Climate Change Baseline Assessment

Northern Manus Outer Islands
Papua New Guinea

May-June 2012

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ACRONYMS

ANOVA	Analysis of Variance
AusAID	Australian Agency for International Development
COTS	Crown-of-thorns starfish
CPC	Coral Point Count
D-UVC	Distance-sampling underwater visual census
EEZ	Exclusive Economic Zone
GDP	Gross Domestic Product
GPS	Global Positioning System
GR	Government Revenue
ha	hectare
ICCAI	International Climate Change Adaptation Initiative (Australia)
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de Recherche pour le Développement
MCRMP	Millennium Coral Reef Mapping Project
NASA	National Aeronautics and Space Administration
NGO	Non-government organisation
PCA	Principle Component Analysis
PCCSP	Pacific Climate Change Science Program
PICT	Pacific Island Countries and Territories
PNG	Papua New Guinea
PNG NFA	Papua New Guinea’s National Fisheries Authority
PROCFish	Pacific Regional Oceanic and Coastal Fisheries Development Programme
RBT	Reef-benthos transect
SCUBA	self-contained underwater breathing apparatus
SEAFRAME	Sea Level Fine Resolution Acoustic Measuring Equipment
SOPAC	Applied Geoscience and Technology Division of SPC
SPC	Secretariat of the Pacific Community
SE	standard error
SST	Sea-surface temperature
TL	Total length
TNC	The Nature Conservancy
USD	United States dollar(s)
WCS	Wildlife Conservation Society

TABLE OF CONTENTS

APPENDICES:

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Introduction

Considering the concerns of climate change and its impacts on coastal fisheries resources, SPC is implementing the 'Monitoring the Vulnerability and Adaptation of Coastal Fisheries to Climate Change' project with funding assistance from the Australian Government's International Climate Change Adaptation Initiative (ICCAI). This project aims to assist Pacific Island Countries and Territories (PICTs) to determine whether changes are occurring in the productivity of coastal fisheries and, if changes are found, to identify the extent to which such changes are due to climate change, as opposed to other causative factors. This report presents the results of baseline field surveys for the project conducted in Manus Province, Papua New Guinea, in May and June 2012.

Survey Design

Survey work in Manus Province covered four disciplines (water temperature monitoring, benthic habitat assessments and assessments of finfish and invertebrate resources), and was conducted by staff from SPC's Coastal Fisheries Science and Management Section, and staff from PNG's National Fisheries Authority (NFA) and Manus Provincial Fisheries. The fieldwork included capacity development of local counterparts by providing training in survey design and methodologies, data collection and entry, and data analysis.

Two survey sites were established in Manus Province: one at Ahus Island and one at eastern end of Ponam Reef (hereafter referred to as Andra Island), off the northern coast of Manus Island. The Ahus site was considered as an 'impacted' site as it has a large surrounding population, and relatively high levels of fishing pressure, nutrient enrichment and pollution. The Andra Island site was considered a 'control' site, as it has no residing population, and low levels of fishing, nutrient enrichment and pollution, allowing for decoupling of the effects of over-fishing and pollution against other factors (i.e. climate change). The data collected provides a quantitative baseline that will be analysed after future monitoring events to examine changes in coastal habitat and fishery resources over time.

Water Temperature

In August 2011, two RBR TR-1060 temperature loggers were deployed at Ahus Island: one on the outer-reef and one on the back-reef. The loggers were calibrated to an accuracy of ±0.002ºC and programmed to record temperature every five minutes. Loggers were housed in a PVC tube with holes to allow flow of water and encased in a concrete block and deployed at a depth of approximately 10 m. The logger on the back-reef of Ahus Island recorded water temperatures from its installation until the 20th December 2011, while the logger installed on the outer-reef recorded water temperatures from 1st August to

22nd November 2011, before the batteries in both loggers failed. Both loggers demonstrated an increase in water temperature from August to November-December, consistent with seasonal patterns. In general, mean daily water temperatures were slightly higher on the outer-reef than the back-reef. Both loggers have been replaced with a newer model (Seabird SBE 56), which is expected to have considerably longer battery power.

