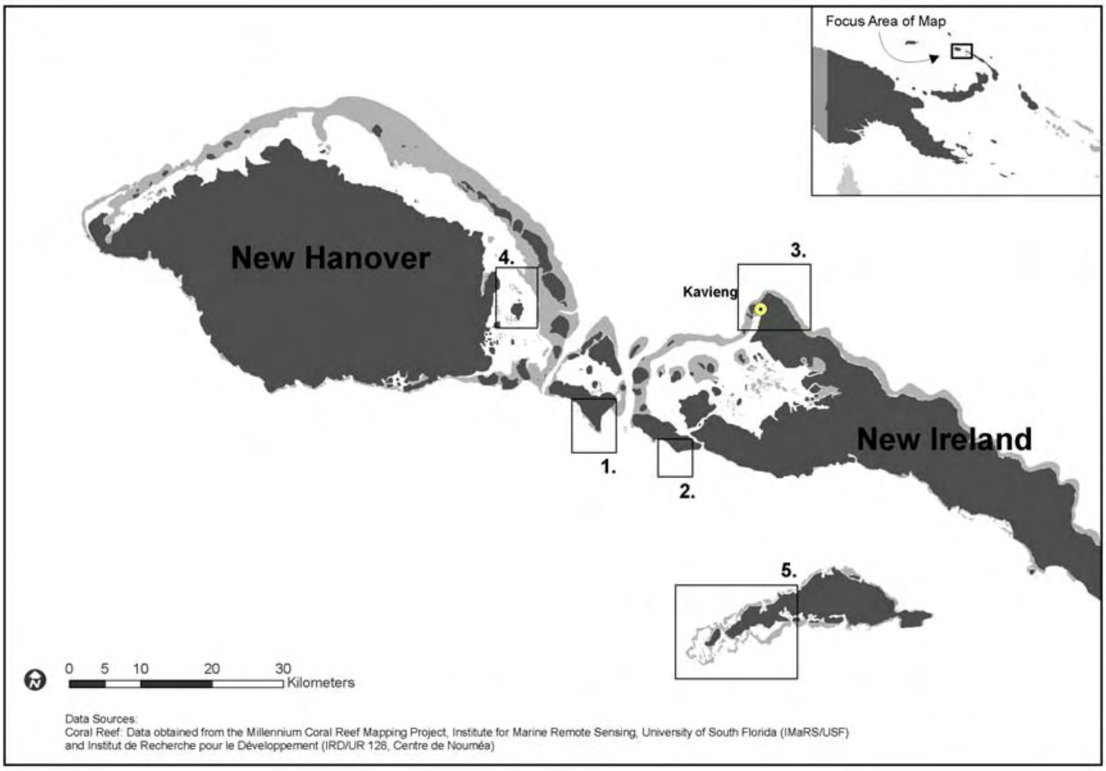

Figure 2. Some of the areas in New Ireland that the survey team believes would make good choices for conservation action.

1. Salapiu Island

The outer reefs of Salapiu Island had the highest biodiversity of fish (234) seen in New Ireland and this is an area where The Nature Conservancy (TNC) is actively engaged in community based conservation. For the past four years the Conservancy has been working with the Salapiu community to monitor a known grouper spawning aggregation site that occurs on their customary reefs. This work has raised the profile of conservation in this community and TNC is currently working with the Salapiu community to assist them in developing a management plan which will see three marine areas formally set aside for conservation.

2. Bauddissin Bay, Bauddissin Island

This areas includes a relatively narrow strip of reef covering less than one square km on the southern coast of Bauddissin (also known as Burusan) Island, one of the two largest islands that form the southern tier of islands linking New Ireland with New Hanover. The site is notable due to the unusual reef structure and rich habitat variability within a very confined area. There is a typical outer reef wall that drops to about 70 m depth that is separated from the coastal reef by a narrow channel with a maximum depth of 10-12 m. The channel then opens into the shallow sandy lagoon of the inner part of Bauddissin Bay. The channel is flushed periodically by clear water from the open sea and consequently supports a wealth of fishes, including numerous snappers and sweetlips. One of the highest fish counts (198 species) was obtained in the back reef channel, an exceptional total considering the sheltered nature of this location.

There is also nearby mangrove environment along the shore. This site also had the third highest coral biodiversity (194) of all the sites surveyed in New Ireland.

3. Nusa Island and western tip of New Ireland

Nusa Island and the western tip of New Ireland are considered suitable for conservation due to their high diversity of coral and fish. The highest and forth highest coral diversity in New Ireland was sighted on the Western tip of New Ireland (198) and at Nusa Island (182). The second and third highest fish biodiversity counts made in New Ireland were also at the Western tip of New Ireland (198) and at Nusa Island (193).

4. North Anelaua Island

This area includes the complex of sheltered reefs lying north of Anelaua Island and its small satellite, Anelik Island. The maze of reef covers approximately six square km. The area, which lies only about 2.6 km off the eastern coast of New Hanover, supports luxurious coral gardens, which unlike much of the Tigak Archipelago, is relatively undamaged by crown of thorns starfish. It appears to be an important nursery area for at least three species: Humphead Wrasse (*Cheilinus undulatus*), Bumphead parrotfish (*Bolbometopon muricatum*), and Spanish flag snapper (*Lutjanus carponotatus*).

5. Djaul Island

The western end of Djaul Island is an ideal location for conservation. The remoteness of this large island and its relatively small human population means that reef fish resources in this area are much healthier than in many areas in the Tigak's and New Hanover. Unlike many areas in New Ireland the reefs around Djaul are unaffected by crown of thorns starfish. Djaul is an area where TNC is actively engaged in community based conservation. For the past four years TNC has been working with the Leon community to monitor and protect a large multispecies grouper spawning aggregation.

Manus

Areas that the survey team believes would make good choices for conservation action in Manus are shown in Figure 3.

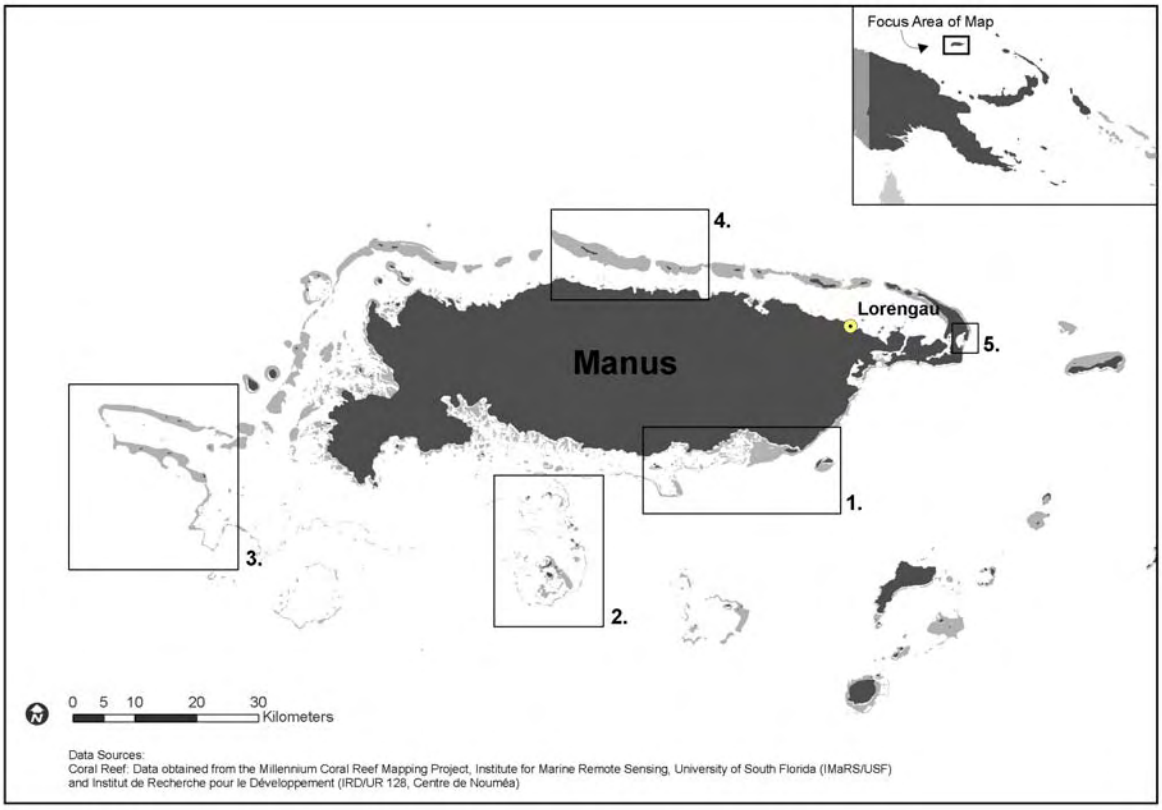

Figure 3. Some of the areas in Manus that the survey team believes would make good choices for conservation action.

1. South coast of Manus

The south coast of Manus has very high fish and coral biodiversity. In this survey Drova Island had the second highest coral count (200) and third highest fish count (198) in Manus Province, and the inner reefs in Patusi Bay have several coral species that are thought to be new to science. The south coast of Manus also has many multi species grouper spawning aggregation sites and nursery areas, and conservation efforts are well underway in this region of Manus. TNC has been working with communities in this area for four years to monitor and protect three large grouper spawning aggregation sites. The Pere community has now established several MPAs on their reefs, and they are working to finalize the Pere environmental and conservation management plan, which will provide a legally recognized framework for managing all of their customary waters. Other communities along the south coast have expressed interest in following Peres lead, and the community owners of Drova Island have approached TNC and expressed their interest in setting aside Drova Island as a conservation area.

2. Mbuke Islands

The outer islands of Mbuke on the south coast of Manus have very high coral diversity and support healthy populations of reef fishes. In this survey Anun Island in Mbuke had the highest coral diversity (211) in Manus. This area also supported healthy numbers of sharks and other large vulnerable reef fishes. With a small nucleated human population and a large reef area Mbuke is an ideal region for community based conservation. Conservation efforts are underway here as the Mbuke community has been working with World Wildlife Foundation (WWF) for the past four years, and they have set aside several of their reefs as MPAs.

3. Sabben Islands

The remote barrier reef and associated low lying islands cover approximately 200 square km off the extreme western end of Manus with the most distant portion of the reef situated 37 km from the mainland. The general environment is similar to that of an atoll with a shallow, sandy lagoon and abrupt outer reef walls. The highest number of fishes for any site on Manus (230) was recorded here. It was also one of the best locations for large vulnerable fishes (sharks, snappers, humphead wrasse, etc.) and was characterised by excellent underwater visibility.

4. Northern Manus outer islands

In this survey islands off the northern coast of Manus had very high coral and fish diversity. The second highest coral biodiversity in Manus (200) was seen on Ponam Reef, and the nearby Hinru Island had exceptionally high live coral cover. The outer islands on the north coast of Manus is an region where traditional fisheries management practices continue to occur, such as the periodic closures of reefs to allow stocks to recover (Cinner, et al. 2005; Hamilton 2003a). World Conservation Society (WCS) has been working with communities in this region to assist them with their marine management issues in recent years.

5. Hayne Harbour

The large bay next to the Manus airport on Los Negros Island covers an area of about 2.7 square km. This sheltered lagoon provides a habitat for a host of reef fishes and is partially lined with mangroves. The site yielded an unusually high fish species count (205) for a protected inshore habitat. The lagoon has a substantial opening to the open sea and is well-flushed by the tides. There is good representation of outer reef fishes in the entrance channel and a transitional zone around the mouth of the lagoon.

Finally, it is noteworthy that many of distant islands that lie to the east and south east of Manus Island were not covered in this survey. This includes the islands of Lou, Pak, Tong and Rabbutyo. Previous underwater observations by some of the authors on this report have revealed that many of these islands support remarkably diverse and healthy reefs that would also be ideal for conservation action.

FISHERIES MANAGEMENT

Marine resources are the mainstay of the subsistence, artisanal and commercial fisheries in New Ireland and Manus, comprising a major component of the protein in the diet of coastal communities and an important source of income. The results of this survey and prior surveys indicate that overfishing of some high value marine resources has already occurred and management action is desirable to prevent further declines.

Groupers and Coral Trout

Many grouper spawning aggregations in Manus and New Ireland have been overfished by a combination of artisanal night time spearfishing and Live Reef Food Fish Trade (LRFFT) operations (Hamilton and Matawai 2006; Hamilton, et al. 2005). One of the species that regularly forms spawning aggregations in Melanesia is the squaretail coral trout , *Plectropomus areolatus*, a species that is now listed as Vulnerable on the IUCN Red list (Chan and Sadovy 2007). In this survey groupers were significantly more abundant in Manus than New Ireland, possibly due to differences in historical fishing pressure. To restore grouper populations in New Ireland and sustain current populations in Manus there is a need for management of this commercially important family of fish. One solution would be to impose provincial wide seasonal bans on the sale of any grouper during periods when they to aggregate to spawn. Two specific recommendations which should be implemented in conjunction with each other are:

- Place a six month seasonal ban on all LRFFT activities in Manus and New Ireland from the 1st of March to the 31st of August each year. This is the period when many species of groupers (e.g. *Epinephelus fuscoguttatus, E. polyphekadion, E. ongus* and *P. areolatus*) aggregate in the 100s or 1000s at known sites in Manus and New Ireland for the purpose of spawning (Manuai Matawai and Tapas Potuku, unpublished data 2004-2008; Hamilton and Matawai, 2006).

- Prevent the sale of all groupers in the 10 days leading up to and including the new moon. This is the lunar period when most groupers aggregate to spawn. A lunar ban would offer some protection to species of groupers such as *P. areolatus* that form different sized spawning aggregations throughout the entire year in New Ireland and Manus (Manuai Matawai and Tapas Potuku, unpublished data 2004-2008; Hamilton and Matawai, 2006).

Humphead wrasse (*Cheilinus undulatus*)

The humphead wrasse (*Cheilinus undulatus*) is a conspicuous indicator of general fishing pressure throughout the coral triangle region. It is a prime target of LRFFT operations and populations typically decline markedly once LRFFT operations occur. This species is listed as Endangered on the IUCN Red list (Russell 2004) in recognition of its slow population turnover (Choat, et al. 2006) and vulnerability to overfishing by the LRFFT (Sadovy, et al. 2003). In this survey *C. undulatus* were present in moderate numbers in both New Ireland and Manus; however *C. undulatus* sighted in Manus were on average far bigger, indicative of more intense LRFFT fishing pressure in New Ireland. To conserve this iconic species we recommend that a national wide ban should be placed on the sale of *Cheilinus undulatus* to LRFFT operations and commercial fisheries centres.

Bumphead parrotfish (*Bolbometopon muricatum*)

Bumphead parrotfish (*Bolbometopon muricatum*) is the largest of all parrotfishes and has recently been listed as Vulnerable on the IUCN Red list (Chan, et al. 2007). This listing is in recognition of the conservative life histories of this species (Hamilton, et al. 2008) and the ease with which nocturnal aggregations of this species can be overfished by night-time spear fishers (Dulvy and Polunin 2004; Hamilton 2003b). Densities of *B. muricatum* have dropped markedly in the Tigak Islands region in the recent years. The density of *B. muricatum* seen in the Tigak Islands on long swims in 2006 was eight times lower than densities of *B. muricatum* that professor Howard Choat recorded in the Tigak Islands on long swims in 2000 (Chan, et al. 2007). This marked drop in the Tigak Islands is almost certainly an indication of heavy night time spearfishing pressure on this species in this decade. Results of this survey indicate that in Manus this species is in somewhat better shape, with densities of *B. muricatum* in Manus being 12 times higher then densities seen in New Ireland. To protect this vulnerable species we recommend placing a national wide ban preventing commercial fisheries centres from purchasing *B. muricatum*.

Sharks

On coral reefs sharks are apex predators that play a key role in maintaining healthy reef ecosystems. In this survey low numbers of reef sharks were sighted in New Ireland and Manus, indicative of overfishing by the shark-fin trade (Figure 4). The shark fin trade is responsible for decimating shark populations globally, reef shark populations are plummeting and at risk of ecological extinction in the next twenty years as a result of shark fishing (Robbins, et al. 2006). We recommend a permanent ban on the shark-fin trade in the Bismarck Sea or, at a minimum, that a moratorium be place on shark-fin fishery until a NFA shark-fin management plan is in place.

Sea Cucumbers

Although not covered in this survey, sea cucumbers were extensity surveyed in the Tigak region in late 2006 (Kaly 2007). The Kaly et al. (2007) survey showed that sea cucumbers are severely overfished in the Tigak region of New Ireland and they recommended that the fishery be closed for several years in order to allow stocks to recover. We support this recommendation and we also recommend that a similar survey be conducted in Manus. A NFA 2001 survey of sea cucumber resources in Manus would provide the baseline data to compare a future survey against (Lokani 2001).

Figure 4. Shark fins and sea cucumbers drying at Loerngau, Manus.

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Overview

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Contents

CONSERVATION CONTEXT

BIOLOGICAL CONTEXT

The global centre of marine biodiversity, known as the Coral Triangle, is a high priority for marine conservation. The Coral Triangle is known to support 76% of the world's coral species (http://www.coralreefresearch.org/html/crr_cg.htm) and 37% of the world's coral reef fish species in an area that covers less than 2% of the planet's oceans (Green and Mous, 2008). The Nature Conservancy and its partners are committed to conserving this extraordinary biodiversity through establishing resilient networks of Marine Protected Areas (MPA) throughout the Coral Triangle. One of the first steps in designing these networks is understanding how biodiversity is distributed throughout the area.

The Conservancy and its partners have recently completed a process to delineate the Coral Triangle, its eco-region and functional seascapes (Green and Mous 2008: Figures 1, 2 & 3), which will serve as a blueprint for establishing MPA networks throughout this high priority area. Within eco-region, MPA networks will be established at the scale of functional seascapes[1], leading to the establishment of a large-scale resilient network of MPAs for each eco-region. While the delineation process was based on the best available information, further information is required to refine these planning units in areas where Rapid Ecological Assessments (REAs) have not been conducted. One high priority area for further surveys is the Bismarck Sea (Figure 1).

Figure 1. Coral Triangle with arrow showing the location of the Bismarck Sea (Green and Mous 2008).

[1] Areas within a wider ecoregion within which there is some geographical or ecological distinctiveness, but over a smaller area that maybe more suitable for the application of management measures such as MPA networks

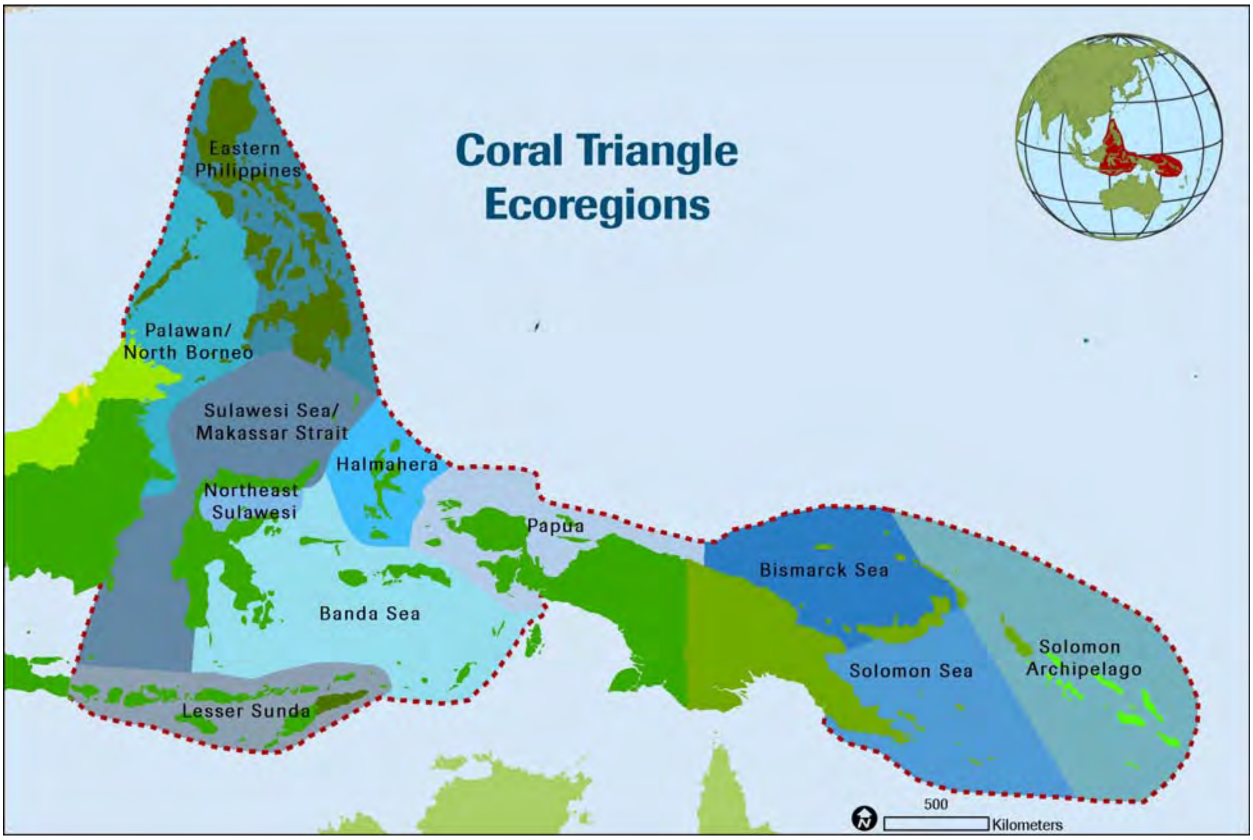

Figure 2. Coral Triangle Ecoregions (Green and Mous 2008).

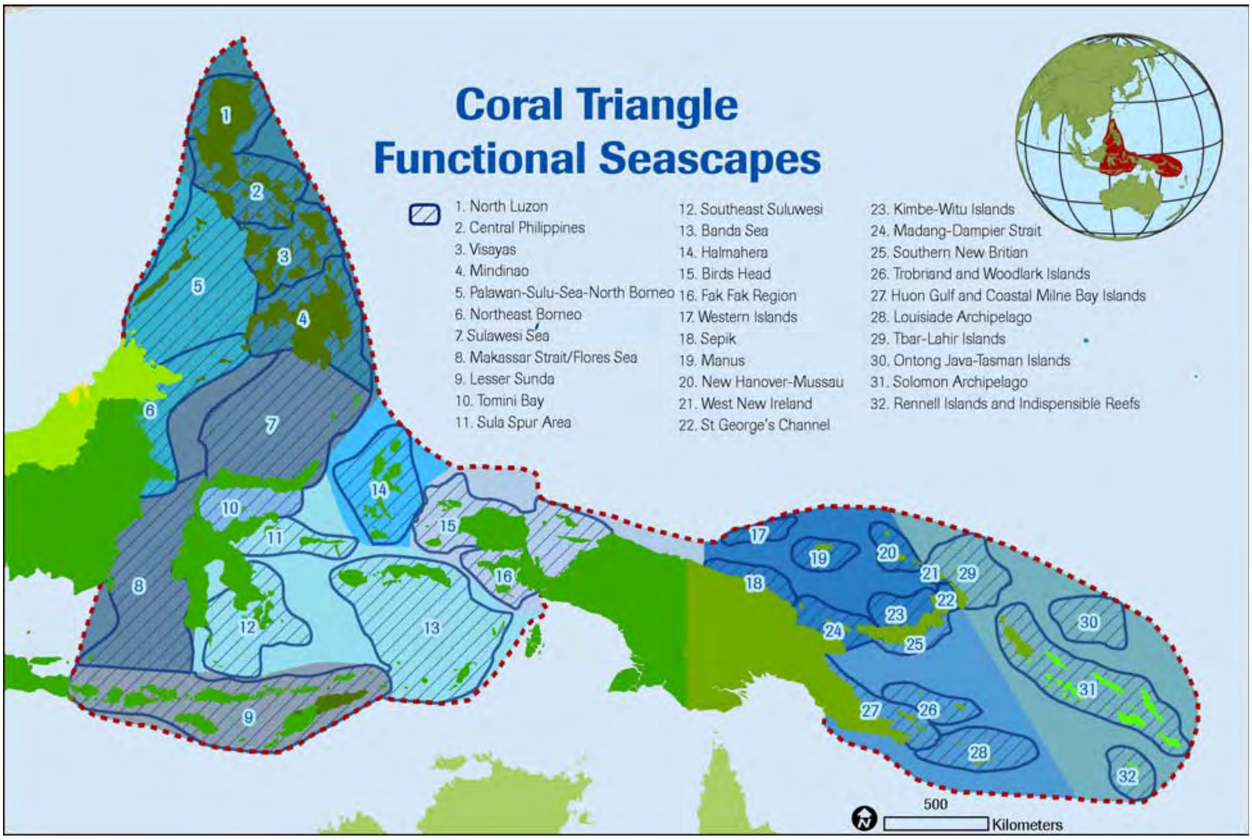

Figure 3. Coral Triangle Functional Seascapes (Green and Mous 2008). Functional seascapes within the Bismarck Sea are numbered 17 -23.

The Bismarck Sea is one of the richest marine environments in the world, inhabited by many thousands of marine plant and animal species. Highly diverse communities live in the ecosystem complexes of coral reefs, lagoons, seagrass beds and mangroves. The biodiversity of the Northern Bismarck Sea remains in relatively good condition, and this region is of high value for marine conservation (Hunnan et al., 2001, WWF 2003).

The Nature Conservancy is working with partners to design and implement resilient MPA networks throughout the Bismarck Sea, starting with the Kimbe Bay – Witu Islands functional seascape (Functional seascape No. 23, Figure 3). Kimbe Bay will be used as a platform site where the process of designing and implementing a resilient MPA network will be developed for the first time in Melanesia. The scientific design of a MPA network was completed for Kimbe in 2006 and current efforts are focused on implementing the MPA design through detailed community based planning processes (Green et al., 2007). Knowledge and lessons learned through the scientific design and implementation processes will be used to assist in the establishment of MPA networks in other functional seascapes in the Northern Bismarck Sea.

The Conservancy set up field stations in Kavieng, New Ireland and Loerngau, Manus in 2004 (Seascapes 19 and 20, Figure 3), and various community based conservation efforts are now underway in these regions (e.g. Hamilton et al., 2005). The results of this survey will give us a better understanding of the patterns of biodiversity in the Northern Bismarck Sea. This information will assist the Conservancy and partners in identifying areas in the Northern Bismarck Sea that, from a biodiversity perspective, would be desirable to include in MPA networks in this region. Additional surveys are planned for other functional seascapes in future, and together with the surveys already conducted in Kimbe Bay (Holthus 1994**,** Beger 2002, Turak 2002), this should provide a more complete understanding of patterns of biological diversity in the Bismarck Sea.

SOCIAL CONTEXT

Melanesians have lived and fished in parts of the Northern Bismarck Sea for over 40 000 years, with midden deposits on New Ireland providing the earliest evidence in the world of human's colonisation of oceanic islands, and some of the earliest evidence of marine fishing technologies (Allen et al., 1989). To this day the sea continues to form an intrinsic component of these people's lives, providing these widespread maritime communities with a means of travel, survival and prosperity.

In the Northern Bismarck Sea, resource owners have traditionally recognized rights over virtually all of their land and coastal marine resources. Subsistence, artisanal and commercial coastal fisheries in this region all operate within well developed Customary Marine Tenure (CMT) systems, where ownership of and hence access to coastal areas depends on a range of culturally defined variables, including descent line. Some communities in Northern Bismarck Sea have used their existing CMT systems as frameworks to manage their valuable marine resources for generations. Examples of contemporary community based fisheries management initiatives in the Northern Bismarck Sea include: restricting access to traditional fishing grounds, placing *tambus* (temporary closures) on reefs in order to allow valuable stocks of to recover, banning destructive fishing practices and placing gear restrictions on certain important stocks (Hamilton, 2003; Cinner et al., 2005).

Despite these positive examples of community-based management, the immediate risks of over exploiting the resources in the narrow coastal zones of the Northern Bismarck Sea is mounting. Rapid population rise, an increasing dependence on cash economies, access to more efficient fishing technologies and the break down of CMT structures and traditional access rights are all factors putting increasing pressure on marine ecosystems in this region. In the Northern Bismarck Sea, critically endangered hawksbill turtles and dugongs continue to form an important component of expanding subsistence economies, and valuable marine invertebrates such as trochus, green snail, sea cucumbers and the globally threatened giant clam have been heavily exploited for decades. In recent years both the shark fin and Live Reef Food Fish Trade (LRFFT) fisheries have expanded rapidly in this region, often with detrimental consequences (Hamilton, 2005; Hamilton and Matawai, 2006).

In the Northern Bismarck Sea, successful biodiversity conservation at the site level hinges on developing long term partnerships with communities that own regions of high conservation priority. Previous experiences in this region has shown that one of the most effective ways to establish these partnerships is to begin by assisting communities in managing their essential marine resources. Supporting community based management initiatives can raise conservation awareness, result in communities actively managing their important marine resources, and build the enabling conditions for further biodiversity conservation work in these regions.

In recognition of this and in response to communities' requests, a component of this survey involved conducting a marine resource assessment. This involved surveying the abundance of a variety of marine species that communities have identified as key fisheries targets. It is hoped that the information collected from the resource assessment will be used by communities and governments to make informed decisions regarding the management of their essential marine resources. The information collected from the marine resource assessment will also be used by the Conservancy to develop appropriate strategies for working with communities in regions identified as high priorities for conservation.

SURVEY DESCRIPTION

AREA OF INTEREST

The survey was conducted from August 13 to September 7, 2006 and focused on two locations in the Northern Bismarck Sea (Figure 4):

- Tigak Islands and New Hanover in New Ireland Province (Figure 5); and
- Manus Island and outer islands and reefs in Manus Province (Figure 6).

Figure 4. Survey area (red line) in the Northern Bismarck Sea.

Figure 5. Survey area in New Ireland: New Hanover and the Tigak Islands.

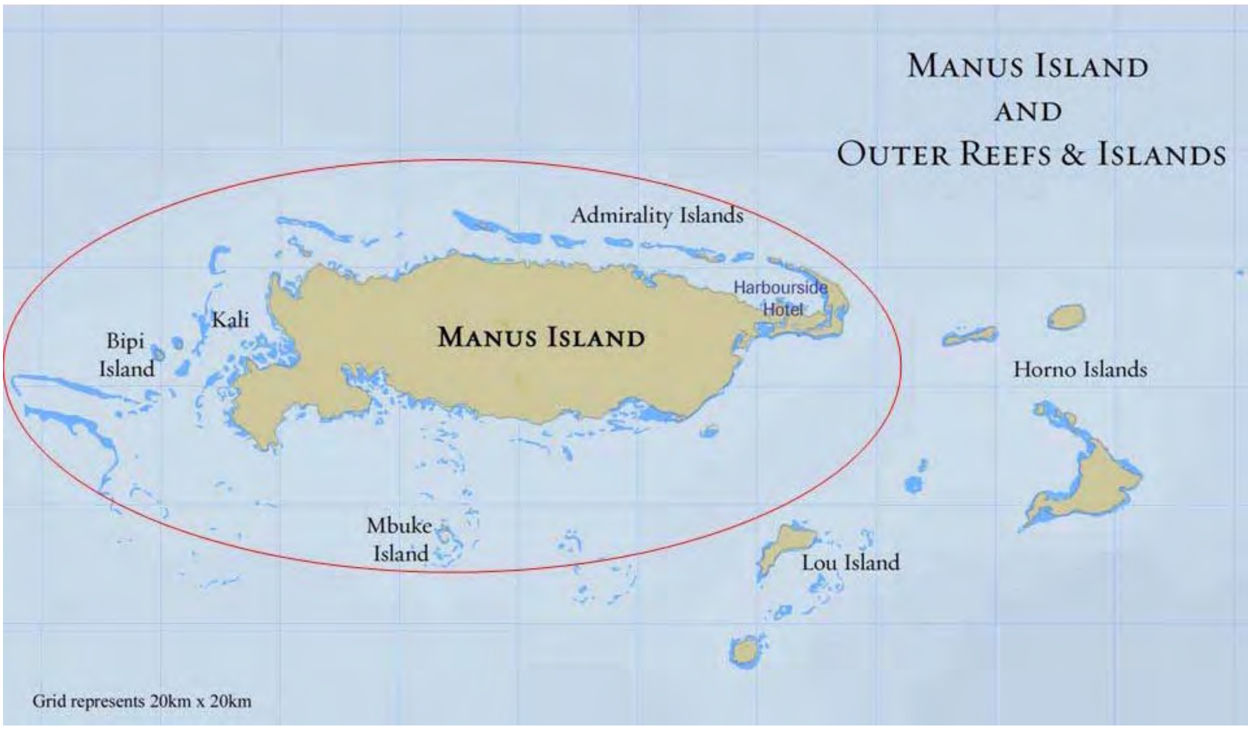

Figure 6. Survey area on Manus Island and outer islands and reefs.

SITE SELECTION & SURVEY PROTOCOL

Survey sites were selected during the survey based on interpretation of satellite images, logistic constraints and the guidance of local scientists, managers and survey participants. Survey sites were selected to provide maximum geographic coverage within the study area, and included representative examples of marine habitats of interest (particularly coral reefs), special and unique areas, and areas of particular interest to partner organisations.

Each day, the survey team assembled to select two general areas to survey the following day, and identify potential study sites within those areas. When the research team arrived in the study area the next day, they would confirm their site selection based on a visual assessment of potential sites. The community liaison team would then visit the local communities and obtain permission to survey those sites. Once permission had been obtained, the survey would proceed. Two survey teams were deployed in separate tenders to complete their surveys: the Coral Reef Biodiversity and Reef Health team; and the Coral Reef Fisheries Resources team.

SURVEY COMPONENTS AND RESEARCH TEAM

The survey provided a rapid ecological assessment of coral reef biodiversity, health and fisheries resources in the Northern Bismarck Sea. The assessment was conducted by a multi-disciplinary team focusing on the following components:

- Coral Reef Biodiversity and Reef Health; and
- Coral Reef Fisheries Resources.

The following is a summary of the survey team, and the role of each member.

Scientific Team Leaders

The scientific team leaders were Dr Richard Hamilton, Dr. Alison Green and Tapas Potuku of The Nature Conservancy.

Dr. Hamilton is the Marine Scientist for the Conservancy's Melanesia Program. He works closely with field teams, communities and government departments in Papua New Guinea and the Solomon Islands to support their conservation and management agendas. He is a coral reef ecologist who is experienced in both anthropological and marine research, and he is particularly interested in understanding the ecology of large vulnerable reef fishes and the threats that are being placed on these iconic species. In recent years his work has focused in part on reef fish spawning aggregations (identification, monitoring, management and connectivity research). Dr. Hamilton speaks Tok Pidgin and has had extensive experience leading scientific surveys in Melanesia.

Dr. Green is the Senior Marine Scientist with the Conservancy's Tropical Marine Conservation Program, Asia Pacific Region. Dr. Green is a coral reef ecologist with expertise in coral reef assessment and monitoring, who has led numerous coral reef surveys in the Pacific Islands in the last 10 years (including the Solomon Islands Marine Assessment). Her other area of expertise include designing MPA networks. In 2006 she led the scientific design of a resilient network of MPAs in Kimbe Bay.

Tapas Potuku has a Diploma in Fisheries Science. Mr Potuku worked for 21 years for the PNG National Fisheries Research Department before he retired in 2000. He has extensive experience conducting invertebrate and fisheries surveys throughout PNG, with much of his survey experience focusing around Wewak, the Gulf of Papua, New Ireland and Manus Province. In the 1990s he participated in biodiversity surveys in Kimbe Bay, and since 2004 he has been employed by The Nature Conservancy as the Community Conservation Officer for New Ireland. Mr Potuku's diverse roles in his current position include coordinating monthly monitoring of grouper spawning aggregation sites, community liaison work and building conservation awareness in the New Ireland region.

The role of the team leaders were to work with the survey team to design and implement the scientific aspects of the survey.

Coral Reef Biodiversity and Reef Health

The primary objectives of this team were to assess and quantify: 1) the biological diversity of corals and reef fishes – two key components of the coral reef communities; and, 2) the current status of the coral reef communities.

The team spent four to five hours diving each day (one-and-a-half to two hours at each of two or three sites). Team members were:

- **Dr. Gerry Allen, Tropical Reef Research and Western Australian Museum:** Dr. Allen is recognized as one of the world's leading experts in coral reef fish taxonomy and has refined the methodology for rapidly assessing fish biodiversity on coral reefs throughout the Coral Triangle. With more than 30 years experience, Dr. Allen has participated in many REAs for the Conservancy and other partners, including surveys in Papua New Guinea, Indonesia and the Solomon Islands. Dr. Allen complied detailed species lists for each site and a complete species inventory for the survey.
- **Emre Turak, Coral Reef Consultant:** Mr. Turak is an experienced coral ecologist who conducted an ecological assessment of the coral communities at each site. In particular, he assessed coral community types, their current status and health, and the extent of impacts on these reefs from disturbances, such as coral bleaching, crown of thorns starfish outbreaks, destructive fishing practices, and terrestrial runoff. He also compiled detailed species lists of corals for each site. Mr Turak has participated in many REAs for the Conservancy and other partners, including surveys in Papua New Guinea, Indonesia and the Solomon Islands.
- **Dr. Charlie Veron, Australian Institute of Marine Science:** Dr. Veron is a world expert on coral taxonomy. He compiled a complete species inventory for the survey, looking beyond the detailed species lists compiled at each site to search for new and rare species. This led to a more complete species list for the Northern Bismarck Sea, and possibly the identification of new species**.** Dr. Veron only partook in the New Ireland part of the survey.

Coral Reef Resources (Food fishes and Benthic communities)

A team of scientists conducted a quantitative baseline assessment of the status of marine resources in the survey area. They assessed the size and structure of populations of key reef fish species, and the cover and composition of benthic communities, including hard and soft corals. Key fisheries species were identified based on discussions with local scientists and local fishers. Large species that are particularly vulnerable to overfishing were a key focus, such as sharks, humphead wrasse, bumphead parrotfish and large groupers. This survey established the basis for the long term monitoring of coral reef resources in the Northern Bismarck Sea.

This team was led by Dr Richard Hamilton and Tapas Potuku (see Team Leaders above), and included:

- Litau Pomat, NFA, Kavieng
- Lawrence Litau, The Nature Conservancy, Kavieng
- Manuai Matawai, The Nature Conservancy, Manus
- Miro Logai, New Ireland Provincial Fisheries
- Jerry Pokiap, The Nature Conservancy Manus
- Mr. Pomat Kaluwin, private contractor

COMMUNITY LIAISON

NEW IRELAND

In New Ireland community liaison was lead by Tapas Potuku. Prior to the survey commencing a steering committee was formed to assist Tapas Potuku with community liaison and awareness raising activates in New Ireland. Members of the New Ireland steering committee were:

Mr. Joel Opnai (late)	Chairman	Gillette Preston Associate
Ms. Sandra Marahang	Committee	NI Provincial Fisheries
Mr. Satarek Taput	Committee	NI Provincial Fisheries Advisor
Mr. John Aini	Committee	Ailan Awareness
Mr. Tatek Buraik	Committee	Principal, National Fisheries College
Manoua Karo	Committee	Wildlife Conservation Society
Mr. Samol Kanawi	Committee	National Fisheries College
Tapas Potuku	v/Chairman	The Nature Conservancy

The New Ireland steering committee visited local communities within the areas of interest and informed them on the impending survey. Awareness of the upcoming survey was also raised through announcements on local radio stations. During the survey the community liaison team maintained communications with the communities and representatives from local communities and provincial government assisted with community liaison in their areas. Their participation greatly facilitated the community liaison team in obtaining permission to work within the areas of interest. Other organizations that assisted in this survey in New Ireland were Lissenung Dive Resort, who provided accommodation and other logistical support in the Tigak Islands component of this survey and Mansava Resort at New Hanover. The National Fisheries College also provided support with the use of their training vessel FTV Leilani to transport equipment to Manus.

MANUS

In Manus community liaison was lead by Manuai Matawai, The Nature Conservancy's Community Conservation Officer for Manus. Prior to the survey the Manus Marine Assessment Coordinating Committee (MMACC) was formed for the sole purpose of raising community awareness about the NBREA. Awareness was raised through 12 LLG Presidents, Radio toksave and a jingle program through NBC local radio station.

The MMACC comprised of members from various government and private agencies. They were;

Mr. Obed Otto	Chairman	MP Policy and Planning Division
Mr. Manuai Matawai	Secretary	The Nature Conservancy
Mrs. Ipau Apas	Assoc. Secretary	Hotel Manageress
Mr. John Malai	Committee	MP Culture and Tourism Division
Mr. Pomat Powayai	Committee	MP Fisheries Division
Mr. Selan Kaluwin	Committee	CBO
Mr. Bernard Menly	Publication Officer	National Broadcasting Commission
Mr. Robert Siwer	Committee	Local Level Government Member

The MMACC organised a traditional welcome ceremony for the survey team at the Loerngau market. During this occasion speeches were made by members of the MMACC and the survey team, which was another effective means of raising public awareness about the survey. In Manus the survey team resided in Mbuke and Kali community for several nights, and in these two communities we gave presentations on the survey and its objectives. At the end of the Manus fieldwork the findings of the survey were presented to the Provincial government assembly by Richard Hamilton and Emere Turuk at Loerngau Harbourside Hotel.

COMMUNICATIONS

The communications efforts were led by Dr Louise Goggin. Dr Goggin is a science writer and marine biologist, who is a communications specialist based in Canberra, Australia. She has written communication strategies, industry reports, scripts for corporate videos, promotional brochures, annual reports, press releases, radio scripts, and newsletters, as well as stories for newspapers, magazines, and the web. Dr. Goggin has been the communications expert on two recent REAs in the Solomon Islands and Pohnpei (Federated States of Micronesia). Dr Goggin provided the key findings produced at the end of this survey (see below). Note that some of numbers reported in the key findings have changed following more rigorous analysis of the data. Emre Turak provided high quality images for Dr. Goggin to use in communications. Jeanine Almany, Director of Communications for the Conservancy's Pacific Island Countries Program, coordinated the publication of communication products for the survey.


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An international team of scientists conducted a rapid ecological assessment of the northern Bismarck Sea in Papua New Guinea between August and November 2006.

Led by The Nature Conservancy, the team assessed the marine biodiversity near the Tigak Islands (New Ireland Province) and Manus Island (Manus Province). The region is less than 2,000 square kilometres in area and is located about 1,000 kilometres north-east of Port Moresby.

The team found high biodiversity of corals and fish, confirming that this region is within the 'Coral Triangle'; the area with the highest marine biodiversity in the world.

The reefs that the team visited around Manus Island were some of the healthiest that the team had visited for sometime. However, they found crown-of-thorns starfish in many areas of the Tigak Islands.

Fishing pressure appears to be considerably less than some areas further west in the Coral Triangle. Fish populations were very healthy in most locations in Manus, with spectacular fish communities and lots of big fish observed at several sites. However, there was some evidence of overexploitation in the Tigak Islands.

CORALS AND REEF CONDITION

Dr John (Charlie) Veron (Australian Institute of Marine Science) and Emre Turak (Consultant) found that the reefs of the region have high coral diversity.

They recorded 408 coral species from reefs around and near the Tigak Islands, and 403 coral species from the reefs around Manus Island. An additional number of corals were not identified and could prove to be new to science. Combined with the 392 species already recorded from Kimbe Bay, New Britain, this brings the total number of coral species for the Bismarck Sea to 478. This number is likely to increase as more areas are surveyed.


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The reefs that the team visited around Manus Island were in very good condition and among the healthiest that the team have seen in sometime. In contrast, the reefs of the Tigak Islands were not in such good condition; there were crown-of-thorns starfish on most reefs with significant coral mortality at some sites.

Dr Veron is a world-recognised coral specialist who has written more than 20 books about corals.

Mr Emre Turak is an experienced coral ecologist who specialises in rapid assessments of coral reef biodiversity and health, and has participated in many REAs throughout the Coral Triangle.

REEF FISH

© Gerald Allen

The survey confirms that the Bismarck Sea has a rich community of fishes that is only slightly less than the world's highest ranked regions.

Dr Gerald Allen (Western Australia Museum) recorded 801 fish species of which 750 were observed during the survey and the rest were described from museum collections. Combined with the number found from Kimbe Bay, this brings the total for the Bismarck Sea to 967 fish species.

Dr Allen found between 65 and 234 fish species per site, with an average of 159 per site. Two hundred species is considered the benchmark for an excellent fish count; Dr Allen exceeded this total at 4 per cent of sites in the Tigak Islands/ New Hanover area, and 11 per cent of sites near Manus Island. The highest fish count he observed was 234 species at the southern coast of Selapiu Island in the New Hanover area.

Dr Allen recorded several range extensions for fish species. He also found an important nursery area for Napoleon wrasse and Bumphead Parrotfish north of Anelaua Island off eastern New Hanover.

Dr Allen is a world expert on coral reef fishes. He has been diving for 35 years and spent more than 7,000 hours underwater. Dr Allen has written more than 20 books about coral reef fishes.

SUPPORT

The survey was led by The Nature Conservancy (TNC) and supported by the National Fisheries Authority of Papua New Guinea, World Wide Fund for Nature, Gillett Preston Associate (Coastal Fisheries Management & Development Project, CFMDP), Manus Provincial Government, New Ireland Provincial Government, The National Fisheries College, Wildlife Conservation Society, Lissenung Dive Resort, Ailan Awareness and Mansava Resort.

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NATIONAL FISHERIES AUTHORITY

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TNC Pacific Island Countries
Report No 1/09

Chapter 1:

Fisheries Resources: Food Fish and Benthic Cover

Rapid Ecological Assessment:

Northern Bismarck Sea, Papua New Guinea

By:
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The Nature Conservancy

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Executive Summary

There was no significant difference between the mean density and mean biomass of all reef fish sighted on transects in New Ireland and Manus. However an examination of five abundant families of coral reef fish (snappers, surgeonfishes, emperors, parrotfishes and groupers) revealed some significant differences. New Ireland had a significantly higher density and biomass of surgeonfishes then Manus, while in Manus the densities and biomasses of parrotfishes and groupers were significantly higher than in New Ireland. While differences seen between the two provinces at the family level could be due to a number of confounding variables, it is likely that the lower densities and biomass of groupers and parrotfishes seen on transects in New Ireland relate in part to higher levels of historical fishing pressure. In the past two decades groupers and parrotfishes have been heavily fished in New Ireland to supply local markets at Kavieng town and, in the case of groupers, the Live Reef Food Fish Trade (LRFFT).

The densities and biomass of large vulnerable reef fishes sighted on long swims was significantly different between the two provinces. For example, bumphead parrotfish densities were 12 times higher in Manus than in New Ireland; grouper densities were 6 times higher in Manus than in New Ireland and humphead wrasse densities were 2.5 times higher in Manus then in New Ireland. The lower densities of indicator species such as bumphead parrotfish and humphead wrasse suggest higher historical fishing pressure in New Ireland.

The results from the benthic cover survey showed that only Macroalgae cover differed significantly between the two provinces, making up on average 25% of benthic cover in New Ireland and 11% in Manus. The much higher levels of Macroalgae in New Ireland is related to the extensive coral mortality that some sites in the Tigak Islands have suffered as a result of relatively recent damage from Crown of Thorns Starfish (COTS) and bleaching events.

INTRODUCTION

Reef finfish are the mainstay of the subsistence and artisanal fisheries in New Ireland and Manus and comprise a major component of the protein in the diet of coastal communities. These reefs also support several commercial fishing operations and a number of tourism operations. The Tigak area of New Ireland is a particularly well known tourist destination in Papua New Guinea, and draws SCUBA divers, surfers and holiday makers to the area. In recent years growing coastal population coupled with an ever increasing move towards artisanal and commercial fishing has resulted in depletion of some marine resources' in both provinces. Valuable macro invertebrates' such as sea cucumbers are now severely overfished in the Tigak region of New Ireland (Kaly 2007) and many grouper spawning aggregations in Manus and New Ireland have been seriously overfished by a combination of artisanal night time spearfishing and Live Reef Food Fish Trade (LRFFT) operations (Hamilton and Matawai 2006; Hamilton, et al. 2005). Anecdotal information from fishers also suggests that abundances of large rare species such as the bumphead parrotfish (*Bolbometopon muricatum*) and the humphead wrasse (*Cheilinus undulatus*) have also declined markedly in both provinces in recent decades (Hamilton, unpublished data). In recent years the reefs around New Ireland have also been detrimentally affects by outbreaks of Crown of Thorns Starfish (COTS) (See Coral communities and reef health) this report. While no COTS outbreaks were sighted in Manus during this survey, in mid 2001 there was a report of a COTS outbreak from Patali Island at Mbuke to Point stone on the south west coast of Manus (Selarn Kaluwin, personal communications, March 2008). Severe coral bleaching was sighted at outer reefs between Mbuke and Anun Island in the same year (Tapas Potuku, personal observations 2001).