Benthic Habitat Assessments

Benthic habitats surrounding Ahus and Andra Islands were assessed via photoquadrat methodologies. Twenty-nine 50 m benthic habitat assessment transects were completed across the back-, lagoon- and outer reef habitats, with 11 transects completed at the Ahus site and 18 transects completed at the Andra site. Up to 50 photographs of the benthos were taken per transect (with one photo taken approximately every metre) using a housed underwater camera and a quadrat frame measuring an area of 0.25 m^2. Photographs were analysed using SPC software. Due to logistical issues and poor weather at the time of survey no lagoon-reef habitats were surveyed at the Ahus site.

Hard coral cover and diversity was largely similar among the sites and habitats. In general, back-reef habitats of the Ahus site were characterised by a relatively high cover of algae (predominantly *Halimeda* spp. and cyanobacteria (blue-green algae)). Back- and lagoon-reef habitats of the Andra site appeared largely similar, with moderate cover of hard corals, soft corals, turf algae, sand and rubble. Outer-reef habitats of both sites were characterised by a high cover of crustose coralline algae and a low cover of soft corals relative to the back- and lagoon-reef habitats.

Finfish Surveys

Finfish resources and their supporting habitats of the Ahus and Andra sites were surveyed using distance-sampling underwater visual census (D-UVC) methodology. Twenty-nine 50 m D-UVC monitoring transects were established across the back-, lagoon- and outer-reef habitats, with 11 transects completed at the Ahus site and 18 at the Andra site. Habitats supporting finfish at both the Ahus and Andra Island sites were largely similar to those recorded during the benthic habitat assessments.

A total of 28 families, 79 genera, 204 species and 14,748 individual fish were recorded from the 29 transects, with 22 families, 60 genera, 132 species and 5,391 individual fish recorded from the Ahus monitoring stations, and 25 families, 71 genera, 177 species and 9,357 individual fish recorded from the Andra monitoring stations. Species diversity was typically highest within back- and lagoon-reef habitats, and lowest within outer-reef habitats. Within both the Ahus and Andra sites, overall mean density appeared higher within the back-reefs compared to the outer-reef habitats. No differences were evident in mean biomass amongst habitats within either site. Similarly, no differences in overall mean density or mean biomass were apparent among the Ahus and Andra sites for any habitat.

Concerningly, the mean densities and biomass of several finfish families at Andra Island stations were found to be significantly lower than those observed during the PROCFish surveys conducted in the region by SPC in 2006. While effort was made to conduct the surveys in the same location, this was not always possible due to differences in survey design (PROCFish surveys typically established one 50 m transect per station, whereas the current survey established three 50 m transects per station). Further monitoring of the locations surveyed in this baseline assessment is required to determine whether these differences are consistent over time.

Invertebrate Surveys

Invertebrate resources and their supporting habitats of the study region were surveyed using two complementary approaches: a broad-scale method, using manta tows, and a fine-scale method, using reef-benthos transects (RBT). Four manta tow stations (6 x 300 m replicates) were established at each site, with two stations completed on the back-reef and two on the outer-reef. Individual species observed in the highest mean densities during the manta tow surveys on back-reef habitats at Ahus included the sea cucumbers *Holothuria atra* (48.61±23.61 individuals/ha) and *Bohadschia argus* (16.67±13.89 individuals/ha) and the starfish *Linckia laevigata* (29.17±29.17 individuals/ha), while at Andra *L. laevigata* (159.72±45.83 individuals/ha), *H. atra* (30.56±8.33 individuals/ha) and *Thelenota anax* (23.61±23.61 individuals/ha) were observed in the highest densities. Mean densities of invertebrate species on the outer-reefs were low (< 25 individuals/ha) at both sites. The mean densities of the sea cucumbers *Bohadschia vitiensis*, *Holothuria edulis* and *Pearsonothuria graeffei*, the starfish *L. laevigata*, and the giant clam *Tridacna maxima* were significantly higher on back-reefs habitats of Andra than those at Ahus. No significant differences in mean density were observed for any species among the outer-reefs of the Ahus and Andra sites.

To assess invertebrate resources at finer-spatial scales, reef-benthos transects (RBT) were used. Six RBT monitoring stations (6 x 40 m replicates) were established on the reef flat and back-reef habitats within each of the Ahus and Andra Island sites. Individual species observed in the highest mean densities during the RBT surveys at the Ahus site included the starfish *Linckia laevigata* (673.61±161.52 individuals/ha), the giant clam *Tridacna maxima* (145.83±129.88 individuals/ha) and the trochus *Tectus niloticus* (152.78±71.90 individuals/ha), while at Andra the urchin *Echinometra mathaei* (354.17±190.86 individuals/ha), the giant clam *T. maxima* (270.83±95.47 individuals/ha) and the sea cucumber *Holothuria atra* (263.89±125.31) were observed in the highest density.