Clearly, the coral reefs and marine resources that they support in the Northern Bismarck Sea are beginning to be negatively impacted upon, a scenario that is unlikely to change given the rate of population growth in Papua New Guinea and climate change predictions for this area of the world. The purpose of this survey was to collect baseline data on reef fishes of importance to local fisheries, as well as information on the benthic cover in each province. This baseline data highlights species and areas of concern and will inform better management of these resources in the future.

METHODS – FOOD FISHES

STUDY SITES

In total 29 sites in New Ireland and Manus were surveyed for food fish and coral cover. 18 sites were surveyed within the Tigak Islands, north New Hanover and Djual Island (Figure 1) and 11 sites were surveyed around Manus (Figure 2). Food fish surveys were not conducted in the northern part of Manus due to logistical problems encountered during the survey period. In both New Ireland and Manus exposed reef slopes (both fringing and barrier reefs) were the most common habitat surveyed although some sheltered sites in New Ireland and Manus (i.e. lagoons or bays) were also surveyed.

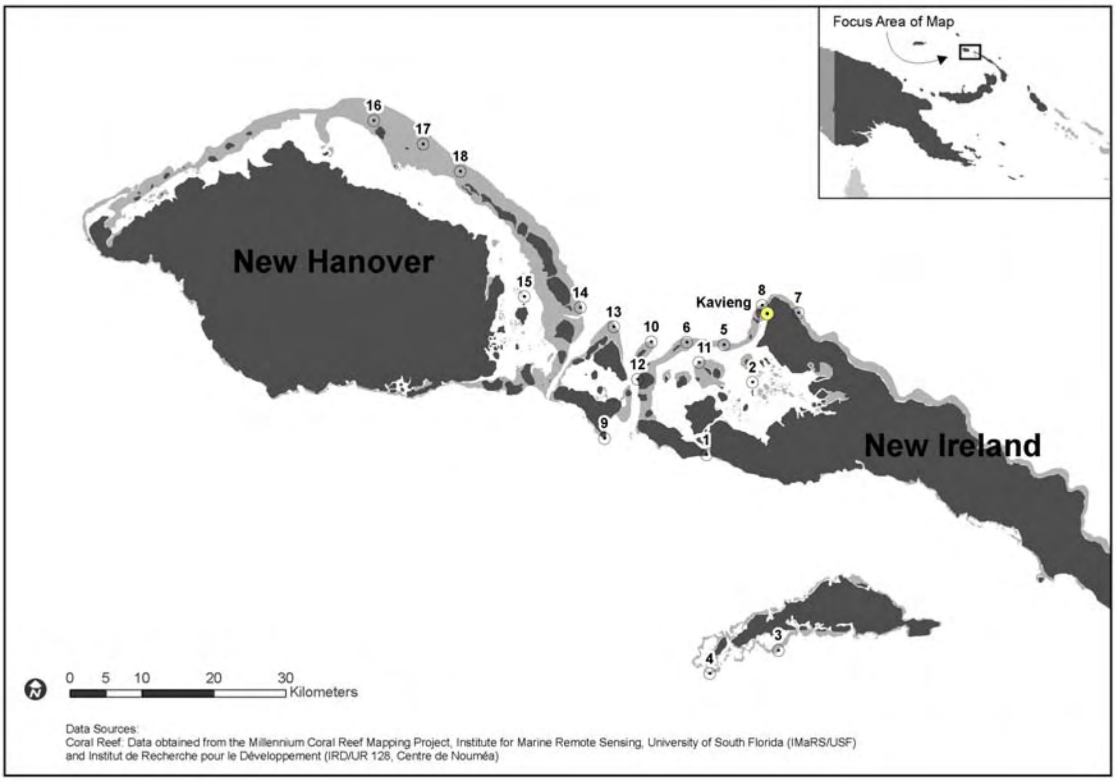

Figure 1. Map of the northern end of New Ireland showing the locations of the 18 sites that were surveyed for food fishes and coral cover.

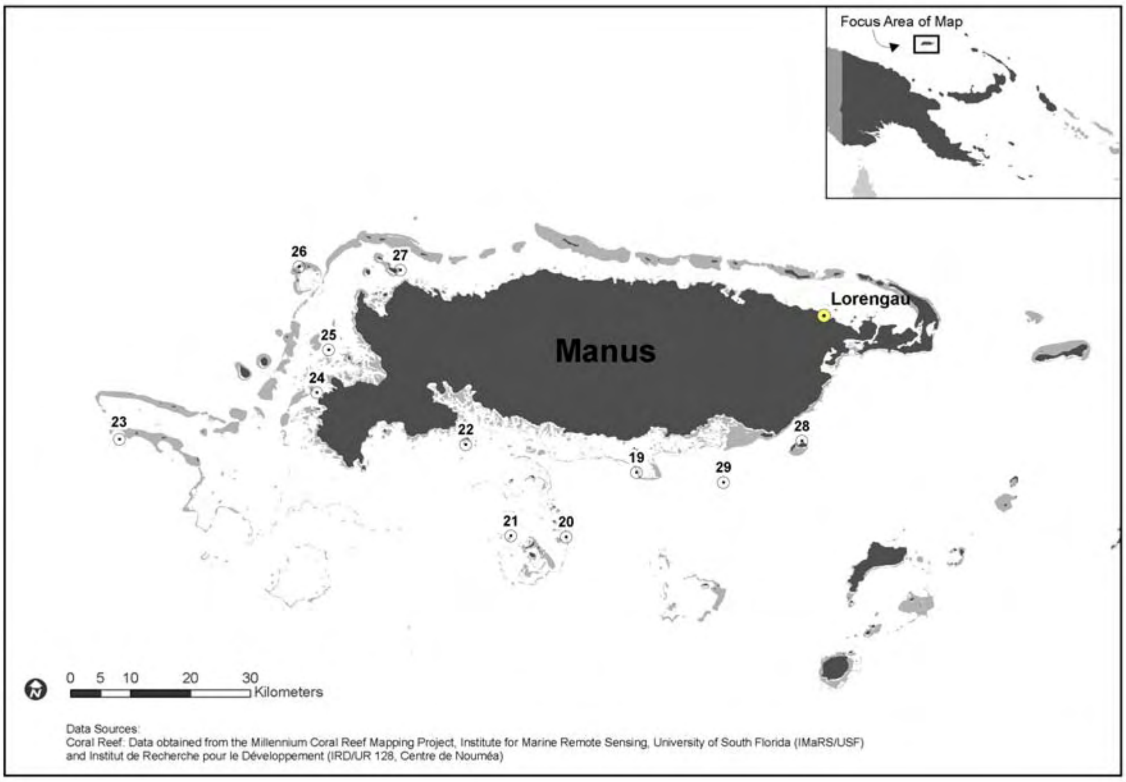

Figure 2. Map of the Manus Island showing the locations of the 11 sites that were surveyed for food fishes and coral cover.

TARGET SPECIES

The list of 111 fishery species that were surveyed is shown in Table 1. This extensive species list was developed by the resource team based on their detailed knowledge of the food fishes of importance to subsistence and commercial reef fisheries in this region. Litau Pomat carried out all transect swims and many of the long swims in this survey and he has over 30 years of experience in carrying out fish surveys in Papua New Guinea.

Table 1. Key species of food fishes surveyed

Taxa/Family	Species	Common Name
Acanthuridae (surgeonfishes)	*Ctenochaetus striatus*	Lined bristletooth
	Acanthurus fowleri	Blackspine surgeonfish
	Acanthurus lineatus	Striped surgeonfish
	Acanthurus maculiceps	White-freckled surgeonfish
	Acanthurus mata	Yellowmask surgeonfish
	Acanthurus nigricaudus	Blackstreak surgeonfish
	Acanthurus nubilus	Dark surgeonfish
	Acanthurus olivaceus	Orangeband surgeonfish
	Acanthurus pyroferus	Mimic surgeonfish
	Acanthurus xanthopterus	Yellowfin surgeonfish
	Naso brevirostris	Spotted unicornfish
	Naso hexacanthus	Sleek unicornfish
	Naso lituratus	Orangespine unicornfish
	Naso unicornis	Bluespine unicornfish
	Naso vlamingii	Bignose unicornfish
Balistidae (triggerfishes)	*Balistapus undulatus*	Orange-lined triggerfish
	Balistoides viridescens	Titan triggerfish
	Odonus niger	Redtooth triggerfish
	Pseudobalistes flavimarginatus	Yellowmargin triggerfish
Carangidae (trevally)	*Carangoides bajad*	Orange-spotted trevally
	Carangoides plagiotaenia	Barcheek trevally
	Caranx ignobilis	Giant trevally
	Caranx melampygus	Bluefin trevally
	Caranx sexfasciatus	Bigeye trevally
	Elagatis bipinnulatus	Rainbow runner
	Gnathanodon speciosus	Golden trevally
Ephippidae (batfish)	*Platax orbicularis*	Circular spadefish
Kyphosidae (drummers)	*Kyphosus cinerascens*	Topsail drummer
	Kyphosus vaigiensis	Lowfin drummer
Haemulidae (sweetlips)	*Plectorhinchus albovittatus*	Giant sweetlips
	Plectorhinchus chaetodonoides	Many-spotted sweetlips
	Plectorhinchus gibbosus	Blubberlip
	Plectorhinchus lessonii	Striped sweetlips
	Plectorhinchus lineatus	Diagonal-banded sweetlips
	Plectorhinchus vittatus	Oriental sweetlips
Holocentridae (soldierfishes and squirrelfishes)	*Sargocentron spiniferum*	Sabre squirrelfish
Labridae (wrasses)	*Cheilinus fasciatus*	Redbreasted wrasse
	Cheilinus trilobatus	Tripletail wrasse
	Cheilinus undulatus	Humphead wrasse
Lethrinidae (emperors)	*Lethrinus erythracanthus*	Yellowfin emperor
	Lethrinus erythropterus	Longfin emperor
	Lethrinus harak	Thumbprint emperor
	Lethrinus obsoletus	Orange-striped emperor
	Lethrinus olivaceus	Longface emperor
	Lethrinus nebulosus	Spangled emperor
	Lethrinus rubrioperculatus	Spotcheek emperor
	Lethrinus xanthochilus	Yellowlip emperor
	Monotaxis grandoculis	Humpnose bigeye bream
Lutjanidae (snappers)	*Aphareus furca*	Smalltooth jobfish

Taxa/Family	Species	Common Name
	Aprion virescens	Green jobfish
	Lutjanus argentimaculatus	Mangrove red snapper
	Lutjanus bohar	Red snapper
	Lutjanus carponotatus	Spanish flag
	Lutjanus fulviflamma	Longspot snapper
	Lutjanus fulvus	Blacktail snapper
	Lutjanus gibbus	Humpback snapper
	Lutjanus kasmira	Bluestripe snapper
	Lutjanus monostigma	Onespot snapper
	Lutjanus rivulatus	Blubberlip snapper
	Lutjanus russelli	Russell's snapper
	Lutjanus semicinctus	Black-banded snapper
	Macolor macularis	Midnight snapper
	Macolor niger	Black snapper
	Symphorichthys spilurus	Sailfin snapper
Mullidae (goatfishes)	*Parupeneus bifasciatus/trifasciatus*	Doublebar/Indian goatfish
	Parupeneus barberinus	Dash-dot goatfish
	Parupeneus cyclostomus	Goldsaddle goatfish
	Parupeneus multifasciatus	Manybar goatfish
Nemipteridae (coral breams)	*Scolopsis monogramma*	Monogram monocle bream
Pomacanthidae (angelfishes)	*Pomacanthus navarchus*	Blue-girdled angelfish
	Pomacanthus sexstriatus	Six-banded angelfish
	Pomacanthus xanthometopon	Yellow-mask angelfish
Scaridae (parrotfishes)	*Bolbometopon muricatum*	Bumphead parrotfish
	Cetoscarus bicolor	Bicolor parrotfish
	Chlorurus microrhinos	Steephead parrotfish
	Hipposcarus longiceps	Pacific longnose parrotfish
	Scarus festivus	Festive parrotfish
	Scarus ghobban	Blue-barred parrotfish
	Scarus oviceps	Dark-capped parrotfish
	Scarus prasiognathos	Greenthroat parrotfish
	Scarus niger	Swarthy parrotfish
Scombridae (tunas and mackerels)	*Scomberomorus commerson*	Narrow barred Spanish mackerel
Siganidae (rabbitfishes)	*Siganus argenteus*	Forktail rabbitfish
	Siganus corallinus	Coral rabbitfish
	Siganus doliatus	Barred rabbitfish
	Siganus fuscescens	Dusky rabbitfish
	Siganus lineatus	Lined rabbitfish
	Siganus puellus	Masked rabbitfish
	Siganus punctatissimus	Fine-spotted rabbitfish
	Siganus punctatus	Gold-spotted rabbitfish
	Siganus stellatus	Honeycomb rabbitfish
	Siganus vulpinus	Foxface rabbitfish
Sphyraenidae (barracudas)	*Sphyraena barracuda*	Great barracuda
	Sphyraena qenie	Blackfin barracuda
Serranidae (groupers)	*Aethaloperca rogga*	Redmouth grouper
	Anyperodon leucogrammicus	Slender grouper
	Cephalopholis argus	Peacock grouper
	Cephalopholis cyanostigma	Bluespotted grouper
	Cromileptes altivelis	Barramundi cod
	Epinephelus fuscoguttatus	Brown-marbled grouper
	Epinephelus hexagonatus	Hexagon grouper
	Epinephelus lanceolatus	Giant grouper
	Epinephelus merra	Honeycomb grouper
	Epinephelus polyphekadion	Camouflage grouper
	Gracila albomarginata	Masked grouper
	Plectropomus areolatus	Squaretail coral grouper
	Plectropomus laevis	Blacksaddle coral grouper
	Plectropomus leopardus	Leopard coral grouper

Taxa/Family	Species	Common Name
	Plectropomus oligacanthus	Highfin coral grouper
	Variola albimarginata	White-edged lyretail
	Variola louti	Yellow-edged lyretail

SURVEY METHODS

Key food fish species were surveyed using underwater visual census techniques that consisted of a combination of transect counts and long swims, based on methods in the Solomon Islands REA (Green et al., 2006).

TRANSECT COUNTS

Five replicate transects were surveyed at each site. Each transect was 50m long and 10m wide, giving a total area surveyed of 500m^2 per transect. Transect lengths were measured using 50m tapes, and transect widths were visually estimated. Transect tapes were laid by an assistant following the observer to minimize disturbance to the fish communities being counted. The tapes then remained *in situ* until all surveys were completed at that site. Benthic communities were surveyed along the same transects after the fish counts were completed. In each pass of a transect the number of individuals of each fish species was counted and recorded onto underwater paper. The size of each individual (length in cm) was also estimated and recorded. Fish identifications were based on (Allen, et al. 2003).

LONG SWIM SURVEYS

Key fisheries species of food fish that are large and particularly vulnerable to overfishing were also counted (and their size estimated) using long swim methods specifically developed for this purpose (Choat and Pears 2003). This method was developed to improve estimates of the abundance of these species, since they tend to be uncommon and clumped in distribution, so smaller transects dimensions (e.g., 50m x 10m) are not suitable for obtaining reasonable estimates of their abundance. In this method, the observer surveyed a 20m wide area during a single pass of the reef slope over a set time period (20 minutes) scanning the reef slope for these species. Average swim speeds for an observer were calculated such that the average distance covered in a timed swim could be estimated. Long swims covered an average area of 8000 m^2.

The species surveyed using the long swim method were:

- Humphead wrasse (*Cheilinus undulatus*);
- Bumphead parrotfish (*Bolbometopon muricatum*) and steephead parrotfish (*Chlorurus microrhinos*);
- Large groupers (*Epinephelus fuscoguttatus, Epinephelus polyphekadion, Epinephelus lanceolatus, Cromileptes altivelis, Plectropomus areolatus, Plectropomus laevis, Plectropomus leopardus, Plectropomus oligacanthus Variola louti* and *Variola albimarginata*);
- Giant trevally (*Caranx ignobilis*); and
- Large and uncommon emperors (*Lethrinus olivaceus, Lethrinus erythropterus, Lethrinus rubrioperculatus* and *Lethrinus xanthochilus*).

DATA ANALYSIS

Key fisheries species were compared among the two provinces based on the density and biomass of all species and key families. Fish density estimates per transect and per long swim were converted to the number of individuals per hectare (ha). Fish biomass was calculated by converting estimated fish lengths to weights (Appendix 1) using the allometric length-weight conversion formulae $W=aL^b$ where a and b are constants for each species. Fish biomass per transect and per long swim were converted to the biomass of fish per hectare (ha). Constants were not available for most species in Papua New Guinea so they were obtained from Fishbase (www.fishbase.org). Typically the median value for a species was used, or when no species-specific information was available, the constants for a closely related species or the constants of the overall mean values of a genus were used. Differences in fish abundances and biomass between the two provinces were investigated using Mann-Whitney Rank Sum tests (SigmaStat) since data was non-normal.

METHODS – BENTHIC COMMUNITIES

STUDY SITES

Benthic cover was surveyed at the same sites that were surveyed for food fishes (Figure 1 and 2).

SURVEY METHODS

Benthic data were collected using a modified version of the Point Intercept Method (Hill and Wilkinson 2004; Hughes, 2006). Benthic data were collected from three points every 2m along a 50m transect tape. Two points were located 1 metre on either side of the transect line and the third was below the transect. A total of five 50m transects were laid at a depth profile of 8-10m at each site. This resulted in a total collection of 75 data points for each transect, and a total of 375 data points for each site.

Benthic composition was recorded based on lifeforms consistent with the categories provided by (English, et al. 1997). For ease of presentation, these were further grouped into four major categories: Corals, Macroalgae, Abiotic and Others (Table 2).

Table 2. Lifeform categories and Major categories

Code	Lifeform	Major category
ACB	*Acropora* Branching	Coral
ACE	*Acropora* Encrusting	Coral
ACD	*Acropora* Digitate	Coral
ACT	*Acropora* Tabular	Coral
ACS	*Acropora* Submassive	Coral
CB	Coral Branching	Coral
CE	Coral Encrusting	Coral
CF	Coral Foliose	Coral
CM	Coral Massive	Coral
CS	Coral Submassive	Coral
CMR	Mushroom Coral	Coral
CHL	Blue Coral	Coral
CME	Fire Coral	Coral
CTU	Organ Pipe Coral	Coral
DCA	Dead Coral with Algae	Macroalgae
AA	Algae Assemblage	Macroalgae
CA	Coralline Algae	Macroalgae
HA	*Halimeda* Algae	Macroalgae
MA	Macroalgae	Macroalgae
TA	Turf Algae	Macroalgae
S	Sand	Non-living
R	Rubble	Non-living
Si	Silt	Non-living
DC l	Dead Coral	Non-living
RCK	Rock	Non-living

Code	Lifeform	Major category
SC	Soft Coral	Others
SP	Sponge	Others
ZO	Zoanthid	Others
OT	Others (Ascidians, anemones, gorgonians etc)	Others

DATA ANALYSIS

Data was grouped at the major lifeform category for the purpose of graphing and analysis. T- tests (SigmaStat) were carried out to investigate if the mean Coral, Macroalgae, Non-living and Other major lifeforms were significantly different between the two provinces.

RESULTS – FOOD FISHES

DENSITY OF FOOD FISHES SIGHTED ON TRANSECT SWIMS

In New Ireland the most five most abundant families were snappers, surgeonfishes, emperors, triggerfish and trevallys, whereas in Manus the five most abundant families were snappers, surgeonfishes, parrotfishes, emperors and rabbitfishes (Table 3).

Table 3. Relative densities of each fish family at New Ireland and Manus

Family	Common names	Relative density (% of total) New Ireland	Relative density (% of total) Manus
LUTJANIDAE	Snappers	41.29	28.32
ACANTHURIDAE	Surgeonfishes	24.41	27.44
LETHRINIDAE	Emperors	7.69	10.22
BALISTIDAE	Triggerfishes	6.81	0.45
CARANGIDAE	Trevally	4.79	0.84
SCARIDAE	Parrotfishes	3.97	11.83
KYPHOSIDAE	Drummers	3.50	6.02
SIGANIDAE	Rabbitfishes	2.35	7.82
MULLIDAE	Goatfishes	1.87	1.39
SERRANIDAE	Groupers	1.11	3.17
SPYYRAENIDAE	Barracudas	0.74	0.00
HAEMULLIDAE	Sweetlips	0.59	1.09
LABRIDAE	Wrasses	0.53	0.75
POMACANTHIDAE	Angelfishes	0.22	0.45
HOLOCENTRIDAE	Squirrelfishes	0.08	0.06
EPHIPPIDAE	Batfishes	0.03	0.02
SCOMBRIDAE	Mackerels	0.00	0.09
NEMIPTERIDAE	Coral breams	0.00	0.04
Total		**100.00**	**100.00**

DENSITY OF TOTAL FISH ASSEMBLAGE

The density of bony food fishes at each site is shown in Figure 3. A Mann-Whitney Rank sum test showed that the mean density of fish sighted on transects in New Ireland and Manus were not significantly different (U statistic = 2631.5, P=0.525).

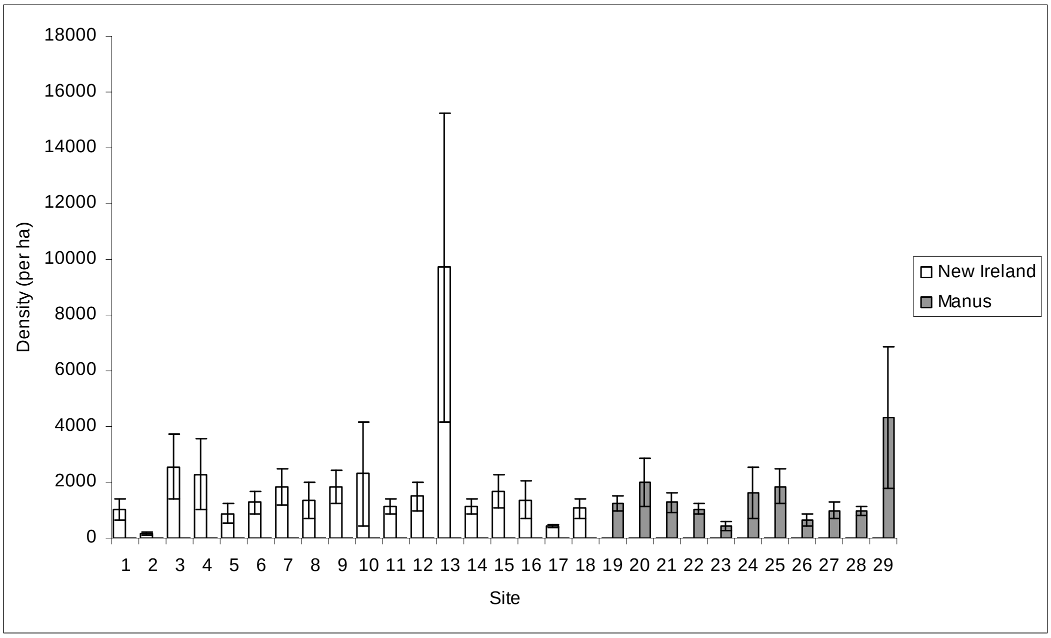

Figure 3. Mean density (+/- 1SE) of food fishes sighted in New Ireland and Manus

DENSITIES OF THE KEY FAMILIES OF FISHES

To examine if densities of key families of fishes differed significantly between the two provinces we compared the total densities of snappers, surgeonfishes, emperors, parrotfishes and groupers. Snappers and surgeonfishes are the first and second most sighted families in both provinces, whereas emperors were the 3rd and 4th most important family in New Ireland and Manus respectively. Parrotfish were examined due to their functional role in maintaining reef health (Hoey and Bellwood 2008) and groupers were examined as they are a key commercial species that is well surveyed by underwater visual census (Zellar and Russ 2000) and declines in their densities are often indicative of overfishing.

Snappers

The density of snappers at each site is shown in Figure 4. The densities of snapper were highly variable both between and within sites, no doubt in part due to the frequency with which many snapper species form large roving schools. A Mann-Whitney Rank sum test showed that the mean density of fish sighted on transects in New Ireland and Manus were not significantly different (U statistic = 2206, P=0.272). Inspection of the raw data revealed that the very high densities of snapper seen at Site 13 are attributable to large schools of *Lutjanus kasmira* being sighted on several of the transects at this site.

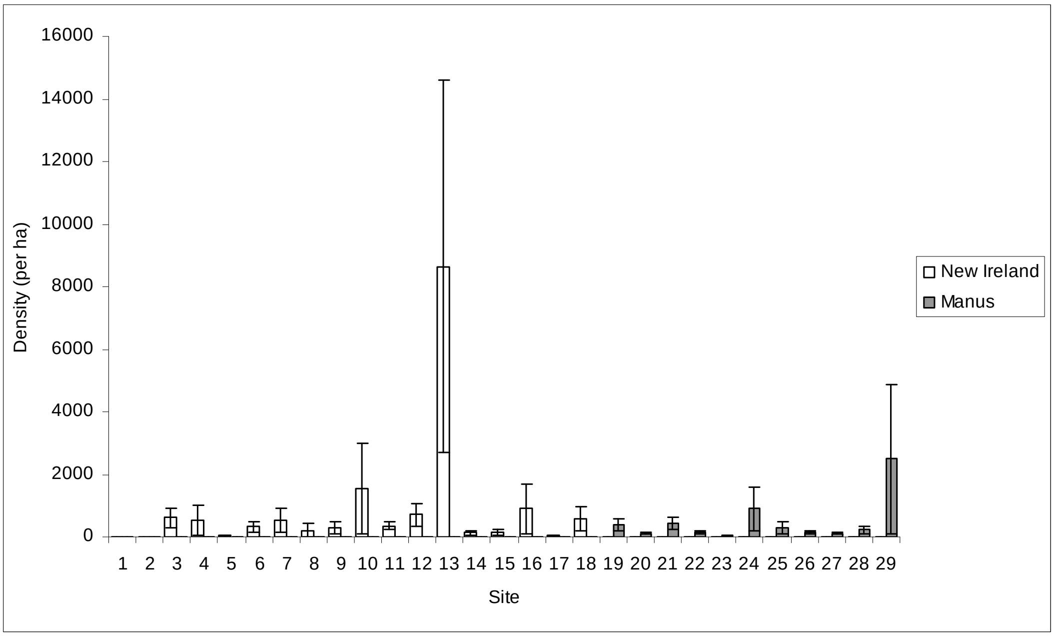

Figure 4. Mean density (+/- 1SE) of snappers sighted in New Ireland and Manus.

Surgeonfishes

The density of surgeonfishes at each site is shown in Figure 5. A Mann-Whitney Rank sum test showed that the mean density of surgeonfishes sighted on transects in New Ireland were significantly higher than at Manus (U statistic = 3036.5, P=0.022).

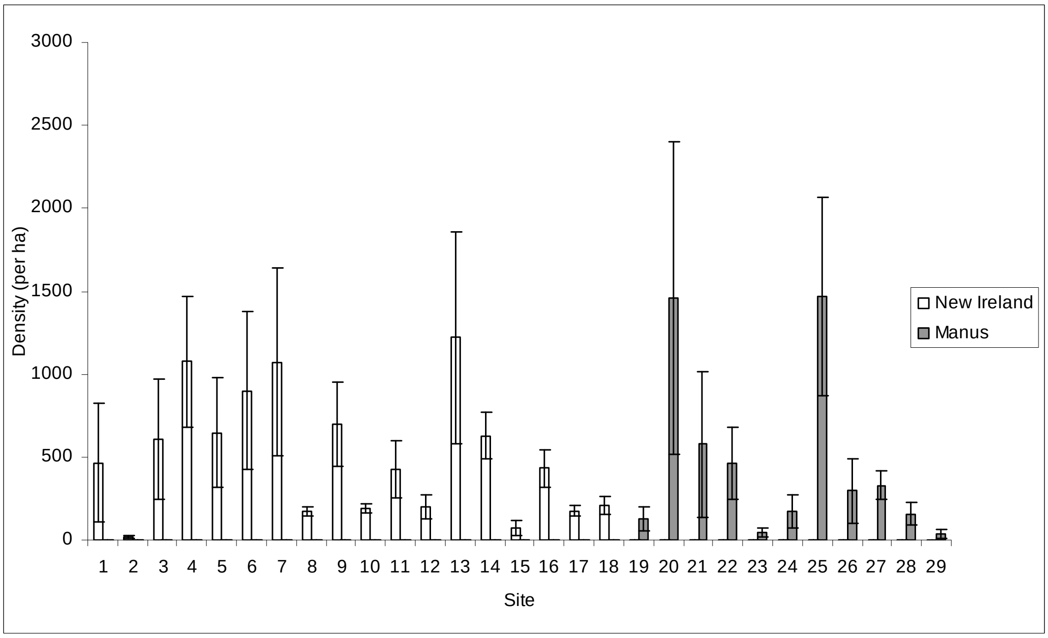

Figure 5. Mean density (+/- 1SE) of surgeonfishes sighted in New Ireland and Manus.

Emperors

The density of emperors at each site is shown in Figure 6. A Mann-Whitney Rank sum test showed that the mean density of emperors sighted on transects in Manus were significantly higher than at New Ireland (U statistic = 1609.5, P<0.001).

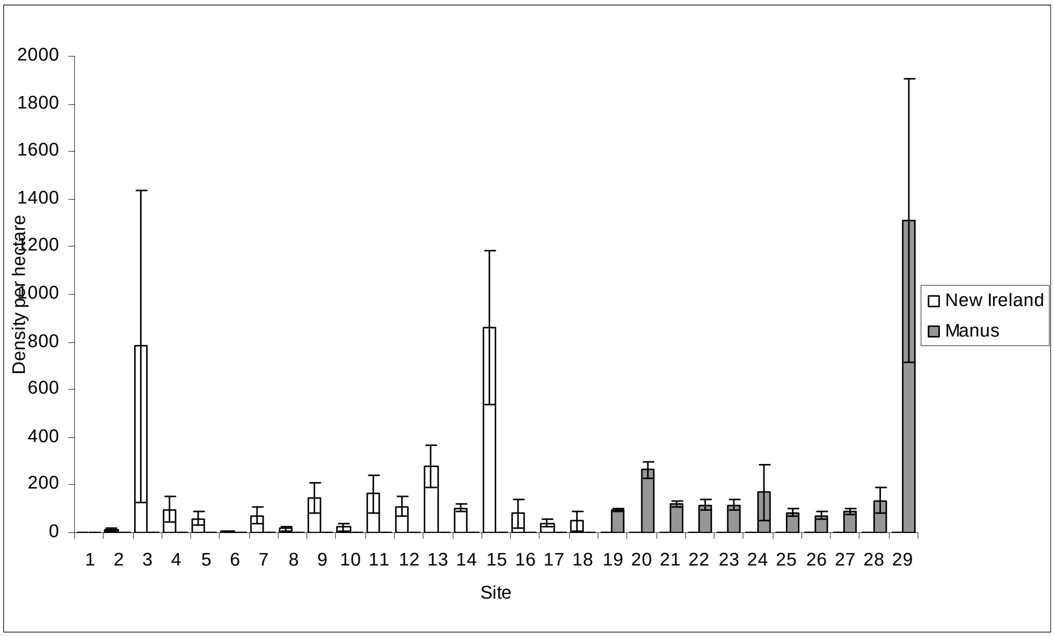

Figure 6. Mean density (+/- 1SE) of emperors sighted in New Ireland and Manus.

Parrotfishes

The density of parrotfishes at each site is shown in Figure 7. A Mann-Whitney Rank sum test showed that the mean density of parrotfishes sighted on transects in Manus were significantly higher than at New Ireland (U statistic =1452, P<0.001).

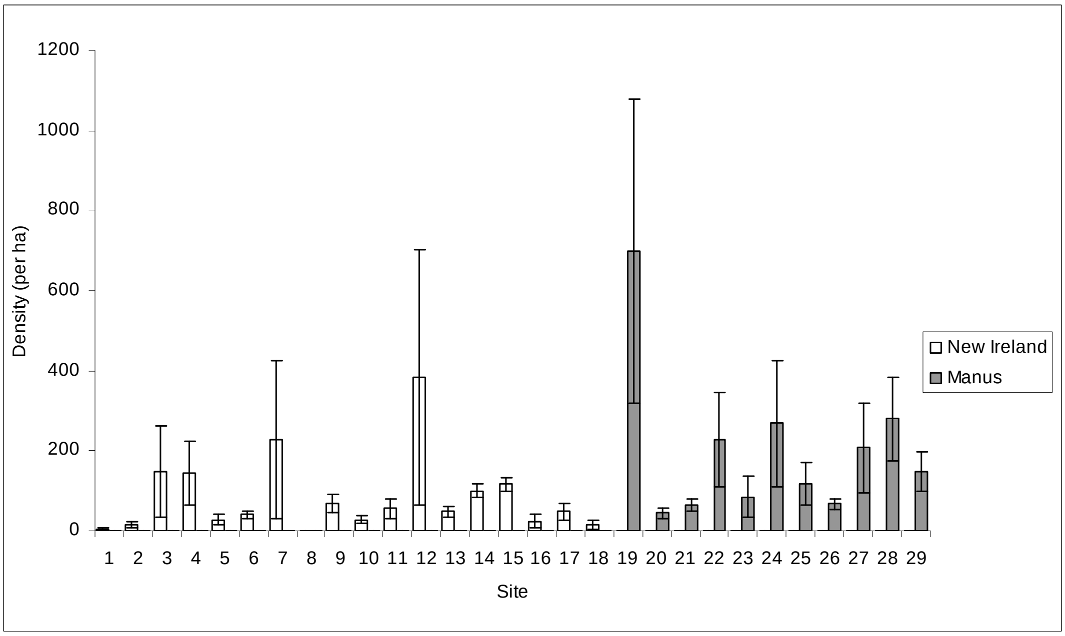

Figure 7. Mean density (+/- 1SE) of parrotfishes sighted in New Ireland and Manus.

Groupers

The density of groupers at each site is shown in Figure 8. A Mann-Whitney Rank sum test showed that the mean density of groupers sighted on transects in Manus were significantly higher than at New Ireland (U statistic =1826, P=0.006).

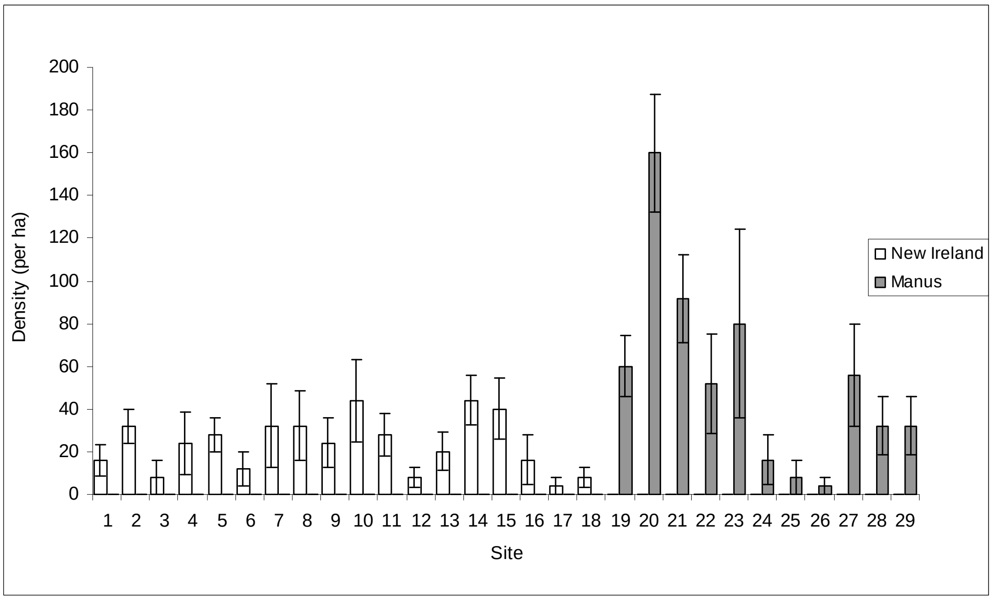

Figure 8. Mean density (+/- 1SE) of groupers sighted in Kavieng and Manus**.**

BIOMASS OF FOOD FISHES SIGHTED ON TRANSECT SWIMS

In New Ireland the five families that made of the majority of fish biomass were snappers, surgeonfishes, trevallys emperors and triggerfish (Table 4), whereas in Manus five families that made up the majority of fish biomass were parrotfishes, emperors, snappers, surgeonfishes and sweetlips (Table 4).

Table 4. Relative biomass of each fish family at Kavieng and Manus

Family	**Common names**	**Relative biomass (% of total) New Ireland**	**Relative biomass (% of total) Manus**
LUTJANIDAE	Snappers	40.24	9.67
ACANTHURIDAE	Surgeonfishes	15.55	4.69
CARANGIDAE	Trevally	13.45	0.56
LETHRINIDAE	Emperors	9.52	28.39
SPYYRAENIDAE	Barracudas	4.33	0.00
KYPHOSIDAE	Drummers	4.12	2.11
SCARIDAE	Parrotfishes	3.59	40.94
BALISTIDAE	Triggerfishes	2.73	0.99
HAEMULLIDAE	Sweetlips	2.67	2.38
SERRANIDAE	Groupers	1.43	3.27
SIGANIDAE	Rabbitfishes	0.83	1.22
LABRIDAE	Wrasses	0.79	0.99
MULLIDAE	Goatfishes	0.47	0.2
POMACANTHIDAE	Angelfishes	0.11	0.08
EPHIPPIDAE	Batfishes	0.10	0.05
HOLOCENTRIDAE	Squirrelfishes	0.08	0.03
SCOMBRIDAE	Mackerels	0.00	1.41
NEMIPTERIDAE	Coral breams	0.00	0.01
Total		**100**	**100**

BIOMASS OF TOTAL FISH ASSEMBLAGE

The biomass of bony food fishes at each site is shown in Figure 9. The mean biomass of fish sighted on transects in New Ireland and Manus were not significantly different (Mann-Whitney U statistic = 2197.5, T = 4292.5, P = 0.259).

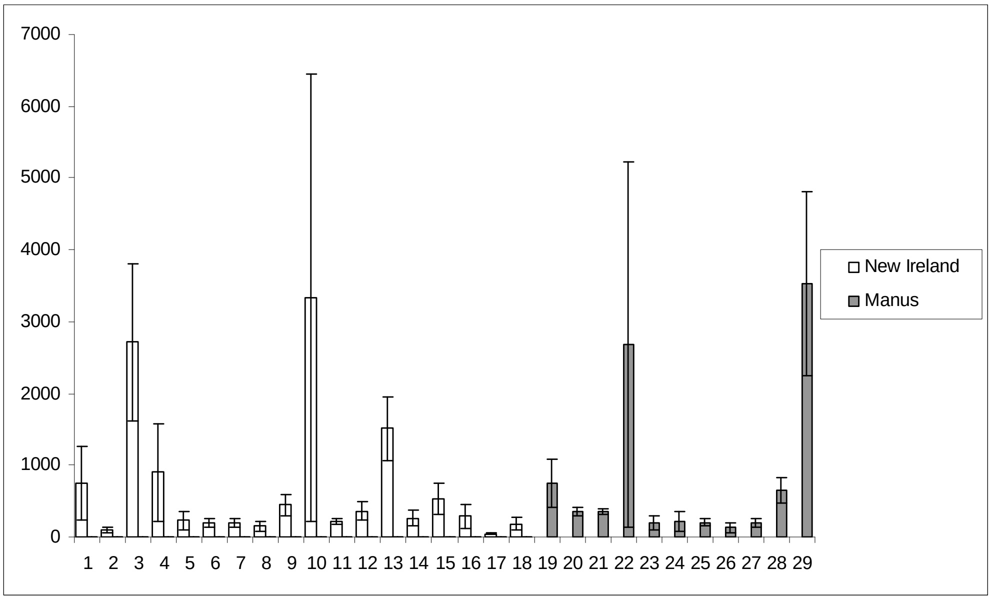

Figure 9. Mean biomass (+/- 1SE) of food fishes sighted in New Ireland and Manus

BIOMASS OF THE KEY FAMILIES OF FISHES

To examine if biomass of key families of fishes differed significantly between the two provinces we compared the total biomass of snappers, surgeonfishes, emperors, parrotfishes and groupers. These being the same five families whose relative densities were compared between both provinces.

Snappers

The biomass of snappers at each site is shown in Figure 10. The biomass of snapper were highly variable both between and within sites and mean biomass of fish sighted on transects in New Ireland and Manus were not significantly different (Mann-Whitney U statistic = 2374.5, T = 4115.5, P = 0.683). Sites 3, 10 and 13 in New Ireland had the highest biomass of all the sites.

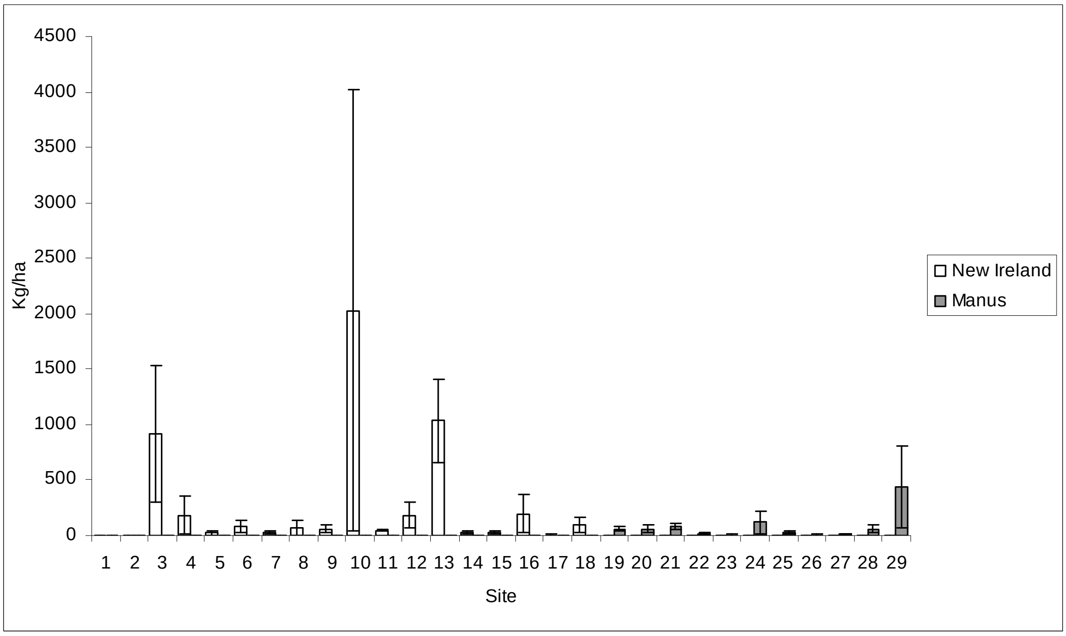

Figure 10. Mean biomass (+/- 1SE) of snappers sighted in New Ireland and Manus.

Surgeonfishes

The biomass of surgeonfishes at each site is shown in Figure 11. The biomass of surgeonfish was significantly higher in New Ireland than in Manus (Mann-Whitney U statistic = 2885, T =3406, P = 0.045).

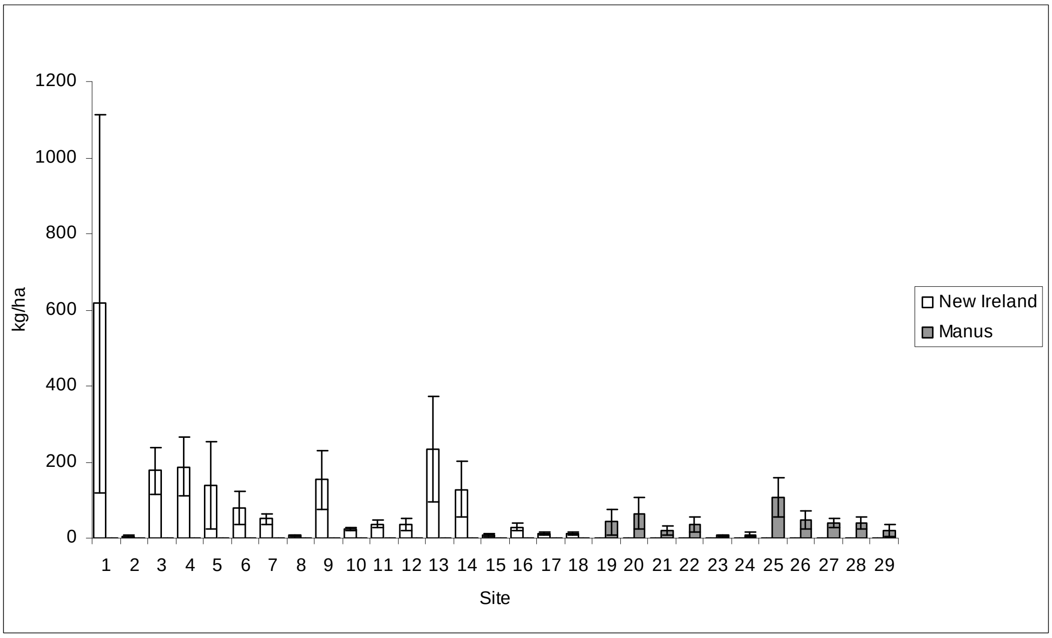

Figure 11. Mean biomass (+/- 1SE) of surgeonfishes sighted in New Ireland and Manus.

Emperors

The biomass of emperors at each site is shown in Figure 12. The mean biomass of emperors sighted on transects in New Ireland and Manus were not significantly different (Mann-Whitney U statistic = 2264, T = 4081, P = 0.486).

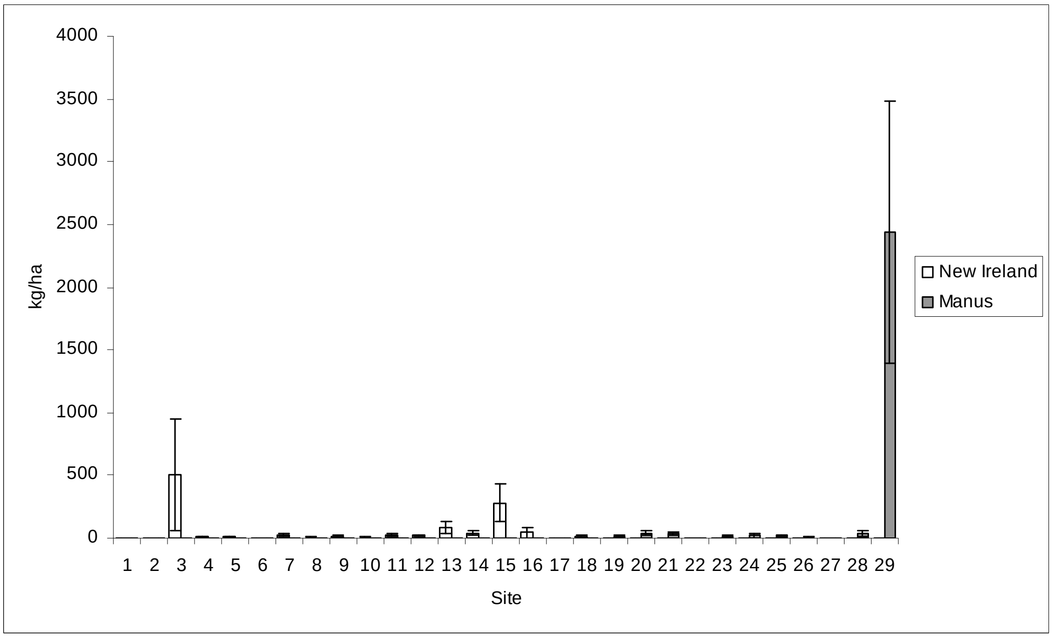

Figure 12. Mean biomass (+/- 1SE) of emperors sighted in New Ireland and Manus.

Parrotfishes

The biomass of parrotfishes at each site is shown in Figure 13. The mean biomass of parrotfishes sighted on transects was significantly higher in Manus than in New Ireland (Mann-Whitney U statistic = 1519.5, T =4970.5, P < 0.001). The very high biomass seen at Site 22 was due to a sighting of a large school of *Bolbometopon muricatum*.

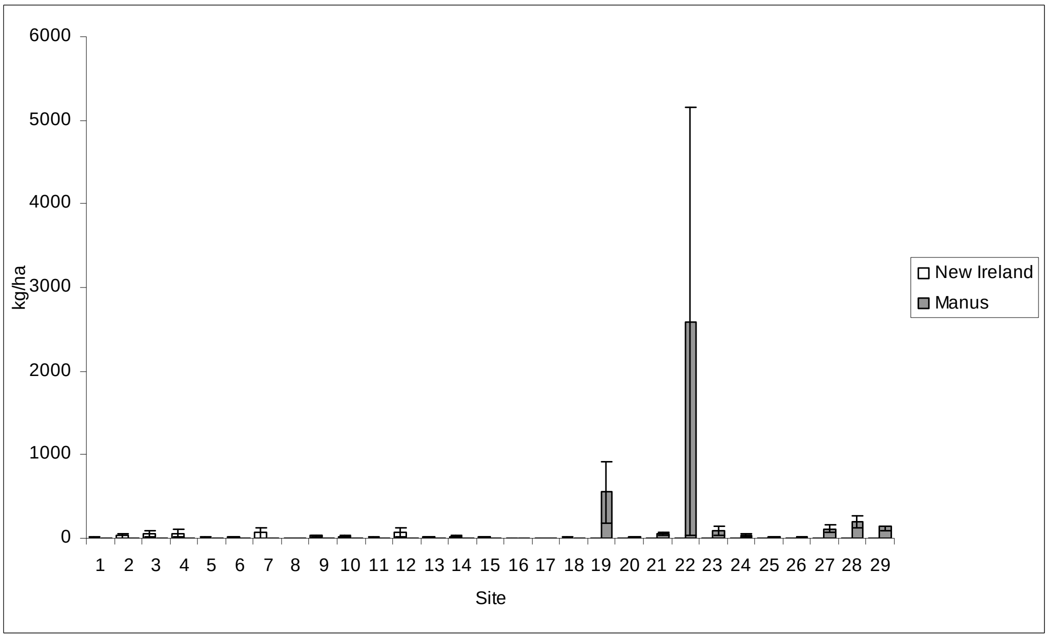

Figure 13. Mean biomass (+/- 1SE) of parrotfishes sighted in New Ireland and Manus.

Groupers

The density of groupers at each site is shown in Figure 14. The mean biomass of groupers sighted on transects was significantly higher in Manus than in New Ireland (Mann-Whitney U statistic = 1853, T =4637, P = 0.009).

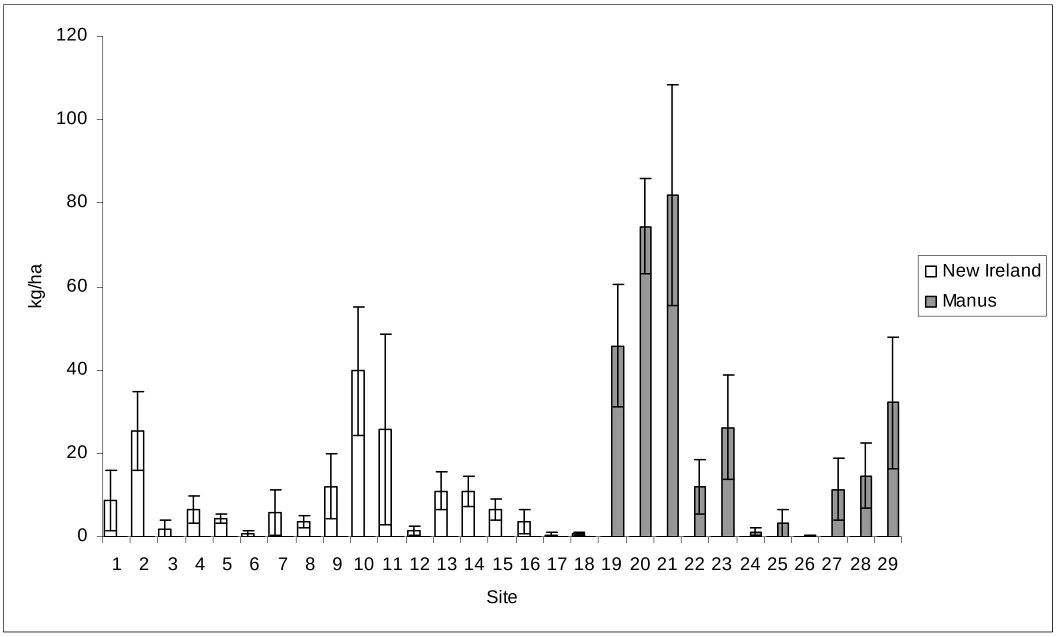

Figure 14. Mean biomass (+/- 1SE) of groupers sighted in New Ireland and Manus.

FOOD FISHES SIGHTED ON LONG SWIMS

The mean density of large vulnerable species sighted on long swims in New Ireland and Manus is shown in Figure 15. The mean density of large vulnerable fishes was significantly higher in Manus than in New Ireland (Mann-Whitney U statistic = 27.5, T = 236.5, P = 0.001).

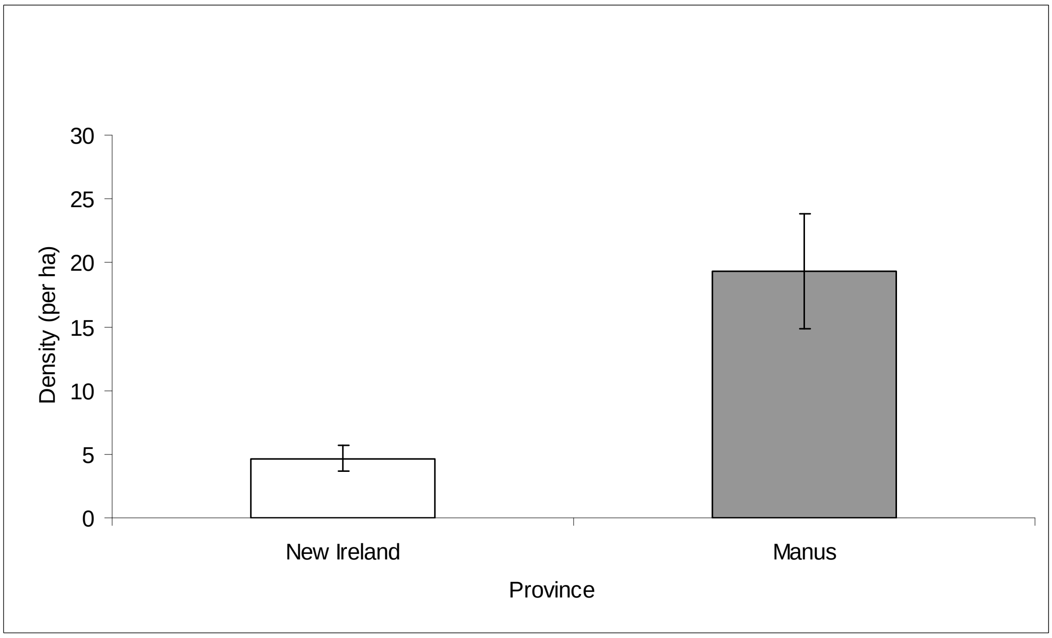

Figure 15. Mean density of large vulnerable fish sighted in New Ireland and Manus

The mean biomass of large vulnerable species sighted on long swims in New Ireland and Manus is shown in Figure 16. The mean biomass of large vulnerable fishes was significantly higher in Manus than in New Ireland (Mann-Whitney U statistic = 54, T = 210, P = 0.045).

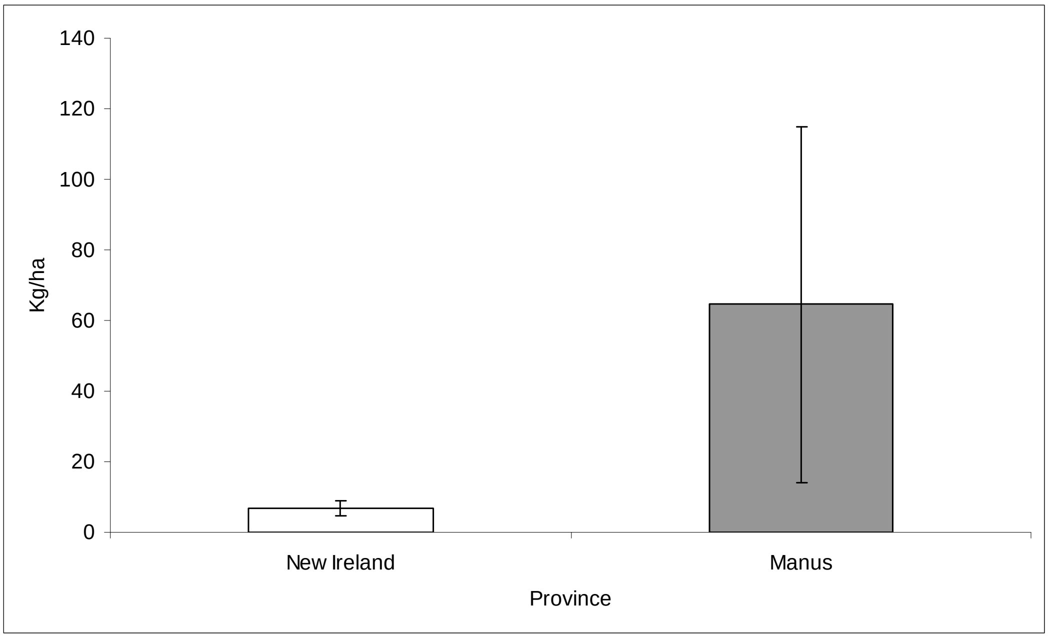

Figure 16. Mean biomass of large vulnerable fish sighted in New Ireland and Manus

The higher densities and biomass of large vulnerable species in Manus was due largely to much higher densities and biomass of groupers in Manus Province (Table 5 and 6). Humphead wrasse and bumphead parrotfish were also in much higher densities and biomass in Manus, although these differences were not statistically significant.

Table 5. Mean density of groupers, humphead wrasse and bumphead parrotfish in each province

Family/Species	**Mean density per ha New Ireland**	**Mean density per ha Manus**	**Differences' significant Yes/No** (Mann-Whitney test)
All Groupers	1.25 (SE = 0.40)	7.27 (SE = 1.81)	Yes (P<0.001)
Humphead wrasse	0.69 (SE = 0.32)	1.71 (SE = 0.68)	No (P = 0.115)
Bumphead parrotfish	0.35 (SE = 0.22)	4.21 (SE = 3.5)	No (P = 0.427)

Table 6. Mean biomass of groupers Humphead wrasse and Bumphead parrotfish in each province

Family/Species	**Mean biomass per ha New Ireland**	**Mean biomass per ha Manus**	**Differences' significant Yes/No** (Mann-Whitney test)
All Groupers	1.21 (SE = 0.49)	3.72 (SE = 0.84)	Yes (P=0.003)
Humphead wrasse	0.54 (SE = 0.35)	3.08 (SE = 1.60)	No (P = 0.071)
Bumphead parrotfish	52.22 (SE = 51.11)	0.54 (SE = 0.32)	No (P=0.465)

RESULTS – BENTHIC COMMUNITIES

The mean percentage of each major lifeform in New Ireland and Manus Province is shown in Figure 17. Non-living made up the highest percentage cover in both provinces (New Ireland 42.4%, Manus 47.3%), followed by Coral in both provinces (New Ireland 25.7%, Manus 30.4%). Macroalgae made up 25.1% of benthic cover in New Ireland but only 10.6% of benthic cover in Manus. Other lifeforms were slightly more abundant in Manus (11.7) than in New Ireland (6.8). To investigate if any of the differences seen were significant each Major lifeform was compared between the two provinces.

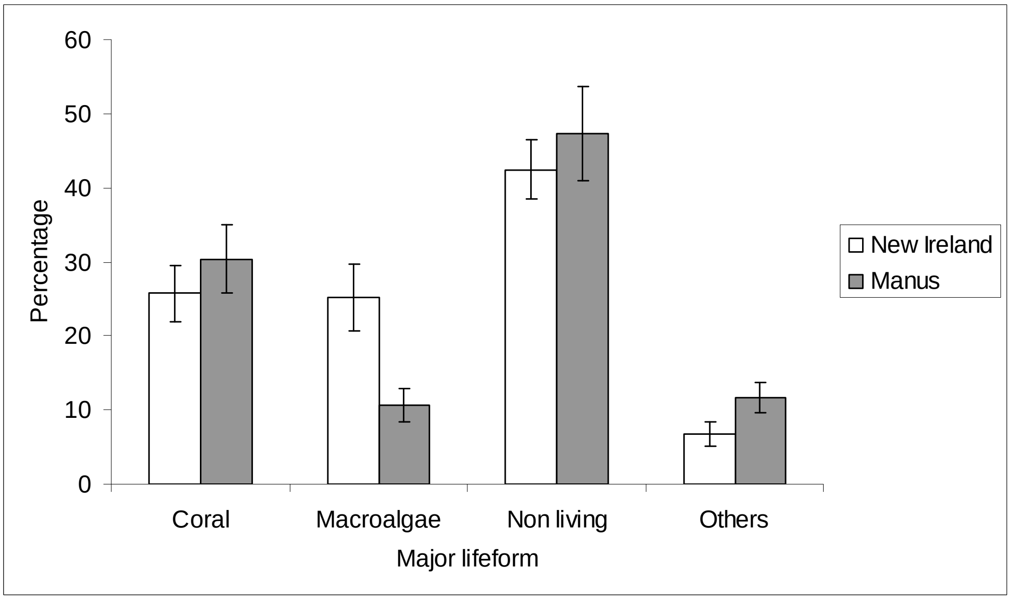

Figure 17. Percentage of the major life forms in New Ireland and Manus Province.

CORAL COVER

The mean percentage of Coral cover at each site is shown in Figure 18. Coral cover was highly variable between sites, ranging from 11.79% (Site 12) to 64.78% (Site 10). The mean percentage of Coral was not significantly different between the two provinces (P=0.438).

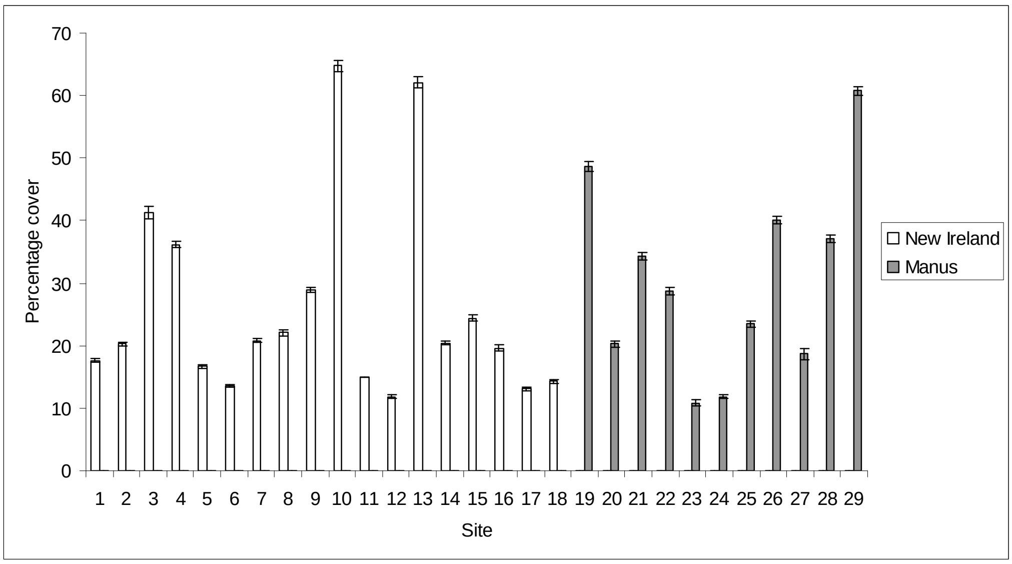

Figure 18. The mean percentage of Coral cover at each site

MACROALGAE

The mean percentage of algal cover at each site is shown in Figure 19. Macroalgae cover was highly variable between sites, ranging from 1.54% (Site 10) to 76.61% (Site 17). The mean percentage of Macroalgae was significantly higher in New Ireland than in Manus (P=0.024).

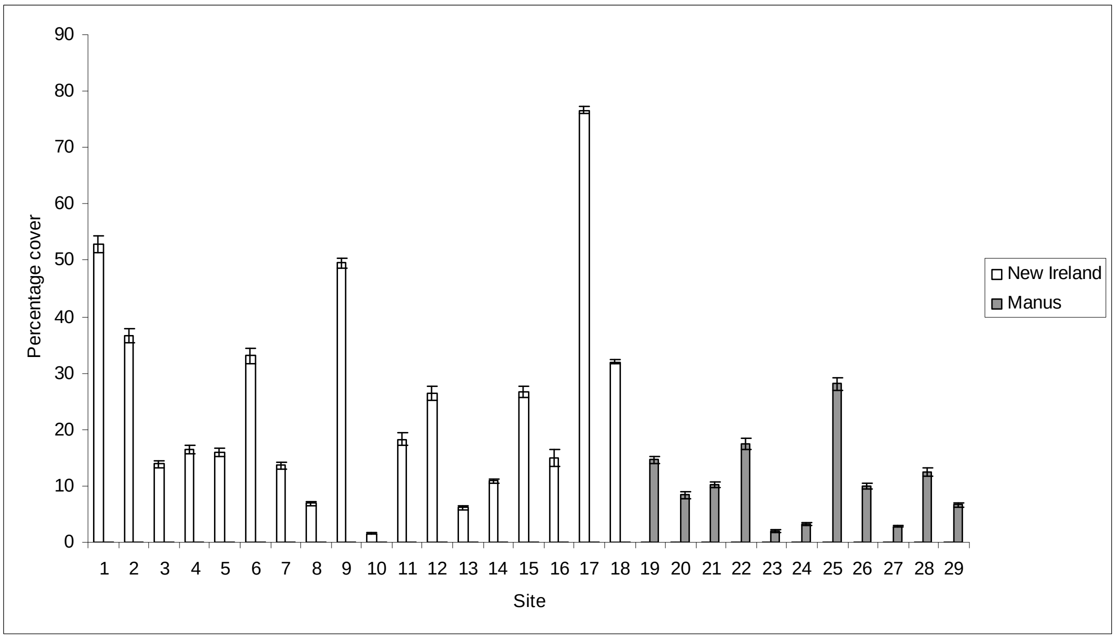

Figure 19. The mean percentage of Macroalgae cover at each site

NON-LIVING

The mean percentage of Non-living cover at each site in each year is shown in Figure 20. Non-living cover ranged from 9.25% (Site 17) to 84.79% (Site 23). The mean percentage of Non-living was not significantly different between the two provinces (P=0.502).

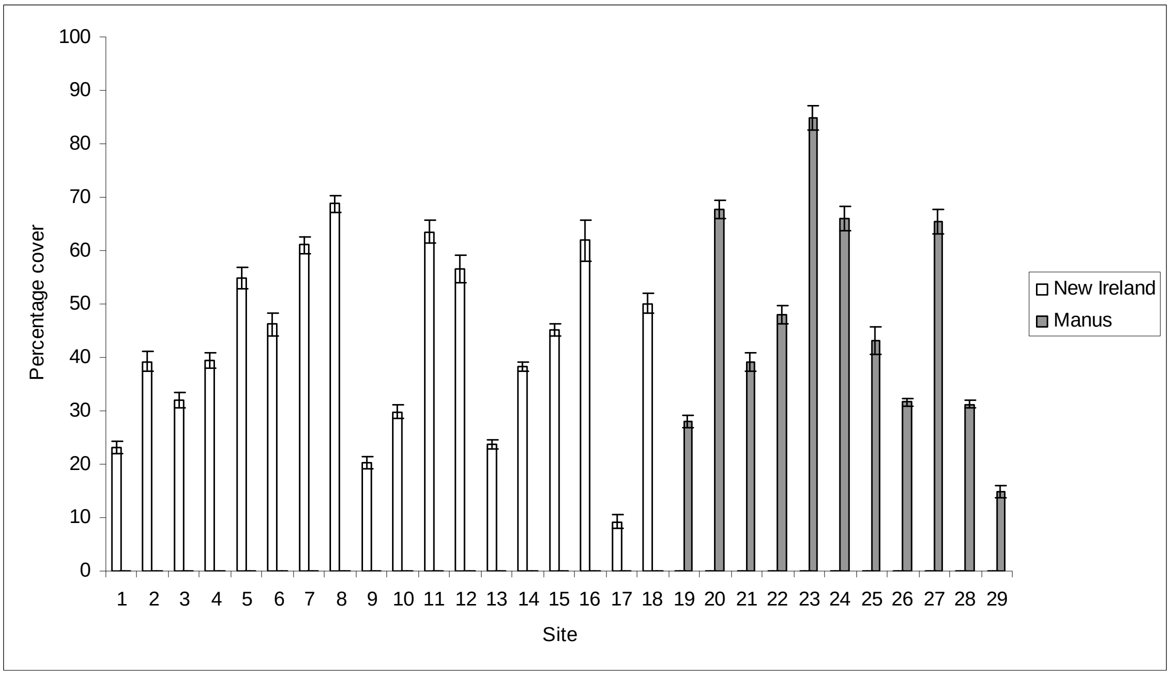

Figure 20. The mean percentage of Non-living cover at each site

OTHER

The mean percentage of Other cover at each site is shown in Figure 21. Other cover ranged from 1.03% (Site 17) to 30.49% (Site 17). The mean percentage of Other cover was not significantly different between the two provinces (P=0.067).

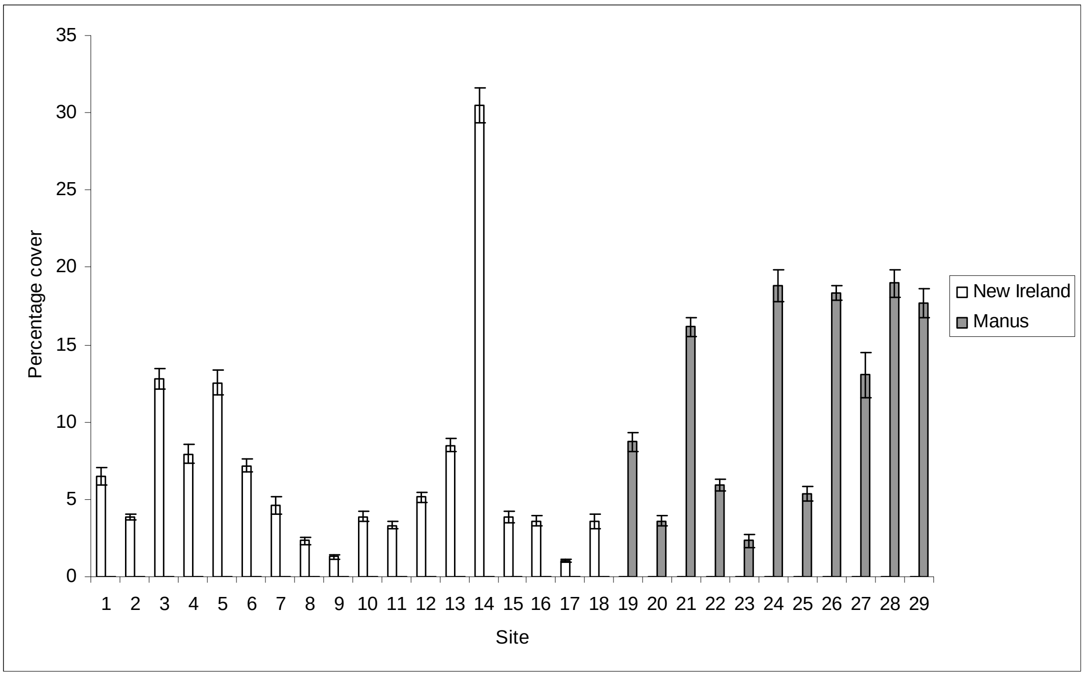

Figure 21. The mean percentage of Other cover at each site

DISCUSSION

Densities and biomass of fish sighted on transects varied considerably within and between sites. Within site variability (as evidenced by large standard errors around many of the means) in part reflects the schooling and patchy nature of many of the target species surveyed. While some of the between site variation is probably due to the variation in the amount of live hard coral habitat at each site, which ranged from approximately 12-65% across all the sites surveyed. When data was pooled by province and compared there was no significant difference between the mean density and mean biomass of all reef fish sighted on transects in New Ireland and Manus. However an examination of five abundant families of coral reef fish (snappers, surgeonfishes, emperors, parrotfishes and groupers) revealed some significant differences between the two provinces. New Ireland had a significantly higher density and biomass of surgeonfishes then Manus and the mean densities of emperors in New Ireland were also significantly higher than at Manus. While in Manus the densities and biomasses of parrotfishes and groupers were significantly higher than in New Ireland.

The differences seen between the two provinces at the family level could be due to a number of confounding variables including geographical variability, recruitment variability, different levels of historical fishing pressure and/or the survey sampling design. Without pre-existing baseline data from the sites surveyed it is difficult to determine with certainty which factors explain the differences seen. One short coming of this survey from an analysis perspective is that site selection was not balanced. We did not get an equal number of exposed or sheltered sites in each province and a greater number of sites were surveyed in New Ireland. These issues aside, one area of potential concern is the much low densities of groupers and parrotfishes in New Ireland.

Groupers are a key target of artisanal and commercial fishers that are easily overfished due to their longevity, reproductive biology and tendency to form spawning aggregations in highly predicable times and places (Sadovy and Domeier 2005). Although targeted in both provinces, groupers have historically been much more heavily targeted in the New Ireland then in Manus Province. LRFFT operations that have been fishing in the Tigak Islands and surrounding areas since the early 1990s have wiped out many of the grouper spawning aggregations known to local fishers (Hamilton, et al. 2004). Furthermore, the close proximity of the Tigak Islands and New Hanover to fisheries centres and restaurants in Kavieng has provided the incentive for artisanal fishers in these regions to heavily target this family of fish. Today artisanal fishers receive premium prices for groupers, and even aggregations of estuarine groupers (*Epinephelus polystigma*) that were historically lightly fished are now being heavily targeted for sale to commercial outlets in Kavieng town (Hamilton and Potuku 2007). In contrast in the areas we surveyed in Manus, commercial LRFFT operations did not commence until 2005 and there are no commercial fisheries centres and few restaurants in the province. Most fish that is taken by artisanal fishers is sold as smoked fish in local markets and groupers do not receive a higher price than numerous other fish species that are consumed by the Manus population.

The differences in parrotfish densities and biomass between the two provinces may also reflect difference levels of historical fishing pressure. Parrotfishes are extremely vulnerable to overexploitation by night divers, and in areas where night spearfishing is practiced their densities and biomass tends to drop rapidly once cash markets for parrotfishes develop (Gillett and Moy 2006; Hamilton 2003). This is a concern given that parrotfishes are ecologically important elements of the coral reef fish fauna that have profound effects on the dynamics of reef growth and sedimentation (Bellwood, et al. 2003).

Perhaps of greatest concern are the differences in densities and biomass of large vulnerable reef fish in the two provinces. Manus had a significantly higher density and biomass of large vulnerable reef fishes than New Ireland. In Manus groupers and the humphead wrasse (*Cheilinus undulatus*) were 6 and 2.5 times more abundant on long swims then in New Ireland. Like groupers, the humphead wrasse is a prime target of LRFFT operations. This species is now listed as Endangered on the IUCN Red list, and is completely protected from recreational and commercial fisheries in Australia.

Although sharks were not recorded in food fish surveys, they were rarely encountered by the marine survey team, consistent with observations made by Gerald Allen during his biodiversity surveys (See Coral Reef Fish Diversity, this report). On coral reefs sharks are apex predators that play a key role in maintaining healthy reef ecosystems. The low numbers of reef sharks sighted in New Ireland and Manus are indicative of overfishing by the shark fin trade. The shark fin trade is responsible for decimating shark populations globally, and even on the Great Barrier Reef, the best managed reef system in the world, reef shark populations are plummeting and at risk of ecological extinction in the next twenty years as a result of shark fishing (Robbins, et al. 2006).

In Manus the densities of bumphead parrotfish (*Bolbometopon muricatum*) sighted on long swims was 12 times higher then in New Ireland[1]. Bumphead parrotfish is the largest of all parrotfishes, and has recently been listed as Vulnerable on the IUCN Red list, in recognition of the ease with which nocturnal aggregations of this species are overfished by night-time spear fishers (Dulvy and Polunin 2004; Hamilton 2003). Being the largest of the parrotfishes and given its size range and the excavating mode of feeding, this is potentially the most important species in the functional group of reef fishes associated with bioerosion, sediment transport and coral removal on tropical reefs (Bellwood, et al. 2003). In the Tigak Islands juvenile bumphead parrotfish that were speared at night with hand held spears formed an important component of artisanal catches in the early 1980's (Wright and Richards 1985). However very large catches of this species were not taken by night time spear fishers until the late 1980s and early 1990s when the increasing availability and affordability of underwater flashlights in trade stores at the regional centre of Kavieng made this practice more common (Hamilton, et al. 2004). For the Tigak Islands we had the ability to compare counts of bumphead parrotfish seen on long swims in this survey with counts made earlier. In 2000 the mean densities of bumphead parrotfish sighted on long swims in the Tigak Islands was 2.7 bumphead parrotfish per hectare (Choat, 2000 unpublished data in (Chan, et al. 2007), a 7.7 times higher density than the 0.35 bumphead parrotfish per hectare seen in the Tigak Islands and New Hanover region during this survey. This marked drop in the Tigak Islands is almost certainly an indication of heavy night time spearfishing pressure on this species in this decade.

The results from the benthic cover survey showed that the major lifeform Non-living (rubble, sand and dead coral) made up the highest percentage of substrate cover in the 8-10 m zones in both provinces. Mean Non –living cover was 43% in New Ireland and 47% in Manus and these differences were not significantly different. Live hard coral was the second dominant major lifeform, comprising of 26% of cover in New Ireland and 30% of cover in Manus and again, these differences were not significantly different. Macroalgae cover differed significantly between the two provinces, making up 25% of benthic cover in New Ireland and 11% in Manus. At Site 17 in New Ireland Macroalgae made up 80% of the benthic cover. This site had suffered extensive coral mortality as a result of relatively recent damage from COTS and bleaching events. Finally, the Lifeform Other made up 7% over cover in New Ireland and 11% of cover in Manus and these differences were not significantly different.

CONSERVATION & MANAGEMENT RECOMMENDATIONS

1. To restore grouper populations in New Ireland and sustain current populations in Manus there is a need for management of this commercially important family of fish. One solution would be to impose provincial wide seasonal bans on the sale of any grouper during periods when they to aggregate to spawn. Two specific recommendations which should be implemented in conjunction with each other are:

    a) Place a six month seasonal ban on all LRFFT activities in Manus and New Ireland from the 1st of March to the 31st of August each year. This is the period when many species of groupers (e.g. *Epinephelus fuscoguttatus, Epinephelus polyphekadion, Epinephelus ongus, Plectropomus areolatus*) aggregate in the 100s or 1000s at known sites in Manus and New

[1] Although bumphead parrotfish densities were higher in Manus than in New Ireland, this species is nevertheless targeted by night spear fishers in Manus (Tapas Potuku, personal observations), and densities are much lower than in other areas of the Indo-Pacific where this species is not targeted (Chan et al., 2007).

Ireland for the purpose of spawning (Manuai Matawai and Tapas Potuku, unpublished data 2004-2008;(Hamilton and Matawai 2006).

b) Prevent the sale of all groupers in the 10 days leading up to and including the new moon. This is the lunar period when most groupers aggregate to spawn. A lunar ban would offer some protection to species of groupers such as *Plectropomus areolatus* that form different sized spawning aggregations throughout the entire year in New Ireland and Manus (Manuai Matawai and Tapas Potuku, unpublished data 2004-2008; (Hamilton and Matawai 2006).

2. Place a national wide ban on the sale of humphead wrasse (*Cheilinus undulatus*). This is in recognition of the extreme vulnerability of this species, the very high desirability of this species in the LRFFT and its listing as Endangered on the IUCN Red list (Russell 2004).

3. Place a national wide ban preventing commercial fisheries centres from purchasing bumphead parrotfish (*Bolbometopon muricatum*). This is in recognition of the extreme vulnerability of this species to night time spearfishing, and its recent listing as Vulnerable on the IUCN red List (Chan, et al. 2007).

4. We recommend a permanent ban on the shark-fin trade in the Bismarck Sea or, at a minimum, that a moratorium be place on shark-fin fishery until a NFA shark-fin management plan is in place.

5. We recommend that a study should be carried out to assess the extent of Crown of thorns starfish damage in New Ireland and the history of outbreaks. The feasibility of managing COTS by mobilising communities to remove COTS from specific reefs of high value should also be investigated.

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APPENDIX

Biomass conversion constants for fish species recorded on the survey. Constants obtained from Fishbase (www.fishbase.org). Typically the median value for a species was used, or when no species-specific information was available, the constants for a closely related species or the constants of the overall mean values of a genus were used.

Family	Genus and species	Biomass constant a	Biomass constant b
ACANTHURIDAE	*Ctenochaetus striatus*	0.0231	3.0635
	Acanthurus fowleri	0.0210	2.9435
	Acanthurus lineatus	0.0126	3.0640
	Acanthurus maculiceps	0.0210	2.9435
	Acanthurus mata	0.0222	3.0080
	Acanthurus nigricaudus	0.0312	2.7590
	Acanthurus nubilus	0.0210	2.9435
	Acanthurus olivaceus	0.0070	3.3980
	Acanthurus pyroferus	0.0210	2.9435
	Acanthurus xanthopterus	0.0267	2.9845
	Naso brevirostris	0.0136	3.1280
	Naso hexacanthus	0.0202	2.9558
	Naso lituratus	0.0487	2.8390
	Naso unicornis	0.0228	2.9220
	Naso vlamingii	0.0525	2.8430
BALISTIDAE	*Balistapus undulatus*	0.0058	3.5540
	Balistoides viridescens	0.0244	3.0180
	Odonus niger	0.0366	3.0000
	Pseudobalistes flavimarginatus	0.0244	3.0180
CARANGIDAE	*Carangoides bajad*	0.0269	2.8891
	Carangoides plagiotaenia	0.0269	2.8891
	Caranx ignobilis	0.0296	2.9780
	Caranx melampygus	0.0211	2.9410
	Caranx sexfasciatus	0.0318	2.9300
	Elagatis bipinnulatus	0.0135	2.9200
	Gnathanodon speciosus	0.0199	2.9950
EPHIPPIDAE	*Platax orbicularis*	0.0425	2.9750
KYPHOSIDAE	*Kyphosus cinerascens*	0.0218	3.0053
	Kyphosus vaigiensis	0.0200	3.0370
HAEMULLIDAE	*Plectorhinchus albovittatus*	0.0270	2.8848
	Plectorhinchus chaetodonoides	0.0148	3.0830
	Plectorhinchus gibbosus	0.0209	2.9474
	Plectorhinchus lessonii	0.0209	2.9474
	Plectorhinchus lineatus	0.0131	3.0663
	Plectorhinchus vittatus	0.0209	2.9474
HOLOCENTRIDAE	*Sargocentron spiniferum*	0.0154	3.1188
LABRIDAE	*Cheilinus fasciatus*	0.0318	3.0000
	Cheilinus trilobatus	0.0162	3.0595
	Cheilinus undulatus	0.0123	3.1123
LETHRINIDAE	*Lethrinus erythracanthus*	0.0219	2.9471
	Lethrinus erythropterus	0.0219	2.9471
	Lethrinus harak	0.0167	3.0371
	Lethrinus obsoletus	0.0185	3.0024
	Lethrinus olivaceus	0.0297	2.8187
	Lethrinus nebulosus	0.0303	2.8697
	Lethrinus rubrioperculatus	0.0201	2.9694
	Lethrinus xanthochilus	0.0219	2.9395
	Monotaxis grandoculis	0.0239	3.0110

Family	Genus and species	Biomass constant a	Biomass constant b
LUTJANIDAE	*Aphareus furca*	0.0186	3.0000
	Aprion virescens	0.0162	2.9050
	Lutjanus argentimaculatus	0.0071	3.1800
	Lutjanus bohar	0.0156	3.0587
	Lutjanus carponotatus	0.0167	2.9773
	Lutjanus fulviflamma	0.0205	2.9599
	Lutjanus fulvus	0.0211	2.9743
	Lutjanus gibbus	0.0131	3.1375
	Lutjanus kasmira	0.0111	3.1540
	Lutjanus monostigma	0.0184	2.9700
	Lutjanus rivulatus	0.0326	3.0000
	Lutjanus russelli	0.0166	2.9779
	Lutjanus semicinctus	0.0040	3.4280
	Macolor macularis	0.0211	3.0000
	Macolor niger	0.0211	3.0000
	Symphorichthys spilurus	0.0189	2.9349
MULLIDAE	*Parupeneus bifasciatus/trifasciatus*	0.0036	3.4510
	Parupeneus barberinus	0.0151	3.0780
	Parupeneus cyclostomus	0.0243	3.0000
	Parupeneus multifasciatus	0.0114	3.2108
NEMIPTERIDAE	*Scolopsis monogramma*	0.0205	2.9840
POMACANTHIDAE	*Pomacanthus navarchus*	0.0193	2.9696
	Pomacanthus sexstriatus	0.0217	2.9079
	Pomacanthus xanthometopon	0.0193	2.9696
SCARIDAE	*Bolbometopon muricatum*	0.0098	3.1329
	Cetoscarus bicolor	0.0240	3.0000
	Chlorurus microrhinos	0.0179	3.0448
	Hipposcarus longiceps	0.0198	3.0000
	Scarus festivus	0.0186	3.0455
	Scarus ghobban	0.0165	3.0412
	Scarus oviceps	0.0224	3.0000
	Scarus prasiognathos	0.0186	3.0455
	Scarus niger	0.0170	3.1300
SCOMBRIDAE	*Scomberomorus commerson*	0.0099	2.9500
SIGANIDAE	*Siganus argenteus*	0.0131	3.0880
	Siganus corallinus	0.0023	3.8208
	Siganus doliatus	0.0104	3.2721
	Siganus fuscescens	0.0137	3.0682
	Siganus lineatus	0.0219	2.9983
	Siganus puellus	0.0246	3.0000
	Siganus punctatissimus	0.0168	3.0326
	Siganus punctatus	0.0344	3.0000
	Siganus stellatus	0.0168	3.0326
	Siganus vulpinus	0.0287	3.0000
SPYYRAENIDAE	*Sphyraena barracuda*	0.0267	2.9200
	Sphyraena qenie	0.0056	3.0000
SERRANIDAE	*Aethaloperca rogga*	0.0152	3.0063
	Anyperodon leucogrammicus	0.0014	3.5481
	Cephalopholis argus	0.0093	3.1807
	Cephalopholis cyanostigma	0.0164	3.0303
	Cromileptes altivelis	0.0962	2.4893
	Epinephelus fuscoguttatus	0.0134	3.0572
	Epinephelus hexagonatus	0.0140	3.0000
	Epinephelus lanceolatus	0.0173	3.0000
	Epinephelus merra	0.0096	3.1960
	Epinephelus polyphekadion	0.0124	3.0570
	Gracila albomarginata	0.0152	3.0063
	Plectropomus areolatus	0.0079	3.1570

Family	Genus and species	Biomass constant a	Biomass constant b
	Plectropomus laevis	0.0059	3.2377
	Plectropomus leopardus	0.0079	3.1570
	Plectropomus oligacanthus	0.0132	3.0000
	Variola albimarginata	0.0139	3.0424
	Variola louti	0.0122	3.0791

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Chapter 2: Coral Reef Fish Diversity

Rapid Ecological Assessment: Northern Bismarck Sea, Papua New Guinea

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Executive Summary

- A list of fishes was compiled for Manus (18 sites and 27 hours of scuba diving) and the Tigak Islands-New Hanover region (25 sites and 36 hours of diving) to a maximum depth of 50 m.

- A combination of historical data and 577 new records from the current survey yields a total of 801 species belonging to 76 families and 274 genera for the northern Bismarck Archipelago.

- A formula for predicting the total reef fish fauna based on the number of species in six key indicator families (Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae) indicates that at least 945 species can be expected to occur at the northern Bismarck Archipelago (Admiralty Islands, New Hanover, and New Ireland).

- Gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), cardinalfishes (Apogonidae), and groupers (Serranidae) are the dominant fish families in the region in both number of species and number of individuals, comprising about 46 percent of the total observed fauna (excluding cryptic species).

- Species numbers at visually sampled sites during ranged from 65 to 234, with an average of 159.0. The average number of species per site for Manus was 154.4 and for the Tigak Islands-New Hanover region was 162.2.

- Outer reef sites generally harboured the richest fish fauna with an average of 177 species (n = 18) compared with averages of 176 and 132 species respectively for channels/passages (n =7) and sheltered lagoon sites (n = 17).

- Fishing pressure appears to be considerably reduced compared to areas farther west in the Coral Triangle, but the scarcity of large Napoleon Wrasse, particularly in the Tigak Islands is cause for concern and may indicate over-exploitation. Relatively large numbers of Napoleon Wrasse were sighted during the survey with average sizes of 70 cm and 37 cm total length recorded at Manus (n = 18) and Tigak Islands-New Hanover (n = 45) respectively.

- Recommended conservation areas based on reef fish observations include the Sabben Islands off western Manus, Hayne Harbour on eastern Manus, Bauddisssin Bay in the Tigak Islands, and the reef complex north of Anelaua Island off eastern New Hanover. The latter area appears to be an important nursery area for both Napoleon Wrasse and Bumphead Parrotfish.

INTRODUCTION

The primary goal of the fish survey was to provide a comprehensive inventory of reef species inhabiting the northern Bismarck Archipelago, specifically the Manus and Tigak Islands-New Hanover regions. This segment of the fauna includes fishes living on or near coral reefs down to the limit of safe sport diving or approximately 50 m depth. It therefore excludes deepwater fishes, offshore pelagic species such as flyingfishes, tunas, and billfishes, and most estuarine forms. Survey results facilitate comparison of key locations within the Bismarck Archipelago as well as inter-regional and global comparisons.

The author was unable to participate in the original reef survey of the Tigak Islands-New Hanover region and Manus during August-September 2006, but was fortunately able to conduct an independent fish survey aided by Manuai Matawai (TNC-Manus) approximately one month later between 18 October and 8 November.

HISTORICAL BACKGROUND

Munro (1967) provided a summary of ichthyological fieldwork in the New Guinea region. The Bismarck Archipelago has a lengthy history of fish collections dating back to the voyage of French naturalists Quoy and Gaimard aboard the vessel *L'Astrolabe,* which visited New Ireland in 1826. Albert Gunther, Curator of Fishes at the British Museum published additional records from the Admiralty Islands collected during an oceanographical expedition on H.M.S. *Challenger* in 1875. During the same year the German vessel S.M.S. *Gazelle* collected specimens at New Ireland and New Hanover for the Royal Academy in Berlin. Additionally, the German South Seas Expedition organised by the Hamburg Museum made collections at the Bismarck Archipelago, including the Admiralty Islands during 1908-09.

Australian ichthyologists have maintained an interest in the Bismarck region beginning with Charles DeVis, who published a paper in 1883 recording 17 species from New Ireland, New Britain, and the Duke of York Islands. Sir William Macleay and the Russian naturalist Miklouho-Maclay, recorded two ray species from the Admiralty and Hermit Islands in 1886. The American ichthyologist Henry Fowler included many species from the Bismarck Archipelago based on collections at the Australian Museum, Sydney in the second supplement of his *Fishes of Oceania* published in 1934. These records were supplied by Gilbert Whitley, who served as Curator of Fishes at AMS. Additional collections from the Bismarck areas were made in 1948-1950 during expeditions aboard the Australian government research vessel *Fairwind*. Collections were obtained from numerous locations around the Territory of Papua, including the Bismarck Archipelago. These were reported by Munro (1958) and consisted of the following species totals: New Ireland – 41, New Hanover – 53, and Admiralty Islands – 38.

Kailola (1975) included 28 records of reef fishes the Bismarck Archipelago in her 1975 catalogue of fishes in the Kanudi Fisheries Research Laboratory collections. She later (1987-1991) summarized the entire fish fauna of Papua New Guinea in an annotated checklist, which included new records of 36 coral reef fishes from the Bismarck area in addition to the G. Allen collections summarised in the following paragraph.

The present author visited Manus Island between 3-13 October 1982 and obtained specimens and underwater photographs during 25 hours of scuba-diving. These collections, consisting of 81 species the majority of which were new records for the Admiralty Islands, are deposited at the Western Australian Museum, Perth, and were reported by Kailola (1987-1991). They include the holotypes of *Chrysiptera sinclairi* (Allen, 1987), and *Meiacanthus limbatus* Smith-Vaniz (1987) and paratypes of *Amsichthys knighti* (Allen, 1987), *Lubbockichthys multisquamatus* (Allen, 1987), and *Pomacentrus aurifrons* (Allen, 2004).

METHODS

The fish portion of the Bismarck survey involved 63 hours of scuba diving by G. Allen to a maximum depth of 50 m. A list of fishes was compiled for 43 sites. The basic method consisted of underwater observations made during a 1-2, 60-90 minute dives at each site. The name of each observed species was recorded in pencil on a plastic sheet attached to a clipboard. The technique usually involved rapid descent to 20-50 m, then a slow, meandering ascent back to the shallows. The majority of time was spent in the 2-12 m depth zone, which consistently harbors the largest number of species. Each dive included a representative sample of all major bottom types and habitat situations, for example rocky intertidal, reef flat, steep drop-offs, caves (utilizing a torch if necessary), rubble and sand patches.

Only the names of fishes for which identification was absolutely certain were recorded. However, very few, less than one percent of those observed, could not be identified to species. This high level of recognition is based on nearly 40 years of diving experience in the Indo-Pacific and an intimate knowledge of the reef fishes of this vast region as a result of extensive laboratory and field studies. The visual survey was supplemented by underwater photography of approximately 165 fish species using a Nikon D-100 digital camera and 105 mm macro lens contained in a Nexus housing.

SITE SELECTION

Emre Turak provided the author with a list of GPS coordinates for the sites that were surveyed by the TNC team during August-September 2006. An effort was made to duplicate the majority of these sites for the fish survey. Consequently, 32 of the 45 sites surveyed for fishes were situated within 200-300 metres of the initial TNC survey sites. The remaining sites were selected primarily by consulting satellite imagery and marine charts. Site selection was also dictated by inclement weather conditions that were experienced during much of the Tigak-New Hanover portion of the survey. A list of the sites with an indication of which ones were also surveyed by the initial TNC team is included in Appendix 2.

RESULTS

Totals of 665 and 572 were recorded for Manus and Tigak Islands-New Hanover respectively during the present survey with a combined total of 750 species. The Manus figure includes 94 species recorded on the basis of photographs and information supplied by Susomu Okamoto, who runs a diving business on the island. These records are especially valuable as they mainly represent species that are rare or infrequently sighted and were compiled by Mr. Okamoto over a 3-year period.

Combining historical collections with records from the present survey yields a total reef fish fauna for the northern Bismarck Archipelago consisting of 801 species belonging to 76 families and 274 genera (Appendix 2). The total consists of the following components: 81 species collected between 1826-1950 that were summarised by Munro (1958), 62 species reported in publications by Kailola (1975 and 1987-1991), 81 species collected at Manus by G. Allen in 1982 and reported by Kailola (1987-1991), and an additional 577 species recorded during the present survey, which represent new records for the northern Bismarck Archipelago (Admiralty Islands, New Hanover, and New Ireland).

GENERAL FAUNAL COMPOSITION

The fish fauna of the Bismarck Archipelago consists mainly of species associated with coral reefs. The most abundant families in terms of number of species are gobies (Gobiidae), wrasses (Labridae), damselfishes (Pomacentridae), cardinalfishes (Apogonidae), groupers (Serranidae), butterflyfishes (Chaetodontidae), surgeonfishes (Acanthuridae), parrotfishes (Scaridae), snappers (Lutjanidae), and blennies (Blenniidae). These 10 families collectively account for 55 percent of the total reef fish fauna (Figure 1).