Recommendations for Future Monitoring

The following recommendations are proposed for future monitoring events:

- Due to logistical difficulties and poor weather at the time of survey, no lagoon-reef transects were completed at the Ahus monitoring site. As a priority, these transects should be established during the re-survey event.
- Depth has been routinely demonstrated to be a significant factor influencing the distribution and abundance of fish and corals (Pittman and Brown 2011; Green 1996; Veron 1986). To avoid pseudoreplication issues associated with replicates being at different depths, it is recommended that depth be standardised among transects within a habitat during future monitoring events where possible (e.g. 10 m of outer-reef environments).
- The substantial differences observed in densities and biomass of several finfish families common to the current study and the PROCFish survey is of considerable concern, as it indicates a significant reduction in finfish populations over a short-term period. Further monitoring of the locations surveyed in this baseline assessment is required to determine whether these differences are consistent over time. Additionally, to ensure that these results, and results of future surveys, were not a result of differences in observer skill or experience, the use of non-observer based monitoring techniques, such as videography, in conjunction with the D-UVC surveys are recommended.

1. Introduction

Project Background

Considering the concerns of climate change and its impacts on coastal fisheries resources, SPC is implementing the 'Monitoring the Vulnerability and Adaptation of Coastal Fisheries to Climate Change' project with funding assistance from Australia's International Climate Change Adaptation Initiative (ICCAI). This project aims to assist Pacific Islands Countries and Territories (PICTs) to determine whether changes are occurring in the productivity of coastal fisheries and, if changes are found, to identify the extent to which such changes are due to climate change, as opposed to other causative factors.

The purpose of this project is to assist PICTs to:

1. Recognise the need for monitoring the productivity of their coastal fisheries and commit to allocating the resources to implement monitoring measures.

2. Design and field-test the monitoring systems and tools needed to:

    i. Determine whether changes to the productivity of coastal fisheries are occurring, and identify the extent to which such changes are due to climate, as opposed to other pressures on these resources, particularly overfishing and habitat degradation from poor management of catchments;

    ii. Identify the pace at which changes due to climate are occurring to 'ground truth' projections; and

    iii. Assess the effects of adaptive management to maintain the productivity of fisheries and reduce the vulnerability of coastal communities.

The Approach

Monitoring impacts of climate change on coastal fisheries is a complex challenge. To facilitate this task, a set of monitoring methods was selected from the SPC expert workshop 'Vulnerability and Adaptation of Coastal Fisheries to Climate Change: Monitoring Indicators and Survey Design for Implementation in the Pacific' (Noumea, 19–22 April 2010) of scientists and representatives of many PICTs. These methods include monitoring of water temperature using temperature loggers, monitoring of finfish and invertebrate resources using SPC resource assessment protocols, and photoquadrat methodologies for monitoring benthic habitats supporting coastal fisheries. The methods were prioritised as they are indicators for the oceanic environment, habitats supporting coastal fisheries, and finfish and invertebrate resources. In parallel, SPC is currently implementing database backend software to facilitate data entry, analysis and sharing between national stakeholders and the scientific community as well as providing long-term storage of monitoring data.

Five pilot sites were selected for monitoring: Federated States of Micronesia (Pohnpei), Kiribati (Abemama), Marshall Islands (Majuro), Papua New Guinea (Manus) and Tuvalu (Funafuti). Their selection was based on existing available data such as fish, invertebrate and socio-economic data from the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish), multi-temporal images (aerial photographs and satellite images) from the Applied Geosciences and Technology Division of SPC (SOPAC), presence of Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME), as well as their geographical location.

This report presents the results of baseline field surveys for the project conducted in Manus Province, Papua New Guinea, in May and June 2012 by a team from SPC's Coastal Fisheries Science and Management Section and staff from PNG's National Fisheries Authority (NFA) and Manus Provincial Fisheries. Recommendations for future monitoring events are also provided.