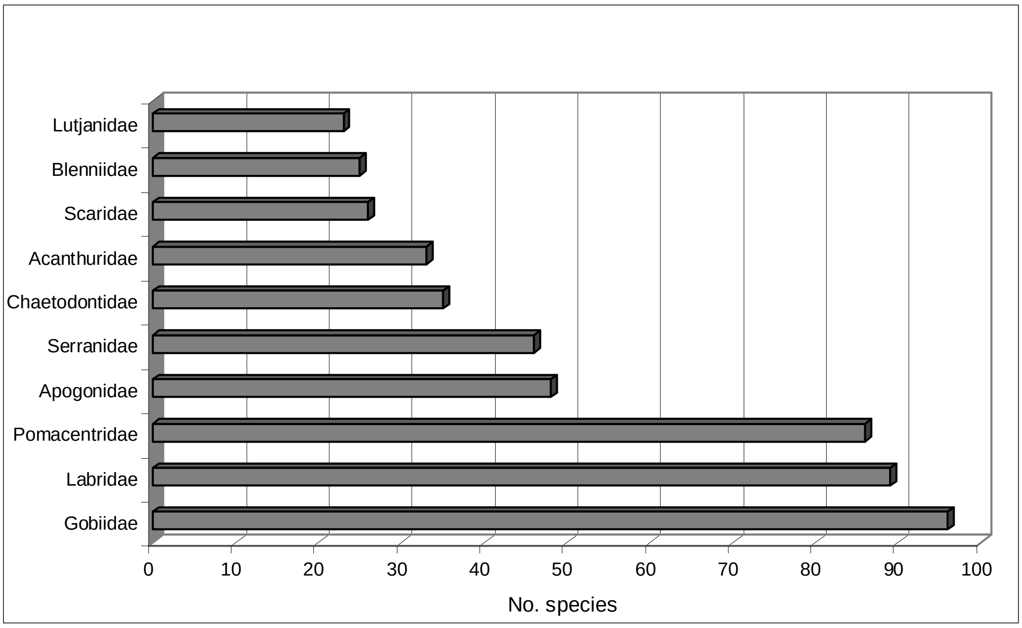

Figure 1. Ten largest families of northern Bismarck Archipelago.

The relative abundance of Bismarck fish families is similar to other reef areas in the Indo-Pacific, although the ranking of individual families is variable. Even though the Gobiidae was one of the leading families, it was not adequately collected due to the small size and cryptic habits of many species. Similarly, the moray eel family Muraenidae is consistently among the most speciose groups at most localities, and is no doubt abundant in the Bismarck Archipelago. However, they are best sampled with icthyocides due to their cryptic habits.

The composition of local reef fish communities in the Indo-Pacific region is dependent on habitat variability. The incredibly rich reef fish fauna of the Coral Triangle region directly reflects a high level of habitat diversity. Nearly every conceivable habitat situation is present from highly sheltered embayments with a large influx of freshwater to oceanic atolls and outer barrier reefs.

Similar to other reef areas in the Indo-Pacific, most Bismarck fishes are benthic (or at least living near the bottom) diurnal carnivores with approximately 80 percent and 60 percent of species being assigned to these respective categories. Approximately 10 percent of Bismarck fishes are nocturnal, 4 percent are cryptic crevice dwellers, 4 percent are durnal mid-water swimmers, and about 3 percent are transient or roving predators. In addition to carnivores, the other major feeding categories include omnivores (16 percent), planktivores (16 percent), and herbivores (8 percent).

SITE FAUNAL COMPOSITION

The fishes at a particular site are generally composed of faunal elements that include both generalist species occurring over a broad range of habitats as well as a suite of specialist species that are adapted to various levels of exposure to general sea conditions. For example, certain species are exclusively encountered on outer or seaward reefs that provide maximum exposure, whereas others are restricted to sheltered silty bays. Between these two extremes there is a vaguely defined situation with variable degrees of moderate exposure, which is also characterized by certain species, although this habitat generally contains a variable mixture of outer and inner reef specialists depending on the level of exposure. Table 1 provides a list of Bismarck species that are typical indicators of the major habitat types.

Table 1. Typical species associated with major habitat types.

Seaward reefs	Moderate exposure	Sheltered reefs
Cephalopholis spiloparea	*Lutjanus biguttatus*	*Cephalopholis microprion*
Caranx sexfasciatus	*Scolopsis margaritifer*	*Scolopsis ciliatus*
Lutjanus monostigma	*Pentapodus aureofasciatus*	*Sphaeramia nematoptera*
Caesio teres	*Caesio cuning*	*Chaetodon octofasciatus*
Hemitaurichthys polylepis	*Chaetodontoplus mesoleucus*	*Chrysiptera cymatilis*
Apolemichthys trimaculatus	*Choerodon anchorago*	*Chrysiptera parasema*
Pomacentrus vaiuli	*Neoglyphidodon nigroris*	*Chrysiptera sinclairi*
Bodianus anthioides	*Pomacentrus nigromanus*	*Pomacentrus burroughi*
Halichoeres biocellatus	*Diproctacanthus xanthurus*	*Pomacentrus albimaculus*
Nemateleotris magnifica	*Halichoeres leucurus*	*Halichoeres chloropterus*
Naso hexacanthus	*Scarus quoyi*	*Amblygobius nocurna*
Balistoides conspicillum	*Acanthurus fowleri*	*Signigobius biocellatus*

There are also suites of species that are closely correlated with various depth regimes. Although most coral reef fishes are encountered at depths between about 3-20 m, certain species are restricted to shallow, wave-swept areas, while others seldom venture above 20 m. Typical members of these categories are listed in Table 2.

Table 2. Typical species that are restricted to shallow and deep habitats.

Shallow, wave-washed reefs	Deep reefs
Cirrhitus pinnulatus	*Myripristis vittata*
Chrysiptera brownriggii	*Cepholopholis spiloparaea*
Plectrglyphidodon leucozonus	*Pseudanthias randalli*
Stegastes fasciolatus	*Hoplolatilus spp.*
Thalassoma jansenii	*Apogon ocellicaudus*
Thalasssoma purpureum	*Chaetodon burgessi*
Blenniella spp.	*Chromis analis*
Acanthurus lineatus	*Chromis elerae*
Acanthurus guttatus	*Halichoeres melasmapomus*

A final category includes species that are closely associated with specific substrate types, the most notable of which are sand or rubble and live coral (Table 3). In addition, another conspicuous group, containing transient predators, is basically pelagic, although they are closely associated with reef environments. Prominent members include certain sharks (Carcharhinidae), manta and devil rays (Mobulidae), half-beaks (Hemiramphidae), needlefishes (Belonidae), trevallies or jacks (Carangidae), tunas and mackerels (Scombridae), and barracuda (Sphyraenidae).

Table 3. Typical species associated with sand/rubble and live coral substrata.

Sand/Rubble species	Coral species
Synodus spp.	*Archamia zosterophora*
Malacanthus spp.	*Apogon similis*
Scolopsis affinis	*Sphaeramia nematoptera*
Upeneus tragula	*Chaetodon baronessa*
Parachaetodon ocellatus	*Chaetodon trifascialis*
Dischistodus perspicillatus	*Plectroglyphidodon dickii*
Cirrhilabrus spp.	*Pomcentrus moluccensis*
Paracheilinus spp.	*Labrichthys lineatus*
Coris batuensis	*Scarid spp. (Chlorurus and Scarus)*
Parapercis spp.	*Eviota bifasciata*
Gobiid spp (*Amblyeleotris*, etc.)	*Eviota sebreei*
Soleiid, bothid spp.	*Oxymonacanthus longirostris*

CORAL FISH DIVERSITY INDEX (CFDI)

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 totaled to obtain the Coral Fish Diversity Index (CFDI) for a single dive site, relatively restricted geographic areas (e.g. Bismarck Archipelago) or countries and large regions (eg. Papua New Guinea).

CFDI values can be used to make a reasonably accurate estimate of the total coral reef fish fauna of a particular locality by means of regression formulas. The latter were obtained after analysis of 35 Indo-Pacific locations for which reliable, comprehensive species lists exist. The data were first divided into two groups: those from relatively restricted localities (surrounding seas encompassing less than 2,000 km^2) and those from much larger areas (surrounding seas encompassing more than 50,000 km^2). Simple regression analysis revealed a highly significant difference ($P = 0.0001$) between these two groups. Therefore, the data were separated and subjected to additional analysis. The Macintosh program Statview was used to perform simple linear regression analyses on each data set in order to determine a predictor formula, using CFDI as the predictor variable (x) for estimating the independent variable (y) or total coral reef fish fauna. The resultant formulae were obtained: 1. total fauna of areas with surrounding seas encompassing more than 50,000 km^2 = 4.234(CFDI) - 114.446 (d.f = 15; $R^2 = 0.964$; $P = 0.0001$); 2. Total fauna of areas with surrounding seas encompassing less than 2,000 km^2 = 3.39 (CFDI) - 20.595 (d.f = 18; $R^2 = 0.96$; $P = 0.0001$).

The CFDI predictor value is especially useful to gauge the thoroughness of a short-term survey that is either currently in progress or already completed. For example, the CFDI for Bismarck Archipelago based on the present survey is 285 and the appropriate regression formula (3.39 x 285 – 20.595) predicts an approximate total of 945 species, indicating that at least 144 additional species can be expected.

On a much larger scale the CFDI can be used to estimate the reef fish fauna of the entire Indo-west Pacific region, a frequent subject of conjecture. Using this method Allen and Adrim (2003) estimated a faunal total of 3,764 species, a figure that is remarkably close to the 3,890 total obtained by the author as a result of a comprehensive species mapping project for this region. It also compares favorably with the approximately 3,950 total proposed by Springer (1982). However, Springer’s figure covers shore fishes rather than reef fishes and therefore includes species not always associated with reefs (e.g. estuarine fishes).

The total CFDI for the Bismarck Archipelago has the following components: Labridae (89), Pomacentridae (86), Chaetodontidae (35), Acanthuridae (33), Scaridae (25), and Pomacanthidae (16). Table 5 presents a ranking of Indo-Pacific areas that have been surveyed to date based on CFDI values. It also includes the number of reef fishes thus far recorded for each area, as well as the total fauna predicted by the CFDI regression formula.

Although situated within the Coral Triangle, the Bismarck Archipelago lies near the margin of this region, which contains the world's greatest concentration of coral reef organisms. Consequently, its reef fish fauna is less diverse than areas in the Philippines and western Indonesia that lie within the centre of the Triangle. Moreover, the results of the Bismark survey are based on a relatively small area, well under 2,000 km^2, compared to most of the locations listed in Table 4. Therefore, considering the size and location of the Bismark Archipelgo, it supports a rich community of reef fishes that is only slightly less diverse than the world's highest ranked regions.

Table 4. Coral fish diversity index (CFDI) values for selected localities in the Indo-west Pacific region. The total number of fishes thus far recorded from each region and estimated total based on the CFDI regression formula (see text for details) are also indicated.

Locality	CFDI	No. reef fishes	Estim. Reef fishes
Bird's Head Peninsula, Indonesia	365	1227	1431
Milne Bay, Papua New Guinea	337	1109	1313
Great Barrier Reef, Australia	343	1325	1338
Maumere Bay, Flores, Indonesia	333	1111	1107
Taiwan	319	1172	1237
New Caledonia	300	1097	1156
Bismarck Archipelago	**285**	**801**	**945**
Komodo Islands, Indonesia	280	722	928
North West Shelf, Australia	273	932	1042
Marshall Islands, Micronesia	221	795	822
Maldive Islands	219	894	813
Christmas Island, Indian Ocean	185	560	606
Society Islands, French Polynesia	160	560	563
Hawaiian Islands	**121**	435	398

SURVEY SITES

Manus

The number of species found at each site is indicated in Table 5. Totals ranged from 65 to 230, with an average of 154.4 per site**.**

Table 5. Number of fish species observed at each site during survey of Manus.

Site	Species	Site	Species	Site	Species
1	198	**7**	160	**13**	110
2	205	**8**	109	**14**	162
3	169	**9**	153	**15**	116
4	167	**10**	180	**16**	167
5	65	**11**	159	**17**	105
6	135	**12**	230	**18**	189

The highest total (230 species) was recorded at site 12, situated in the relatively remote Sabben Islands. This site was characterised by an outer reef dropoff and extensive shallow reef top with variable amounts of wave exposure. The underwater visibility was exceptionally good (estimated 40 m) and the location is subject to periodic strong currents that support rich schools of fusiliers, trevallies, and plankton-feeding surgeonfishes. In general, outer reefs were significantly more diverse than sheltered inner reefs as indicated in Table 6.

Table 6. Average number of fish species per site recorded for major habitats at Manus.

General habitat	No. Sites	Site nos.	Avg. species/site
Outer reef slopes and dropoffs	11	1, 3-4, 6-7, 10-12, 14, 16, 18	174.3
Sheltered inner reefs	7	2, 5, 8-9, 13, 15, 17	123.3

Tigak - New Hanover

The number of species found at each site is indicated in Table 7. Totals ranged from 110 to 234, with an average of 162.2 per site**.**

Table 7. Number of fish species observed at each site in Tikak Islands- New Hanover region.

Site	Species	Site	Species	Site	Species	Site	Species
1	151	**8**	193	**15**	120	**22**	127
2	189	**9**	123	**16**	162	**23**	161
3	110	**10**	188	**17**	149	**24**	118
4	159	**11**	154	**18**	172	**25**	174
5	198	**12**	173	**19**	151		
6	165	**13**	234	**20**	184		
7	198	**14**	165	**21**	137		

The highest number of species (230) was recorded at site 13 situated on the southern coast of Selapiu Island. The site was characterized by a typical assemblage of outer reef species, but also contained a nearby community associated with sheltered reefs. This apparent contradiction resulted from the unusual reef structure consisting of a narrow prong of reef paralleling the shore that was exposed to the open sea on one side, but completely protected from surge on the other. Consequently, the conditions were dramatically different within a linear distance of only 20-30 metres, grading from clear oceanic waters to a turbid lagoon. Similar to the situation at Manus and most areas in the tropical Indo-Pacific, outer reefs supported the most diverse fish community (Table 8).

The Tigak-New Hanover region is bisected by numerous channels and passages ranging in depth from few metres to more than 30 m. They support a reef community that is similar to that of the outer slopes, but slightly less diverse. Turbid inshore reefs and lagoon patch reefs exhibited the lowest diversity, but represent a unique habitat situation containing many species that are restricted to sheltered waters. This habitat also provides important nursery grounds for species such as Napoleon Wrasse and parrotfishes.

Table 8. Average number of fish species per site recorded for major habitat situations in Tigak Islands- New Hanover region.

General habitat	No. sites	Site nos.	Avg. species/site
Outer reefs	8	1, 4, 7-8, 10, 13-14, 23	181.1
Channels and passages	7	2, 5, 1112, 16, 20, 25	176.3
Sheltered lagoonal reefs	10	3, 6, 9, 15, 17-19, 21-22, 24	137.2

Combined Results

A total of 750 species were recorded during the 2006 surveys of Manus and the Tigak Islands-New Hanover region. Combined with previous collections between 1826 and 1982 the overall total for the northern Bismarck region is currently 801 species (Table 9).

Species totals for individual survey sites ranged from 65 to 234, with an average of 159 per site**.**

Table 9. Summary of results for northern Bismarck Archipelago fish survey.

Location	Total spp.	CFDI	Est. Spp.
Manus	665	263	871
Tigak Is. – New Hanover	572	241	796
Combined No. Bismarck	801	283	939

The most speciose sites for fishes during the present survey is summarised in Table 10.

Table 10. Richest fish sites during northern Bismarck survey.

Site no.	General locations	No. spp.
T-13	Nausen Island	234
M-12	Yambon Island	230
M-2	Hayne Harbour	205
M-1	Little Ndrova Island	198
T-5	Baudissin Island	198
T-7	West New Ireland	198
T-8	Nusa Island	193
T-2	NW Globig Island (Nusa Channel)	189
M-18	Pityilu Island	188

Most of the high-diversity sites were situated on outer reef slopes with the exception of M-2, which was in a sheltered lagoon near the airport at Manus. The high number of species is attributed to the location near the mouth of the bay. Besides the regular component of lagoon fishes, there was a mix of species that are generally seen on more exposed outer reefs.

DR. ALISON GREEN FISH OBSERVATIONS

Due to my last minute withdrawal from the initial survey, the task of assessing reef fish biodiversity at each site was graciously assumed by Dr. Alison Green. Although not a trained ichthyologist, she has wide experience in general reef ecology and did an excellent job of conducting the necessary inventory work. Essentially her overall list of fishes was similar to my own, except for the omission of a relatively small number of cryptic or non-descript species. The following species (not seen by G. Allen) were observed by Dr. Green and no doubt constitute valid records, but are not included on the overall list presented in Appendix 1: *Sargocentrum rubrum, S. melanospilos* and *S. tiere* (Holocentridae), *Epinephelus hexagonatus, E. howlandi, E. melanostigma*, and *E. spilotoceps* (Serranidae), *Cypho purpurascens* (Pseudochromidae), *Leiognathus* sp. (Leiognathidae), *Ambassis* sp. (Ambassidae), *Lutjanus lunulatus* (Lutjanidae), *Toxotes jaculatrix* (Toxotidae), *Chaetodon speculum* (Chaetodontidae), *Scarus globiceps* (Scaridae), *Acanthurus auranticavus* (Acanthuridae), and *Xanthichthys auromarginatus* (Balistidae).

The results of Dr. Green's inventories for Manus and the Tigak-Hanover regions are presented in Tables 11 and 12.

Table 11. Number of fish species observed at each site during initial reef survey at Manus by Alison Green.

Site	Species	Site	Species	Site	Species
1	204	**7**	217	**13**	171
2	155	**8**	156	**14**	176
3	190	**9**	195		
4	176	**10**	101		
5	225	**11**	218		
6	156	**12**	217		

Table 12. Number of fish species observed at each site during initial reef survey at Tigak Islands-New Hanover by Alison Green.

Site	Species	Site	Species	Site	Species
1	164	**8**	171	**15**	178
2	103	**9**	169	**16**	103
3	111	**10**	159	**17**	152
4	169	**11**	196	**18**	164
5	153	**12**	127	**19**	167
6	166	**13**	169		
7	180	**14**	209		

The average number of species per site was 183 at Manus and 158 at Tigak Islands-New Hanover with a combined average for both areas of 169 species per site.

OVERALL FAUNAL RESULTS FOR BISMARCK ARCHIPELAGO

Allen and Munday (unpublished) conducted a comprehensive reef fish survey at Kimbe Bay, New Britain in the southern portion of the Bismarck Archipelago between1994-2000. Although visual observation methods were primarily involved, collections of cryptic reef species with the use of chemical ichthyocides were also employed. A total of 851 species were recorded, including 23 species of pelagic or deep reef species. Therefore, the overall total of shallow reef fishes for the entire Bismarck Archipelago is 969 species, consisting of 801 species reported from the current survey and previous historical records combined with 151 Kimbe Bay species that were not seen during the present survey of the northern Bismarcks (Appendix 3).

INTER-REGIONAL COMPARISONS

The Coral Triangle (CT) of southeastern Asia (Figure 2) is universally acknowledged as the centre of marine biodiversity with the richest concentration of fishes, corals, and other reef-associated organisms (Allen, 2002). Species richness gradually decreases with increasing distances from the heart of the CT consisting of the southern Philippines and eastern Indonesia. This trend is particularly evident in the tropical Pacific (Table 13).

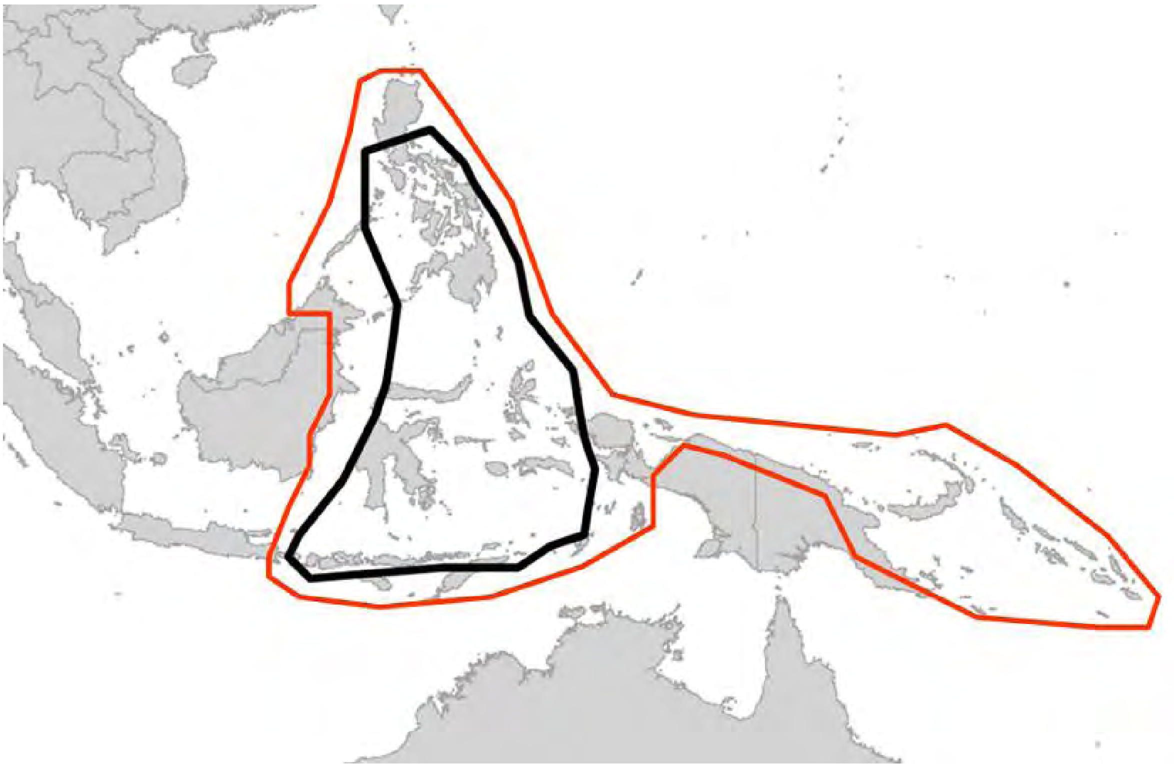

Figure 2. Map of southeastern Asia-Melanesia showing boundary of the Coral Triangle (red) and the species-rich "heart" of the Triangle (bold black).

Table 13. Number of reef species for various Pacific locations.

Location	Distance from CT (km)	Total reef species
Molucca Islands, Indonesia	0	1647
Milne Bay Province, PNG	2,400	1109
Solomon Islands	3,000	1019
Marshall Islands	4,300	899
Phoenix Islands	6,200	509
Line Islands	7,600	488
Hawaiian Islands	8,200	421
Easter Island	13,800	86

Papua New Guinea forms an integral part of the CT, lying at distances of about 1,300-3,000 km from the "heart" of the Triangle. The richest area for fishes in PNG is Milne Bay Province, due to its large area and wide range of habitat variability including mainland coast, variable-sized coastal islands, large high-island archipelagos (i.e. D'Entrecasteaux Group), and oceanic atolls. Although slightly less rich than Milne Bay, the northern Bismarck Archipelago supports an extensive reef fish fauna that in a global context is notable for both its high number of species and diverse range of families. Nearly all the same habitat situations described for Milne Bay are represented, except those associated with the mainland coast. Although the current reef-fish total for the area is now 801 species, nearly 1000 species are expected to occur, based on the CFDI. This is a remarkable total, given the physical area occupied by the northern Bismarcks and the fact that only 13 of the world's countries have 1000 or more reef fishes (Allen, 2006 - submitted manuscript). Table 14 presents a comparison of estimated faunal totals for various locations in the New Guinea-Solomons region based on CFDI values. Although the values for Manus and the Tigak-New Hanover areas may not seem impressive in comparison to other locations, they are based on surveys covering significantly smaller areas.

Table 14. Comparison of CFDI and estimated faunal totals for the New Guinea-Solomon Islands. Locations in the Indonesian portions of New Guinea are indicated with an asterisk. These data are from G. Allen surveys during 1994-2006.

Location	**Approx. area km^2**	**CFDI**	**Est. Fauna**
Raja Ampat Islands*	14,000	345	1346
Milne Bay	17,000	337	1313
Fak-Fak Kaimana region*	15,000	309	1194
Cenderawasih Bay*	40,000	295	1156
Kimbe Bay	770	265	877
Solomon Islands	166,000	264	874
Manus	**1,800**	**263**	**871**
Madang area	950	257	850
Tigak Islands-New Hanover	**730**	**241**	**796**

Table 15 presents the average number of species per site, number of sites where more than 200 species were observed, and the greatest number seen at a single site for recent marine surveys by the author in the Coral Triangle region of South East Asia. A total of 200 or more species is generally considered as the benchmark for an excellent fish count for a single site. This figure was obtained at five of 33 sites by Alison Green during the initial TNC survey and two of 43 sites during the present ichthyological survey. Although the 200 mark was achieved at only a few of the northern Bismarck sites, the actual survey area was much less than for most of the other areas in Table 15.

Table 15. Comparison of site data for marine surveys in the coral triangle 1997-2002.

Location	**No. sites**	**Average spp./site**	**No. 200+ sites**	**Most spp. one site**
Fak Fak-Kaimana Coast (CI 2006)	34	216	19 (56%)	330
Cenderawasih Bay (2006)	32	175	12 (38%)	257
Raja Ampat Islands (CI 2001 and TNC 2002)	95	184	49 (52%)	284
Halmahera (New England Aquarium 2005)	27	229	24(86%)	304
Solomon Islands (TNC 2004)	65	184.7	37 (57%)	279
NE Kalimantan (TNC 2003)	42	187	18 (43%)	273
Milne Bay, PNG (CI 1997 and 2000)	110	192	46 (42%)	270
Togean/Banggai Is., Sulawesi (CI 1998)	47	173	9 (19%)	266
NO. Bismarck Archipelago (Green - 2006)	**33**	**169**	**5 (15.2%)**	**225**
NO. Bismarck Archipelago (Allen -2006)	**43**	**159**	**2 (4.4%)**	**234**
Calamianes Is., Philippines (CI 1998)	21	158	4 (10.5%)	208

BISMARCK ENDEMISM AND NOTEWORTHY RECORDS

The presence of endemic species is a considerable asset in promoting and justifying conservation action for a particular area. Considering the broad dispersal capabilities via the pelagic larval stage of most reef fishes it is not surprising that very few endemics are known to occur in the Bismarck region. At present only two species, a damselfish *Chrysiptera sinclairi* and blenny *Meiacanthus limbatus* are considered as northern Bismarck endemics. These species as well as two notable range extensions are discussed in the following paragraphs.

***Chrysiptera sinclairi* Allen, 1987 (Figure 3) -** It was first collected at Hayne Harbour on Manus in 1982 and subsequently described by the author. This small (about 6 cm total length), colourful fish is common in sheltered coastal bays and lagoons with moderate sedimentation levels at depths between about 3-12 m. During the present survey it was abundant at both Manus and the Tigak-New Hanover region.

Figure 3. *Chrysiptera sinclairi*, adult, approximately 5 cm total length, Manus Island (G. Allen photo).

***Meiacanthus limbatus* Smith-Vaniz, 1987** – Also first collected by the author at Manus in October 1982. The holotype (only known specimen) was collected on the outer reef slope about 3 km east of the air strip on Los Negros Island at a depth between 35-41 m. Despite a deliberate attempt to locate additional specimens during the present survey, it was not seen and is therefore presumed to be rare.

***Meiacanthus crinitus* Smith-Vaniz, 1987 (Figure 4) -** The species was originally described from the Raja Ampat Islands off the western tip of New Guinea (Indonesian province of Irian Jaya Barat). Surprisingly, it was collected by the author from sheltered lagoon environments in the Solomon Islands during the TNC marine survey of 2004. It was also observed at a single site (T-22) near Anelaua Island off eastern New Hanover during the current survey. Despite numerous dives on sheltered coastal reefs during the present survey it was only recorded at this location where it was relatively common. Tissue samples were collected for DNA comparison with Raja Ampat fish.

Figure 4. *Meiacanthus crinitus*, adult, approximately 5 cm total length, New Hanover (G. Allen photo).

The Solomons and Tigak records are particularly important, as they may provide the first example of a coral reef fish that has dispersed to the Coral Triangle via island arc fragments. Polhemus (1996) described this mechanism to account for the dispersal of a number of aquatic insects, which are distributed on Melanesian islands as well as mainland New Guinea. According to paleogeographic reconstructions by Hill and Hall (2004) there was a continuous chain of island fragments (South Caroline Arc) linking the Solomon Islands and New Ireland with western New Guinea during a period that extended approximately 3-10 million years ago.

***Paracheilinus rubricaudalis* Randall and Allen, 2003 (Figure 5)** – The species was originally described on the basis of two specimens collected at Fiji and was later reported from Vanuatu (Allen, unpublished data). During the current survey it was collected and photographed near Pityilu Island (site 18) on Manus, representing a considerable range extension for the species. Members of this genus, collectively known as flasher wrasses, inhabit dead coral rubble/algal substrate, usually at depths below about 15 m. They feed in aggregations on zooplankton and therefore occur in areas exposed to moderate current. The group is among the most brilliantly coloured of all coral reef fishes. The display patterns of courting males are particularly brilliant and responsible for their common name of flasherwrasses. The neon-like “flasher” pattern is produced instantaneously during a spectacular display that is reminiscent of the courtship display of certain birds of paradise. The dazzling fins are fully erected, including a spectacular filamentous dorsal fin that is characteristic of several species. Females, by contrast, are relatively dull, usually shades of red, without distinguishing marks, and are generally much smaller. Fourteen species are currently known with most taxa concentrated in the Coral Triangle region.

Figure 5. *Paracheilinus rubricaudalis*, adult, approximately 6 cm total length, Manus Island (G. Allen photo).

GENERAL HABITAT CONDITION AND FISHING PRESSURE

Reef habitats were generally in good condition with an abundance of fishes around Manus, but extensive damage, presumably due to crown-of-thorns starfish, was noted throughout the Tikak-New Hanover region. This phenomenon, as observed by Emre Turak, is discussed elsewhere in the Bismark report.

Fishing pressure is definitely less intense in Papua New Guinea waters compared to other portions of the Coral Triangle farther west, particularly Indonesia and the Philippines. This is a direct reflection of a much smaller, more widely scattered human population and far less commercial exploitation of reef fishes, especially for the Hong Kong-based live restaurant fish trade. Sharks were seen at several sites and are reported to be common in some areas by commercial dive operators at Manus and New Ireland. However, as is the case elsewhere in the Coral Triangle, the shark-fin trade has caused a serious decline in local populations.

The Napoleon Wrasse (*Cheilinus undulatus*) is a conspicuous indicator of general fishing pressure throughout the Coral Triangle region. Apparently it has been harvested for the live fish trade for several years at both Manus and the Tigak Islands. However, relatively high numbers were noted during the current survey (Table 16). The average size of Manus fish was approximately 70 cm total length (n = 18) compared with an average size of only 37 cm (n = 45) at Tigak-New Hanover. The smaller size noted at the latter location may be due to more intense pressure by the live reef fish trade. A large live fish collector ship was seen moored off the south coast of Bangatang Island in the middle of the Tigak Archipelago during our survey.

Table 16. Frequency of Napoleon Wrasse (*Cheilinus undulatus*) for various locations in the Indo-Pacific (G. Allen data).

Location	**No. sites where seen**	**% of total sites**	**No. seen**
Phoenix Islands 2002	47	83.92	412
Tigak Islands-New Hanover - 2006	**19**	**76.00**	**45**
Milne Bay, PNG – 1997	28	52.83	85
Milne Bay, PNG – 2000	28	49.12	90
Solomon Islands - 2004	31	47.69	56
Manus - 2006	**8**	**44.44**	**18**
Cenderawasih Bay - 2006	12	37.5	33
Fak Fak-Kaimana Coast	11	32.35	23
Raja Ampat Islands – 2002	9	18.0	14
Raja Ampat Islands – 2001	7	15.55	7
Togean/Banggai Islands – 1998	6	12.76	8
Calamianes Is., Philippines – 1998	3	7.89	5
Weh Island, Sumatra – 1999	0	0.00	0

CONSERVATION RECOMMENDATIONS

The Bismarck Archipelago has good potential for reef conservation, based on the results of the present fish survey. A wide variety of habitats are represented, frequently within relatively confined areas, an ideal scenario for establishing marine protected areas or reserves. The following locations seem particularly well suited for MPA establishment:

1. Sabben Islands, west Manus (Figure 6) – The remote barrier reef and associated low-lying islands that cover approximately 200 square km off the extreme western end of Manus with the most distant portion of the reef situated 37 km from the mainland. The general environment is similar to that of an atoll with a shallow, sandy lagoon and abrupt outer reef walls. The highest number of fishes for any site on Manus was recorded here (site M-12). It was also one of the best locations for large fishes (sharks, snappers, Napoleon wrasse, etc.) and was characterised by the best underwater visibility (about 40 m). One of the advantages of MPA establishment would be the relatively remote location and consequent natural protection from over-fishing.

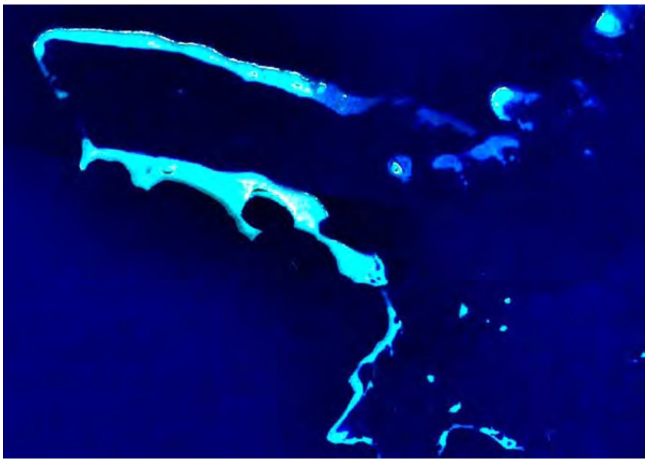

Figure 6. Satellite image of Sabben Islands area, west Manus.

2. Hayne Harbour, East Manus (Figure 7) – The large bay next to the Manus airport on Los Negros Island covering an area of about 2.7 square km. This sheltered lagoon provides a habitat for a host of reef fishes and is partially lined with mangroves. The site yielded an unusually high species count (205) for a protected inshore habitat. The lagoon has a substantial opening to the open sea and is well-flushed by the tides. There is good representation of outer reef fishes in the entrance channel and a transitional zone around the mouth of the lagoon.

Figure 7. Satellite image of Hayne Harbour lagoon, Manus.

3. Bauddissin Bay, Bauddissin Island, Tigak Archipelago (Figure 8) – A relatively narrow strip of reef covering less than one square km on the southern coast of Bauddissin (also known as Binnegem) Island, one of the two largest islands that form the southern tier of islands linking New Ireland with New Hanover. The site is notable due to the unusual reef structure and rich habitat variability within a very confined area. There is typical outer reef wall that drops to about 70 m depth that is separated from the coastal reef by a narrow channel with a maximum depth of 10-12 m. The channel then opens into the shallow sandy lagoon of the inner part of Bauddissin Bay. The channel is flushed periodically by clear water from the open sea and consequently supports a wealth of fishes, including numerous snappers and sweetlips. One of the highest fish counts (198 species) was obtained in the back reef channel (site T-5), an exceptional total considering the sheltered nature of this location. There is also nearby mangrove environment along the shore.

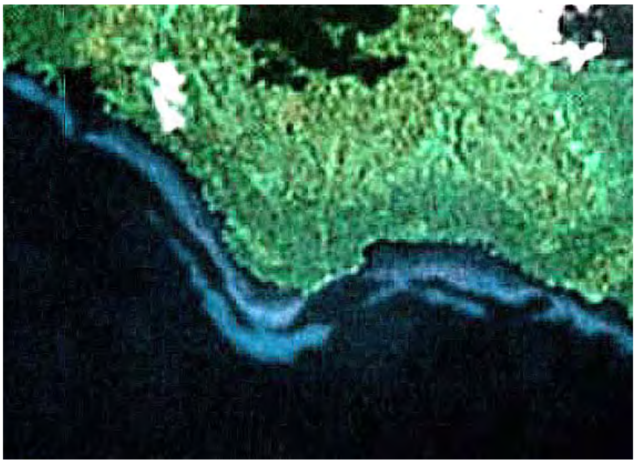

Figure 8. Satellite image of Bauddissin Bay, Tigak Archipelago. Note the unusual reef formation around the protruding point consisting of an outer reef wall and back reef channel.

4. North Anelaua Island, Tigak Archipelago – The complex of sheltered reefs lying north of Anelaua Island and its small satellite, Anelik Island. The maze of reef covers approximately six square km. I was so impressed with this site (T-16) that I did an extra dive there with total dive duration of approximately three hours. The area, which lies only about 2.6 km off the eastern coast of New Hanover, supports luxurious coral gardens, which unlike much of the Tigak Archipelago, is relatively undamaged by COTS. Judging from my brief visit, it appears to be an important nursery area for at least three species: Napoleon Wrasse (*Cheilinus undulatus*), Bumphead Parrotfish (*Bolbometopon muricatum*), and Spanish Flag Snapper (*Lutjanus carponotatus*). I observed 15 small Napoleons ranging in size from 4-10 cm and at least 20 similar sized Bumpheads (Figure 9). These totals would certainly have increased substantially if I had concentrated on these species at the expense of the overall inventory. Young Napoleons are especially wary and remain close to cover, unlike the adults. This site is particularly significant given that *Cheilinus undulatus* is one of the very few reef fishes designated as an endangered species on the IUCN Redlist and is also listed in Appendix II of CITES.

Figure 9. Small juveniles of the Napoleon Wrasse (left, 7 cm) and Bumphead Parrotfish (right, 6 cm total length) were common at the Anelaua reef complex (site T-22).

The above locations obviously represent a small sample of potential MPA or marine reserve sites. One of the challenges of local TNC staff will be to locate an array of sites of similar importance. Excellent progress has already been made on Manus where a number of important spawning aggregation sites for coral trout (*Plectropomus areolatus*) and grouper (*Epinephelus fuscoguttatus*) have been identified. I had the fortunate opportunity to dive on two of these sites during the survey. Large aggregations of *Plectropomus areolatus* numbering between 60-100 individuals were witnessed at both sites.

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APPENDICES

APPENDIX 1. List of Sites

Emre no.	Site	Date	Area	Location	Coordinates	Time	Duration	Depth	Habitat
7	M-1	18/10/2006	Manus	Shark Point	02° 03.149’ S, 147° 25.852’ E	930	150	0-38 m	sheltered outer
8	M-2	18/10/2006	Manus	Hayne Harbour	02° 03.048’ S, 147° 25.532’ E	1300	70	1-25 m	lagoon
3	M-3	19/10/2006	Manus	Dramolow Point	02° 06.321’ S, 147° 17.063’ E	1030	90	2-25 m	sheltered outer
1	M-4	19/10/2006	Manus	Little Ndrova Island	02°13.751’ S, 147° 12.816’ E	1430	65	1-35 m	outer reef wall
new	M-5	19/10/2006	Manus	Big Ndrova Island	02° 12.831’ S, 147° 14.098’ E	1600	80	1-20 m	sheltered lagoon
2	M-6	20/10/2006	Manus	Patui Bay - outside reef	02° 13.669’ S, 147° 06.866’ E	800	70	1-36 m	sheltered outer slope
9	M-7	20/10/2006	Manus	Ndruval Reef	02° 16.148’ S, 147° 01.242’ E	1230	60	1-45 m	outer slope (mod shel)
new	M-8	20/10/2006	Manus	Peli Island	02° 13.107’ S, 146° 57.721’ E	1530	60	2-23 m	lagoon patch
12	M-9	21/10/2006	Manus	Yambon Island	02° 18.764’ S, 146° 51.316’ E	1300	70	2-40 m	patch reef
new	M-10	21/10/2006	Manus	Mbuke Island	02° 18.869’ S, 146° 51.240’ E	1630	70	2-45 m	outer wall (mod shel)
13	M-11	22/10/2006	Manus	Southwest Point	02° 14.460’ S, 146° 31.991’ E	1000	90	1-37 m	sheltered outer slope
14	M-12	22/10/2006	Manus	Sabben Islands	02° 14.646’ S, 146° 17.385’ E	1400	160	2-35 m	outer patch drop off
15	M-13	23/10/2006	Manus	Salihau Island	02° 05.712’ S, 146° 33.192’ E	800	100	1-15 m	inner fringing shletered
16	M-14	23/10/2006	Manus	Massong Islands	01° 57.850’ S, 146° 28.424’ E	1200	70	3-28 m	outer moderate slope
17	M-15	23/10/2006	Manus	Noru Island	01° 57.554’ S, 146° 37.558’ E	1415	80	1-15 m	island fringing reef (current)
5	M-16	24/10/2006	Manus	Ponam Reef	01° 55.076’ S, 146° 55.457’ E	1030	60	5-28 m	outer slope
6	M-17	24/10/2006	Manus	Hinru Island	01° 58.056’ S, 147° 00.291’ E	1500	90	1-12 m	inner coastal reef
4	M-18	25/10/2006	Manus	Pityilu Island	01° 57.219’ S, 147° 13.994’ E	1000	180	5-30 m	outer slope and lagoon
5	T-1	30/10/2006	Tigak	N Nusalomon I.	02° 36.556’ S, 150° 40.683’ E	945	70	1-24 m	outer slope to rubble
6	T-2	30/10/2006	Tigak	NW Globig I. (Nusa Channel)	02° 38.388’ S, 150° 43.877’ E	1115	90	1-19 m	sheltered passage
12	T-3	30/10/2006	Tigak	N Limmelon I. (Balgai Bay)	02° 40.290’ S, 150° 46.599’ E	1430	85	1-14 m	sheltered fringing
1	T-4	31/10/2006	Tigak	Baudissin Island	02° 44.606' S, 150° 39.034’ E	930	70	1-50 m	outer dropoff
new	T-5	31/10/2006	Tigak	Baudissin Island	02° 44.606' S, 150° 39.901’ E	1130	90	1-19 m	lagoon channel
new	T-6	31/10/2006	Tigak	Lissenung Island	02° 44.618' S, 150° 39.166’ E	1430	85	1-10 m	island fringing reef (sheltered)
7	T-7	11/01/2006	Tigak	W New Ireland	02° 34.806' S, 150° 49.925’ E	930	70	2-24 m	outer slope

Emre no.	Site	Date	Area	Location	Coordinates	Time	Duration	Depth	Habitat
8	T-8	11/01/2006	Tigak	Nusa I.	02° 34.857' S, 150° 46.214’ E	1130	80	1-27 m	outer slope
13	T-9	11/01/2006	Tigak	Nausen I.	02° 38.777' S, 150° 46.083’ E	1430	95	3-18 m	sheltered lagoon patch
15	T-10	11/02/2006	Tigak	Konokorr I.	02° 35.406 S, 150° 35.610’ E	900	85	3-27 m	outer slope w/ big cave
10	T-11	11/02/2006	Tigak	Bangatang I. (Steffen Strait)	02° 37.074 S, 150° 36.426’ E	1115	80	1-21 m	channel slope
11	T-12	11/02/2006	Tigak	Lemus I. (Steffen Strait)	02° 36.665 S, 150° 38.470’ E	1400	85	1-25 m	channel slope
9	T-13	11/03/2006	Tigak	Selapiu I.	02° 43.084 S, 150° 34.265’ E	930	85	1-48 m	outer slope and dropoff
new	T-14	11/03/2006	Tigak	Selapiu I.	02° 36.665 S, 150° 38.470’ E	1115	80	1-31 m	outer dropoff
new	T-15	11/03/2006	Tigak	Selapiu I.	02° 42.033 S, 150° 36.109’ E	1400	100	1-6 m	backreef lagoon
new	T-16	11/04/2006	Tigak	Kulaumis I (north)	02° 42.519 S, 150° 38.406’ E	1000	75	1-10 m	narrow channel w/ current
new	T-17	11/04/2006	Tigak	Kulaumis I (south)	02° 42.009 S, 150° 38.746’ E	1145	100	1-10 m	sheltered fringing reef
new	T-18	11/05/2006	Tigak	Ra I. (Nusa Channel)	02° 36.794' S, 150° 42.420’ E	900	70	2-16 m	island fringing reef - lagoon
new	T-19	11/05/2006	Tigak	Ungan I.	02° 38.706 S, 150° 41.501’ E	1045	75	1-6 m	island fringing reef - lagoon
new	T-20	11/05/2006	Tigak	Lemus I.	02° 38.034 S, 150° 38.788’ E	1530	65	1-30 m	channel dropoff
19	T-21	11/06/2006	New Hanover	Balang I.	02° 36.029' S, 150° 28.012’ E	900	90	0-18 m	shletered island fringing
16	T-22	11/06/2006	New Hanover	Anelaua I.	02° 33.956' S, 150° 28.758’ E	1200	180	2-16 m	sheltered island fringing
17	T-23	11/07/2006	New Hanover	Nemto I.	02° 21.110' S, 150° 20.392’ E	930	70	4-15 m	outer slope
18	T-24	11/07/2006	New Hanover	Lagoon patch south of Nemto I.	02° 23.659' S, 150° 20.077’ E	1130	70	1-12 m	lagoon patch
new	T-25	11/08/2006	Tigak	Ribnitz I. (Steffen Strait)	02° 40.116' S, 150° 37.091’ E	1045	80	2-24 m	channel slope

APPENDIX 2. List of the reef fishes of the northern Bismarck Archipelago, Papua New Guinea.

This list includes all species of shallow (to 50 m depth) coral reef fishes observed during the 2006 survey of Manus and the Tigak Islands-New Hanover region as well as historical records (indicated by an asterisk) from Munro (1958 and 1967), Kailola (1975 and 1987-1991), and Allen (collections at Manus in 1982). The column titled "Okamoto" refers to records of Manus fishes obtained from Susomu Okamoto. The column titled "GRA 1982" contains records of fishes collected by G. Allen on Manus in 1982 (reported by Kailola, 1987-1991), which are deposited at the Western Australian Museum, Perth. The column titled "Kailola" contains records of reef fishes reported by Patricia Kailola in her three-part annotated checklist of the fishes of Papua New Guinea (1987-1991). The column titled "Munro" contains records of northern Bismarck reef fish summarised by Ian Munro (1958) in Fishes of the New Guinea Region.The phylogenetic sequence of the families appearing in this list follows Eschmeyer (Catalog of Fishes, California Academy of Sciences, 1998) with slight modification (e.g.. placement of Cirrhitidae). Genera and species are arranged alphabetically within each family. The Author name(s) and year of publication have been omitted from each species entry, but this information is readily accessed on the California Academy of Sciences Catalog of Fishes website.

Terms relating to relative abundance that appear in the first column to the right of the species name are as follows: Abundant (A) - Common at most sites in a variety of habitats with up to several hundred individuals being routinely observed on each dive. Common (C) - seen at the majority of sites in numbers that are relatively high in relation to other members of a particular family, especially if a large family is involved. Moderately common (MC) - not necessarily seen on most dives, but may be relatively common if the correct habitat conditons are encountered. Occasional (O) - infrequently sighted and usually in small numbers, but may be relatively common in a very limited habitat. Rare (R) - less than 10, often only one or two individuals seen on all dives. Cryptic (Cr) - primarily cave, crevice, or shallow surge zone dwelling fishes that are seldom seen unless collected with ichthyocides. This category also includes very small gobies that easily escape notice as well as sand-dwelling gobies that dwell along the fringe of reefs and are difficult to properly assess. Species previously reported from the Bismarck Archipelago by various authors mentioned in the previous paragraph are indicated with an asterisk (*).