Papua New Guinea

Background

The independent state of Papua New Guinea consists of the eastern half of New Guinea Island and approximately 700 offshore islands between the equator and 12°S, and 140°E–160°E (Figure 1). The country's geography is diverse and, in places, extremely rugged. A spine of mountains, the New Guinea Highlands, runs the length of New Guinea Island, which is mostly covered with tropical rainforest. Dense rainforests can also be found in the lowland and coastal areas as well as the very large wetland areas surrounding the Sepik and Fly Rivers. The highest peak is Mount Wilhelm at 4,697 m (SOPAC 2010). The total land area of PNG is around 462,243 km^2, while the Exclusive Economic Zone (EEZ) totals approximately 2.4 million km^2 (Bell et al. 2011). The population of Papua New Guinea is approximately 6,744,955 with 40% living in the highlands and 18% in urban areas (SOPAC 2010). The capital, Port Moresby, is located in the south-east and has a population of approximately 500,000. Eighty-five percent of the population live a subsistence lifestyle in rural areas. These people depend on traditional agriculture and fishing for their livelihoods. Mining and oil production are the main sources of revenue for Papua New Guinea, accounting for 60% of export earnings and 20% of government revenue (GR). Agricultural crops are still a major source of revenue, in particular copra, coffee, palm oil and cocoa (PCCSP 2011).

Figure 1 **Papua New Guinea (from PCCSP 2011).**

Fisheries

Oceanic fisheries

PNG has an important, locally based industrial purse-seine tuna fishery that operates within its exclusive economic zone (EEZ). Recent average catches (2004–2008) by this fishery have exceeded 225,000 tonnes per year, with a value of over USD 280 million (Bell et al. 2011). PNG also licenses foreign purse-seine vessels to fish for tuna in its EEZ; these foreign vessels have a recent average annual catch of more than 220,000 tonnes (1999–2008) with a worth of approximately USD 200 million (Bell et al. 2011). Licence fees from vessels involved in this fishery contributed 0.6% to government revenue (GR) in 2007 (Bell et al. 2011).

Coastal fisheries

The coastal fisheries of PNG are comprised of four broad-scale categories: demersal fish (bottom-dwelling fish associated with mangrove, seagrass and coral reef habitats), nearshore pelagic fish (including tuna, wahoo, mackerel, rainbow runner and mahi-mahi), invertebrates targeted for export, and invertebrates gleaned from intertidal and subtidal areas (Bell et al. 2011). In 2007, the total annual catch of the coastal sector was estimated to be 35,700 tonnes, worth approximately USD 62.5 million (Gillet 2009) (Table 1). The commercial component of this catch was an estimated 5,700 tonnes, while the subsistence catch was an estimated 30,000 tonnes (Gillet 2009) (Table 1). Approximately 80% of the total coastal catch is estimated to be made up of demersal and nearshore pelagic fish (Bell et al. 2011) (Table 2).

Table 1 **Annual fisheries and aquaculture harvest in Papua New Guinea, 2007 (Gillet 2009)**

Harvest sector	Quantity (tonnes)	Value (Kina)
Offshore locally-based	256,397	1,024,089,635
Offshore foreign-based	327,471	1,143,631,355
Coastal commercial	5,700	80,000,000
Coastal subsistence	30,000	105,000,000
Freshwater	17,500	49,000,000
Aquaculture	200	2,000,000
Total	**637,268**	**2,403,720,990**

Table 2 **Estimated catch and value of coastal fisheries sectors in Papua New Guinea, 2007 (Bell et al. 2011)**

Coastal fishery category	Quantity (tonnes)	Contribution of catch (%)
Demersal finfish	14,520	41
Nearshore pelagic finfish	13,760	38
Targeted invertebrates	1,300	4
Inter/subtidal invertebrates	6,120	17
Total	**35,700**	**100**

Climate Change Projections for PNG

Air temperature

Historical air temperature data records for PNG are available for Port Moresby (Figure 1). These records show an increase in average daily temperatures of approximately 0.21°C per decade since recording began in 1950 (Figure 2) (PCCSP 2011). Mean air temperatures are projected to continue to rise, with increases of +0.7, +0.8 and +0.7°C (relative to 1990 values) projected for 2030, under the IPCC B1 (low), A1B (medium) and A2 (high) emissions scenarios, respectively (PCCSP 2011) (Table 3).