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Rhincodontidae (1 spp.)								
Rhincodon typus	R	1		1	1			
Stegostomatidae (1 spp.)								
Stegostoma fasciatum	R	1		1	1			
Ginglymostomatidae (1 spp.)								
Nebrius ferrugineum	R	1	1	1	1			
Carcharhinidae (5 spp.)								
Carcharhinus albimarginatus	R	1		1				
Carcharhinus amblyrhynchos	O	1	1	1				
*Carcharhinus melanopterus**	O	1	1	1				1
Galeocerdo cuvier	R	1		1	1			
Triaenodon obesus	R	1		1	1			
Dasyatidae (5 spp.)								
Dasyatis kuhlii	R	1		1	1			
Himantura granulata	R	1		1	1			
*Taeniura lymma**	R	1	1	1	1			1
Taeniura meyeni	R	1	1	1	1			
Urogymnus asperrimus	R	1		1	1			

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Myliobatidae (1 spp.)								
*Aetobatus narinari**	R	1		1	1			1
Mobulidae (1 spp.)								
Manta birostris	R	1	1	1	1			
Chlopsidae (1 spp.)								
*Kaupichthys brachychirus**				1		1		
Muraenidae (10 spp.)								
*Enchelycore bayeri**				1		1		
Gymnothorax bredeni	Cr	1		1	1			
*Gymnothorax eurostus**				1		1		
Gymnothorax flavimarginatus	Cr	1		1	1			
Gymnothorax javanicus	O	1	1	1				
*Gymnothorax margaritophorus**				1		1		
*Gymnothorax melatremus**				1		1		
*Gymnothorax zonipectis**				1		1		
*Pseudechidna brummeri**				1			1	
Rhinomuraena quaesita	R	1		1	1			
Congridae (2 spp.)								
Gorgasia preclara	R	1		1	1			
Heteroconger hassi	O	1	1	1	1			
Clupeidae 3 spp.)								
Clupeid sp. (collected)	O		1	1				
*Spratelloides delicatulus**	O	1		1				1
Spratelloides gracilis	O		1	1				
Plotosidae (1 spp.)								
Plotosus lineatus	O	1		1				
Synodontidae 6 spp.)								
Saurida gracilis	O	1	1	1				
Synodus binotatus	O		1	1				
Synodus dermatogenys	O	1	1	1				
*Synodus jaculum**	O		1	1		1		
Synodus rubromarmoratus	O	1		1				
Synodus variegatus	O	1	1	1				
Bythitidae (1spp.)								
*Brosmophyciops pautzkei**				1		1		
Antennariidae (3 spp.)								
Antennarius biocellatus	Cr	1		1	1			
Antennarius nummifer	Cr	1		1	1			
Histrio histrio	Cr	1		1	1			
Gobiesocidae (3 spp.)								
*Diademichthys lineatus**	O	1	1	1				
Discotrema crinophila	Cr	1		1	1			
Lepadichthys bolini	R	1		1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Mugilidae (4 spp.)								
*Liza vaigiensis**				1			1	
Atherinidae (1 spp.)								
Atherinomorus enddrachtensis	O	1		1				
Belonidae (1 spp.)								
*Tylosurus crocodilus**	O	1	1	1			1	
Hemiramphidae (1 spp.)								
*Hyporhmphus dussumieri**				1			1	
Zenarchopterus dispar	O	1	1	1				
Holocentridae 16 spp.)								
Myripristis adusta	MC	1	1	1				
*Myripristis berndti**	MC	1	1	1		1		
Myripristis hexagona	R		1	1				
*Myripristis kuntee**	Cr	1	1	1		1		
Myripristis murdjan	O	1		1				
*Myripristis pralinia**	MC	1	1	1			1	
Myripristis violacea	Cr	1	1	1				
*Myripristis vittata**	MC	1		1		1		
*Neoniphon argenteus**	O	1	1	1				1
Neoniphon aurolineatus	R	1		1				
Neoniphon opercularis	O	1	1	1				
*Neoniphon sammara**	C	1	1	1				1
Sargocentron caudimaculatum	C	1	1	1				
Sargocentron microstoma	R	1	1	1				
Sargocentron spiniferum	O	1	1	1				
*Sargocentron violaceum**	R	1	1	1			1	
Pegasidae (1 spp.)								
Eurypegasus draconis	R	1		1	1			
Aulostomidae (1 spp.)								
Aulostomus chinensis	O	1	1	1				
Fistulariidae (1 spp.)								
Fistularia commersonii	O	1	1	1				
Centriscidae (2 spp.)								
*Aeoliscus strigatus**		1	1	1	1			
Centriscus scutatus		1		1				1
Solenostomidae (2 spp.)								
Solenostomus cyanopterus	Cr	1		1	1			
Solenostomus paradoxus	Cr	1		1	1			
Syngnathidae (6 spp.)								
Corythoichthys flavofasciatus	R		1					
Corythoichthys haematopterus	R	1	1	1	1			
Doryrhamphus melanopleura	R	1		1	1			
Dunckerocampus dactyliophorus	R	1		1	1			

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Hippocampus denise	Cr	1	1	1	1			
Hippocampus kuda	Cr	1		1	1			
*Phoxocampus diacanthus**				1			1	
Scorpaenidae (9 spp.)								
Dendrochirus zebra	R	1	1	1	1			
*Pterois antennata**	R	1	1	1				1
Pterois radiata	R		1	1				
Pterois volitans	R	1		1				
*Scorpaenodes albaiensis**				1		1		
Scorpaenopsis diabolus	Cr	1		1	1			
Scorpaenopsis papuensis	Cr	1		1	1			
Sebastapistes cyanostigma	Cr	1		1				
Taenianotus triacanthus	Cr	1		1	1			
Synanceiidae (1 spp.)								
*Inimicus didactylus**	Cr	1		1	1			1
Platycephalidae (2 spp.)								
*Cymbacephalus beauforti**	Cr	1		1	1		1	
*Thysanophrys chiltonae**		1		1		1		
Caracanthidae (1 spp.)								
Caracanthus maculatus	Cr	1	1	1				
Dactylopteridae (1 spp.)								
Dactyloptena orientalis	R	1		1	1			
Centropomidae (1 spp.)								
*Psammoperca waigiensis**				1			1	
Serranidae (46 spp.)								
Aethaloperca rogaa	O	1	1	1				
Anyperodon leucogrammicus	O	1	1	1				
Belonoperca chabanaudi	Cr	1	1	1				
Cephalopholis argus	O	1	1	1				
Cephalopholis boenak	R	1		1				
*Cephalopholis cyanostigma**	C	1	1	1				1
*Cephalopholis leopardus**	O	1	1	1				1
Cephalopholis microprion	O	1	1	1				
Cephalopholis miniata	O	1	1	1	1			
Cephalopholis sexmaculata	O	1	1	1				
Cephalopholis sonnerati	R	1	1	1				
Cephalopholis spiloparaea	O	1	1	1				
Cephalopholis urodeta	C	1	1	1				
Cromileptes altivelis	R	1	1	1	1			
Diploprion bifasciatum	R	1		1				
Epinephelus caeruleopunctatus	O	1	1	1				
Epinephelus corallicola	R	1		1	1			
Epinephelus fasciatus	R	1		1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Epinephelus fuscoguttatus	O	1	1	1	1			
*Epinephelus hexagonatus**				1			1	
*Epinephelus howlandi**				1			1	
Epinephelus lanceolatus	R	1		1	1			
*Epinephelus maculatus**	R	1		1	1			1
*Epinephelus melanostigma**				1			1	
Epinephelus merra	O	1	1	1	1			
*Epinephelus microdon**				1			1	
*Epinephelus spilotoceps**				1			1	
*Gracila albomarginata**	O	1	1	1			1	
*Liopropomum multilineatum**				1			1	
*Plectranthias inermis**	Cr		1	1		1		
*Plectranthias longimanus**				1		1		
Plectropomus areolatus	O	1		1				
*Plectropomus laevis**	R		1	1			1	
*Plectropomus leopardus**	O	1	1	1			1	
*Plectropomus maculatus**	R		1	1			1	
Plectropomus oligocanthus	O	1	1	1				
*Pseudanthias dispar**	O	1	1	1			1	
Pseudanthias huchtii	R	1		1				
Pseudanthias hypselosoma	R	1		1				
*Pseudanthias pleurotaenia**	O	1	1	1		1		
Pseudanthias randalli	R		1	1				
Pseudanthias smithvanizi	R	1		1	1			
Pseudanthias squamipinnis	R	1	1	1	1			
*Pseudanthias tuka**	A	1	1	1		1		
*Variola albimarginata**	O	1	1	1			1	
*Variola louti**	R	1	1	1				1
Cirrhitidae (5 spp.)								
*Cirrhitichthys falco**	O	1	1	1	1	1		
*Cirrhitichthys oxycephalus**	O	1	1	1		1		
Cirrhitus pinnulatus	R		1	1				
Paracirrhites arcatus	C	1	1	1				
Paracirrhites forsteri	C	1	1	1				
Pseudochromidae (13 spp.)								
Amsichthys knighti	Cr		1	1				
*Cypho purpurescens**				1		1		
Labracinus cyclophthalmus	R	1		1				
Lubbockichthys multisquamatus	Cr		1	1				
*Pictichromis paccagnellae**	O	1	1	1		1		
*Pictichromis porphyreus**				1		1		
*Pseudochromis bitaeniatus**	O	1	1	1		1		
Pseudochromis cyanotaenia	Cr		1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Pseudochromis fuscus	C	1	1	1				
*Pseudochromis marshallensis**	Cr	1	1	1		1		
Pseudochromis sp.	R	1		1				
*Pseudoplesiops immaculatus**				1		1		
*Pseuodplesiops rosae**				1		1		
Plesiopidae (1 spp.)								
Assessor flavissimus	R		1	1				
*Plesiops corallicola**				1			1	
Terapontidae (1 spp.)								
*Terapon jarbua**	O	1	1	1			1	
Opistognathidae (1 spp.)								
Opistognathus sp.	R	1		1	1			
Priacanthidae 1 spp.)								
Priacanthus hamrur	O	1	1	1				
Apogonidae (48 spp.)								
Apogon angustatus	R		1	1				
Apogon apogonides	O		1	1				
Apogon bandanensis	O			1				
Apogon compressus	MC	1	1	1				
Apogon crassiceps				1		1		
Apogon cyanosoma	MC	1	1	1				
Apogon dispar	O	1	1	1				
*Apogon exostigma**	O		1	1			1	
Apogon fraenatus	MC	1	1	1				
*Apogon fragilis**	MC	1	1	1			1	
Apogon gilberti	O	1		1				
Apogon hartzfeldii	O	1	1	1				
Apogon hoevenii	O	1		1				
Apogon jenkinsi	O	1	1	1				
*Apogon kallopterus**	MC	1	1	1		1		
Apogon leptacanthus	O	1	1	1				
*Apogon melanoproctus**				1		1		
Apogon moluccensis	O	1		1				
Apogon nanus	O		1	1				
Apogon neotes	MC	1		1				
*Apogon nigrofasciatus**	O	1	1	1		1		
Apogon novemfasciatus	O	1	1	1				
Apogon ocellicaudus	O	1		1				
Apogon perlitus	O		1	1				
*Apogon savayensis**				1		1		
Apogon sealei	O	1	1	1				
Apogon selas	R	1		1				
Apogon similis	O		1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Apogon thermalis	O	1		1				
*Archamia biguttata**	O	1	1	1			1	
*Archamia fucata**	C	1	1	1				
Archamia macroptera	O	1	1	1				
Archamia zosterophora	MC	1	1	1				
Cheilodipterus alleni	R	1		1				
Cheilodipterus artus	MC	1	1	1				
*Cheilodipterus isostigma**				1			1	
*Cheilodipterus macrodon**	O	1	1	1				
Cheilodipterus parazonatus	MC	1	1	1				
Cheilodipterus quinquelineatus	C	1	1	1				
*Fowleria aurita**				1		1		
*Gymnapogon sp.**				1		1		
*Pseudamia amblyuroptera**				1			1	
*Pseudamia gelatinosa**				1			1	
*Pseudamia hayashi**				1			1	
Pseudamia zonata	Cr	1		1	1			
*Rhabdamia cypselurus**	O	1	1	1			1	
Rhabdamia gracilis	O	1		1				
Sphaeramia nematoptera	O	1	1	1				
Sphaeramia orbicularis	O	1		1				
Malacanthidae (3 spp.)								
Hoplolatilus starcki	R	1		1				
*Malacanthus brevirostris**	O	1	1	1			1	
Malacanthus latovittatus	O	1	1	1	1			
Echeneidae (1 spp.)								
Echeneis naucrates	O	1		1				
Carangidae (13 spp.)								
*Carangoides bajad**	O	1	1	1			1	
Carangoides ferdau	R		1	1				
Carangoides fulvoguttatus	R		1	1				
*Carangoides oblongus**	R	1		1				1
Carangoides plagiotaenia	R	1	1	1				
*Caranx ignobilis**	O	1		1				1
*Caranx melampygus**	C	1	1	1				1
Caranx papuensis	R		1	1				
Caranx sexfasciatus	C	1		1				
*Elagatis bipinnulata**	O	1	1	1				1
*Gnathanodon speciosus**	O	1		1	1			1
*Scomberoides lysan**	O	1	1	1	1			1
*Selar crumenophthalmus**				1			1	
Trachinotus blochii	R	1		1				
Lutjanidae (23 spp.)								

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Aphareus furca	O	1	1	1				
*Aprion virescens**	R	1	1	1				1
*Lutjanus argentimaculatus**	O	1		1				1
Lutjanus biguttatus	C	1	1	1				
*Lutjanus bohar**	O	1	1	1				1
Lutjanus boutton	R		1	1				
Lutjanus carponotatus	C	1	1	1				
Lutjanus ehrenbergii	O	1		1				
Lutjanus fulviflamma	O	1	1	1				
Lutjanus fulvus	O	1	1	1				
*Lutjanus gibbus**	C	1	1	1				1
*Lutjanus kasmira**	O	1	1	1				1
Lutjanus monostigma	C	1	1	1				
Lutjanus quinquelineatus	O		1	1				
*Lutjanus rivulatus**	R	1	1	1				1
Lutjanus russelli	O	1	1	1				
*Lutjanus semicinctus**	C	1	1	1				1
*Lutjanus vitta**	O	1	1	1				1
Macolor macularis	C	1	1	1				
*Macolor niger**	MC	1	1	1				1
Pinjalo lewisi	R	1		1				
*Symphorichthys spilurus**	O	1		1				1
Symphorus nematophorus	O		1	1				
Caesionidae (11 spp.)								
*Caesio caerulaurea**	C	1	1	1			1	
Caesio cuning	A	1	1	1				
*Caesio lunaris**	MC	1	1	1				1
Caesio teres	O	1	1	1				
*Gymnocaesio gymnoptera**	O	1	1	1			1	
Pterocaesio diagramma	O	1	1	1				
Pterocaesio lativittata	R	1		1	1			
Pterocaesio pisang	MC	1	1	1				
Pterocaesio tessellata	MC	1	1	1				
Pterocaesio tile	C	1	1	1				
Pterocaesio trilineata	O	1	1	1				
Gerridae (2 spp.)								
*Gerres erythrourus**				1			1	
Gerres oyena	O	1		1				
Haemulidae (9 spp.)								
Diagramma pictum	O	1	1	1				
Plectorhinchus albovittatus	R		1	1				
Plectorhinchus chaetodontoides	MC	1	1	1				
Plectorhinchus chrysotaenia	C	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Plectorhinchus gibbosus	R		1	1				
Plectorhinchus lessonii	R	1	1	1				
*Plectorhinchus lineata**	MC	1	1	1				1
Plectorhinchus picus	R	1		1				
*Plectorhinchus vittatus**	O	1	1	1				1
Lethrinidae (14 spp.)								
Gnathodentex aurolineatus	O		1	1				
Gymnocranius sp.	O	1	1	1				
Lethrinus atkinsoni	R		1	1				
*Lethrinus erythracanthus**	O	1	1	1				1
Lethrinus erythropterus	MC	1	1	1				
*Lethrinus harak**	MC	1	1	1				1
*Lethrinus lentjan**	O	1	1	1				
*Lethrinus microdon**				1			1	
Lethrinus obsoletus	O	1	1	1				
*Lethrinus olivaceus**	O	1		1				1
*Lethrinus reticulatus**				1			1	
*Lethrinus variegatus**	R	1		1				1
Lethrinus xanthochilus	O		1	1				
Monotaxis grandoculis	C	1	1	1				
Nemipteridae (10 spp.)								
Pentapodus aureofasciatus	MC	1	1	1				
*Pentapodus caninus**	R		1	1			1	
Pentapodus trivittatus	MC	1	1	1				
Scolopsis affinis	O	1	1	1				
Scolopsis bilineatus	C	1	1	1				
Scolopsis ciliatus	C	1	1	1				
Scolopsis lineatus	O	1	1	1				
Scolopsis margaritifer	C	1	1	1				
Scolopsis temporalis	MC	1	1	1				
Scolopsis xenochrous	MC	1	1	1				
Mullidae (10 spp.)								
Mulloidichthys flavolineatus	O		1	1				
Mulloidichthys vanicolensis	O	1	1	1				
Parupeneus barberinus	C	1	1	1				
Parupeneus crassilabris	C	1	1	1				
Parupeneus cyclostomus	MC	1	1	1				
Parupeneus heptacanthus	O	1	1	1				
Parupeneus indicus	O	1	1	1				
Parupeneus multifasciatus	C	1	1	1				
*Parupeneus pleurostigma**	O	1	1	1			1	
*Upeneus tragula**	O	1	1	1				1
Pempheridae (3 spp.)								

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
*Parapriacanthus dispar**	O	1	1	1			1	
Pempheris oualensis	O	1		1				
Pempheris vanicolensis	O	1	1	1				
Kyphosidae (3 spp.)								
Kyphosus bigibbus	O	1	1	1				
Kyphosus cinerascens	O	1	1	1				
Kyphosus vaigensis	O	1	1	1				
Chaetodontidae (35 spp.)								
Chaetodon auriga	MC	1	1	1				
*Chaetodon baronessa**	C	1	1	1				1
Chaetodon bennetti	MC	1	1	1				
Chaetodon burgessi	R	1		1	1			
Chaetodon citrinellus	C	1	1	1				
Chaetodon ephippium	C	1	1	1				
Chaetodon kleinii	C	1	1	1				
Chaetodon lunula	O	1	1	1				
*Chaetodon lunulatus**	C	1	1	1				1
*Chaetodon melannotus**	O	1	1	1				1
Chaetodon meyeri	MC	1	1	1				
*Chaetodon ocellicaudus**	O	1	1	1			1	
*Chaetodon octofasciatus**	MC	1	1	1				1
*Chaetodon ornatissimus**	C	1	1	1				1
*Chaetodon oxycephalus**	MC	1	1	1				1
Chaetodon pelewensis	R	1		1				
Chaetodon plebius	R	1		1	1			
Chaetodon punctatofasciatus	O	1	1	1				
*Chaetodon rafflesi**	C	1	1	1				1
Chaetodon semion	C	1	1	1				
Chaetodon trifascialis	MC	1	1	1				
Chaetodon ulietensis	C	1	1	1				
Chaetodon unimaculatus	O	1	1	1				
Chaetodon vagabundus	C	1	1	1			1	
Chelmon rostratus	O	1	1	1				
Coradion chrysozonus	O	1	1	1				
Forcipiger flavissimus	C	1	1	1				
Forcipiger longirostris	O	1	1	1				
Hemitaurichthys polylepis	O	1		1				
*Heniochus acuminatus**	R	1	1	1				1
Heniochus chrysostomus	C	1	1	1				
Heniochus monoceros	O	1	1	1				
Heniochus singularius	O	1	1	1				
Heniochus varius	C	1	1	1				
Parachaetodon ocellatus	R		1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Pomacanthidae (16 spp.)								
Apolemichthys trimaculatus	O	1	1	1				
Centropyge bicolor	C	1	1	1				
Centropyge bispinosa	O	1	1	1	1			
*Centropyge flavicauda**	O	1	1	1		1		
Centropyge loricula	R	1		1	1			
Centropyge nox	MC	1	1	1				
Centropyge vroliki	C	1	1	1				
Chaetodontoplus mesoleucus grey	MC	1	1	1				
*Paracentropyge multifasciata**	O	1	1	1		1		
Pomacanthus annularis	R	1		1	1			
*Pomacanthus imperator**	R	1	1	1	1			1
*Pomacanthus navarchus**	O	1	1	1				1
Pomacanthus semicirculatus	R	1		1	1			
Pomacanthus sexstriatus	MC	1	1	1				
*Pomacanthus xanthometopon**	MC	1	1	1				1
*Pygoplites diacanthus**	C	1	1	1				1
Pomacentridae (86 spp.)								
*Abudefduf lorenzi**	O	1		1				1
Abudefduf sexfasciatus	O	1	1	1				
Abudefduf vaigiensis	MC	1	1	1				
Acanthochromis polyacanthus	C	1	1	1				
*Amblyglyphidodon aureus**	MC	1	1	1		1		
*Amblyglyphidodon curacao**	C	1	1	1				
*Amblyglyphidodon leucogaster**	C	1	1	1			1	
Amblyglyphidodon ternatensis	O	1	1	1				
*Amphiprion chrysopterus**	O	1	1	1		1		
*Amphiprion clarkii**	C	1	1	1		1		
*Amphiprion leucokranos**	R	1		1		1		
Amphiprion melanopus	O	1	1	1				
*Amphiprion percula**	O	1	1	1			1	
Amphiprion perideraion	O	1	1	1				
Amphiprion polymnus	O	1		1				
Amphiprion sandaracinos	O	1		1				
*Chromis alpha**	O	1	1	1		1		
Chromis amboinensis	A	1	1	1				
Chromis analis	R	1		1				
Chromis atripectoralis	O	1	1	1				
*Chromis atripes**	A	1	1	1		1		
Chromis delta	MC	1	1	1				
*Chromis elerae**	O	1	1	1		1		
*Chromis lepidolepis**	C	1	1	1		1		

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
*Chromis lineata**	MC	1	1	1		1		
Chromis margaritifer	A	1	1	1				
*Chromis retrofasciata**	C	1	1	1		1		
Chromis ternatensis	A	1	1	1				
Chromis viridis	C	1	1	1				
*Chromis weberi**	C	1	1	1		1		
Chromis xanthochira	O	1	1	1				
Chromis xanthura	C	1	1	1				
*Chrysiptera biocellata**	O		1	1				1
Chrysiptera brownriggii	MC	1	1	1				
*Chrysiptera cyanea**	O	1	1	1				1
Chrysiptera cymatilis	MC	1	1	1				
Chrysiptera flavipinna	O	1	1	1				
*Chrysiptera parasema**	O	1	1	1		1		
Chrysiptera rex	O	1	1	1				
*Chrysiptera rollandi**	C	1	1	1		1		
Chrysiptera sinclairi	MC	1	1	1				
Chrysiptera talboti	C	1	1	1				
Chrysiptera unimaculata	O		1	1				
*Dascyllus aruanus**	MC	1	1	1				1
*Dascyllus melanurus**	MC	1	1	1			1	
Dascyllus reticulatus	C	1	1	1				
Dascyllus trimaculatus	C	1	1	1				
Dischistodus chrysopoecilus	O	1		1				
*Dischistodus melanotus**	MC	1	1	1				1
Dischistodus perspicillatus	O	1	1	1				
Dischistodus prosopotaenia	O	1	1	1				
Hemiglyphidodon plagiometopon	MC	1	1	1				
Neoglyphidodon melas	O	1	1	1				
Neoglyphidodon nigroris	C	1	1	1				
Neoglyphidodon thoracotaeniatus	O	1		1				
Neopomacentrus azysron	MC	1	1	1				
Neopomacentrus cyanomos	R	1		1				
Neopomacentrus filamentosus	O	1	1	1				
Neopomacentrus nemurua	MC	1	1	1				
Plectroglyphidodon dickii	MC	1	1	1				
Plectroglyphidodon lacrymatus	A	1	1	1				
Plectroglyphidodon leucozona	O	1	1	1				
Pomacentrus adelus	C	1	1	1				
Pomacentrus albimaculus	O	1	1	1				
Pomacentrus amboinensis	A	1	1	1				
*Pomacentrus aurifrons**	MC	1	1	1		1		

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Pomacentrus bankanensis	C	1	1	1				
Pomacentrus brachialis	C	1	1	1				
*Pomacentrus burroughi**	C	1	1	1		1		
*Pomacentrus coelestis**	C	1	1	1		1		
Pomacentrus grammorhynchus	O	1	1	1				
*Pomacentrus lepidogenys**	C	1	1	1		1		
Pomacentrus moluccensis	A	1	1	1				
Pomacentrus nagasakiensis	O	1	1	1				
Pomacentrus nigromanus	C	1	1	1				
*Pomacentrus nigromarginatus**	MC	1	1	1		1		
*Pomacentrus pavo**	O	1	1	1			1	
Pomacentrus philippinus	O		1	1				
*Pomacentrus reidi**	MC	1	1	1		1		
Pomacentrus simsiang	MC	1	1	1				
Pomacentrus vaiuli	MC	1		1				
Premnas biaculeatus	MC	1	1	1				
Stegastes albifasciatus	O		1	1				
Stegastes fasciolatus	MC	1	1	1				
Stegastes lividus	O	1	1	1				
Stegastes nigricans	O	1	1	1				
Labridae (89 spp.)								
Anampses caeruleopunctatus	R	1		1				
Anampses geographicus	R	1		1				
Anampses meleagrides	O	1	1	1				
*Anampses neoguinaicus**	R		1	1		1		
Anampses twistii	R	1	1	1				
Bodianus anthoides	R	1		1				
*Bodianus axillaris**				1		1		
Bodianus bimaculatus	O	1	1	1				
Bodianus diana	C	1	1	1				
Bodianus mesothorax	C	1	1	1				
Cheilinus chlorourus	O	1	1	1				
Cheilinus fasciatus	C	1	1	1				
Cheilinus oxycephalus	C	1	1	1				
Cheilinus trilobatus	MC	1	1	1				
Cheilinus undulatus	MC	1	1	1				
*Cheilio inermis**	O	1	1	1				1
*Choerodon anchorago**	MC	1	1	1				1
Choerodon zosterophorus	R	1		1				
Cirrhilabrus condei	O	1		1				
Cirrhilabrus exquisitus	MC	1	1	1				
Cirrhilabrus punctatus	A	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Cirrhilabrus walindi	O	1		1				
Coris batuensis	O	1	1	1				
Coris gaimardi	MC	1	1	1				
*Diproctacanthus xanthurus**	MC	1	1	1			1	
Epibulus insidiator	C	1	1	1				
Gomphosus varius	C	1	1	1				
Halichoeres argus	O	1	1	1				
Halichoeres biocellatus	O	1	1	1				
Halichoeres chloropterus	MC	1	1	1				
*Halichoeres chrysus**	C	1	1	1		1		
Halichoeres hartzfeldii	O	1		1				
Halichoeres hortulanus	C	1	1	1				
Halichoeres leucurus	O	1	1	1				
Halichoeres margaritaceus	C	1	1	1				
Halichoeres marginatus	C	1	1	1				
Halichoeres melanochir	R		1	1				
Halichoeres melanurus	C	1	1	1				
Halichoeres melasmapomus	R		1	1				
Halichoeres miniatus	O	1	1	1				
Halichoeres nebulosus	R	1		1				
Halichoeres ornatissimus	R		1	1				
Halichoeres papilionaceus	O	1		1				
Halichoeres podostigma	R	1		1				
Halichoeres prosopeion	C	1	1	1				
Halichoeres richmondi	O	1		1				
Halichoeres scapularis	C	1	1	1				
Halichoeres trimaculatus	O	1	1	1				
*Hemigymnus fasciatus**	C	1	1	1				1
*Hemigymnus melapterus**	C	1	1	1				1
Hologymnosus doliatus	R	1	1	1				
Iniistius pavo	Cr		1	1				
Labrichthys unilineatus	C	1	1	1				
Labroides bicolor	C	1	1	1				
Labroides dimidatus	A	1	1	1				
Labroides pectoralis	C	1	1	1				
Labropsis alleni	O	1		1				
Labropsis xanthonota	O	1	1	1				
Leptojulis cyanopleura	O	1	1	1				
Macropharyngodon meleagris	C	1	1	1				
Macropharyngodon negrosensis	O	1	1	1				
Novaculichthys taeniourus	O	1	1	1				
Oxycheilinus arenatus	R		1	1				
Oxycheilinus bimaculatus	O	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
*Oxycheilinus celebicus**	MC	1	1	1		1		
Oxycheilinus digramma	C	1	1	1				
Oxycheilinus unifasciatus	R		1	1				
*Paracheilinus filamentosus**	C	1	1	1		1		
Paracheilinus sp.	O	1	1	1				
Pseudocheilinops ataenia	R	1		1				
*Pseudocheilinus evanidus**	MC	1	1	1		1		
Pseudocheilinus hexataenia	C	1	1	1				
Pseudocheilinus octotaenia	R	1		1				
*Pseudocoris yamashiroi**	O	1	1	1		1		
*Pseudodax moluccanus**	MC	1	1	1		1		
Pseudojuloides ceracinus	R	1		1				
Pteragogus cryptus	O	1	1	1				
Pteragogus enneacanthus	O		1	1				
Stethojulis bandanensis	MC	1	1	1				
Stethojulis interrupta	MC	1	1	1				
Stethojulis strigiventer	O	1	1	1				
Stethojulis trilineata	C	1	1	1				
Thalassoma amblycephalus	C	1	1	1				
*Thalassoma hardwicke**	A	1	1	1				1
Thalassoma jansenii	MC	1	1	1				
Thalassoma lunare	A	1	1	1				
Thalassoma purpureum	O		1	1				
Thalassoma quinquevittatum	MC	1	1	1				
Wetmorella albofasciata	Cr		1	1				
Scaridae (26 spp.)								
Bolbometopon muricatum	O	1	1	1				
Calotomus carolinus	O	1	1	1				
*Calotomomus spinidens**				1			1	
Cetoscarus ocellatus	MC	1	1	1				
*Chlorurus bleekeri**	A	1	1	1				1
Chlorurus frontalis	R	1		1				
Chlorurus japanensis	MC	1	1	1				
Chlorurus microrhinos	MC	1	1	1				
Chlorurus sordidus	A	1	1	1				
Hipposcarus longiceps	MC	1	1	1				
Scarus chameleon	O	1	1	1				
Scarus dimidatus	O	1	1	1				
Scarus flavipectoralis	C	1	1	1				
Scarus forsteni	O	1	1	1				
Scarus frenatus	O	1	1	1				
Scarus ghobban	MC	1	1	1				
Scarus niger	A	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Scarus oviceps	C	1	1	1				
*Scarus prasiognathos**	O	1	1	1				1
Scarus psittacus	O		1	1				
Scarus quoyi	C	1	1	1				
Scarus rivulatus	MC	1	1	1				
Scarus rubroviolaceus	MC	1	1	1				
Scarus schlegeli	O	1	1	1				
Scarus spinus	C	1	1	1				
Scarus tricolor	O	1		1				
Pinguipedidae (4 spp.)								
*Parapercis clathrata**	MC	1	1	1		1		
Parapercis cylindrica	R	1		1	1			
Parapercis lineopunctata	O	1	1	1				
Parapercis sp. 6 xanth	O	1	1	1				
Pholidichthyidae (1 spp.)								
Pholidichthys leucotaenia	O	1	1	1				
Tripterygiidae (1 spp.)								
*Helcogramma striatum**	R	1	1	1			1	
Blenniidae (25 spp.)								
Aspidontus taeniatus	O		1	1				
Atrosalarias fuscus	O	1	1	1				
Blenniella chrysospilos	Cr		1	1				
*Blenniella interrupta**				1			1	
*Cirripectes castaneus**	O	1	1	1				1
Cirripectes filamentosus	O		1	1				
Cirripectes springeri	O		1	1				
Cirripectes stigmaticus	O	1	1	1				
Ecsenius bicolor	O	1	1	1				
Ecsenius lividanalis	R	1		1				
Ecsenius namiyei	O	1	1	1				
Ecsenius pictus	O	1		1				
*Ecsenius prooculis**	MC	1	1	1		1		
*Ecsenius trilineatus**	O	1		1		1		
Ecsenius yaeyamaenis	O	1	1	1				
*Meiacanthus atrodorsalis**	C	1	1	1		1		
Meiacanthus crinitus	O		1	1				
Meiacanthus grammistes	MC	1	1	1				
Meiacanthus limbatus				1		1		
*Plagiotremus laudanus**	O	1	1	1		1		
Plagiotremus rhinorhynchus	C	1	1	1				
Plagiotremus tapeinosoma	O	1	1	1				
Salarias alboguttatus	R	1		1				
Salarias segmentatus	MC	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Stanulus seychellensis	R		1	1				
Callionymidae (5 spp.)								
Callionymus enneactis	O	1	1	1	1			
Dactylopus dactylopus	R	1		1	1			
Diplogrammus goramensis	R	1		1	1			
Synchiropus morrisoni	Cr	1		1				
Synchiropus splendidus	Cr	1		1	1			
Gobiidae (96 spp.)								
Amblyeleotris diagonalis	Cr	1		1	1			
Amblyeleotris fasciata	Cr	1	1	1				
Amblyeleotris fontanesii	Cr	1	1	1				
Amblyeleotris guttata	Cr	1	1	1				
Amblyeleotris gymnocephala	Cr	1	1	1				
Amblyeleotris periophthalma	Cr	1	1	1				
*Amblyeleotris randalli**	Cr	1	1	1			1	
Amblyeleotris sp.	Cr		1	1				
Amblyeleotris steinitzi	Cr	1	1	1				
Amblyeleotris yanoi	Cr	1		1	1			
*Amblygobius decussatus**	O	1	1	1		1		
Amblygobius nocturnus	O	1	1	1				
*Amblygobius phalaena**	O	1	1	1			1	
Ancistrogobius yanoi	Cr	1		1				
Asterropteryx bipunctatus	Cr	1	1	1				
Asterropteryx semipunctata	Cr		1	1				
Asterropteryx striata	Cr	1		1				
Bryaninops amplus	Cr	1		1	1			
Bryaninops loki	Cr	1		1				
Bryaninops yongei	Cr	1		1				
Cryptocentrus cinctus	Cr	1	1	1				
Cryptocentrus cyanotaenia	Cr		1	1				
Cryptocentrus fasciatus	Cr		1	1				
Cryptocentrus leptocephalus	Cr	1	1	1	1			
Cryptocentrus strigilliceps	Cr	1	1	1				
Cryptocentrus sp A. (vent. barred)	Cr	1	1	1				
Cryptocentrus sp. B (blue-spotted)	Cr		1	1				
Ctenogobiops aurocingulus	Cr	1	1	1				
Ctenogobiops feroculus	Cr	1	1	1				
Ctenogobiops pomastictus	Cr	1	1	1				
*Ctenogobiops tangaroai**	Cr			1		1		
Eviota albolineata	Cr	1		1				
Eviota bifasciata	Cr	1	1	1				
Eviota guttata	Cr	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Eviota nigriventris	Cr	1	1	1				
Eviota pellucidus	Cr	1	1	1				
Eviota prasites	Cr	1	1	1				
Eviota punctulata	Cr		1	1				
Eviota sebreei	Cr	1		1				
Eviota sigillata	Cr	1	1	1				
Exyrias akihito	Cr	1		1				
Exyrias belissimus	Cr	1	1	1				
Fusigobius duospilus	Cr		1	1				
Fusigobius melacron	Cr		1	1				
Fusigobius neophytus	Cr		1	1				
Fusigobius signipinnis	Cr		1	1				
Fusigobius sp. (photo)	Cr		1	1				
Gladiogobius ensifer	Cr	1	1	1				
Gnatholepis anjerensis	Cr		1	1				
Gnatholepis cauerensis	Cr	1	1	1				
Gobiid sp. (sand - photo)	Cr		1	1				
Gobiodon histrio	Cr	1		1	1			
Gobiodon okinawae	Cr	1		1				
*Gobiopsis angustifrons**				1		1		
Istigobius decoratus	Cr		1	1				
Istigobius goldmanni	Cr		1	1				
Istigobius ornatus	Cr	1		1				
Istigobius rigilius	Cr		1	1				
*Koumansetta rainfordi**	MC	1	1	1		1		
Lotilia graciliosa	Cr	1		1	1			
Macrodontogobius wilburi	Cr	1	1	1				
Mahidolia mystacinus	Cr	1	1	1				
Mahidolia sp. (black)	Cr	1		1	1			
Oplopomus oplopomus	Cr	1	1	1				
Oxyurichthys papuensis	Cr	1		1	1			
Paragobiodon echinocephalus	Cr	1		1				
Paragobiodon lacunicola	Cr	1		1	1			
Phyllogobius platycephalops	Cr	1		1				
Pleurosicya elongata	Cr	1	1	1				
Pleurosicya labiata	Cr	1		1				
Pleurosicya mossambica	Cr		1	1				
Priolepis cinctus	Cr	1		1	1			
*Signigobius biocellatus**	O	1	1	1		1		
Stonogobiops xanthorhinica	Cr	1		1	1			
Tomiyamichthys oni?	Cr	1		1				
Tomayamichthys sp.	Cr	1		1	1			
Trimma benjamini	Cr	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Trimma caesiura	Cr	1		1				
Trimma griffithsi	Cr	1		1				
*Trimma hoesei**	Cr	1		1		1		
*Trimma macrophthalma**				1		1		
Trimma rubromaculatus	Cr	1	1	1				
Trimma sp. (cf sheppardi)	Cr	1		1				
*Trimma striata**	Cr		1	1		1		
*Trimma taylori**				1		1		
*Trimma tevegae**	Cr	1	1	1		1		
Tryssogobius sp.	Cr	1		1	1			
Valenciennea immaculata	R	1		1				
Valenciennea muralis	O	1	1	1				
Valenciennea puellaris	O	1	1	1				
Valenciennea randalli	R	1		1				
Valenciennea sexguttata	O	1	1	1				
Valenciennea strigata	O		1	1				
Vanderhorstia ambanoro	Cr	1	1	1	1			
Vanderhorstia dorsomacula	Cr	1	1	1	1			
Vanderhorstia flavilineata	Cr	1		1	1			
Ptereleotridae (10 spp.)								
Aioliops megastigma	O	1		1				
Aioliops novaeguineae	R		1	1				
*Nemateleotris decora**	O	1	1	1		1		
Nemateleotris magnifica	O	1	1	1				
*Parioglossus nudus**	R	1		1		1		
*Ptereleotris evides**	C	1	1	1			1	
Ptereleotris hanae	R	1		1				
Ptereleotris heteroptera	MC	1	1	1				
Ptereleotris microlepis	O	1	1	1				
Ptereleotris zebra	O		1	1				
Ephippidae (4 spp.)								
Platax boersi	O	1	1	1				
Platax orbicularis	R	1		1				
Platax pinnatus	O	1	1	1				
*Platax teira**	O	1		1				1
Siganidae (11 spp.)								
*Siganus argenteus**	MC	1	1	1			1	
Siganus corallinus	C	1	1	1				
Siganus doliatus	C	1	1	1				
*Siganus fuscescens**	O	1		1				1
*Siganus lineatus**	MC	1	1	1			1	
Siganus puellus	C	1	1	1				
Siganus punctatissimus	MC	1	1	1				

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Siganus punctatus	R		1	1				
*Siganus spinus**	R		1	1				1
Siganus vermiculatus	R	1		1				
Siganus vulpinus	C	1	1	1				
Zanclidae (1 spp.)								
Zanclus cornutus	C	1	1	1				
Acanthuridae (33 spp.)								
Acanthurus barine	R		1	1				
Acanthurus blochii	O	1	1	1				
Acanthurus fowleri	O	1		1				
Acanthurus guttatus	O	1	1	1	1			
Acanthurus leucocheilus	O	1		1				
Acanthurus lineatus	C	1	1	1				
Acanthurus maculiceps	O	1		1				
Acanthurus mata	MC	1	1	1				
Acanthurus nigricans	MC	1	1	1				
Acanthurus nigricauda	C	1	1	1				
Acanthurus nigrofuscus	C	1	1	1				
Acanthurus nubilus	O	1		1				
Acanthurus olivaceus	O	1	1	1				
Acanthurus pyroferus	C	1	1	1				
Acanthurus thompsoni	O	1	1	1				
*Acanthurus triostegus**	O		1	1				1
Acanthurus xanthopterus	O	1	1	1				
*Ctenochaetus binotatus**	C	1	1	1				1
Ctenochaetus cyanocheilus	O	1	1	1				
Ctenochaetus striatus	A	1	1	1				
Ctenochaetus tominiensis	MC	1	1	1				
Naso annulatus	O	1		1				
Naso brachycentron	O		1	1				
Naso brevirostris	O	1	1	1				
Naso caeruleacauda	O	1		1				
Naso hexacanthus	O	1		1				
*Naso lituratus**	C	1	1	1				1
Naso tonganus	O		1	1				
Naso unicornis	O	1	1	1				
Naso vlamingii	O	1	1	1				
Paracanthurus hepatus	O	1	1	1	1			
Zebrasoma scopas	A	1	1	1				
*Zebrasoma veliferum**	C	1	1	1			1	
Sphyraenidae (5 spp.)								
*Sphyraena barracuda**	R	1	1	1				1
*Sphyraena forsteri**	O	1		1	1		1	

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
*Sphyraena jello**	R	1		1				1
*Sphyraena obtusata**	O	1	1	1			1	
Sphyraena qenie	O	1		1	1			
Scombridae (5 spp.)								
Euthynnus affinis	O	1	1	1				
*Grammatorcynus bilineatus**	O	1	1	1				1
*Gymnosarda unicolor**	O	1		1				1
*Rastrelliger kanagurta**	O		1	1				1
*Scomberomorus commersonnianus**	O	1	1	1				1
Bothidae (2 spp.)								
Bothus mancus	Cr	1		1	1			
Bothus pantherinus	Cr	1		1	1			
Balistidae (14 spp.)								
*Balistapus undulatus**	C	1	1	1				1
*Balistoides conspicillum**	O	1	1	1				1
Balistoides viridescens	MC	1	1	1				
*Canthidermis maculatus**	O	1		1				1
Melichthys niger	O	1		1				
Melichthys vidua	MC	1	1	1				
Odonus niger	MC	1	1	1				
Pseudobalistes flavimarginatus	MC	1	1	1				
Rhinecanthus aculeatus	R	1		1	1			
Rhinecanthus rectangulus	O		1	1				
Rhinecanthus verrucosus	O	1	1	1				
Sufflamen bursa	C	1	1	1				
Sufflamen chrysopterus	C	1	1	1				
*Sufflamen frenatus**			1	1			1	
Monacanthidae (6 spp.)								
*Aluterus scriptus**	R	1	1	1	1			1
Amanses scopas	O	1	1	1				
Cantherhines pardalis	O	1	1	1				
Oxymonacanthus longirostris	O	1		1				
*Pervagor nigrolineatus**	R		1	1		1		
*Rudarius minutus**				1			1	
Ostraciidae (3 spp.)								
*Ostracion cubicus**	O	1	1	1				1
Ostracion meleagris	O	1	1	1				
Ostracion solorensis	O	1	1	1	1			
Tetraodontidae (7 spp.)								
Arothron hispidus	O	1	1	1				
*Arothron manilensis**	R	1		1	1			1
Arothron mappa	O	1	1	1	1			

Family/species	abundance	Manus 2006	Tigak 2006	Combined Bismarck	Okamoto	GRA 1982	Kailola	Munro
Arothron nigropunctatus	MC	1	1	1				
*Arothron stellatus**	R	1		1	1			1
Canthigaster papua	O	1	1	1				
*Canthigaster valentini**	O	1	1	1				1
Diodontidae (1 spp.)								
Diodon hystrix	R	1	1	1	1			
Species totals		665	572	801	94	81	62	82

APPENDIX 3. List of fishes collected or observed at Kimbe Bay, New Britain by G. Allen and P. Munday that were not seen during 2006 northern Bismarck survey.

Rhincodontidae

Rhincodon typus (Smith, 1828)

Carcharhinidae

Carcharhinus

falciformis (Muller and Henle, 1841)

longimanus (Poey, 1861)

Sphyrnidae

Sphyrna

lewini (Griffith and Smith, 1834)

mokarran (Rüppell, 1835)

Moringuidae

Moringua

bicolor (Kaup, 1856)

microchir (Bleeker, 1853)

Chlopsidae

Kaupichthys

atronasus (Schultz, 1953)

hypoproroides (Stromann, 1896)

Muraenidae

Echidna

nebulosa (Thunberg, 1789)

polyzona (Richardson, 1845)

rhodochilus (Bleeker, 1863)

Gymnothorax

monochrous (Bleeker, 1856)

pictus (Ahl, 1789)

Uropterygius

nagoensis (Hatooka, 1984)

sp.

Congridae

Conger cinereus (Rüppell, 1828)

*Gorgasia maculata (*Klausewitz and Eibl-Eibesfeldt, 1959)

Ophichthidae

Callechelys marmoratus (Bleeker, 1852)

Muraenichthys macropterus (Bleeker, 1857)

Clupeidae

Herklotsichthys quadrimaculatus (Rüppell, 1837)

Chandidae

Chanos chanos (Forsskal, 1775)

Antennariidae

Antennarius pictus (Shaw and Nodder, 1794)

Ophidiidae

Brotula multibarbata (Temminck and Schlegel, 1846)

Microbrotula randalli (Cohen and Wourms, 1976)

Bythitidae

Ogilbya sp.

Hemiramphidae

Hemirhamphus far (Forsskäl, 1775)

Belonidae

Platybelone platyura (Bennett, 1832)

Atherinidae

Hypoatherina barnesi (Schultz, 1953)

Holocentridae

Sargocentron

cornutum (Bleeker, 1853)

melanospilos (Bleeker, 1858)

tieroides (Bleeker, 1853)

Syngnathidae

Corythoichthys

intestinalis (Ramsay, 1881)

ocellatus (Herald, 1953)

Cosmocampus banner (Herald & Randall, 1972)

Doryrhamphus dactyliophorus (Bleeker, 1853)

Halicampus dunckeri (Chabanaud, 1929)

Hippocampus bargibanti (Whitley, 1970)

Micrognathus andersonii (Bleeker, 1858)

Syngnathoides biaculeatus (Bloch, 1785)

Scorpaenidae

Scorpaenodes hirsutus (Smith, 1957)

Scorpaenopsis macrochir (Ogilby, 1910)

Synanceia

alula (Eschmeyer and Rama Rao, 1973)

verrucosa (Bloch and Schneider, 1801)

Caracanthidae

Caracanthus unipinnis (Gray, 1831)

Ambassidae

Ambassis buruensis (Bleeker, 1857)

Serranidae

Epinephelus

areolatus (Forsskäl, 1775)

chlorostigma (Valenciennes, 1828)

ongus (Bloch, 1790)

polyphekadion (Bleeker, 1849)

quoyanus (Valenciennes, 1830)

Grammistops ocellatus (Schultz, 1953)

Liopropoma susumi (Jordan & Seale, 1906)

Luzonichthys waitei (Fowler, 1931)

Pseudanthias

bartlettorum (Randall and Lubbock, 1981)

bicolor (Randall, 1979)

rubrizonatus (Randall, 1983)

Pseudogramma polyacantha (Bleeker, 1856)

Pseudoplesiops annae (Weber, 1913)

Plesiopidae

Plesiopscoeruleolineatus (Rüppell, 1835)

Steeneichthys plesiopsus (Allen and Randall, 1985)

Terapontidae

Mesopristes argenteus (Cuvier, 1829)

Apogonidae

Apogon

lateralis (Valenciennes, 1832)

multilineatus (Bleeker, 1865)

taeniophorus (Regan, 1908)

trimaculatus (Cuvier, 1828)

unicolor (Doederlein, 1901)

Cercamia eremia (Allen, 1987)

Foa brachygramma (Jenkins, 1903)

Fowleria marmorata (Alleyne & Macleay, 1877)

Neamia octospina (Smith & Radcliffe, 1912)

Siphamia jebbi (Allen, 1993)

Malacanthidae

Hoplolatilus cuniculus (Randall and Dooley, 1974)

Carangidae

Caranx tille (Valenciennes, 1833)

Scomberoides commersonnianus (Lacepède, 1801)

Selar boops (Cuvier, 1833)

Lutjanidae

Lutjanus

sebae (Cuvier, 1828)

timorensis (Quoy and Gaimard, 1824)

Paracaesio sordidus (Abe and Shinohara, 1962)

Pinjalo pinjalo (Bleeker, 1850)

Nemipteridae

Scolopsis monogramma (Cuvier, 1830)

Lethrinidae

Lethrinus nebulosus (Forsskäl, 1775)

Mullidae

Parupeneus barberinoides (Lacepède, 1801)

Monodactylidae

Monodactylus argenteus (Linnaeus, 1758)

Scatophagidae

Scatophagus argus (Bloch, 1788)

Chaetodontidae

Chaetodon speculum (Cuvier, 1831)

Pomacanthidae

Genicanthus

lamarck (Lacepède, 1798)

melanospilos (Bleeker, 1857)

Pomacentridae

Abudefduf septemfasciatus (Cuvier, 1830)

Amblypomacentrus breviceps (Schlegel and Muller, 1839-44)

Cheiloprion labiatus (Day, 1877)

Chrysiptera oxycephala (Bleeker, 1877)

Neopomacentrus violascens (Bleeker, 1848)

Cirrhitidae

Cyprinocirrhites polyactis (Bleeker, 1875)

Oxycirrhitus typus (Bleeker, 1857)

Labridae

Anampses melanurus (Bleeker, 1857)

Labropsis manabei (Schmidt, 1930)

Pseudocoris aurantifasciata (Fourmanoir, 1971)

Xyrichtys

baldwini (Jordan and Evermann, 1903)

tricolor (Bleeker, 1849)

Pinguipedidae

Parapercis

millepunctata (Günther, 1860)

multiplicata Randall, 1984

Trichonotidae

Trichonotus

elegans (Shimada and Yoshino, 1984)

setiger (Bloch and Schneider, 1801)

Blenniidae

Aspidontus dussumieri (Valenciennes, 1836)

Cirripectes polyzona (Bleeker, 1868)

Crossosalarias macrospilus (Smith-Vaniz and Springer, 1971)

Ecsenius

axelrodi (Springer, 1988)

midas (Starck, 1969)

Exallias brevis (Kner, 1868)

Istiblennius

lineatus (Valenciennes, 1836)

periopthalmus (Valenciennes, 1836)

Petroscirtes

thepassi (Bleeker, 1853)

xestus (Jordan and Seale, 1906)

Tripterygiidae

Enneapterygius mirabilis (Fricke, 1994)

Helcogramma sp.

Callionymidae

Anaora tentaculata (Gray, 1835)

Gobiidae

Amblyeleotris

*arcupinna (*Mohlmann and Munday, 1999)

*rubrimarginata (*Mohlmann and Randall, 2002)

Amblygobius sphynx (Valenciennes, 1837)

Callogobius

sp. 1

sp. 2

Cryptocentrus

leucostictus (Günther, 1871)

octofasciatus (Regan, 1908)

polyophthalmus (Bleeker, 1853)

Ctenogobiops crocineus (Smith, 1959)

Eviota
lachdeberei (Giltay, 1933)
sparsa (Jewett & Lachner, 1983)
Exyrias puntang (Bleeker, 1851)
Favonigobius reichei (Bleeker, 1853)
Gnatholepis davaoensis (Seale, 1909)
Gobiodon
*acicularis (*Harold and Winterbottom, 1995)
axillaris (De Vis, 1884)
erythrospilus (Bleeker 1875)
oculolineatus (Wu, 1979)
quinquestrigatus (Valenciennes, 1837)
rivulatus (Rüppell, 1828)
spilopthalmus (Fowler, 1944)
unicolor (Castelnau, 1873)
sp A (as per Munday et al. 1999)
sp C (as per Munday et al. 1999)
sp D (as per Munday et al. 1999)
n. sp. (goldlined species, collected by Munday)
Myersina lachneri (Hoese and Lubbock, 1982)
Paragobiodon xanthosomus (Bleeker, 1852)
Trimma
marinae (Winterbottom, 2005)
nasa (Winterbottom, 2005)
Trimmatom zapotes (Winterbottom, 1989)
Tryssogobius colini (Larson and Hoese 2001)
Valenciennea
helsdingenii (Bleeker, 1858)
parva (Hoese and Larson, 1994)
Vanderhorstia lanceolata (Yanagisawa, 1978)
Yongeichthys nebulosus (Forsskäl, 1775)
Eleotridae
Calumia profunda (Larson and Hoese, 1980)
Xenisthmidae
Xenisthmus polyzonatus (Klunzinger, 1871)
Microdesmidae
Gunnelichthys
curiosus (Dawson, 1968)
monostigma (Smith, 1958)
Ptereleotris monoptera (Randall and Hoese, 1985)
Acanthuridae
Acanthurus auranticavus (Randall, 1956)
Naso
lopezi (Herre, 1927)
thynnoides (Valenciennes, 1835)
Monacanthidae
Cantherines dumerilii (Hollard, 1854)
Paraluteres prionurus (Bleeker, 1851)

Tetraodontidae

Arothron caeruleopunctatus (Matsuura, 1994)

Canthigaster

bennetti (Bleeker, 1854)

compressa (Proce, 1822)

Chelonodon patoca (Hamilton-Buchanan, 1822)

Diodontidae

Diodon liturosus (Shaw, 1804)

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NATIONAL FISHERIES AUTHORITY

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TNC Pacific Island Countries
Report No 1/09

Chapter 3:

Coral Communities & Reef Health

Rapid Ecological Assessment:

Northern Bismarck Sea, Papua New Guinea

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Executive Summary

The rationale for the present study is based on TNC's goal of furthering the development of a resilient network of MPAs in the Bismarck Sea. Towards this purpose, the main objectives of the present study were to:

1. Conduct a survey of species diversity by identifying hard and soft corals and other benthic marine organisms and by compiling a detailed list of species for each site and for the survey region in general;

2. Assess coral community types, their current status and health, and the extent of impacts on these reefs from disturbances such as coral bleaching, crown-of-thorns seastar outbreaks, destructive fishing practices, and terrestrial runoff;

3. Collect samples of hard corals and other benthic organisms which were difficult to identify in the field for further identification;

4. Map and rank the coral reefs for biodiversity conservation value.

Coral diversity, community structure and reef status was assessed by SCUBA surveys at 72 sites at 36 locations around the Tigak and Manus areas of the North Bismarck Sea. The region hosts high hard coral species richness with some 452 species belonging to 70 genera in 15 families recorded overall. The Manus communities had higher alpha diversity than those around Tigak and were also less impacted by disturbance. For the Tigak area, a total of 408 hermatypic coral species was recorded by E. Turak and J.E.N. Veron. For Manus, 403 hermatypes were recorded by E. Turak. Tigak shared close to 90 % of its coral fauna with Manus. For Tigak, mean location (alpha) diversity of hermatypic corals was 140 species. For Manus, mean alpha diversity of hermatypes was 174 species.

Comparison of coral community structure between the two areas and that of Kimbe Bay revealed six main coral community types in the Bismarck Sea. There was a moderate to high degree of dissimilarity among the seascapes. Three communities were composed predominantly of Kimbe Bay locations. The remaining three communities were composed by Tigak and Manus locations, one of which was composed of sheltered locations from both Tigak and Manus areas, one was predominantly formed by exposed locations of the Tigak area while another was mostly exposed Manus locations. Thus the broader scale analysis demonstrated a high degree of dissimilarity in coral community structure between the eastern (Kimbe Bay) and northern areas (Tigak and Manus) of the Bismarck Sea.

There was a broad range in ecological condition or reef 'health' in the Northern Bismarck Sea, with the Tigak area being more impacted by crown-of-thorns starfish predation, bleaching and other impacts than the Manus area. Sediment impact was rarely noted. However such areas were usually avoided for the purpose of this survey. There was evidence of over harvesting of commercially targeted reef species, such as giant clams, *Trochus* and sea cucumbers. Locations of particular conservation importance were identified.

INTRODUCTION

REGIONAL AND LOCAL SETTING

The Bismarck Sea is a semi-enclosed equatorial sea located to the north-east of Papua New Guinea, bordered by the latter island to the south-west, New Britain to the south-east, New Ireland, New Hanover and the Tigak Islands to the north-east and Manus Island to the north (Figure 1). The area is active tectonically, with volcanic (e.g. Rabaul) and earthquake activity on a regular basis, resulting in episodic tsunamis. The Bismarck Sea has only moderate tidal exchange, of the order of 1 m.

In respect of its biodiversity, the Nature Conservancy (TNC) has identified 7 functional seascapes within the greater Bismarck Sea, two of which are directly relevant to the present study – Manus (Seascape 14) and New Hanover-St. Matthias group (Seascape 16, herein referred to as the Tigak area or seascape). A major objective of the present study was to determine the overall coral diversity of the Northern Bismarck Sea, and to place its coral fauna into the biogeographic framework of the seascapes of the broader region more generally.

BIODIVERSITY, ECOLOGICAL STATUS, IMPACTS AND THREATS

'The Bismarck Sea is one of the richest marine environments in the world, inhabited by many thousands of marine plant and animal species. Highly diverse communities live in the ecosystem complexes of coral reefs, lagoons, seagrass beds and mangroves. The biodiversity of the Northern Bismarck Sea remains in relatively good condition, and this region is of high value for marine conservation (Hunnam et al., 2001, WWF 2003)".

The coral biodiversity of the area remains little known, although prior coral surveys (using the same method as the present study) in Milne Bay (Seascape 21), Kimbe Bay (Seascape 17) and the Solomon Islands (Seascape 26) have revealed highly diverse coral faunas, each of more than 350 species of hermatypic Scleractinia. Kimbe Bay was the least diverse of these three areas, with some 390 coral species recorded (Brodie and Turak 2004, Turak and Aitsi 2002). Milne Bay was significantly more diverse, with the present tally, derived from several independent surveys, of some 436 species, while the Solomon Islands hosts approximately 474 species (Turak 2006).

MARINE MANAGEMENT AND CONSERVATION

The present REA falls within the strategic goal of The Nature Conservancy and its partners to delineate the Coral Triangle, its ecoregions and functional seascapes (Green and Mous 2008).

This "… will serve as a blueprint for establishing MPA networks throughout this high priority area. Within ecoregions, MPA networks will be established at the scale of functional seascapes, leading to the establishment of a large-scale resilient network of MPAs for each ecoregion. While the delineation process was based on the best available information, further information is required to refine these planning units in areas where Rapid Ecological Assessments (REAs) have not been conducted. One high priority area for further surveys is the Bismarck Sea." (Lokani and Green 2006).

Previous studies in the area have indicated that the local coastal people have a strong ethic of coastal and marine resource ownership as exemplified by Customary Marine Tenure Systems:

"In the Northern Bismarck Sea, resource owners have traditionally recognized rights over virtually all of their land and coastal marine resources. Subsistence, artisanal and commercial coastal fisheries in this region all operate within well developed Customary Marine Tenure (CMT) systems, where ownership of and hence access to coastal areas depends on a range of culturally defined variables, including descent line. Some communities in Northern Bismarck Sea have used their existing CMT systems as frameworks to manage their valuable marine resources for generations. … Despite … positive examples of community-based management, the immediate risks of over exploiting the resources in the narrow coastal zones of the Northern Bismarck Sea is mounting. Rapid population rise, an increasing dependence on cash economies, access to more efficient fishing technologies and the break down of CMT structures and traditional access rights are all factors putting increasing pressure on marine ecosystems in this region." (Lokani and Green 2006).

As has already occurred elsewhere, these increasing pressures may lead to the depletion of marine biodiversity and degradation of marine habitats. In this respect, a major objective of this study was to document the present ecological condition of the coral communities of the area, as exemplified by levels of living and dead coral cover and injury on the coral species present (see Methods).

RATIONALE

As introduced above, the rationale for the present study is based on furthering the development of a resilient network of MPAs in the Bismarck Sea, and follows from initial work in Kimbe Bay, West New Britain.

"… the Conservancy initiated the Kimbe Bay Project in West New Britain, Papua New Guinea with the goal of protecting and managing its rich marine biodiversity and marine resources and mitigating the growing threats posed by a rapid increase in population and development within the Bay. … TNC with partners has begun to design and implement resilient MPA networks throughout the Bismarck Sea, starting with Kimbe Bay. Kimbe Bay will be used as a platform site where the process of designing and implementing a resilient MPA network will be developed for the first time in Melanesia. Once this process has been established, we will use this knowledge to establish MPA networks in other functional seascapes of the Bismarck Sea, starting with two functional seascapes in the Northern Bismarck Sea: the Tigak Islands in the New Hanover-St. Matthais group and Manus Island." (Lokani and Green 2006).

A RAPID ECOLOGICAL ASSESSMENT (REA)

The present REA aims to provide detailed ecological information for marine management initiatives, and falls within TNC's overall strategic objectives of strengthening protected areas management both locally and regionally. The assessment forms part of a series of biological surveys in the terrestrial and marine ecosystems within and adjacent to the Northern Bismarck Sea.

This report documents the biodiversity and present status of the reef-building corals and allied sessile Cnidarian taxa, providing ecological data on the environmental setting, composition, diversity and community structure of corals at 36 widely distributed locations around the Tigak and Manus areas of the Northern Bismarck Sea (Figure 2).

OBJECTIVES

The main objectives of the present study were to:

1. Conduct a survey of species diversity by identifying hard and soft corals and other benthic marine organisms and by compiling a detailed list of species for each site and for the survey region in general;

2. Assess coral community types, their current status and health, and the extent of impacts on these reefs from disturbances such as coral bleaching, crown-of-thorns seastar outbreaks, destructive fishing practices, and terrestrial runoff;

3. Collect samples of hard corals and other benthic organisms which were difficult to identify in the field for further identification;

4. Map and rank the coral reefs for biodiversity conservation value.

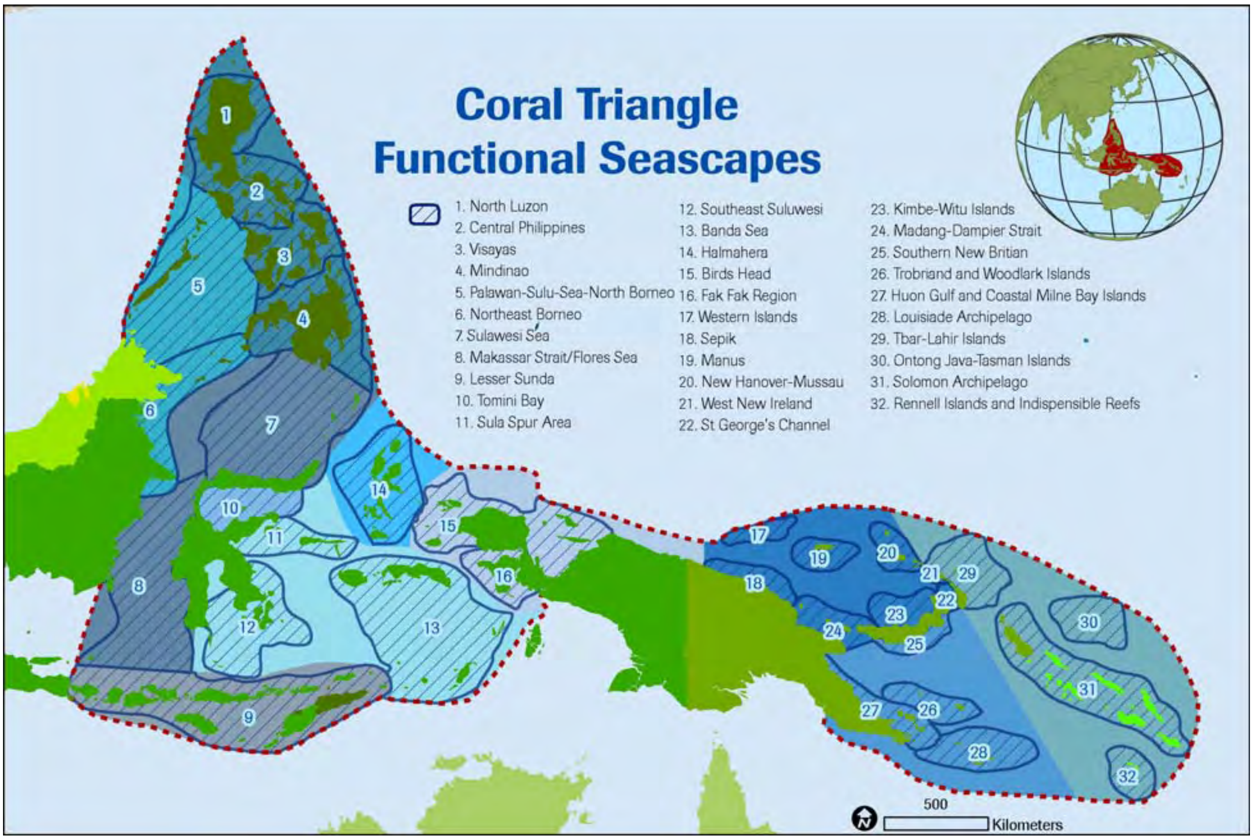

Figure 1. Functional seascapes within the Coral Triangle (Green and Mous, 2008).

METHODS

Rapid Ecological Assessment (REA) surveys were conducted using SCUBA at 36 fringing reef locations (Tigak Islands: 19 locations; Manus Island: 17 locations; Figure 2, Appendix I) in August-September 2006. Locations, each of approx. 1 ha in total area, were selected to provide the broadest range of reef habitat types, developed in relation to different environmental conditions (e.g. exposure, slope angle, depth). At all locations, deep and shallow sites (designated as site #1 and #2 respectively) were surveyed concurrently, representing the deeper reef slope (> 10m depth) and the shallow slope, reef crest and flat (< 10m depth). Deep sites were surveyed first, in accordance with safe diving practice, with the observer swimming initially to the maximum survey depth (max. of 40-45 m), then working steadily into shallower waters. In total, 72 sites at the 36 locations were surveyed. The method was similar to that employed during biodiversity assessments for TNC and other agencies in other parts of the Indo-West Pacific, Indonesia and Australia (see e.g. DeVantier et al. 1998, 2000, DeVantier 2002, 2003, Turak 2002, Turak, 2003, Turak and Fenner 2002, Turak and DeVantier, 2003, Turak and Shouhoko 2003, Turak and Aitsi 2003, Turak et al. 2003, DeVantier et al., 2006). It thus provides the opportunity for future comparisons of species diversity, composition and community structure of these different areas in terms of their coral communities.

At each site, the survey swim covered an area of approx. 5,000m^2 (ca. 50m x 100 m), such that each survey location represented approx. one ha in total. Although 'semi-quantitative', this method has proven far superior to more traditional quantitative methods (transects, quadrats) in terms of biodiversity assessment, allowing for the active searching for new species records at each site, rather than being restricted to a defined quadrat area or transect line (DeVantier et al. 1998, 2000). For example, the present method has regularly returned a two- to three-fold increase in coral species records in comparison with line transects conducted concurrently at the same sites (e.g. Red Sea, Great Barrier Reef).

Two types of information were recorded on water-proof data-sheets during the ca. one and a half hour SCUBA survey swims at each location:

1. an inventory of species, genera and families of sessile benthic taxa (Appendices 2 and 3); and

2. an assessment of the percent cover of the substrate by the major benthic groups and status of various environmental parameters (Appendix I, after Done 1982, DeVantier et al. 1998, 2000).

TAXONOMIC INVENTORIES

A detailed inventory of sessile benthic taxa was compiled during each swim. Taxa were identified in situ to the following levels:

- stony (hard) corals were identified to species level wherever possible (based on Veron and Pichon 1976, 1980, 1982, Veron, Pichon and Wijsman-Best 1977, Veron and Wallace 1984, Veron 1986, 1993, 1995, 2000, Hoeksema 1989, Wallace and Wolstenholme 1998, Wallace 1999, Veron and Stafford-Smith 2002), otherwise genus and growth form (e.g. Porites sp. of massive growth-form).

- soft corals, zoanthids, corallimorpharians, anemones and some macro-algae were identified to genus, family or broader taxonomic group (Allen and Steene 1995, Colin and Arneson 1995, Goslinger et al. 1996, Fabricius and Alderslade 2000);

- other sessile macro-benthos, such as sponges, ascidians and most algae were usually identified to phylum plus growth-form (Allen and Steene 1995, Colin and Arneson 1995, Goslinger et al. 1996).

At the end of each survey swim, the inventory was reviewed, and each taxon was categorized in terms of its relative abundance in the community (Table 1). The categories reflect relative numbers of individuals in each taxon, rather than its contribution to benthic cover and are analogous to those long employed in vegetation analysis (van der Maarel 1979, Jongman et al. 1995, DeVantier et al. 1998).

For each coral taxon present, a visual estimate of the total amount of injury (dead surface area) present on colonies at each site was made, in increments of 0.1, where 0 = no injury and 1 = all colonies dead. The approximate proportion of colonies of each taxon in each of three size classes was also estimated. The size classes were 1 - 10 cm diameter, 11 - 50 cm diameter and > 50 cm diameter (Table 1).

Table 1. Categories of relative abundance, injury and sizes (maximum diameter) of each benthic taxon in the biological inventories.

Rank	Relative abundance	Injury	Size frequency distribution
0	absent	0 - 1 in increments of 0.1	proportion of corals in each of 3 size classes: 1) 1 - 10 cm 2) 11 - 50 cm 3) > 50 cm
1	rare		
2	uncommon		
3	common		
4	abundant		
5	dominant		

Taxonomic Certainty

Despite recent advances in field identification and stabilizing of coral taxonomy (e.g. Hoeksema 1989, Veron 1986, Wallace 1999, Veron 2000, Veron and Stafford-Smith 2002), substantial taxonomic uncertainty and disagreement among different workers remains. This is particularly so in the families Acroporidae and Fungiidae, with different workers each providing different taxonomic classifications and synonymies for various corals (see e.g. Hoeksema 1989, Wallace 1999, Veron 2000). In the present study, extensive use of digital underwater photography and collection of specimens of taxonomically difficult reef-building coral species were made to confirm field identifications (eg. Plate 1). Small samples, usually < 10 cm on longest axis, were removed from living coral colonies in situ, leaving the majority of the sampled colony intact. Living tissue was removed from the specimens by bleaching with household bleach. The dried specimens were examined and identified, as far as possible to species level. Most of these specimens were identified in the field using all the above reference materials, resulting in a comprehensive list of reef-building coral taxa for the area. Most specimens were left with the local TNC office as a basis for a reference collection for the local researchers. Some specimens required additional detailed study, and were prepared for shipping to the Museum of Tropical Queensland, Australia.

Plate 1. Unidentified species of Acropora from the Manus area.

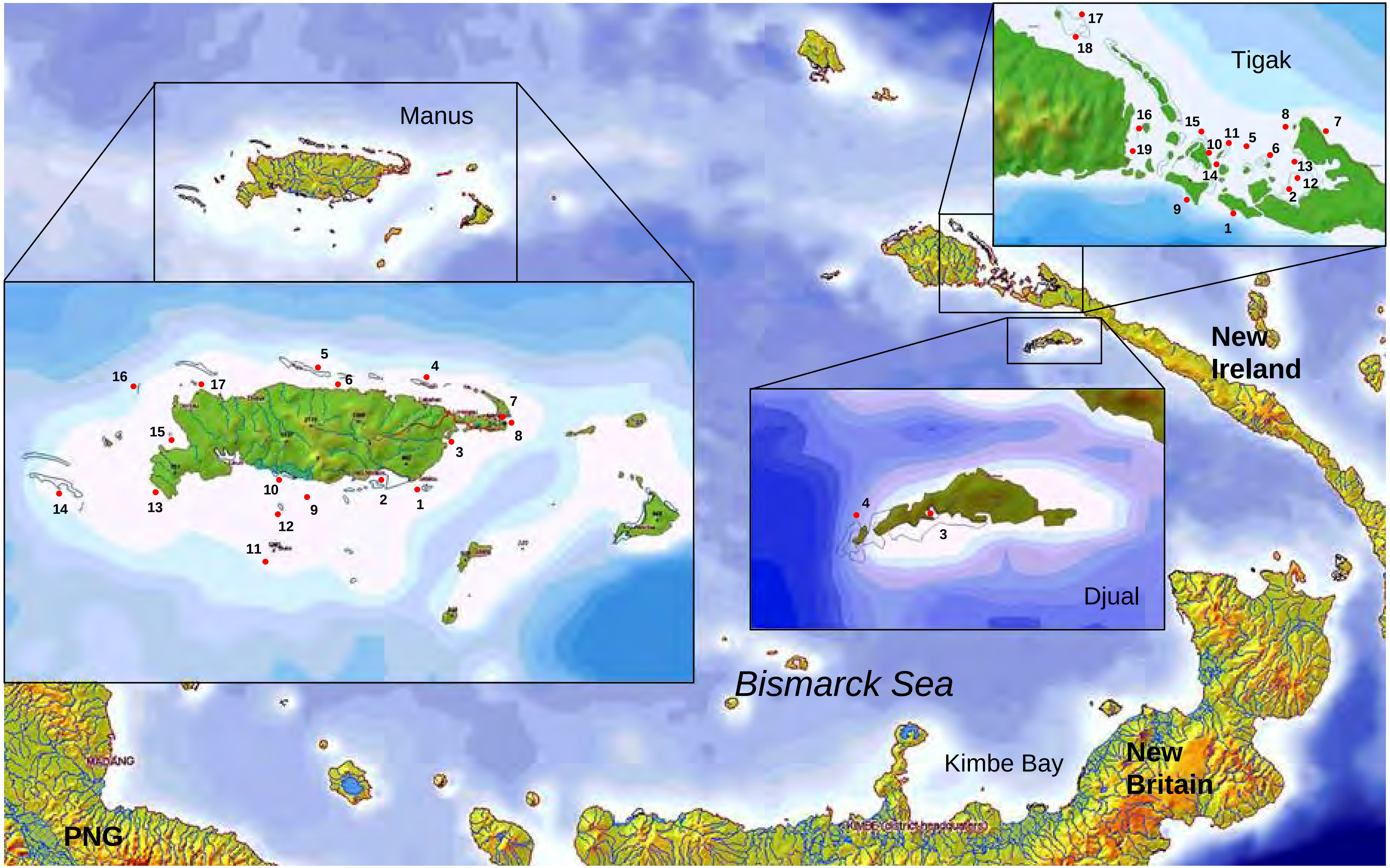

Figure 2. Full study area showing all numbered locations. At all locations two sites were surveyed, each corresponding to deep (10m to maximum depth) and shallow. (minimum depth to 8m).

BENTHIC COVER AND REEF DEVELOPMENT

At completion of each swim, six ecological and six substratum attributes were assigned to 1 of 6 standard categories (Table 2), based on an assessment integrated over the length of the swim (after Done 1982, DeVantier et al. 1998, 2000).

Table 2. Categories of benthic attributes and % cover categories

Attribute		
ecological	**physical**	**% cover**
Hard coral	Hard substrate	not present
Dead standing coral	Continuous pavement	1 - 10 %
Soft coral	Large blocks (diam. > 1 m)	11 - 30 %
Coralline algae	Small blocks (diam. < 1 m)	31 - 50 %
Turf algae	Rubble	51 - 75 %
Macro-algae	Sand	76 - 100 %

The sites were classified into one of four categories based on the amount of biogenic reef development (after Hopley 1982, DeVantier et al. 1998):

1. Coral communities developed directly on non-biogenic rock, sand or rubble;
2. Incipient reefs, with some calcium carbonate accretion but no reef flat;
3. Reefs with moderate flats (< 50m wide); and
4. Reefs with extensive flats (> 50m wide).

The sites were also classified arbitrarily on the degree of exposure to wave energy, where:

1. sheltered;
2. semi-sheltered;
3. semi-exposed; and
4. exposed.

The depths of the sites (maximum and minimum in m), average angle of reef slope to the horizontal (estimated visually to the nearest 10 degrees), and underwater visibility (to the nearest m) were also recorded. The presence of any unique or outstanding biological features, such as particularly large corals or unusual community composition, and evidence of impacts, were also recorded, such as:

- sedimentation;
- blast fishing;
- poison fishing;
- anchoring;
- bleaching impact;
- crown-of-thorns seastars predation;

- *Drupella* snails predation; and
- coral diseases.

Digital underwater photos were taken of sampled corals for which field identifications were uncertain, and of the representative coral community types. All data were input to EXCEL spreadsheets for storage and preliminary analysis.

SPECIES DIVERSITY

Diversity was determined for the individual sites (within-habitat – *alpha*), among sites (Pohnpei, And and Pakin Atolls – *beta*) and regionally (FSM – *gamma*) (after Whittaker 1972, also see Paulay 1997). Herein diversity is considered simply as the number of species present (richness), rather than as an index of evenness - dominance (e.g. H') which takes no account of rare species, important in conservation planning.

COMMUNITY TYPES

Site groups defined by community type were generated by hierarchical cluster analysis using abundance ranks of all corals in the inventories. The analysis used Squared Euclidean Distance as the clustering algorithm and Ward's Method as the fusion strategy to generate site groups of similar community composition and abundance. Analyses were conducted on the raw (untransformed) data. The clustering results were plotted as a dendrogram to illustrate the relationships among sites in terms of levels of similarity among the different community groups. Four separate analyses were conducted, for the Tigak and Manus areas independently at the site (depth) level, for the two areas combined (location level – two depths/sites combined), and with the Kimbe Bay area also included (location level). Kimbe Bay data is from a combination of two surveys; east Kimbe Bay (Turak and Aitsi, 2002) and west Kimbe Bay (Stettin Bay, Brodie and Turak, 2004).

CORAL INJURY

Each coral species in the sites was assigned a score for its level of injury, from 0 – 1 in increments of 0.1 (from 0 for no injury to any colony of that species at that site to 1 where all colonies of the species were dead, see *Methods* above). Sites were compared for the amounts of injury to their coral communities, for the proportion of the total number of species present in each site that were injured, and the average injury to those coral species in each site.

RESULTS

I. ENVIRONMENTAL SETTING

There was substantial reef development throughout the area, with large sub-tidal - inter-tidal reef flats usually wider than 50 m at most stations (Table 3, Appendix I). The coral communities were developed from low-tide level to > 40 m depth, on reef slopes ranging from c. 2^o (reef flats) to 90^o to the horizontal (steep – near vertical reef walls). The communities were distributed over exposure regimes from sheltered to exposed (Table 3), some outer reefs being exposed to regular heavy seasonal oceanic swell. Sea temperatures throughout the survey area averaged 28.9 ^oC, ranging from a minimum of 28 ^oC to a maximum if 31 ^oC (Table 3). Water clarity overall averaged 12 m, ranging from 4 m to 35 m, with highest clarity in the Manus area.

Table 3. Summary statistics for environmental variables, for the Overall survey region (O) and for Tigak (T) and Manus (M) areas, Northern Bismarck Sea, 2006.

Environmental variable	Mean (s.d.)			Range		Median		Mode	
	O	T	M	T	M	T	M	T	M
Reef development (rank 1-4)	3.9 (0.2)	3.9 (0.3)	4 (0)	3-4	4	4	4	4	4
Slope angle (degrees)	23 (21)	21 (19)	26 (22)	5-80	2-90	15	20	10	30
Exposure (rank 1 - 4)	2.3 (0.8)	2.3 (0.9)	2.4 (0.8)	1-4	1-4	2	2	2	2
Water Clarity (Visibility m)	12 (7)	9 (4)	15 (9)	4-20	4-35	8	15	6	20
Sea temperature (^{o}C)	28.9 (0.5)	28.8 (0.5)	29.0 (0.5)	28-31	28-30	29	29	29	29
Hard substrate (%, using untransformed field estimates)	87 (12)	87 (12)	87 (11)	60-100	60-100	90	90	100	90
Sand (%, using untransformed field estimates)	8 (10)	9 (11)	8 (10)	0-30	0-40	5	5	0	0

Tigak

Most of the coral communities surveyed were developed in areas of hard reefal substrate (mean of 87 % cover) with only small areas of sand (mean 9 %), and were subject to variable levels of current flow, in part related to tidal movements. There was a range in levels of sedimentation, particularly near-shore. The lower silt levels offshore contributed to the moderate mean water clarity, which averaged 9 m, ranging from 4 m at the most turbid sites to 20 m on the outer barrier reef slopes during the survey period (Table 3).

Manus

Similarly to the Tigak area, most coral communities surveyed were developed in areas of hard substrate (mean of 87 % cover) with only small areas of sand (mean 8 %), and were subject to variable levels of current flow, in part related to tidal movements. Water clarity on average was better than the Tigak area, with a mean of 15 m, ranging from 4 m in the most turbid sites to c. 35 m during the survey period (Table 3).

II. CORAL COVER

Overall, cover of living hard corals ranged from 1 – 80 %, with a mean of 29 %; recently dead coral ranged from 0 – 10 % with a mean of 1 %; rubble ranged from 0 – 30 %, with a mean of 4 % and soft corals ranged from 0 – 40 % with a mean of 4 %. Algal cover was typically low, with highest cover of macro-algae, turf and coralline algae being less than 40 % and with mean values of 5 %, 11 % and 9 % respectively (Figure 3). Of the two areas, the Manus area had higher live coral cover than Tigak area.

Tigak

Living cover of reef-building corals ranged from ~ 1 % to 80 %, and was high in locations of most exposure regimes (e.g. Appendix II). On average in the stations surveyed, cover of living hard corals was c. 23 % (Figure 3), with a strong overall positive ratio of living : recently dead coral cover (mean 2 %) of some 12 : 1. Highest live coral cover (estimated at 50 % or higher) occurred at sites 12.2, 13.2, 14.2, 15.2 and 18.2 (Appendix II). Recently dead coral was present, if a relatively minor component of cover, at most sites (Appendix II), with an overall mean of 2 % (Figure 3). Highest cover of recently dead corals (c. 5 - 10 %) occurred at sites 1.1, 1.2, 6.1, 6.2, 8.2, 11.2, 12.2, 14.1, 14.2 and 17.2. Large coral rubble areas (cover of 20 % or greater) occurred at sites 2.2, 9.2 and 10.1, variously attributable to predation and bleaching. Coral growth, particularly in most shallower sites (< 10 m depth) appeared vigorous, although continuing episodic and chronic disturbances continued to reduce cover in some locations. Cover of soft corals ranged from 0 to 30 %, with an overall mean of 3 % and with highest cover (10 % or higher) occurring at sites 8.1, 18.1 and 18.2. Algae cover was generally low to moderate throughout, with cover of macro, turf and coralline algae typically of 10 % or less. Notably, there were no sites with high cover (> 30 %) of fleshy macro-algae.

Manus

Living cover of reef-building corals ranged from ~ 10 % to 70 %, and was high in locations of most exposure regimes (e.g. Appendix II), composed of large monospecific and multi-specific coral stands (e.g. *Acropora, Porites* spp.). On average in the locations surveyed, cover of living hard corals was c. 36 % (Figure 3), with a very strong overall positive ratio of living: recently dead coral cover (mean 1 %). Coral growth, particularly in most of the shallower sites (< 10 m depth) appeared vigorous. Highest live coral cover (estimated at 50 % or higher) occurred at sites 6.1, 7.1, 7.2 (Plate 2), 8.2, 10.2, 12.2, 14.2 and 15.2. Many other sites had living coral cover of 30 % or higher (Appendix II). Recently dead coral was only a minor component of cover at most sites (Appendix II), with an overall mean of < 1 % (Figure 3). Importantly, no site had dead coral cover of > 3 %, in contrast with Tigak area (Appendix II). Extensive rubble areas (cover of 20 %) were also rare, occurring only at sites 7.2 and 17.2. Cover of soft corals ranged from 1 to 40 %, with an overall mean of 6 % and with highest cover (20 % or greater) occurring at sites 6.2, 15.2 and 17.2. As with Tigak area, there was generally low cover of algae, ranging up to 20 % maximums for macro-algae, turf algae and coralline algae respectively (Appendix II).

Plate 2. Very high coral cover in site 7.2, Momote, Manus Island.

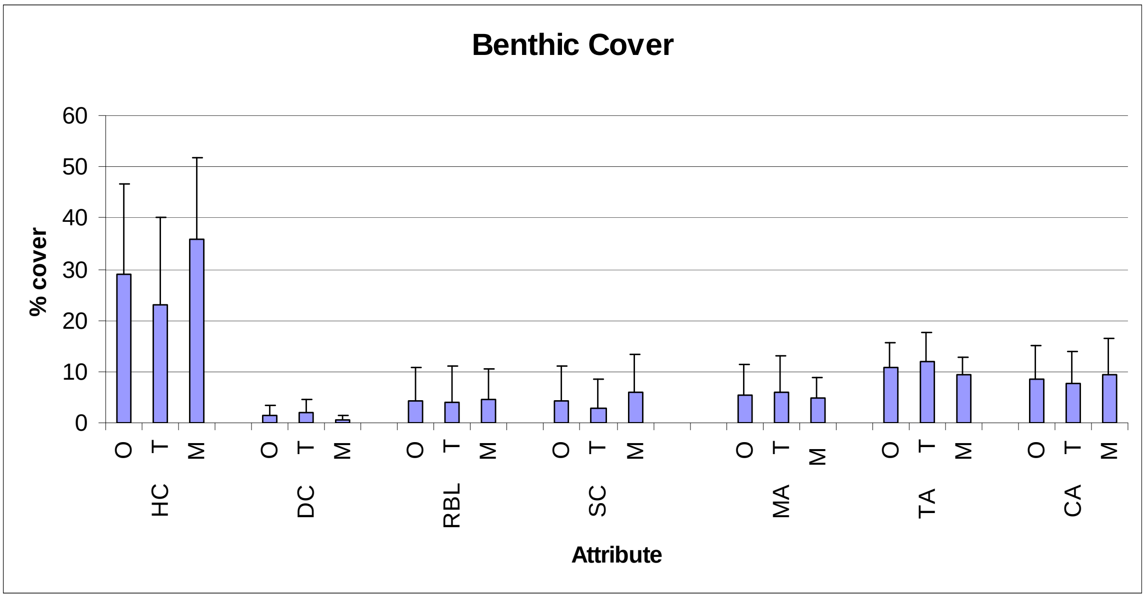

Figure 3. Mean % cover (+ s.d.) of benthic attributes, Northern Bismarck Sea, 2006, where HC - Hard Coral; DC - Recently Dead Coral; RBL - Rubble; SC - Soft Coral; MA – Macro-algae; TA - Turf Algae; CA - Coralline Algae; O - Overall, T - Tigak; M - Manus.

III. SPECIES DIVERSITY

Diversity is here equated with species richness, and assessed at three levels, local or site (*alpha*), within-region (Tigak and Manus areas, *beta*) and among regions within the Indo-west Pacific (*gamma*, after Pauly 1997).

IIIa. Site (Alpha) diversity

Tigak

For all cnidarians, including Scleractinia, the alcyonarian soft corals, gorgonians and related sessile Anthozoa (e.g. zoanthids, corallimorpharians, anemones) and Hydrozoa (*Millepora* spp.), average site diversity was 101 taxa (s.d. 23, range: 46-137). Importantly, this is an underestimate of total diversity, as species-level identifications were not possible for the groups other than the reef-building Scleractinia. These accounted for more than 90 % of the site tallies, with mean site diversity of 91 species (s.d. 22 spp., range: 36-126 spp.). High coral diversity occurred in both shallow and deep sites. The richest sites, hosting > 100 species of reef-building corals, were widely distributed (Table 4). For the locations, with the two sites (depths) combined, mean alpha diversity of hermatypes was 140 species (Table 5 and 7). For all cniderian taxa, mean alpha diversity was 156 species (Table 5).

Manus

For all cnidarians, mean site diversity was 130 taxa (s.d. 23, range: 79-171). As noted above, this is an underestimate of total diversity, as species-level identifications were not possible other than for reef-building Scleractinia (the latter with mean: 116 spp.; s.d. 20 spp., range: 76-146 spp.). High coral diversity occurred in both deep and shallow sites (Table 4). The richest sites, hosting > 150 species of hermatypes, were widely distributed (Plate 3). For the locations, with the two sites (depths) combined, mean alpha diversity for all cniderians was 196 taxa (s.d 24, Table5). For hermatypes, mean alpha diversity was 174 spp. (s.d. 21).

Plate 3. High diversity and coral cover in site 6.2, Hinrun, Manus Island.

Table 4. Ranking of the top 20 sites for coral richness, Tigak and Manus areas, 2006**.**

Tigak					Manus			
Site	**Hermatype species**	**Other Cniderian taxa**	**Total**		**Site**	**Hermatype species**	**Other Cniderian taxa**	**Total**
11.1	123	14	137		17.1	142	29	171
12.2	126	10	136		5.2	146	21	167
18.2	117	16	133		16.1	144	20	164
1.2	114	17	131		12.1	142	18	160
4.1	121	8	129		1.2	145	14	159
1.1	106	16	122		12.2	143	12	155
8.1	105	15	120		14.1	134	19	153
16.1	116	3	119		7.1	134	13	147
14.1	98	21	119		9.1	125	22	147
18.1	96	23	119		3.1	126	19	145
12.1	105	13	118		11.1	123	20	143
9.1	108	8	116		6.1	118	25	143
13.1	97	18	115		1.1	125	17	142
16.2	107	6	113		2.2	126	13	139
7.1	104	9	113		5.1	125	13	138
2.2	102	6	108		6.2	126	9	135
8.2	98	8	106		4.1	117	16	133
4.2	96	10	106		13.1	120	12	132
2.1	99	3	102		16.2	114	14	128
9.2	92	9	101		2.1	117	10	127

Table 5. Ranking of locations for coral richness, Tigak and Manus area, 2006.

Tigak				Manus			
Location	Hermatype species	Other Cniderian taxa	Total	Location	Hermatype species	Other Cniderian taxa	Total
18	195	28	223	12	211	25	236
1	194	25	219	1	200	27	227
12	198	18	216	5	200	23	223
8	182	19	201	3	186	27	213
4	182	13	195	16	186	24	210
13	166	23	189	6	181	29	210
16	172	8	180	17	177	32	209
9	168	12	180	2	187	16	203
11	164	16	180	9	173	24	197
14	157	23	180	13	171	20	191
7	157	11	168	14	167	21	188
6	150	18	168	7	169	15	184
2	155	8	163	4	153	21	174
15	142	14	156	11	150	23	173
10	134	14	148	8	156	13	169
5	129	13	142	15	143	18	161
19	106	19	125	10	137	14	151
17	104	18	122				
3	107	4	111				

IIIb. Tigak and Manus (Beta) diversity

Comparison between the two areas for species richness indicated that both were highly diverse, sharing a similar overall number of reef-building coral genera (Tigak 68 and Manus 69). Some 408 hermatypic coral species were confirmed from the Tigak area, while the Manus area hosted some 403 species (Table 6). In total from the two seascapes, 452 hermatypic Scleractinia were confirmed during the survey, with an additional six species unconfirmed and likely new to science, several of which have been previously recorded from other seascapes (e.g. Solomon Islands). Of the total confirmed species pool, 359 species were shared between Tigak and Manus and a further 93 species were recorded from just one of the seascapes. Of the smaller Manus species pool, 89 % of the species recorded were shared with Tigak, indicating a high degree of coral faunal similarity between these two seascapes.

Table 6. Species and generic composition of reef-building corals in 15 scleractinian coral families, Tigak and Manus areas. Species tallies include confirmed species only and do not include taxa for which identifications remain provisional.

Scleractinian family	Number of genera		Number of species	
	Tigak	Manus	Tigak	Manus
Astrocoeniidae	3	3	4	4
Pocilloporidae	3	3	13	13
Acroporidae	4	4	125	138
Euphylliidae	3	4	8	9
Oculinidae	1	1	7	7
Siderastreidae	3	3	13	13
Agariciidae	5	5	27	28

Scleractinian family	Number of genera		Number of species	
	Tigak	Manus	Tigak	Manus
Fungiidae	13	13	42	39
Pectiniidae	5	4	17	17
Merulinidae	3	3	8	7
Dendrophylliidae	1	1	7	6
Mussidae	7	7	25	20
Faviidae	14	14	78	68
Trachyphylliidae	0	1	0	1
Poritidae	3	3	34	33
Total	**68**	**69**	**408**	**403**

IIIc. Bismarck Sea (Gamma) diversity

The overall and within-location richness recorded here is moderate to high by comparison with other areas throughout the Indowest Pacific (Table 7). In the Northern Bismarck Sea for the two areas of Tigak and Manus combined, 452 coral species were recorded. The combined total for the Bismarck Sea, including Kimbe Bay, currently stands at 478 species of hard corals (Appendix III).

Table 7. Comparison of diversity and various other ecological characteristics of Tigak and Manus with other Indo-West Pacific coral reef areas.; TIG – Tigak Islands, New Ireland (includes data from C. Veron), PNG; MAN – Manus Island, PNG; T/M – Tigak and Manus combined; KIM - Kimbe Bay, Bismarck Sea, PNG; MB - Milne Bay, PNG; SOL – Solomon Islands; TC – Teluk Cendereewasih, Papua, Indonesia; F/K – Fakfak region, Papua, Indonesia; C/F - Cenderewasih and Fakfak combined RA - Rajah Ampat area, Papua, Indonesia; GBR - North Great Barrier Reef, Australia; POH - Pohnpei, And and Pakin Atolls (Federated States of Micronesia). Data from Turak 2002, Turak and Fenner 2002, Turak and Shouhoko 2003, Turak et al. 2003, , Turak & DeVantier 2005, Turak 2006, Turak & DeVantier 2006 and for N GBR - Turak, unpublished data.

*** Combined two surveys in Kimbe Bay (Turak and Aitsi 2002, Brodie & Turak 2004).**

	TIG	**MAN**	**T/M**	KIM*	MB	SOL	TC	F/K	C/F	RA	GBR	POH
Total number of species	408	403	452	390	393	485	456	456	504	487	318	323
Average no. of species per station	140	174	156	124	147	135	178	171	174	131	100	84
% of stations with over 1/3 rd species	42	100	61	47	82	12	79	65	48	18	-	3
Average % hard coral cover	23	36	29	25	33.3	32	27	26	27	33	34.8	35
Number of stations surveyed	19	17	36	43	28	59	33	34	67	51	26	36
Area covered (x1000 km^2) approx.	4.9	8.1	13	11.2	15	120	27	12	39	30	0.8	0.8

IV. CORAL COMMUNITIES

Tigak

The corals formed four major community types (tA – tD) broadly distributed in relation to incident environmental conditions, particularly depth and exposure, separating into one shallow (tA), one deep (tD) and two mixed depth communities (tB and tC, Figures 4 and 5). The environmental variables and coral taxa that characterize each community are listed in Tables 8 and 9.

Manus

The corals formed 3 major community types (mA - mC, Figures 6 and 7) distributed in relation to incident environmental conditions, particularly depth and exposure, separating into one mostly shallow (mA), one mostly deep (mC) and one mixed depth community (mB, Figures 6 and 7). The environmental variables and coral taxa that characterize each community are listed in Tables 10 and 11.

Northern Bismarck Sea

Pooling of the Tigak and Manus datasets, with and analysed at the level of locations (2 depths/sites combined per location), revealed three major community 'types' (nA – nC). Communities nA and nB were composed predominantly of locations from the Tigak seascape while Community nC was predominantly composed of Manus locations, with some Tigak locations (Figures 8 and 9).

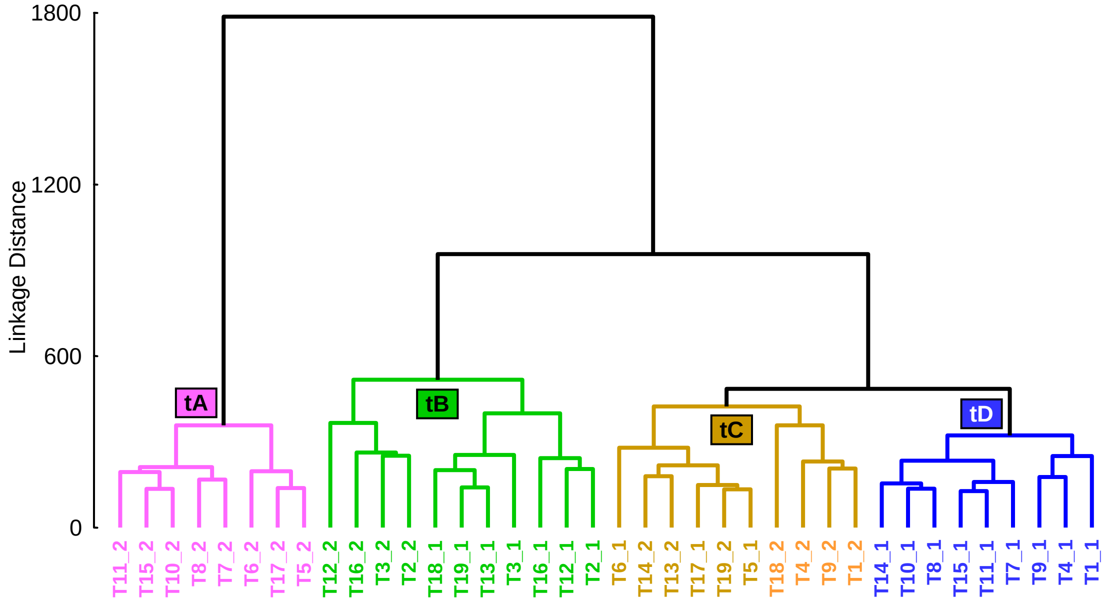

Figure 4. Dendrogram of similarity in coral community types in the Tigak area, derived from the species - abundances of corals in 19 deep (#1) and shallow (#2) sites.

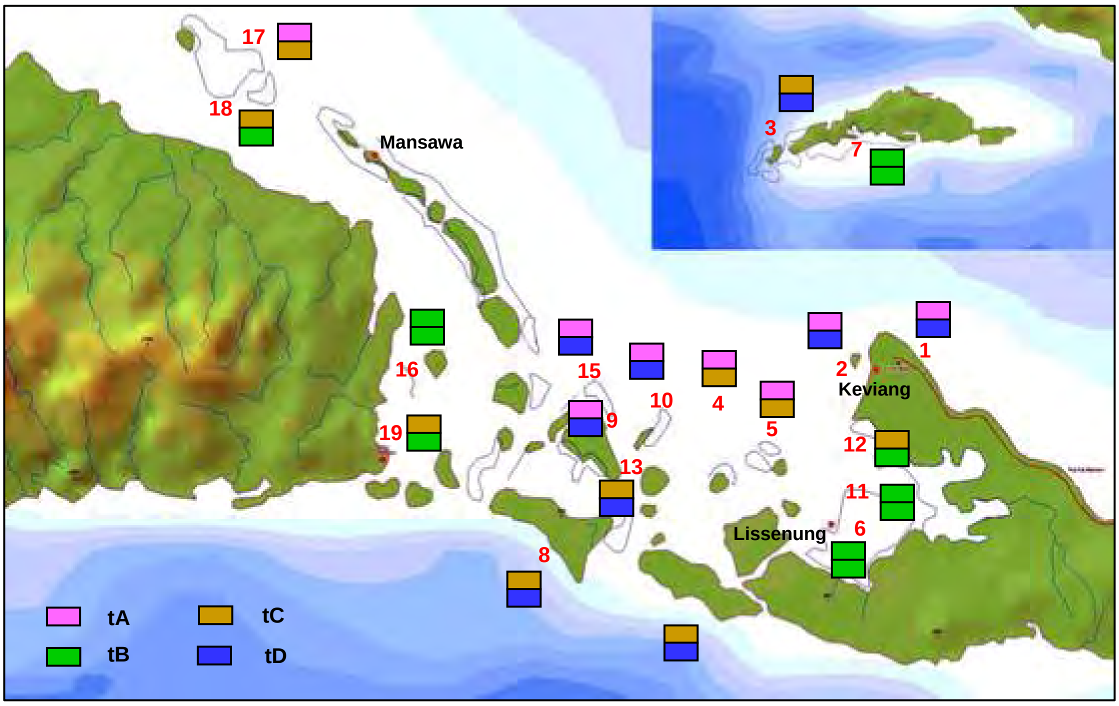

Figure 5. Distribution of the four coral communities among 19 locations, Tigak area, 2006, where: pink – community tA; green – community tB; brown – community tC; blue – community tD.