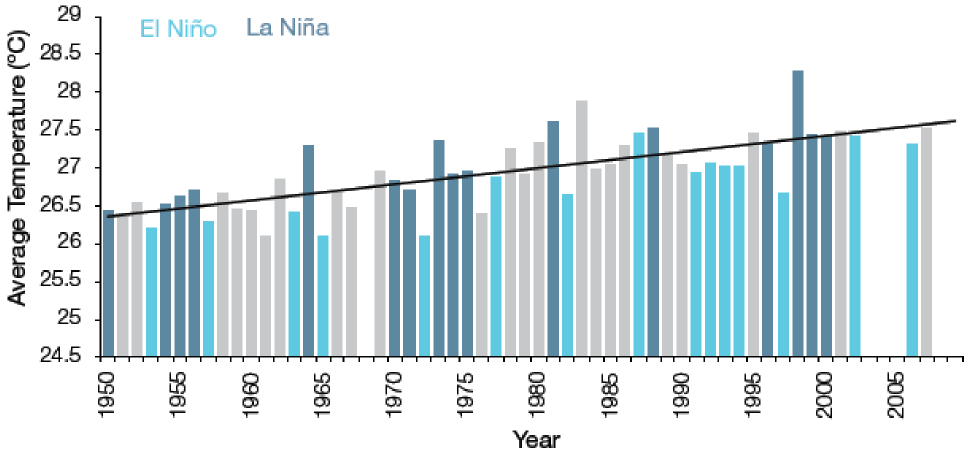


Figure 2 **Mean annual air temperature at Port Moresby (1950-2009) (from PCCSP 2011).**

Table 3 **Projected changes in mean air temperature (in °C) projected for Papua New Guinea under various IPCC emission scenarios (from PCCSP 2011)**

Emission scenario	2030	2055	2090
B1	+0.7 ± 0.4	+1.1 ± 0.5	+1.6 ± 0.6
A1B	+0.8 ± 0.4	+1.5 ± 0.5	+2.4 ± 0.8
A2	+0.7 ± 0.3	+1.5 ± 0.4	+2.8 ± 0.6

Sea-surface temperature

Sea-surface temperatures in the PNG region have risen gradually since recording began in the 1950s. Since the 1970s the rate of warming has been approximately 0.11°C per decade (PCCSP 2011). In accordance with mean air surface temperatures, sea-surface temperatures are projected to further increase, with increases of +0.6, +0.7 and +0.7°C (relative to 1990 values) projected for 2030, under the IPCC B1 (low), A1B (medium) and A2 (high) emissions scenarios, respectively (PCCSP 2011) (Table 4).

Table 4 **Projected changes in sea-surface temperature (in °C) projected for Papua New Guinea under various IPCC emission scenarios (from PCCSP 2011)**

Emission scenario	2030	2055	2090
B1	+0.6 ± 0.5	+1.0 ± 0.5	+1.4 ± 0.6
A1B	+0.7 ± 0.4	+1.3 ± 0.5	+2.2 ± 0.7
A2	+0.7 ± 0.5	+1.3 ± 0.5	+2.6 ± 0.7

Sea level rise

As part of the AusAID-sponsored South Pacific Sea Level and Climate Monitoring Project (‘Pacific Project’) a SEAFRAME (Sea Level Fine Resolution Acoustic Measuring Equipment) gauge was installed at Manus Island, in northern PNG, in September 1994. According to the 2010 Pacific country report on sea level and climate for PNG (http://www.bom.gov.au/pacificsealevel/picreports.shtml), the gauge had been returning high resolution, good quality scientific data since installation and as of 2010 the net trend in sea-level rise at Manus Island (accounting for barometric pressure and tidal gauge movement) was calculated at +5.7 mm per year. Based on empirical modeling, mean sea-level is projected to continue to rise during the 21st century, with increases of up to +20 to +30 cm projected for 2035 and +70 to +140 cm projected for 2100 (Bell et al. 2011). Sea level rise may potentially create severe problems for low lying coastal areas, namely through increases in coastal erosion and saltwater intrusion (Mimura 1999). Such processes may result in increased fishing pressure on coastal habitats, as traditional garden crops fail, further exacerbating the effects of climate change on coastal fisheries.

Ocean acidification

Based on the large-scale distribution of coral reefs across the Pacific and seawater chemistry, Guinotte et al. (2003) suggested that aragonite saturation states above 4.0 were optimal for coral growth and for the development of healthy reef ecosystems, with values from 3.5 to 4.0 adequate for coral growth, and values between 3.0 and 3.5 were marginal. There is strong evidence to suggest that when aragonite saturation levels drop below 3.0 reef organisms cannot precipitate the calcium carbonate that they need to build their skeletons or shells (Langdon and Atkinson 2005).