Table 8. Environmental parameters for four coral communities, Tigak area, 2006.

Tigak area	tA		tB		tC		tD
Number of sites	8		11		10		9
Maximum	8		13		12		29
Minimum	1		5		3		10
Slope	7		24		12		40
Hard substrate	99		77		88		88
Hard coral	27		27		24		13
Soft coral	1		4		5		2
Macro algae	3		9		7		3
Turf algae	11		11		14		13
Coralline algae	14		2		8		9
Dead coral	4		1		2		2
Continuous pavement	94		54		66		80
Large blocks	4		14		12		2
Small blocks	1		10		9		7
Rubble	1		3		6		7
Sand	1		20		7		4
exposure	3		2		3		2
Reef develop.	4		4		4		4
Visibility	13		5		9		11
Water temp.	29		29		29		29
Average species	86		97		82		108

Table 9. Characteristic species among four coral communities, Tigak area, 2006.

Community	tA	8	Community	tB	11
Scleractinia	**abn**	**site**	**Scleractinia**	**abn**	**site**
Acropora nana	27	8	*Porites massive*	24	11
Acropora palifera	24	8	*Favia favus*	21	11
Galaxea fascicularis	24	8	*Pachyseris foliosa*	20	10
Acropora gemmifera	23	8	*Pectinia alcicornis*	20	10
Pocillopora verrucosa	22	8	*Astreopora myriophthalma*	19	10
Acropora digitifera	20	8	*Psammocora contigua*	19	9
Coeloseris mayeri	20	8	*Scolymia vitiensis*	18	9
Stylophora pistillata	19	8	*Favia danae*	18	9
Acropora valida	19	8	*Goniastrea pectinata*	18	9
Favia stelligera	19	7	*Porites vaughani*	18	9
Pocillopora eydouxi	18	8	*Pachyseris speciosa*	17	9
Acanthastrea subechinata	18	8	*Cyphastrea serailia*	16	9
Montastrea curta	18	8	*Galaxea fascicularis*	16	8
Montipora grisea	18	7	*Favites russelli*	16	8
Porites lichen	18	7	*Porites cylindrica*	16	8
Goniastrea retiformis	17	8	*Acropora divaricata*	15	9
Platygyra daedalea	16	8	*Hydnophora exesa*	15	9
Leptoria phrygia	16	8	*Pocillopora damicornis*	15	8
Acropora monticulosa	15	8	*Pavona cactus*	15	8
Hydnophora microconos	15	8	*Hydnophora rigida*	15	8
Others	**abn**	**site**	**Others**	**abn**	**site**
CRA	23	8	*Caulerpa*	17	8
Millepora exesa	18	8	*Paralemnalia*	14	7
Halimeda	16	8	*Peyssonnelia*	14	6
Lissoclinum	15	6	*Sarcophyton*	13	7
Millepora intricata	10	7	*Sinularia spp.*	12	7
Palythoa	9	7	*Halimeda*	12	6
Sinularia spp.	9	5	*Polycarpa*	11	7
Carterospongia	8	4	*Lobophytum*	11	6
Lobophytum	7	4	*Nephthea*	10	5
Linckia	7	4	Sponge	10	5
Chlorodesmis	7	4	Sponge blue tubes	10	5
Tridacna maxima	6	4	*Rumphella*	8	5
Acanthaster planci	6	4	*Sinularia tree*	8	4
Paralemnalia	6	3	Sponge foliose	8	4
Millepora dichotoma	5	4	*Annella*	7	4
Sarcophyton	5	3	*Linckia*	7	4
Xenia	5	3	*Clavularia*	7	3
Entophysalis	5	2	*Tridacna crocea*	7	3
Anemon	4	3	Anemon	6	5
Sargassum	4	2	*Xestospongia*	6	5

Community	tC	10
Scleractinia	**abn**	**site**
Porites massive	29	10
Porites lichen	23	9
Pocillopora danae	21	9
Porites cylindrica	19	9
Porites nigrescens	19	8
Ctenactis crassa	16	10
Diploastrea heliopora	16	10
Acropora formosa	16	8
Favia pallida	15	9
Pocillopora verrucosa	15	8
Acropora cerealis	15	8
Porites rus	15	7
Platygyra daedalea	14	9
Fungia fungites	14	8
Goniastrea pectinata	14	8
Coeloseris mayeri	14	7
Physogyra lichtensteini	13	8
Fungia concinna	13	8
Stylophora pistillata	13	7
Sandalolitha robusta	13	7
Others	**abn**	**site**
Sinularia spp.	22	10
Sarcophyton	21	10
Polycarpa	16	7
Paralemnalia	15	8
Lissoclinum	15	6
Halimeda	14	7
Sponge	13	6
Millepora exesa	12	6
Carterospongia	12	6
Lobophytum	11	6
CRA	11	4
Anemon	10	6
Linckia	10	6
Tridacna crocea	10	5
Sinularia tree	9	4
Palythoa	8	6
Clavularia	8	4
Diademnum	8	4
Peyssonnelia	8	3
Millepora tenella	7	6

Community	tD	9
Scleractinia	**abn**	**site**
Porites massive	19	9
Porites vaughani	18	8
Favia matthai	17	9
Favites russelli	17	9
Goniastrea pectinata	17	9
Galaxea fascicularis	15	9
Sandalolitha dentata	15	9
Cyphastrea serailia	14	9
Scolymia vitiensis	14	8
Merulina ampliata	13	9
Montipora grisea	13	8
Acropora formosa	13	8
Favia pallida	13	8
Platygyra daedalea	13	8
Cyphastrea microphthalma	13	8
Echinopora gemmacea	13	8
Acropora divaricata	12	8
Fungia paumotensis	12	8
Mycedium elephatotus	12	8
Porites rus	12	8
Others	**abn**	**site**
CRA	19	8
Sinularia spp.	17	9
Polycarpa	16	8
Millepora exesa	15	9
Sarcophyton	15	9
Halimeda	14	7
Clavularia	11	7
Dendronephthya	10	8
Millepora tenella	10	5
Didemnum	10	5
Scleronephthya	9	6
Sponge	8	5
Carterospongia	8	4
Cirrhipathes	6	4
Nephthea	6	3
Dictyota	6	3
Peyssonnelia	6	3
Distichopora	5	3
Capnella	5	3
Paralemnalia	5	3

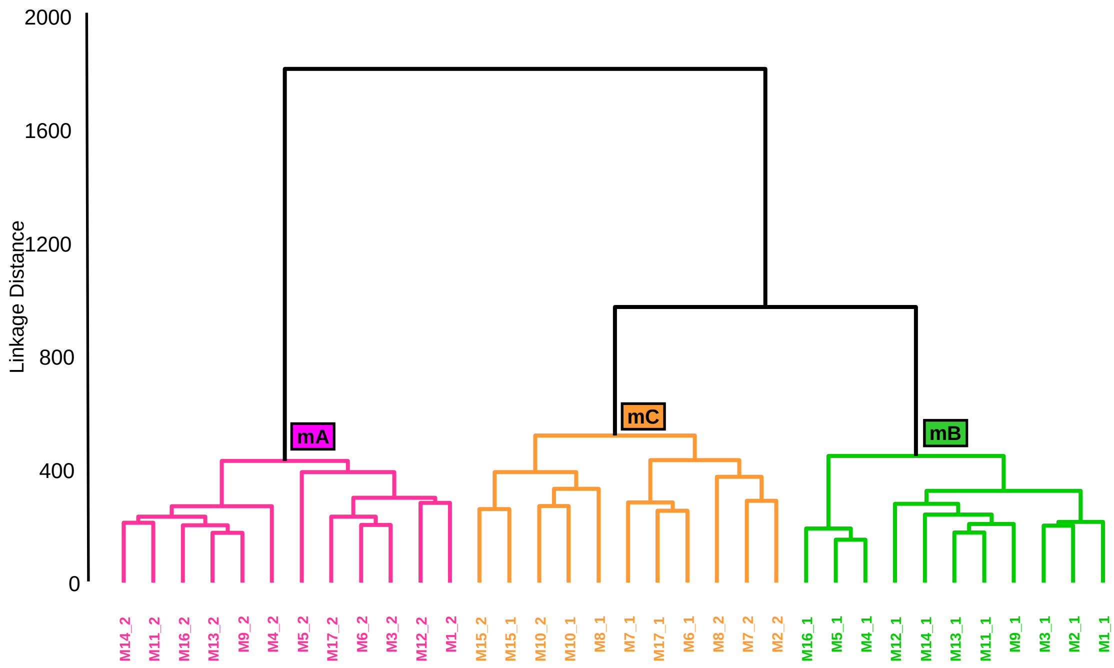

Figure 6. Dendrogram of similarity in coral community types in the Manus area, derived from the species - abundances of corals in 17 deep (#1) and shallow (#2) sites.

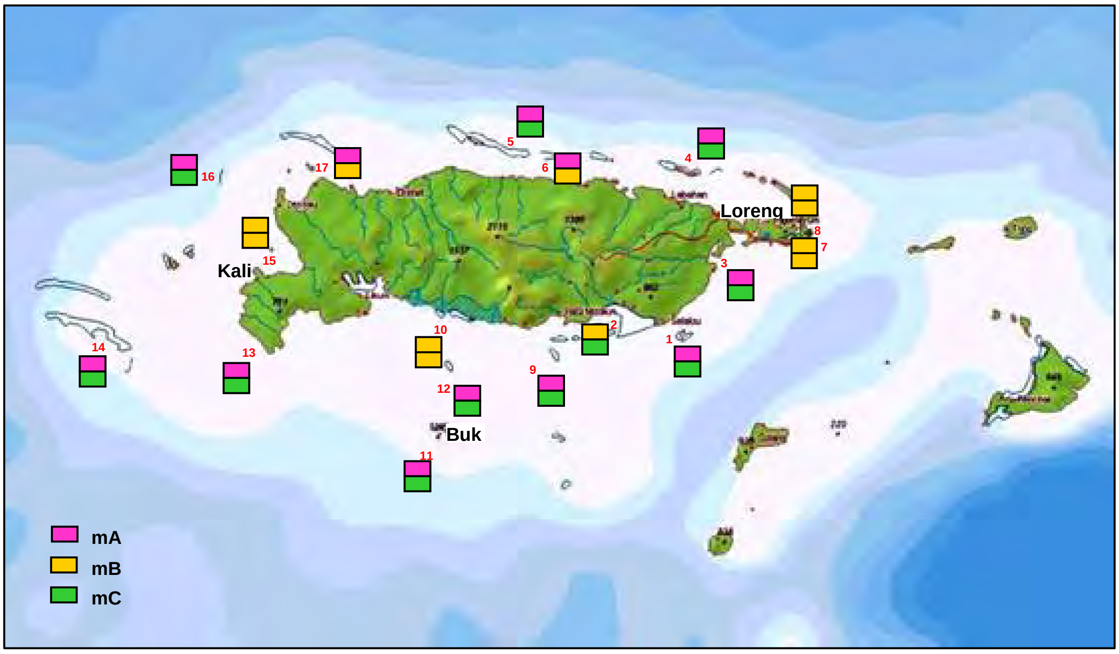

Figure 7. Distribution of the three coral communities among the 17 locations, Manus area, 2006, where: pink – community mA; orange – community mB; green – community mC.

Table 10. Environmental parameters for three coral communities, Manus area, 2006**.**

Manus area		**Shallow**		**Mixed**		**Deep**
Community type		**mA**		**mB**		**mC**
Number of sites		12		11		11
Maximum		8		15		32
Minimum		1		5		10
slope		8		25		46
Hard substrate		94		77		90
Hard coral		35		45		27
Soft coral		8		7		3
Macro algae		4		7		5
Turf algae		10		9		8
Coralline algae		14		3		11
Dead coral		1		0		1
Continuous pavement		83		56		82
Large blocks		5		11		4
Small blocks		5		10		5
Rubble		4		5		5
Sand		3		18		5
Exposure rating		3		2		2
Reef development		4		4		4
Visibility		16		10		19
Average species		114		113		130

Table 11. Characteristic species among three coral communities, Manus area, 2006.

Comunity	mA	12	Comunity	mB	11	Comunity	mC	11
Scleractinia	**abn**	**site**	**Scleractinia**	**abn**	**site**	**Scleractinia**	**abn**	**site**
Acropora palifera	29	12	*Fungia paumotensis*	24	11	*Porites vaughani*	28	11
Favia stelligera	29	12	*Pavona cactus*	24	10	*Montipora grisea*	23	11
Acropora hyacinthus	27	12	*Pachyseris foliosa*	24	10	*Favites russelli*	22	11
Pocillopora verrucosa	26	12	*Merulina ampliata*	22	11	*Goniastrea pectinata*	22	11
Stylophora pistillata	26	12	*Echinopora lamellosa*	22	11	*Porites massive*	22	11
Montipora grisea	25	12	*Acropora formosa*	22	10	*Fungia fungites*	21	11
Hydnophora microconos	25	12	*Seriatopora hystrix*	21	10	*Platygyra daedalea*	21	11
Goniastrea retiformis	25	12	*Galaxea fascicularis*	21	10	*Cyphastrea microphthalma*	21	11
Acropora gemmifera	25	11	*Fungia danai*	21	10	*Echinopora lamellosa*	21	11
Galaxea fascicularis	25	11	*Echinopora mammiformis*	21	10	*Astreopora myriophthalma*	20	11
Favites complanata	24	12	*Porites cylindrica*	21	9	*Mycedium elephatotus*	20	11
Platygyra daedalea	24	12	*Fungia fungites*	20	10	*Diploastrea heliopora*	20	11
Acropora cerealis	24	11	*Goniastrea pectinata*	20	10	*Seriatopora hystrix*	20	10
Porites massive	24	11	*Fungia concinna*	20	9	*Stylophora pistillata*	20	10
Acropora millepora	23	12	*Ctenactis crassa*	20	9	*Acropora granulosa*	20	10
Pocillopora danae	23	11	*Porites massive*	19	9	*Fungia paumotensis*	20	10
Porites cylindrica	23	11	*Pocillopora damicornis*	18	10	*Merulina ampliata*	20	10
Acropora nana	23	10	*Astreopora myriophthalma*	18	10	*Cyphastrea serailia*	20	10
Fungia fungites	22	12	*Herpolitha limax*	18	10	*Oxypora lacera*	19	11
Echinopora gemmacea	22	12	*Acropora selago*	17	9	*Galaxea fascicularis*	19	10
Others	**abn**	**site**	**Others**	**abn**	**site**	**Others**	**abn**	**site**
CRA	30	11	*Sarcophyton*	20	9	*Halimeda*	23	10
Millepora exesa	24	12	*Sinularia spp.*	19	9	*Paralemnalia*	22	11
Halimeda	24	11	*Millepora intricata*	18	9	CRA	22	10
Sinularia spp.	22	11	*Paralemnalia*	18	8	*Sarcophyton*	21	11
Tridacna maxima	16	11	*Halimeda*	17	8	*Nephthea*	20	10
Aglophenia	16	8	*Briareum*	16	8	*Sinularia spp.*	18	9
Sarcophyton	15	8	*Millepora dichotoma*	12	9	*Millepora exesa*	17	9
Nephthea	15	7	*Lobophytum*	12	6	*Lobophytum*	15	8
Millepora platyphylla	14	8	*Nephthea*	12	6	*Scleronephthya*	15	8
Palythoa	14	8	*Isis*	12	5	Sponge	14	7
Carterospongia	14	7	*Sinularia* tree	10	5	*Dendronephthya*	13	7
Lobophytum	13	7	*Diademnum*	10	5	*Polycarpa*	13	7
Millepora dichotoma	12	9	*Polycarpa*	10	5	*Caulerpa racemosa*	11	6
Heliopora coerolea	11	6	*Millepora tenella*	9	6	*Distichopora*	11	5
Millepora intricata	11	5	*Lemnalia*	9	4	Sponge encrusting	10	5
Paralemnalia	10	5	*Millepora exesa*	8	4	*Elisella*	9	7
Sponge encrusting	10	5	Sponge	8	4	*Carterospongia*	9	5
Polycarpa	9	5	*Padina*	8	3	*Sinularia brascica*	9	4
Chlorodesmis	9	5	*Dictyota*	8	3	*Tubipora musica*	8	7
Tridacna squamosa	8	6	*Cirrhipathes*	7	4	*Palythoa*	8	5

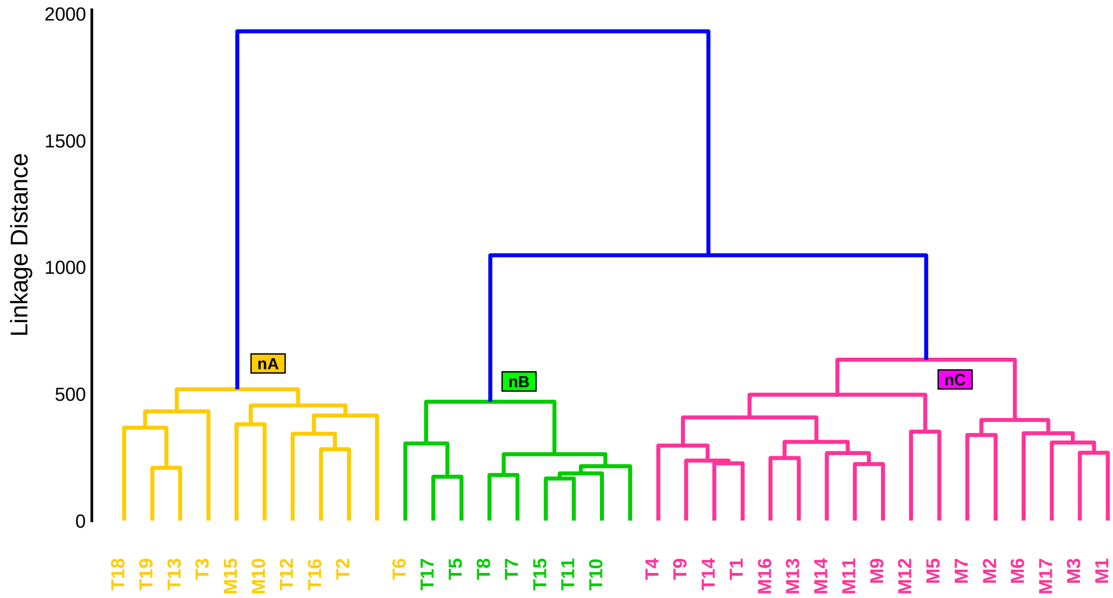

Figure 8. Dendrogram of similarity in three coral community types in the Northern Bismarck Sea (Tigak and Manus areas) derived from the species - abundances of corals in 36 locations (2 depths/sites at each location pooled).

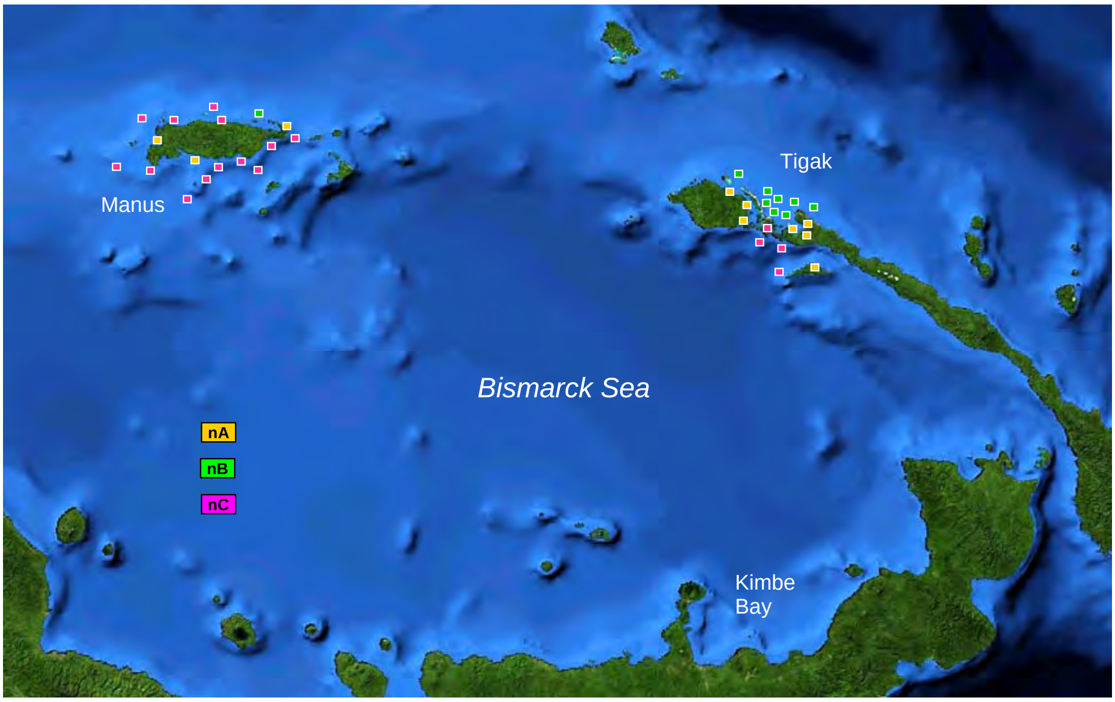

Figure 9. Distribution of the three coral communities among the 36 locations, Northern Bismarck Sea (Tigak and Manus areas combined), 2006, where: brown – community nA; green – community nB; pink – community nC.

V. ECOLOGICAL STATUS – DISTURBANCES

Tigak

At some locations surveyed, there was evidence of recent damage to coral communities, mostly attributed to storm damage, predation by Crown-of-thorns starfish and/or coral bleaching. This was evidenced in the levels of injury sustained by coral species, with most sites exhibiting low levels of species' injury (Figure 10). Coral species exhibiting highest average levels of injury were mostly the longer-lived massive species that typically suffer partial mortality but survive disturbances that may kill corals of other growth forms.

Storm damage was particularly prevalent on south-facing reefs. This was attributable to a large swell, the largest in living memory reported at some 6-8 m in height, which impacted the reefs in August 2006. The worst affected locations included Tigak 1 and 9, and most exposed south-facing reefs in the Manus area. These reefs are typically relatively protected in relation to the north-facing exposed reefs on the north coasts of the islands, which receive regular seasonal open-ocean ground swell from the North Pacific.

Crown-of-thorns starfish were present in low to moderate numbers in most locations in the Tigak area, particularly at Tigak 5, 8 and 17. Outbreaks have recently occurred in other areas of the Northern Bismarck Sea, such as around Buke (Manus area) in 2005 and Kavieng (Enuk and Nusa Islands) more recently (T. Potuku, TNC, pers. comm.). The coral-feeding snails Drupella spp. were also present, notably at Tigak 17 and most sites in the Manus area, although these were not usually in excessive abundances.

Damage consistent with coral bleaching was apparent at several sites, likely attributable to elevated sea surface temperatures in early 2000. This was most apparent at Tigak 1, 8, 9 and adjacent to 17 (Plate 4). There was little apparent impact from sedimentation, although there has been some land clearing. The low levels of impact are likely attributable to the small stream and river catchments and to the fact that most reefs surveyed were well offshore. There was some destructive fishing damage from fish bombing and/or poison fishing (eg. Tigak 9), but compared with other areas these impacts were relatively minor.

Plate 4. Extensive coral mortality in site 17.1, Nemto, New Hanover.

Manus

At most locations surveyed, coral communities were in good condition (Plate 5), exhibiting moderate to high living coral cover, low dead coral cover (strong positive ratio of live : dead cover) and high diversity (Figure 3, Appendix II). This was also reflected in the levels of injury sustained by coral species, with all sites exhibiting low levels of species' injury (Figure 11). There was some apparent storm damage at Manus (Buke) 11 and some old bomb-fishing damage at Manus 13. Generally however there was little evidence of recent poison fishing, which apparently occurs only sporadically in the area when the transport vessels for the live food-fish trade are present.

Plate 5. Healthy coral fields on Anun reef, site 12.2, Buke, Manus Island.

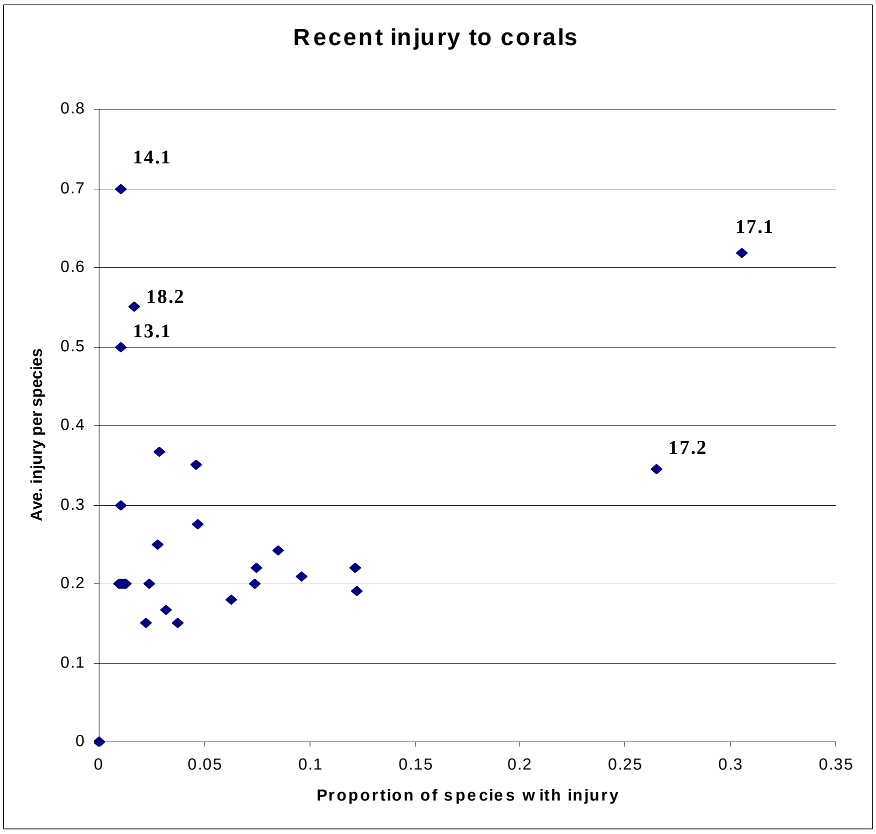

Figure 10. Scatterplot of the average injury per species versus proportion of injured species in each of 38 sites, Tigak area 2006.

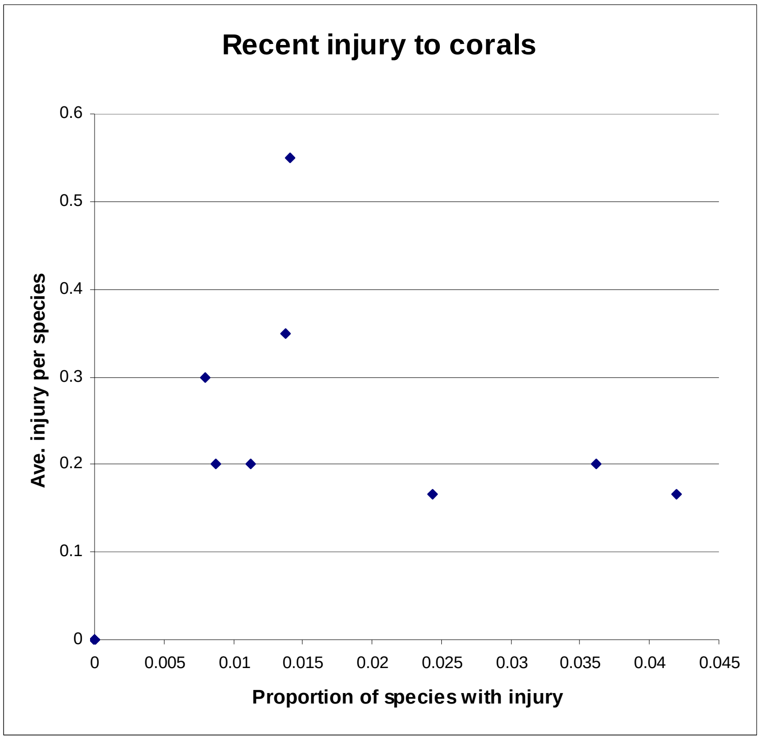

Figure 11. Scatterplot of the average injury per species versus proportion of injured species in each of 34 sites, Manus area 2006. All sites had insignificant proportions of species with injury.

DISCUSSION

Tigak and Manus areas, Northern Bismarck Sea support diverse reef-building coral assemblages, composed of more than 450 species from 70 genera in 15 scleractinian families, including some species that may be undescribed. The corals form three major community types (Figure 8), broadly distributed (Figure 9) in relation to distance from shore, depth (influencing both illumination and exposure), wave energy, slope angle and other environmental factors.

The area supports regionally important populations of a wide array of coral species, including some species considered to be globally rare. In most locations surveyed, the coral communities were in good condition, with positive ratios of live: dead coral cover (Figure 3). There was some evidence of recent coral damage, particularly in the Tigak area, and any future increases in use may threaten incident coral communities. Key recommendations in the latter regard include:

- Avoid destructive fishing practices, including both bomb and poison fishing
- Avoid pollution of coastal waters from land run-off
- Avoid over-fishing and poor water quality, particularly nutrient enrichment from inapproprriate land-use practices, as these can lead to severe crown-of-thorns starfish outbreaks and other forms of coral damage.
- Monitor the harvesting of branching Acropora coral for lime use. Consider alternatives to collecting.

RECOMMENDATIONS FOR CONSERVATION PLANNING

Of the 36 locations surveyed in the two seascapes of the Northern Bismarck Sea, many had high coral species richness and other attributes of high conservation value (Tables 4-11). The most diverse 20 locations, all hosting more than 160 hermatypic Scleractinia, are listed in Table 12.

FUNCTIONAL SEASCAPES OF THE BISMARCK SEA

As introduced above, TNC identified 7 functional seascapes within the greater Bismarck Sea (Figure 1), two of which were the focus of the present study – Manus (Seascape 14) and New Hanover-St. Matthias group (herein 'Tigak area', Seascape 16). The above analyses indicate that both seascapes are highly diverse in terms of their overall coral richness, with some 408 species of hermatypic Scleractinia recorded from the Tigak area and some 403 species from the Manus area, with most species shared between the two seascapes. Despite the high degree of coral faunal similarity (~ 90 %), there was a moderate degree of dissimilarity in the community types present (Figures 8 and 9). The Manus communities had higher alpha diversity than those around Tigak (Tables 5, 6, 8 and 10), and were also less impacted by disturbance (Figures 10 and 11)

In order to place the coral fauna of the Northern Bismarck Sea into the biogeographic framework of the seascapes of the region more generally, a further cluster analysis was undertaken, incorporating prior data from Kimbe Bay. This indicated that these three seascapes of the Bismarck Sea host six major coral community types (bA – bF, Figures 12 and 13). There was a moderate to high degree of dissimilarity among the seascapes. Three communities were composed predominantly of Kimbe Bay locations (bA – Kimbe East; bB – Stettin West and bC – very sheltered locations from both areas with two Tigak locations). The remaining three communities were composed by Tigak and Manus locations (bD – bF). Community bD was composed of sheltered locations from both Tigak and Manus areas. Community bE was predominantly formed by exposed locations of the Tigak area while Community bF was mostly exposed Manus locations. Thus the broader scale analysis demonstrated a high degree of dissimilarity in coral community structure between the eastern (Kimbe Bay) and northern areas (Tigak and Manus) of the Bismarck Sea.

Table 12. The most diverse 20 locations (> 160 spp. reef-building corals), Tigak and Manus areas. Coral cover is the mean of the 2 sites at each location. Site numbers correspond with those in Figures 2, 4 and 6, community types with those in Figures 8 and 9.

Location name (no.)	Spp. diversity	Coral cover %	Community types
Manus (12)	211	45	C
Manus (1)	200	30	C
Manus (5)	200	35	C
Tigak (12)	198	55	A
Tigak (18)	195	35	A
Tigak (1)	194	10	C
Manus (2)	187	25	C
Manus (16)	186	40	C
Manus (3)	186	20	C
Tigak (8)	182	18	B
Tigak (4)	182	20	C
Manus (6)	181	50	C
Manus (17)	177	25	C
Manus (9)	173	35	C
Tigak (16)	172	23	A
Manus (13)	171	25	C
Manus (7)	169	60	C
Tigak (9)	168	10	C
Manus (14)	167	40	C
Tigak (11)	164	20	B

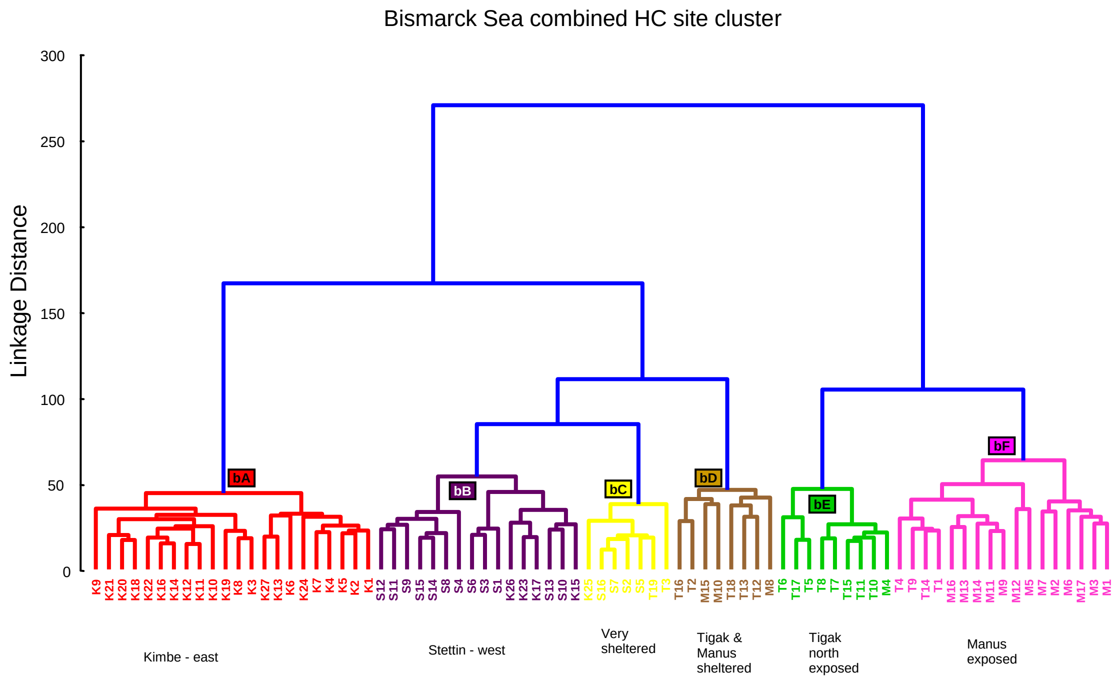

Figure 12. Dendrogram of similarity in coral community types in the Bismarck Sea (Tigak, Manus and Kimbe Bay areas).

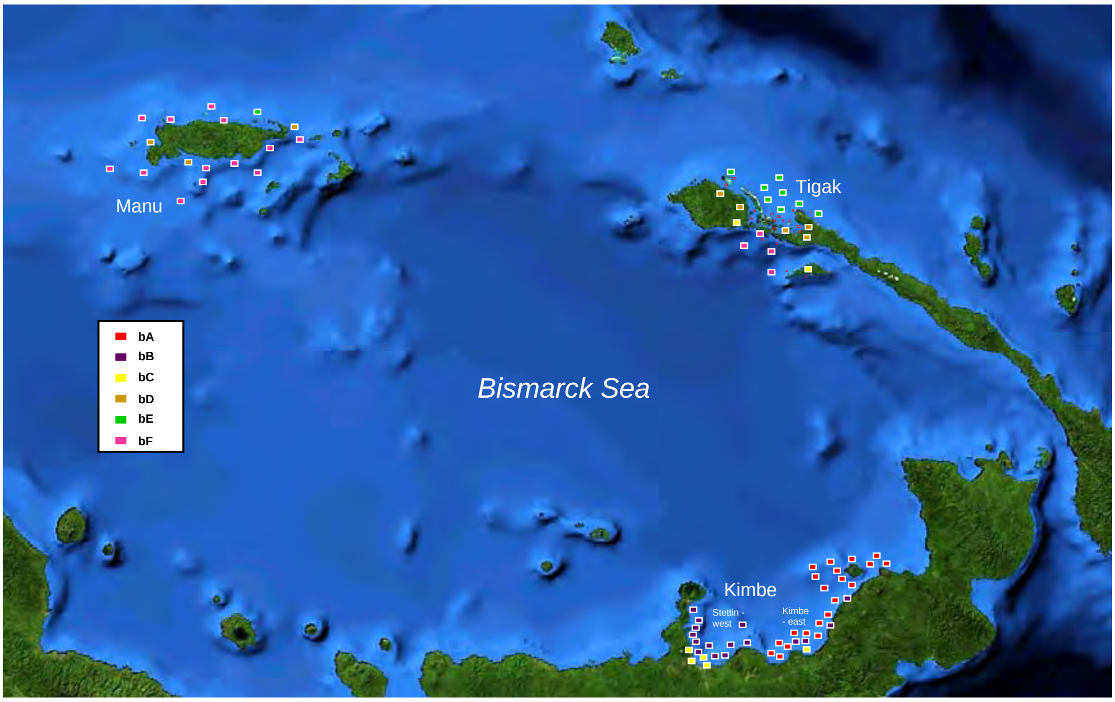

Figure 13. Distribution of coral communities, Bismarck Sea, where: red – community bA; purple – community bB; yellow – community bC; brown – community bD; green – community bE; pink – community bF.

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APPENDICES

APPENDIX I. Details of sites surveyed in the Northern Bismarck Sea, 2006. GPS locations using WGS 84 datum. Site #.1 - deep. Site #.2- shallow. RD – Reef development.

Location	Site name	site	lat. deg.	lat. dec. min.	long. deg	long. dec. min.	Max. depth (m)	Min. depth (m)	Slope	RD	Date
Tigak	Baudisson	**1.1**	2	44.611	150	39.396	35	10	80	4	15-Aug-06
Tigak	Baudisson	**1.2**	2	44.611	150	39.396	8	1	5	4	15-Aug-06
Tigak	Limalam	**2.1**	2	41.112	150	46.708	16	7	40	3	15-Aug-06
Tigak	Limalam	**2.2**	2	41.112	150	46.708	7	1	10	3	15-Aug-06
Djual	Banabis	**3.1**	2	57.764	150	49.02	19	8	30	4	16-Aug-06
Djual	Banabis	**3.2**	2	57.764	150	49.02	8	1	5	4	16-Aug-06
Djual	Lakaiang	**4.1**	2	58.593	150	43.513	33	10	70	4	16-Aug-06
Djual	Lakaiang	**4.2**	2	58.593	150	43.513	8	1	10	4	16-Aug-06
Tigak	Nusalaman	**5.1**	2	36.541	150	40.655	26	10	20	4	17-Aug-06
Tigak	Nusalaman	**5.2**	2	36.541	150	40.655	8	0.5	10	4	17-Aug-06
Tigak	Enuk	**6.1**	2	38.271	150	43.879	18	10	10	4	17-Aug-06
Tigak	Enuk	**6.2**	2	38.271	150	43.879	8	0.5	10	4	17-Aug-06
Tigak	Maiom	**7.1**	2	34.771	150	49.96	23	10	20	4	18-Aug-06
Tigak	Maiom	**7.2**	2	34.771	150	49.96	8	0.5	10	4	18-Aug-06
Tigak	Nusalik	**8.1**	2	34.933	150	46.215	26	10	20	4	18-Aug-06
Tigak	Nusalik	**8.2**	2	34.933	150	46.215	8	0.5	5	4	18-Aug-06
Tigak	Salabiu	**9.1**	2	42.727	150	34.051	38	10	70	4	19-Aug-06
Tigak	Salabiu	**9.2**	2	42.727	150	34.051	8	1	10	4	19-Aug-06
Tigak	Bangatan East	**10.1**	2	37.013	150	36.503	22	10	20	4	19-Aug-06
Tigak	Bangatan East	**10.2**	2	37.013	150	36.503	8	1	5	4	19-Aug-06
Tigak	Lemus North	**11.1**	2	36.574	150	38.456	23	10	20	4	20-Aug-06
Tigak	Lemus North	**11.2**	2	36.574	150	38.456	8	1	5	4	20-Aug-06
Tigak	Limalom	**12.1**	2	40.175	150	46.637	15	6	30	4	20-Aug-06
Tigak	Limalom	**12.2**	2	40.175	150	46.637	6	1	5	4	20-Aug-06
Tigak	Eusen	**13.1**	2	38.698	150	45.986	17	8	40	4	21-Aug-06
Tigak	Eusen	**13.2**	2	38.698	150	45.986	8	1	5	4	21-Aug-06
Tigak	Lemus South	**14.1**	2	38.255	150	37.487	32	10	40	3	21-Aug-06
Tigak	Lemus South	**14.2**	2	38.255	150	37.487	8	1	10	3	21-Aug-06
Tigak	Bangatan North	**15.1**	2	35.306	150	35.635	26	10	20	4	22-Aug-06
Tigak	Bangatan North	**15.2**	2	35.306	150	35.635	8	1	5	4	22-Aug-06
New Hanover	Anelava	**16.1**	2	33.93	150	28.834	14	7	30	4	22-Aug-06
New Hanover	Anelava	**16.2**	2	33.93	150	28.834	7	0.5	10	4	22-Aug-06
New Hanover	Nemto	**17.1**	2	21.098	150	20.563	18	8	10	4	23-Aug-06
New Hanover	Nemto	**17.2**	2	21.098	150	20.563	8	0.5	5	4	23-Aug-06
New Hanover	Nasalik	**18.1**	2	23.714	150	19.878	15	8	40	4	23-Aug-06
New Hanover	Nasalik	**18.2**	2	23.714	150	19.878	8	0.5	20	4	23-Aug-06
New Hanover	Palang	**19.1**	2	36.041	150	28.042	18	8	20	4	24-Aug-06
New Hanover	Palang	**19.2**	2	36.041	150	28.042	8	0.5	20	4	24-Aug-06
Manus SE	Drover	**1.1**	2	13.751	147	12.816	41	10	80	4	26-Aug-06
Manus SE	Drover	**1.2**	2	13.751	147	12.816	9	0.5	20	4	26-Aug-06
Manus SE	Onai	**2.1**	2	12.897	147	6.93	29	10	50	4	26-Aug-06
Manus SE	Onai	**2.2**	2	12.897	147	6.93	8	0.5	20	4	26-Aug-06

Location	Site name	site	lat. deg.	lat. dec. min.	long. deg	long. dec. min.	Max. depth (m)	Min. depth (m)	Slope	RD	Date
Manus SE	Portmor	**3.1**	2	6.251	147	17.07	33	10	60	4	27-Aug-06
Manus SE	Portmor	**3.2**	2	6.251	147	17.07	8	1	5	4	27-Aug-06
Manus North	Pityilu	**4.1**	1	57.126	147	14.054	24	10	10	4	27-Aug-06
Manus North	Pityilu	**4.2**	1	57.126	147	14.054	8	2	2	4	27-Aug-06
Manus North	Ponam	**5.1**	1	54.998	146	55.492	26	10	20	4	28-Aug-06
Manus North	Ponam	**5.2**	1	54.998	146	55.492	8	0.5	5	4	28-Aug-06
Manus North	Hinrun	**6.1**	1	57.978	147	0.287	11	5	30	4	28-Aug-06
Manus North	Hinrun	**6.2**	1	57.978	147	0.287	5	0.5	5	4	28-Aug-06
Manus SE	Momote	**7.1**	2	3.029	147	25.77	29	10	30	4	29-Aug-06
Manus SE	Momote	**7.2**	2	3.029	147	25.77	8	0.5	30	4	29-Aug-06
Manus SE	Momote Lagoon	**8.1**	2	2.487	147	25.586	18	10	30	4	29-Aug-06
Manus SE	Momote Lagoon	**8.2**	2	2.487	147	25.586	8	0.5	10	4	29-Aug-06
Buke	Prenpat	**9.1**	2	16.252	146	59.496	43	10	90	4	30-Aug-06
Buke	Prenpat	**9.2**	2	16.252	146	59.496	8	0.5	20	4	30-Aug-06
Buke	Tawi	**10.1**	2	11.818	146	51.082	19	10	30	4	30-Aug-06
Buke	Tawi	**10.2**	2	11.818	146	51.082	8	1	10	4	30-Aug-06
Buke	Nampom	**11.1**	2	25.818	146	48.009	40	10	50	4	31-Aug-06
Buke	Nampom	**11.2**	2	25.818	146	48.009	8	1	3	4	31-Aug-06
Buke	Anun	**12.1**	2	18.764	146	51.316	31	10	30	4	31-Aug-06
Buke	Anun	**12.2**	2	18.764	146	51.316	8	1	10	4	31-Aug-06
Kali	West of Stone Point	**13.1**	2	14.361	146	31.996	23	10	30	4	1-Sep-06
Kali	West of Stone Point	**13.2**	2	14.361	146	31.996	8	0.5	10	4	1-Sep-06
Kali	Parinte	**14.1**	2	14.625	146	17.425	33	10	70	4	1-Sep-06
Kali	Parinte	**14.2**	2	14.625	146	17.425	8	2	5	4	1-Sep-06
Kali	Salihau	**15.1**	2	5.617	146	33.257	18	9	30	4	2-Sep-06
Kali	Salihau	**15.2**	2	5.617	146	33.257	8	0.5	20	4	2-Sep-06
Kali	Moseley (Three Islands)	**16.1**	1	57.787	146	28.463	30	10	20	4	3-Sep-06
Kali	Moseley (Three Islands)	**16.2**	1	57.787	146	28.463	8	0.5	5	4	3-Sep-06
Kali	Noru (Herengan Islands)	**17.1**	1	57.554	146	37.558	25	10	30	4	3-Sep-06
Kali	Noru (Herengan Islands)	**17.2**	1	57.554	146	37.558	8	1	5	4	3-Sep-06

APPENDIX II. Ecological and environmental attributes of coral communities, Northern Bismarck Sea, 2006, where HC - Hard Coral, DC - Dead Coral, SC - Soft Coral, MA - Macro-Algae, TA - Turf Algae, CA - Coralline Algae. VIS - Underwater visibility (water clarity m), EXP - Exposure (rank 1 - 4); DIV - Species diversity of reef-building Scleractinian corals.