In the PNG region, the aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of about 3.9±0.1 by 2000 (PCCSP 2011). Ocean acidification is projected to increase, and thus aragonite saturation states are projected to decrease during the 21st century (PCCSP 2011). Climate models suggest that by 2040 the annual maximum aragonite saturation state for PNG will reach values below 3.5 (the lowest saturation level considered adequate for coral growth (Guinotte et al. 2003)) and continue to decline thereafter (PCCSP 2011). These projections suggest that coral reefs of PNG will be vulnerable to actual dissolution as they will have trouble producing the calcium carbonate needed to build their skeletons. This will impact the ability of coral reefs to have net growth rates that exceed natural bioerosion rates. Increasing acidity and decreasing levels of aragonite saturation are also expected to have negative impacts on ocean life apart from corals; including calcifying invertebrates, non-calcifying invertebrates and fish. High levels of CO_2 in the water are expected to negatively impact the lifecycles of fish and large invertebrates through habitat loss and impacts on reproduction, settlement, sensory systems and respiratory effectiveness (Kurihara 2008, Munday et al. 2009a, Munday et al. 2009b). The impact of acidification change on the health of reef ecosystems is likely to be compounded by other stressors including coral bleaching, storm damage and fishing pressure (PCCSP 2011).

Projected Effects of Climate Change of Coastal Fisheries of PNG

PNG has considerable areas of corals reefs (22,000 km^2), and significant areas of mangroves, deepwater and intertidal seagrasses, and intertidal sand and mud flat habitats (Bell et al. 2011). Climate change is expected to add to the existing local threats to the aquatic ecosystems of PNG, resulting in declines in the quality and area of all habitats (Table 5). Accordingly, all coastal fisheries categories in PNG are projected to show progressive declines in productivity due to both the direct (e.g. increased SST) and indirect effects (e.g. changes to fish habitats) of climate change (Table 6) (Bell et al. 2011).

Table 5 Projected changes in coastal fish habitat in PNG under various IPCC emission scenarios (from Bell et al. 2011)

Habitat	**Projected change (%)**		
	B1/A2 2035	**B1 2100***	**A2 2100**
Coral cover[a]	-25 to -65	-50 to -75	> -90
Mangrove area	-10	-50	-60
Seagrass area	-5 to -20	-5 to -30	-10 to -35

* Approximates A2 in 2050; a = assumes there is strong management of coral reefs.

Table 6 Projected changes to coastal fisheries production in PNG under various IPCC emission scenarios (from Bell et al. 2011)

Coastal fisheries category	**Projected change (%)**		
	B1/A2 2035	**B1 2100***	**A2 2100**
Demersal fish	-2 to -5	-20	-20 to -50
Nearshore pelagic fish[a]	0	-10	-15 to -20
Targeted invertebrates	-2 to -5	-10	-20
Inter/subtidal invertebrates	0	-5	-10

* Approximates A2 in 2050; a = tuna contribute to the nearshore pelagic fishery.

2. Site and Habitat Selection

Site Selection

Manus Province, and more specifically the northern outer islands of Ahus and Andra, was selected as a pilot site for the 'Monitoring the Vulnerability and Adaptation of Coastal Fisheries to Climate Change' project within PNG following consultations with PNG's NFA. Ahus and Andra Islands were selected as they offered a number of advantages as a study site, most notably:

- A SEAFRAME gauge was installed in the region in September 1994 as part of the South Pacific Sea Level and Climate Monitoring project for purposes of recording sea level rise, air temperature, water temperature, wind speed and direction and atmospheric pressure;
- Fish, invertebrate and socio-economic data were collected by SPC under the PROCFish/C project in Andra Island in 2006 (Friedman et al. 2008);
- Andra and Ahus Islands are monitored by the Wildlife Conservation Society (WCS) and were one of the areas flagged for conservation action in Manus by The Nature Conservancy (TNC) in 2009 (Hamilton et al. 2009);
- Both Ahus and Andra Islands represent closed systems (people from the site fish in well-defined fishing grounds);
- Non-governmental organization (NGOs) and provincial fisheries offices are located in Lorengau, the capital of Manus Province, which simplifies logistics.