Location	Site name	site	HC	DC	SC	MA	TA	CA	VIS	EXP	DIV
Tigak	Baudisson	**1.1**	10	5	2	1	10	20	6	2	106
Tigak	Baudisson	**1.2**	10	5	2	2	30	2	7	3	114
Tigak	Limalam	**2.1**	30	1	2	5	10	5	6	1	99
Tigak	Limalam	**2.2**	40	1	2	2	10	5	6	2	102
Tigak	Banabis	**3.1**	10	0	0	20	10	2	4	1	44
Tigak	Banabis	**3.2**	10	0	1	30	10	0	4	4	71
Tigak	Lakaiang	**4.1**	20	0	2	0	10	10	7	2	121
Tigak	Lakaiang	**4.2**	20	0	0	0	20	5	8	3	96
Tigak	Nusalaman	**5.1**	2	1	0	20	20	20	15	2	67
Tigak	Nusalaman	**5.2**	5	1	0	5	20	10	20	4	81
Tigak	Enuk	**6.1**	30	5	3	10	10	10	8	2	82
Tigak	Enuk	**6.2**	30	5	1	3	10	10	10	3	82
Tigak	Maiom	**7.1**	10	1	1	10	10	5	15	2	104
Tigak	Maiom	**7.2**	40	1	2	5	10	10	15	4	82
Tigak	Nusalik	**8.1**	5	0	10	5	20	10	12	2	105
Tigak	Nusalik	**8.2**	30	10	0	5	10	10	12	3	98
Tigak	Salabiu	**9.1**	10	0	1	5	10	10	12	2	108
Tigak	Salabiu	**9.2**	10	0	0	2	10	10	8	3	92
Tigak	Bangatan East	**10.1**	5	0	0	2	20	0	8	2	78
Tigak	Bangatan East	**10.2**	10	5	0	1	20	10	10	3	80
Tigak	Lemus North	**11.1**	10	2	1	2	20	10	10	2	123
Tigak	Lemus North	**11.2**	30	5	0	3	5	20	12	3	94
Tigak	Limalom	**12.1**	30	0	2	2	20	3	5	1	105
Tigak	Limalom	**12.2**	80	5	3	1	10	2	5	2	126
Tigak	Eusen	**13.1**	20	0	5	20	10	2	4	1	97
Tigak	Eusen	**13.2**	50	1	5	20	10	5	8	3	79
Tigak	Lemus South	**14.1**	20	5	2	1	10	10	10	2	98
Tigak	Lemus South	**14.2**	50	5	0	0	5	10	10	3	85
Tigak	Bangatan North	**15.1**	30	1	0	3	5	10	15	2	91
Tigak	Bangatan North	**15.2**	50	2	0	2	5	20	12	3	87
New Hanover	Anelava	**16.1**	15	0	0	0	10	0	7	1	116
New Hanover	Anelava	**16.2**	30	0	0	0	10	2	7	2	107
New Hanover	Nemto	**17.1**	1	1	0	2	10	10	15	2	36
New Hanover	Nemto	**17.2**	20	5	1	3	5	20	15	4	68
New Hanover	Nasalik	**18.1**	20	1	20	5	10	2	4	1	96
New Hanover	Nasalik	**18.2**	50	3	30	5	10	5	6	2	117
New Hanover	Palang	**19.1**	10	1	5	10	10	2	6	1	63
New Hanover	Palang	**19.2**	20	2	5	10	10	0	6	2	43
Manus SE	Drover	**1.1**	20	1	3	5	10	10	20	2	125
Manus SE	Drover	**1.2**	40	1	5	5	10	10	15	3	145
Manus SE	Onai	**2.1**	20	0	3	2	10	3	6	1	117
Manus SE	Onai	**2.2**	30	0	10	5	10	2	6	2	126
Manus SE	Portmor	**3.1**	20	1	2	3	10	5	10	2	126
Manus SE	Portmor	**3.2**	20	1	2	2	20	5	8	3	112
Manus North	Pityilu	**4.1**	20	1	2	3	10	20	15	2	117
Manus North	Pityilu	**4.2**	10	0	1	5	10	10	12	4	87

Location	Site name	site	HC	DC	SC	MA	TA	CA	VIS	EXP	DIV
Manus North	Ponam	**5.1**	30	1	2	10	5	10	25	2	125
Manus North	Ponam	**5.2**	40	1	3	3	10	20	20	4	146
Manus North	Hinrun	**6.1**	40	0	10	5	10	0	5	2	118
Manus North	Hinrun	**6.2**	60	0	20	5	10	5	5	3	126
Manus SE	Momote	**7.1**	50	0	3	10	5	10	25	2	134
Manus SE	Momote	**7.2**	70	0	2	10	10	5	20	3	99
Manus SE	Momote Lagoon	**8.1**	40	0	5	20	10	0	6	1	112
Manus SE	Momote Lagoon	**8.2**	70	0	2	10	10	2	6	3	95
Buke	Prenpat	**9.1**	30	0	3	5	5	10	25	2	125
Buke	Prenpat	**9.2**	40	0	5	3	10	20	20	3	97
Buke	Tawi	**10.1**	30	0	5	10	10	2	5	1	76
Buke	Tawi	**10.2**	50	0	10	1	10	5	5	3	99
Buke	Nampom	**11.1**	30	2	2	2	10	10	20	2	123
Buke	Nampom	**11.2**	20	0	1	1	20	20	20	3	83
Buke	Anun	**12.1**	40	2	2	2	10	20	25	2	142
Buke	Anun	**12.2**	50	3	2	1	5	20	20	3	143
Kali	West of Stone Point	**13.1**	20	1	2	10	10	2	8	2	120
Kali	West of Stone Point	**13.2**	30	0	3	5	10	10	8	3	103
Kali	Parinte	**14.1**	30	0	2	3	5	20	25	2	134
Kali	Parinte	**14.2**	50	1	3	2	5	20	20	3	103
Kali	Salihau	**15.1**	20	0	5	0	10	2	4	1	101
Kali	Salihau	**15.2**	70	0	20	0	5	0	6	2	91
Kali	Moseley (Three Islands)	**16.1**	40	1	5	5	5	10	35	2	144
Kali	Moseley (Three Islands)	**16.2**	40	1	5	5	5	20	30	3	114
Kali	Noru (Herengan Islands)	**17.1**	30	2	10	2	10	3	20	2	142
Kali	Noru (Herengan Islands)	**17.2**	20	2	40	5	10	5	12	3	89

APPENDIX III. Reef-building (hermatypic) coral species of the Northern Bismarck Sea, 2006, including comparison with Kimbe Bay and the rest of PNG. The list includes confirmed species. Tigak list includes species from Charlie Veron.

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Family Astrocoeniidae Koby, 1890						
Genus Acanthastrea Milne Edwards and Haime, 1848						
Stylocoeniella armata (Ehrenberg, 1834)	•	•	•	•	•	•
Stylocoeniella cocosensis Veron, 1990		U	U	•	•	•
Stylocoeniella guentheri Bassett-Smith, 1890	•	•	•	•	•	•
Genus *Palauastrea* Yabe and Sugiyama, 1941						
Palauastrea ramosa Yabe and Sugiyama, 1941	•	•	•	•	•	•
Genus *Madracis* Milne Edwards and Haime, 1849						
Madracis kirbyi Veron and Pichon, 1976	•	•	•	•	•	•
Family Pocilloporidae Gray, 1842						
Genus *Pocillopora* Lamarck, 1816						
Pocillopora ankeli Scheer and Pillai, 1974		•	•		•	•
Pocillopora damicornis (Linnaeus, 1758)	•	•	•	•	•	•
Pocillopora danae Verrill, 1864	•	•	•	•	•	•
Pocillopora elegans Dana, 1846	•		•		•	•
Pocillopora eydouxi Milne Edwards and Haime, 1860	•	•	•	•	•	•
Pocillopora kelleheri Veron, 2000	•	•	•		•	•
Pocillopora meandrina Dana, 1846	•	•	•	•	•	•
Pocillopora verrucosa (Ellis and Solander, 1786)	•	•	•	•	•	•
Pocillopora woodjonesi Vaughan, 1918	•	•	•	•	•	•
Genus *Seriatopora* Lamarck, 1816						
Seriatopora aculeata Quelch, 1886	•	•	•	•	•	•
Seriatopora caliendrum Ehrenberg, 1834	•	•	•	•	•	•
Seriatopora dendritica Veron, 2000				•	•	•
Seriatopora guttatus Veron, 2000	U	U	U	•	•	•
Seriatopora hystrix Dana, 1846	•	•	•	•	•	•
Seriatopora stellata Quelch, 1886	•		•		•	•
Genus *Stylophora* Schweigger, 1819						
Stylophora pistillata Esper, 1797	•	•	•	•	•	•
Stylophora subseriata (Ehrenberg, 1834)		•	•	•	•	•
Family Acroporidae Verrill, 1902						
Genus *Montipora* Blainville, 1830						
Montipora aequituberculata Bernard, 1897	•	•	•	•	•	•
Montipora altasepta Nemenzo, 1967	U		U			
*Montipora angulata (*Lamarck, 1816)						•
Montipora australiensis Bernard, 1897	U	•	•		•	•
Montipora cactus Bernard, 1897	U	•	•	•	•	•
Montipora calcarea Bernard, 1897	•	•	•	•	•	•
Montipora caliculata (Dana, 1846)	•	•	•	•	•	•
Montipora capitata Dana, 1846	•		•	•	•	•
Montipora capricornis Veron, 1985	•		•		•	•
Montipora cebuensis Nemenzo, 1976	•	•	•		•	•
Montipora cocosensis Vaughan, 1918	U		U			
Montipora confusa Nemenzo, 1967	•	•	•	•	•	•
Montipora corbetensis Veron and Wallace, 1984	•	•	•		•	•
Montipora crassituberculata Bernard, 1897	•	•	•	•	•	•
Montipora danae (Milne Edwards and Haime, 1851)	•	•	•	•	•	•
Montipora deliculata Veron, 2000	•	•	•		•	•
Montipora digitata (Dana, 1846)	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Montipora efflorescens Bernard, 1897	•	•	•	•	•	•
Montipora effusa Dana, 1846	•		•		•	•
Montipora florida Nemenzo, 1967	•	•	•	•	•	•
Montipora floweri Wells, 1954	•	•	•	•	•	•
Montipora foliosa (Pallas, 1766)	•	•	•	•	•	•
*Montipora foveolata (*Dana, 1846)	•	•	•		•	•
Montipora friabilis Bernard, 1897		•	•		•	•
Montipora grisea Bernard, 1897	•	•	•	•	•	•
Montipora hirsuta Nemenzo, 1967	•	•	•		•	•
Montipora hispida (Dana, 1846)	•	•	•	•	•	•
Montipora hodgsoni Veron, 2000	U		U			•
Montipora hoffmeisteri Wells, 1954	•	•	•	•	•	•
Montipora incrassata (Dana, 1846)	•	•	•	•	•	•
Montipora informis Bernard, 1897	•	•	•	•	•	•
Montipora mactanensis Nemenzo, 1979	•	•	•	•	•	•
Montipora malampaya Nemenzo, 1967	•		•	•	•	•
Montipora meandrina (Ehrenberg, 1834)	•	U	•		•	•
Montipora millepora Crossland, 1952	•	•	•		•	•
Montipora mollis Bernard, 1897	•	•	•		•	•
Montipora monasteriata (Forskäl, 1775)	•	•	•	•	•	•
Montipora niugini Veron, 2000	•		•	•	•	•
Montipora nodosa (Dana, 1846)	•	•	•	•	•	•
Montipora orientalis Nemenzo, 1967	U		U			
Montipora plawanensis Veron, 2000	•		•	•	•	•
Montipora peltiformis Bernard, 1897	•	•	•	•	•	•
Montipora porites Veron, 2000	•	U	•	•	•	•
Montipora samarensis Nemenzo, 1967	•	U	•		•	•
Montipora spongodes Bernard, 1897	•	•	•	•	•	•
Montipora spumosa (Lamarck, 1816)	•	•	•	•	•	•
Montipora stellata Bernard, 1897	•	•	•	•	•	•
Montipora tuberculosa (Lamarck, 1816)	•	•	•	•	•	•
Montipora turgescens Bernard, 1897	•	•	•	•	•	•
Montipora turtlensis Veron and Wallace, 1984	•	•	•		•	•
Montipora undata Bernard, 1897	•	•	•	•	•	•
Montipora venosa (Ehrenberg, 1834)	•	•	•	•	•	•
Montipora verrucosa (Lamarck, 1816)	•	•	•		•	•
Montipora verruculosus Veron, 2000	•	•	•	•	•	•
Montipora vietnamensis Veron, 2000	•	•	•	•	•	•
Genus *Anacropora* Ridley, 1884						
Anacropora forbesi Ridley, 1884	•	•	•	•	•	•
Anacropora matthai Pillai, 1973	•		•		•	•
Anacropora pillai Veron, 2000	U	U	U			
Anacropora puertogalerae Nemenzo, 1964	•	•	•	•	•	•
Anacropora reticulata Veron and Wallace, 1984	•	•	•	•	•	•
Anacropora spinosa Rehberg, 1892	•	U	•	•	•	•
Genus *Acropora* Oken, 1815						
*Acropora abrolhosensis*Veron, 1985	•		•		•	•
Acropora abrotanoides (Lamarck, 1816)	•	•	•	•	•	•
Acropora aculeus (Dana, 1846)	•	•	•	•	•	•
Acropora acuminata (Verrill, 1864)	•	•	•	•	•	•
Acropora anthocercis (Brook, 1893)	•	•	•	•	•	•
Acropora aspera (Dana, 1846)	•		•	•	•	•
Acropora austera (Dana, 1846)	•	•	•	•	•	•
Acropora awi Wallace and Wolstenholme, 1998	•	•	•	•	•	•
Acropora batunai Wallace, 1997				•	•	•
Acropora bifurcata Nemenzo, 1971	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Acropora brueggemanni (Brook, 1893)	•	•	•	•	•	•
Acropora carduus (Dana, 1846)	•	•	•	•	•	•
Acropora caroliniana Nemenzo, 1976	•	•	•	•	•	•
Acropora cerealis (Dana, 1846)	•	•	•	•	•	•
Acropora clathrata (Brook, 1891)	•	•	•	•	•	•
Acropora cophodactyla (Brook, 1892)	•	•	•	•	•	•
Acropora copiosa Nemenzo, 1967				•	•	•
Acropora crateriformis (Gardiner, 1898)						•
Acropora cuneata (Dana, 1846)	•	•	•	•	•	•
Acropora cylindrica Veron and Fenner, 2000	•		•		•	•
Acropora cytherea (Dana, 1846)	•	•	•	•	•	•
Acropora dendrum (Bassett-Smith, 1890)	•	U	•		•	•
Acropora derewanensis Wallace (1997)						•
Acropora desalwii Wallace, 1994	•	•	•	•	•	•
Acropora digitifera (Dana, 1846)	•	•	•	•	•	•
Acropora divaricata (Dana, 1846)	•	•	•	•	•	•
Acropora donei Veron and Wallace, 1984	•		•		•	•
Acropora echinata (Dana, 1846)	•	•	•	•	•	•
Acropora elegans Milne Edwards and Haime, 1860	U		U	•	•	•
Acropora elseyi (Brook, 1892)	•	•	•	•	•	•
Acropora exquisita Nemenzo, 1971						•
Acropora florida (Dana, 1846)	•	•	•	•	•	•
Acropora formosa (Dana, 1846)	•	•	•	•	•	•
Acropora gemmifera (Brook, 1892)	•	•	•	•	•	•
Acropora glauca (Brook, 1893)	U		U			
Acropora globiceps (Dana, 1846)		•	•		•	•
Acropora grandis (Brook, 1892)	•	•	•	•	•	•
Acropora granulosa (Milne Edwards and Haime, 1860)	•	•	•	•	•	•
Acropora hoeksemai Wallace, 1997		•	•		•	•
Acropora horrida (Dana, 1846)	•	•	•	•	•	•
Acropora humilis (Dana, 1846)	•	•	•	•	•	•
Acropora hyacinthus (Dana, 1846)	•	•	•	•	•	•
Acropora inermis (Brook, 1891)	U		U			
Acropora insignis Nemenzo, 1967	•	U	•	•	•	•
Acropora irregularis (Brook, 1892)		•	•		•	•
Acropora jacquelineae Wallacew, 1994	•	•	•	•	•	•
Acropora kimbeensis Wallace, 1999	•	•	•	•	•	•
Acropora kirstyae Veron and Wallace, 1984				•	•	•
Acropora latistella (Brook, 1891)	•	•	•	•	•	•
Acropora lianae Nemenzo, 1967	U		U			
Acropora listeri (Brook, 1893)	U	•	•	•	•	•
Acropora lokani Wallace, 1994	•	•	•	•	•	•
Acropora longicyathus (Milne Edwards and Haime, 1860)	•	•	•	•	•	•
Acropora loripes (Brook, 1892)	•	•	•	•	•	•
Acropora lutkeni Crossland, 1952	•	•	•	•	•	•
Acropora microclados (Ehrenberg, 1834)	•	•	•	•	•	•
Acropora microphthalma (Verrill, 1859)	•	•	•	•	•	•
Acropora millepora (Ehrenberg, 1834)	•	•	•	•	•	•
Acropora monticulosa (Brüggemann, 1879)	•	•	•	•	•	•
Acropora multiacuta Nemenzo, 1967						•
Acropora nana (Studer, 1878)	•	•	•	•	•	•
Acropora nasuta (Dana, 1846)	•	•	•	•	•	•
Acropora navini Veron, 2000		•	•		•	•
Acropora nobilis (Dana, 1846)	•	•	•	•	•	•
Acropora palifera (Lamarck, 1816)	•	•	•	•	•	•
Acropora palmerae Wells, 1954	•	•	•		•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Acropora paniculata Verrill, 1902	•	•	•	•	•	•
Acropora papillarae Latypov, 1992	•	•	•		•	•
Acropora parilis (Quelch, 1886)						•
Acropora pichoni Wallace, 1999	•		•	•	•	•
Acropora pinguis Wells, 1950		•	•		•	•
Acropora plana Nemenzo, 1967	U			•	•	•
Acropora plumosa Wallace and Wolstenholme, 1998	•	•	•	•	•	•
Acropora polystoma (Brook, 1891)	•	•	•	•	•	•
Acropora prostrata (Dana, 1846)	•		•		•	•
Acropora pruinosa (Brook, 1893)		•	•		•	•
Acropora pulchra (Brook, 1891)	•	•	•		•	•
Acropora rambleri (Bassett-Smith, 1890)						•
Acropora robusta (Dana, 1846)	•	•	•	•	•	•
Acropora rosaria (Dana, 1846)		U	U			•
Acropora russelli, Wallace, 1994	•		•		•	•
*Acropora samoensis (*Brook, 1891)	•	•	•	•	•	•
Acropora sarmentosa (Brook, 1892)	•	•	•	•	•	•
Acropora secale (Studer, 1878)	•	•	•	•	•	•
Acropora sekiseiensis Veron, 1990						•
Acropora selago (Studer, 1878)	•	•	•	•	•	•
Acropora seriata Ehrenberg, 1834						•
Acropora simplex Wallace and Wolstenholme, 1998	•		•		•	•
Acropora solitaryensis Veron and Wallace, 1984	•	•	•	•	•	•
Acropora spathulata (Brook, 1891)		•	•	•	•	•
Acropora speciosa (Quelch, 1886)	•	•	•	•	•	•
Acropora spicifera (Dana, 1846)						•
Acropora striata (Verrill, 1866)	•	U	•	•	•	•
Acropora subglabra (Brook, 1891)	•	•	•	•	•	•
Acropora subulata (Dana, 1846)	•	•	•	•	•	•
Acropora tenella (Brook, 1892)				•	•	•
Acropora tenuis (Dana, 1846)	•	•	•	•	•	•
Acropora turaki Wallace, 1994	•	•	•		•	•
Acropora tutuilensis Hoffmeister, 1925		•	•		•	•
Acropora valenciennesi (Milne Edwards and Haime, 1860)	•	•	•	•	•	•
Acropora valida (Dana, 1846)	•	•	•	•	•	•
*Acropora vaughani*Wells, 1954	•	•	•		•	•
Acropora verweyi Veron and Wallace, 1984	•	•	•	•	•	•
Acropora walindii Wallace, 1999				•	•	•
Acropora wallaceae Veron, 1990						•
Acropora willisae Veron and Wallace, 1984						•
Acropora yongei Veron and Wallace, 1984	•	•	•	•	•	•
Genus *Astreopora* Blainville, 1830						
Astreopora cuculata Lamberts, 1980	•	•	•	•	•	•
Astreopora expansa Brüggemann, 1877	•		•	•	•	•
Astreopora gracilis Bernard, 1896	•	•	•	•	•	•
Astreopora incrustans Bernard, 1896	U		U			•
Astreopora listeri Bernard, 1896	•	•	•	•	•	•
Astreopora macrostoma Veron and Wallace, 1984	•		•		•	•
Astreopora moretonensis Veron and Wallace, 1984	U					
Astreopora myriophthalma (Lamarck, 1816)	•	•	•	•	•	•
Astreopora ocellata Bernard, 1896	•	•	•		•	•
Astreopora randalli Lamberts, 1980	•	•	•	•	•	•
Astreopora scabra Lamberts, 1982	•		•		•	•
Astreopora suggesta Wells, 1954	•	•	•	•	•	•
Family Euphilliidae Veron, 2000						

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Genus *Euphyllia* Dana, 1846						
Euphyllia ancora Veron and Pichon, 1979	•	•	•	•	•	•
Euphyllia cristata Chevalier, 1971	•	•	•	•	•	•
Euphyllia divisa Veron and Pichon, 1980						•
Euphyllia glabrescens (Chamisso and Eysenhardt, 1821)	•	•	•	•	•	•
Euphyllia paraancora Veron, 1990	•		•	•	•	•
Euphyllia paradivisa Veron, 1990		•	•		•	•
Euphyllia yaeyamensis (Shirai, 1980)	•	•	•	•	•	•
Genus *Catalaphyllia* Wells, 1971						
Catalaphyllia jardinei (Saville-Kent, 1893)	•		•	•	•	•
Genus *Plerogyra* Milne Edwards and Haime, 1848						
Plerogyra simplex Rehberg, 1892	•	•	•	•	•	•
Plerogyra sinuosa (Dana, 1846)	•	•	•	•	•	•
Genus *Physogyra* Quelch, 1884						
*Physogyra lichtensteini (*Milne Edwards and Haime, 1851)	•	•	•	•	•	•
Family Oculinidae Gray, 1847						
Genus *Galaxea* Oken, 1815						
Galaxea acrhelia Veron, 2000	•	•	•	•	•	•
Galaxea astreata (Lamarck, 1816)	•	•	•	•	•	•
Galaxea cryptoramosa Fenner and Veron, 2000	•	•	•	•	•	•
Galaxea fascicularis (Linnaeus, 1767)	•	•	•	•	•	•
Galaxea horrescens (Dana, 1846)	•	•	•	•	•	•
Galaxea longisepta Fenner & Veron, 2000	•	•	•	•	•	•
Galaxea paucisepta Claereboudt, 1990	•	•	•	•	•	•
Family Siderasteridae Vaughan and Wells, 1943						
Genus *Pseudosiderastrea* Yabe and Sugiyama, 1935						
Pseudosiderastrea tayami Yabe and Sugiyama, 1935	•	•	•	•	•	•
Genus *Psammocora* Dana, 1846						
Psammocora contigua (Esper, 1797)	•	•	•	•	•	•
Psammocora digitata Milne Edwards and Haime, 1851	•	•	•	•	•	•
Psammocora explanulata Horst, 1922	•	•	•	•	•	•
Psammocora haimeana Milne Edwards and Haime, 1851	•	•	•	•	•	•
Psammocora nierstraszi Horst, 1921	•	•	•	•	•	•
Psammocora obtusangula (Lamarck, 1816)	•	•	•	•	•	•
Psammocora profundacella Gardiner, 1898	•	•	•	•	•	•
Psammocora superficialis Gardiner, 1898	•	•	•	•	•	•
Genus *Coscinaraea* Milne Edwards and Haime, 1848						
Coscinaraea columna (Dana, 1846)	•	•	•	•	•	•
Coscinaraea crassa Veron and Pichon, 1980						•
Coscinaraea exesa (Dana, 1846)	•	•	•	•	•	•
Coscinaraea monile (Foskål, 1775)	•	•	•		•	•
Coscinaraea wellsi Veron and Pichon, 1980	•	•	•	•	•	•
Family Agariciidae Gray, 1847						
Genus *Agaricia* Lamarck, 1801						
Genus *Pavona* Lamarck, 1801						
Pavona bipartita Nemenzo, 1980	•	•	•	•	•	•
Pavona cactus (Forskål, 1775)	•	•	•	•	•	•
Pavona clavus (Dana, 1846)	•	•	•	•	•	•
Pavona decussata (Dana, 1846)	•	•	•	•	•	•
Pavona duerdeni Vaughan, 1907	•	•	•	•	•	•
Pavona explanulata (Lamarck, 1816)	•	•	•	•	•	•
Pavona frondifera (Lamarck, 1816)	•	•	•	•	•	•
Pavona maldivensis (Gardiner, 1905)	U	U	U			•
Pavona minuta Wells, 1954	•	•	•	•	•	•
Pavona varians Verrill, 1864	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Pavona venosa (Ehrenberg, 1834)	•	•	•	•	•	•
Genus *Leptoseris* Milne Edwards and Haime, 1849						
Leptoseris amitoriensis Veron, 1990	•		•		•	•
Leptoseris explanata Yabe and Sugiyama, 1941	•	•	•	•	•	•
Leptoseris foliosa Dineson, 1980	•	•	•	•	•	•
Leptoseris gardineri Horst, 1921	•	•	•	•	•	•
Leptoseris hawaiiensis Vaughan, 1907	•	•	•	•	•	•
Leptoseris incrustans (Quelch, 1886)	•	•	•	•	•	•
Leptoseris mycetoseroides Wells, 1954	•	•	•	•	•	•
Leptoseris papyracea (Dana, 1846)	•		•	•	•	•
Leptoseris scabra Vaughan, 1907	•	•	•	•	•	•
Leptoseris solida (Quelch, 1886)	•	•	•	•	•	•
Leptoseris striata (Fenner & Veron 2000)	•	•	•	•	•	•
Leptoseris tubulifera Vaughan, 1907	•	•	•	•	•	•
Leptoseris yabei (Pillai and Scheer, 1976)	•	•	•	•	•	•
Genus *Coeloseris* Vaughan, 1918						
Coeloseris mayeri Vaughan, 1918	•	•	•	•	•	•
Genus *Gardineroseris* Scheer and Pillai, 1974						
Gardineroseris planulata Dana, 1846	•	•	•	•	•	•
Genus *Pachyseris* Milne Edwards and Haime, 1849						
Pachyseris foliosa Veron, 1990	•	•	•	•	•	•
Pachyseris gemmae Nemenzo, 1955		U	U	•	•	•
Pachyseris involuta (Studer, 1877)	U	•	•		•	•
Pachyseris rugosa (Lamarck, 1801)	•	•	•	•	•	•
Pachyseris speciosa (Dana, 1846)	•	•	•	•	•	•
Family Fungiidae Dana, 1846						
Genus *Cycloseris* Milne Edwards and Haime, 1849						
Cycloseris colini Veron, 2000		•	•		•	•
Cycloseris costulata (Ortmann, 1889)	U	•	•	•	•	•
Cycloseris curvata (Hoeksema, 1989)	U	U	U			•
Cycloseris cyclolites Lamarck, 1801		•	•	•	•	•
Cycloseris erosa (Döderlein, 1901)	•	•	•		•	•
Cycloseris patelliformis (Boschma, 1923)	•	•	•	•	•	•
Cycloseris sinensis Milne Edwards and Haime, 1851)	•	•	•	•	•	•
Cycloseris somervillei (Gardiner, 1909)	•	•	•	•	•	•
Cycloseris tenuis (Dana, 1846)	•		•		•	•
Cycloseris vaughani (Boschma, 1923)	•	U	•		•	•
Genus *Diaseris*						
Diaseris fragilis Alcock, 1893	•	•	•		•	•
Genus *Cantharellus* Hoeksema and Best, 1984						
Cantharellus jebbi Hoeksema, 1993	•	•	•	•	•	•
Cantharellus nuomeae Hoeksema & Best, 1984		•	•	•	•	•
Genus *Helliofungia* Wells, 1966						
Heliofungia actiniformis Quoy and Gaimard, 1833	•	•	•	•	•	•
Genus *Fungia* Lamarck, 1801						
Fungia concinna Verrill, 1864	•	•	•	•	•	•
Fungia danai Milne Edwards and Haime, 1851	•	•	•	•	•	•
Fungia fralinae Nemenzo, 1955	•	•	•		•	•
Fungia fungites (Linneaus, 1758*)*	•	•	•	•	•	•
Fungia granulosa Klunzinger, 1879	•	•	•	•	•	•
Fungia gravis Nemenzo, 1955	•	•	•	•	•	•
Fungia horrida Dana, 1846	•	•	•	•	•	•
Fungia klunzingeri Döderlein, 1901	•	•	•	•	•	•
Fungia moluccensis Horst, 1919	•	•	•	•	•	•
Fungia paumotensis Stutchbury, 1833	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Fungia repanda Dana, 1846	•	•	•	•	•	•
Fungia scabra Döderlein, 1901		•	•	•	•	•
Fungia scruposa Klunzinger, 1879	•	•	•	•	•	•
Fungia scutaria Lamarck, 1801	•	•	•	•	•	•
Fungia spinifer Claereboudt and Hoeksema, 1987	•	•	•	•	•	•
Fungia taiwanensis Hoeksema and Dai, 1991	•	•	•		•	•
Genus *Ctenactis* Verrill, 1864						
Ctenactis albitentaculata Hoeksema, 1989	•	•	•	•	•	•
Ctenactis crassa (Dana, 1846)	•	•	•	•	•	•
Ctenactis echinata (Pallas, 1766)	•	•	•	•	•	•
Genus *Herpolitha* Eschscholtz, 1825						
Herpolitha limax (Houttuyn, 1772)	•	•	•	•	•	•
Herpolitha weberi Horst, 1921	•	•	•	•	•	•
Genus *Polyphyllia* Quoy and Gaimard, 1833						
Polyphyllia novaehiberniae (Lesson, 1831)	•		•	•	•	•
Polyphyllia talpina (Lamarck, 1801)	•	•	•	•	•	•
Genus *Sandalolitha* Quelch, 1884						
Sandalolitha dentata (Quelch, 1886)	•	•	•	•	•	•
Sandalolitha robusta Quelch, 1886	•	•	•	•	•	•
Genus *Halomitra* Dana, 1846						
Halomitra clavator Hoeksema, 1989				•	•	•
Halomitra pileus (Linnaeus, 1758)	•	•	•	•	•	•
Genus *Zoopilus* Dana, 1864						
Zoopilus echinatus Dana, 1846	•	•	•	•	•	•
Genus *Lithophyllum* Rehberg, 1892						
Lithophyllon lobata Hoeksema, 1989	•	•	•		•	•
Lithophyllon mokai Hoeksema, 1989	•	•	•	•	•	•
Lithophyllon undulatum Rehberg, 1892		•	•	•	•	•
Genus *Podabacia* Milne Edwards and Haime, 1849						
Podabacia crustacea (Pallas, 1766)	•	•	•	•	•	•
Podabacia motuporensis Veron, 1990	•	•	•	•	•	•
Family Pectinidae Vaughan and Wells, 1943						
Genus *Echinophyllia* Klunzinger, 1879						
Echinophyllia aspera (Ellis and Solander, 1788)	•	•	•	•	•	•
Echinophyllia echinata (Saville-Kent, 1871)	•	•	•	•	•	•
Echinophyllia echinoporoides Veron and Pichon, 1979	•	•	•	•	•	•
Echinophyllia orpheensis Veron and Pichon, 1980	•	•	•	•	•	•
Echinophyllia patula (Hodgson and Ross, 1982)	U		U	•	•	•
Genus *Echinomorpha* Veron, 2000						
Echinomorpha nishihirea (Veron, 1990)		•	•		•	•
Genus *Oxypora* Saville-Kent, 1871						
Oxypora crassispinosa Nemenzo, 1979	•	•	•	•	•	•
Oxypora glabra Nemenzo, 1959	•	•	•	•	•	•
Oxypora lacera Verrill, 1864	•	•	•	•	•	•
Genus *Mycedium* Oken, 1815						
Mycedium elephatotus (Pallas, 1766)	•	•	•	•	•	•
Mycedium robokaki Moll and Best, 1984	•	•	•	•	•	•
Mycedium mancaoi Nemenzo, 1979	•	•	•	•	•	•
Genus *Pectinia* Oken, 1815						
Pectinia alcicornis (Saville-Kent, 1871)	•	•	•	•	•	•
Pectinia ayleni (Wells, 1935)	•		•	•	•	•
Pectinia elongata Rehberg, 1892	•	•	•	•	•	•
Pectinia lactuca (Pallas, 1766)	•	•	•	•	•	•
Pectinia maxima (Moll and Borel Best, 1984)	•	•	•		•	•
Pectinia paeonia (Dana, 1846)	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Pectinia pygmaeus Veron, 2000	U		U	•	•	•
Pectinia teres Nemenzo and montecillo, 1981	•	•	•	•	•	•
Family Merulinidae Verrill, 1866						
Genus *Hydnophora* Fischer de Waldheim, 1807						
Hydnophora exesa (Pallas, 1766)	•	•	•	•	•	•
Hydnophora grandis Gardiner, 1904		•	•	•	•	•
Hydnophora microconos (Lamarck, 1816)	•	•	•	•	•	•
Hydnophora pilosa Veron, 1985	•	•	•		•	•
Hydnophora rigida (Dana, 1846)	•	•	•	•	•	•
Genus *Paraclavarina* Veron, 1985						
Paraclavarina triangularis (Veron & Pichon, 1980)		•	•		•	•
Genus *Merulina* Ehrenberg, 1834						
Merulina ampliata (Ellis and Solander, 1786)	•	•	•	•	•	•
Merulina scabricula Dana, 1846	•	•	•	•	•	•
Genus *Scapophyllia* Milne Edwards and Haime, 1848						
Scapophyllia cylindrica Milne Edwards and Haime, 1848	•	U	•	•	•	•
Family Dendrophylliidae Gray, 1847						
Genus *Turbinaria* Oken, 1815						
Turbinaria frondens (Dana, 1846)	•	•	•	•	•	•
Turbinaria irregularis, Bernard, 1896	•	•	•	•	•	•
Turbinaria mesenterina (Lamarck, 1816)	•	•	•	•	•	•
Turbinaria patula (Dana, 1846)				•	•	•
Turbinaria peltata (Esper, 1794)	•	•	•	•	•	•
Turbinaria radicalis Bernard, 1896		•	•		•	•
Turbinaria reniformis Bernard, 1896	•	•	•	•	•	•
Turbinaria stellulata (Lamarck, 1816)	•	•	•	•	•	•
Family Mussidae Ortmann, 1890						
Genus *Blastomussa* Wells, 1961						
Genus *Micromussa* Veron, 2000						
Micromussa amakusensis (Veron, 1990)	•	•	•	•	•	•
Micromussa minuta (Moll and Borel-Best, 1984)				•	•	•
Genus *Acanthastrea* Milne Edwards and Haime, 1848						
Acanthastrea brevis Milne Edwards and Haime, 1849	•	•	•	•	•	•
Acanthastrea echinata (Dana, 1846)	•	•	•	•	•	•
Acanthastrea faviaformis Veron, 2000		•	•		•	•
Acanthastrea hemprichii (Ehrenberg, 1834)	•	•	•		•	•
Acanthastrea hillae Wells, 1955						•
Acanthastrea lordhowensis Veron & Pichon, 1982		•	•		•	•
Acanthastrea regularis Veron, 2000	•	•	•	•	•	•
Acanthastrea rotundoflora Chevalier, 1975	•	•	•	•	•	•
Acanthastrea subechinata Veron, 2000	•	•	•	•	•	•
Genus *Lobophyllia* Blainville, 1830						
Lobophyllia corymbosa (Forskål, 1775)	•	•	•	•	•	•
Lobophyllia dentatus Veron, 2000	•	•	•	•	•	•
Lobophyllia diminuta Veron, 1985		•	•		•	•
Lobophyllia flabelliformis Veron, 2000		•	•	•	•	•
Lobophyllia hataii Yabe and Sugiyama, 1936	•	•	•	•	•	•
Lobophyllia hemprichii (Ehrenberg, 1834)	•	•	•	•	•	•
Lobophyllia pachysepta Chevalier, 1975						•
Lobophyllia robusta Yabe and Sugiyama, 1936	•	•	•	•	•	•
Lobophyllia serratus Veron, 2000						•
Genus *Symphyllia* Milne Edwards and Haime, 1848						
Symphyllia agaricia Milne Edwards and Haime, 1849	•	•	•	•	•	•
Symphyllia hassi Pillai and Scheer, 1976	•	•	•		•	•
Symphyllia radians Milne Edwards and Haime, 1849	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Symphyllia recta (Dana, 1846)	•	•	•	•	•	•
Symphyllia valenciennesii Milne Edwards and Haime, 1849	•	•	•	•	•	•
Genus *Scolymia* Haime, 1852						
Scolymia australis (Milne Edwards and Haime, 1849)	U	•	•	•	•	•
Scolymia vitiensis Brüggemann, 1878	•	•	•	•	•	•
Genus *Australomussa* Veron, 1985						
Australomussa rowleyensis Veron, 1985	•	•	•		•	•
Genus *Cynarina* Brüggemann, 1877						
Cynarina lacrymalis (Milne Edwards and Haime, 1848)	•	•	•	•	•	•
Family Faviidae Gregory, 1900						
Genus *Caulastrea* Dana, 1846						
Caulastrea curvata Wijsmann-Best, 1972	•	•	•	•	•	•
Caulastrea echinulata (Milne Edwards and Haime, 1849)						•
Caulastrea furcata Dana, 1846	•	•	•	•	•	•
Genus *Favia* Oken, 1815						
Favia danae Verrill, 1872	•	•	•	•	•	•
Favia favus (Forskål, 1775)	•	•	•	•	•	•
Favia helianthoides Wells, 1954		•	•		•	•
Favia laxa (Klunzinger, 1879)	•	•	•	•	•	•
Favia lizardensis Veron and Pichon, 1977	•	•	•	•	•	•
Favia maritima (Nemenzo, 1971)	•	•	•	•	•	•
Favia marshae Veron, 2000	•	•	•		•	•
Favia matthai Vaughan, 1918	•	•	•	•	•	•
Favia maxima Veron, Pichon & Wijsman-Best, 1972	•	•	•		•	•
Favia pallida (Dana, 1846)	•	•	•	•	•	•
Favia rosaria Veron, 2000	•	•	•		•	•
Favia rotumana (Gardiner, 1899)	•	•	•	•	•	•
Favia rotundata Veron, Pichon & Wijsman-Best, 1972	•	•	•	•	•	•
Favia speciosa Dana, 1846	•	•	•	•	•	•
Favia stelligera (Dana, 1846)	•	•	•	•	•	•
Favia truncatus Veron, 2000	•	•	•	•	•	•
Favia veroni Moll and Borel-Best, 1984		•	•	•	•	•
Genus *Barabattoia* Yabe and Sugiyama, 1941						
Barabattoia amicorum (Milne Edwards and Haime, 1850)	•	•	•	•	•	•
Barabattoia laddi (Wells, 1954)	U		U	•	•	•
Genus *Favites* Link, 1807						
Favites abdita (Ellis and Solander, 1786)	•	•	•	•	•	•
Favites acuticulis (Ortmann, 1889)	U	•	•		•	•
Favites bestae Veron, 2000	U	U	U			
Favites chinensis (Verrill, 1866)	•	•	•	•	•	•
Favites complanata (Ehrenberg, 1834)	•	•	•	•	•	•
Favites flexuosa (Dana, 1846)	•	•	•	•	•	•
Favites halicora (Ehrenberg, 1834)	•	•	•	•	•	•
Favites micropentagona Veron, 2000				•	•	•
Favites paraflexuosa Veron, 2000	•		•	•	•	•
Favites pentagona (Esper, 1794)	•	•	•	•	•	•
Favites russelli (Wells, 1954)	•	•	•	•	•	•
Favites spinosa (Klunzinger, 1879)				•	•	•
Favites stylifera (Yabe and Sugiyama, 1937)	•	•	•	•	•	•
Favites vasta (Klunzinger, 1879)	•	•	•	•	•	•
Genus *Goniastrea* Milne Edwards and Haime, 1848						
Goniastrea aspera Verrill, 1905	•	•	•	•	•	•
Goniastrea australensis (Milne Edwards and Haime, 1857)	•	•	•	•	•	•
Goniastrea deformis Veron, 1990		•	•		•	•
Goniastrea edwardsi Chevalier, 1971	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Goniastrea favulus (Dana, 1846)		•	•		•	•
Goniastrea minuta Veron, 2000				•	•	•
Goniastrea palauensis (Yabe and Sugiyama, 1936)		•	•		•	•
Goniastrea pectinata (Ehrenberg, 1834)	•	•	•	•	•	•
Goniastrea ramosa Veron, 2000				•	•	•
Goniastrea retiformis (Lamarck, 1816)	•	•	•	•	•	•
Genus *Platygyra* Ehrenberg, 1834						
Platygyra acuta Veron, 2000	•	•	•	•	•	•
Platygyra contorta Veron, 1990	•	•	•	•	•	•
Platygyra daedalea (Ellis and Solander, 1786)	•	•	•	•	•	•
Platygyra lamellina (Ehrenberg, 1834)	•	•	•	•	•	•
Platygyra pini Chevalier, 1975	•	•	•	•	•	•
Platygyra ryukyuensis Yabe and Sugiyama, 1936	•	•	•	•	•	•
Platygyra sinensis (Milne Edwards and Haime, 1849)	•	•	•	•	•	•
Platygyra verweyi Wijsman-Best, 1976	•	•	•	•	•	•
Platygyra yaeyemaensis Eguchi and Shirai, 1977	•	•	•	•	•	•
Genus *Australogyra* Veron & Pichon, 1982						
Australogyra zelli (Veron & Pichon, 1977)		•	•		•	•
Genus *Oulophyllia* Milne Edwards and Haime, 1848						
Oulophyllia bennettae (Veron & Pichon, 1977)	•	•	•	•	•	•
Oulophyllia crispa (Lamarck, 1816)	•	•	•	•	•	•
Oulophyllia levis Nemenzo, 1959	•	•	•		•	•
Genus *Leptoria* Milne Edwards and Haime, 1848						
Leptoria irregularis Veron, 1990		•	•	•	•	•
Leptoria phrygia (Ellis and Solander, 1786)	•	•	•	•	•	•
Genus *Montastrea* Blainville, 1830						
Montastrea annuligera (Milne Edwards and Haime, 1849)	•	•	•	•	•	•
Montastrea colemani Veron, 2000		•	•	•	•	•
Montastrea curta (Dana, 1846)	•	•	•	•	•	•
Montastrea magnistellata Chevalier, 1971	•	•	•	•	•	•
Montastrea multipunctata Hodgson, 1985						•
Montastrea salebrosa (Nemenzo, 1959)	•		•	•	•	•
Montastrea valenciennesi (Milne Edwards and Haime, 1848)	•	•	•	•	•	•
Genus *Plesiastrea* Milne Edwards and Haime, 1848						
Plesiastrea versipora (Lamarck, 1816)	•	•	•	•	•	•
Genus *Oulastrea* Milne Edwards and Haime, 1848						
Oulastrea crispata (Lamarck, 1816)				•	•	•
Genus *Diploastrea* Matthai, 1914						
Diploastrea heliopora (Lamarck, 1816)	•	•	•	•	•	•
Genus *Leptastrea* Milne Edwards and Haime, 1848						
Leptastrea aequalis Veron, 2000	•	•	•		•	•
Leptastrea bewickensis Veron & Pichon, 1977						•
Leptastrea inaequalis Klunzinger, 1879	•	•	•		•	•
Leptastrea pruinosa Crossland, 1952	•	•	•	•	•	•
Leptastrea purpurea (Dana, 1846)	•	•	•	•	•	•
Leptastrea transversa Klunzinger, 1879	•	•	•	•	•	•
Genus *Parasimplastrea* Sheppard, 1985						
Genus *Cyphastrea* Milne Edwards and Haime, 1848						
Cyphastrea agassizi (Vaughan, 1907)		•	•	•	•	•
Cyphastrea chalcidium (Forskål, 1775)	•	•	•	•	•	•
Cyphastrea decadia Moll and Best, 1984		•	•	•	•	•
Cyphastrea japonica Yabe and Sugiyama, 1932	•		•		•	•
Cyphastrea microphthalma (Lamarck, 1816)	•	•	•	•	•	•
Cyphastrea ocellina (Dana, 1864)	•	•	•	•	•	•
Cyphastrea serailia (Forskål, 1775)	•	•	•	•	•	•
Genus *Echinopora* Lamarck, 1816						

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Echinopora gemmacea Lamarck, 1816	•	•	•	•	•	•
Echinopora hirsutissima Milne Edwards and Haime, 1849		•	•	•	•	•
Echinopora horrida Dana, 1846	•	•	•	•	•	•
Echinopora lamellosa (Esper, 1795)	•	•	•	•	•	•
Echinopora mammiformis (Nemenzo, 1959)	•	•	•	•	•	•
Echinopora pacificus Veron, 1990	•	•	•	•	•	•
Echinopora taylorae (Veron, 2000)		•	•		•	•
Family Trachyphyllidae Verrill, 1901						
Genus *Trachyphyllia* Milne Edwards and Haime, 1848						
Trachyphyllia geoffroyi (Audouin, 1826)	•		•	•	•	•
Family Poritidae Gray, 1842						
Genus *Porites* Link, 1807						
Porites annae Crossland, 1952	•		•	•	•	•
Porites aranetai Nemenzo, 1955				•	•	•
Porites attenuata Nemenzo 1955	•	•	•	•	•	•
*Porites australiensis*Vaughan, 1918	•	•	•		•	•
Porites cumulatus Nemenzo, 1955	U	•	•		•	•
Porites cylindrica Dana, 1846	•	•	•	•	•	•
Porites deformis Nemenzo, 1955	•	•	•	•	•	•
Porites densa Vaughan, 1918	U		U			•
Porites evermanni Vaughan, 1907	•	•	•	•	•	•
Porites flavus Veron, 2000						•
Porites heronensis Veron, 1985	U		U			•
Porites horizontalata Hoffmeister, 1925	U	•	•	•	•	•
Porites latistellata Quelch, 1886	U	U	U	•	•	•
Porites lichen Dana, 1846	•	•	•	•	•	•
Porites lobata Dana, 1846	•	•	•		•	•
Porites lutea Milne Edwards & Haime, 1851	•	•	•		•	•
Porites mayeri Vaughan, 1918						•
Porites monticulosa Dana, 1846	•	•	•	•	•	•
Porites murrayensis Vaughan, 1918	U		U			•
Porites myrmidonensis Veron, 1985		•	•		•	•
Porites negrosensis Veron, 1990				•	•	•
Porites nigrescens Dana, 1846	•	•	•	•	•	•
Porites rugosa Fenner & Veron, 2000	•	•	•	•	•	•
Porites rus (Forskål, 1775)	•	•	•	•	•	•
Porites solida (Forskål, 1775)	•	•	•	•	•	•
Porites stephensoni Crossland, 1952	•	•	•		•	•
Porites tuberculosa Veron, 2000	•	•	•	•	•	•
Porites vaughani Crossland, 1952	•	•	•	•	•	•
Genus *Goniopora* Blainville, 1830						
Goniopora albiconus Veron, 2000	U	U	U			
Goniopora burgosi Nemenzo, 1955	•	•	•		•	•
Goniopora columna Dana, 1846	•	•	•	•	•	•
Goniopora djiboutiensis Vaughan, 1907	•	•	•	•	•	•
Goniopora eclipsensis Veron and Pichon, 1982	•	•	•	•	•	•
Goniopora fruticosa Saville-Kent, 1893	•	•	•	•	•	•
Goniopora lobata Milne Edwards and Haime, 1860	•	•	•	•	•	•
Goniopora minor Crossland, 1952	•	•	•	•	•	•
Goniopora palmensis Veron and Pichon, 1982	•	•	•	•	•	•
Goniopora pandoraensis Veron and Pichon, 1982	•	•	•	•	•	•
Goniopora pendulus Veron, 1985	•		•	•	•	•
Goniopora planulata (Ehrenberg, 1834)	U		U			
Goniopora somaliensis Vaughan, 1907	•	•	•	•	•	•
Goniopora stokesi Milne Edwards and Haime, 1851	•	•	•	•	•	•

Zooxanthellate Scleractinia	Manus	Tigak	M/T	Kimbe	BS	PNG
Goniopora stutchburyi Wells, 1955	•	•	•	•	•	•
Goniopora tenella (Quelch, 1886)	U	U	U			
Goniopora tenuidens (Quelch, 1886)	•	•	•	•	•	•
Genus *Alveopora* Blainville, 1830						
Alveopora allingi Hoffmeister, 1925				•	•	•
Alveopora catalai Wells, 1968		•	•		•	•
Alveopora fenestrata (Lamarck, 1816)	•		•	•	•	•
Alveopora marionensis Veron & Pichon, 1982						•
Alveopora spongiosa Dana, 1846		•	•	•	•	•
Alveopora tizardi Bassett-Smith, 1890	•		•		•	•
Alveopora verrilliana Dana, 1872						•
TOTAL	403	408	452	390	478	510
Unconfirmed	40	20	27			
Possible new species						
Acropora plating Manus	•		•			
Acropora branching Manus	•		•			
Acropora side corymbose Manus	•		•			
Anacropora smooth Manus	•		•			
Pectinia large *pygmeus* Manus	•	•	•			
Monitpora plate Manus	•		•			

The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

The Conservancy's Pacific Island Countries Program supports marine and terrestrial conservation projects in Melanesia and Micronesia including Papua New Guinea, Solomon Islands, Republic of Palau, Federated States of Micronesia, Republic of the Marshall Islands, U.S. Territory of Guam and the Commonwealth of the Northern Mariana Islands.

The Nature Conservancy

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