Andra and Ahus are coral islands located on the barrier reef on the northern part of the high island of Manus, located at latitude 1°55´S and longitude 146°57´E. Both islands are relatively small in size, measuring approximately one kilometre long and less than 500 m wide. Travel to the islands from Lorengau (the provincial centre of Manus) takes about an hour by fibreglass speed boat, which is the principal mode of transport to these islands. The communities of both islands are divided into clans. There is no principal chief on either island, but there are heads of clans and a village council (Friedman et al. 2008). Reef ownership is by clan. Ownership of the reef at Ahus extends from the outer-, lagoon and back-reefs surrounding the island to the mainland coastline. Ownership of the reef at Andra extends from the outer reef across the lagoons right to the mainland coastline and halfway between Ahus to the east and Ponam Island to the west, including the eastern side of Ponam reef (Figure 3). Access to the reefs is restricted to community members (Friedman et al. 2008).

Two survey sites were established: one at Ahus Island and one at eastern end of Ponam Reef (Figure 3). The Ahus site was considered as an 'impacted' site as it has a relatively large surrounding population, and relatively high levels of fishing pressure, nutrient enrichment and pollution. The Ponam Reef site (hereafter referred to as the Andra Island site, given the Andra communities' ownership over this section of reef) was considered a 'control' site, as it has no residing population, and low levels of fishing, nutrient enrichment and pollution, allowing for decoupling of the effects of over-fishing and pollution against other factors (i.e. climate change).

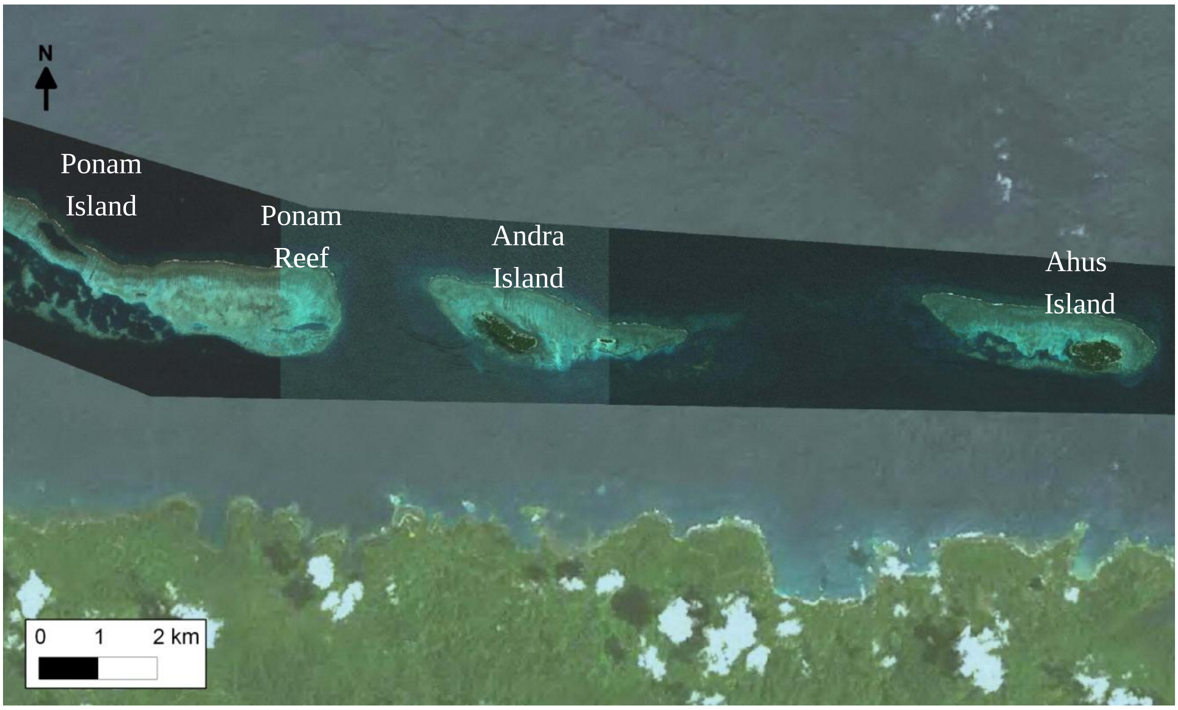


Figure 3 **Northern Manus outer islands showing the study sites of Ahus Island and Ponam Reef (Andra Island).**

Fisheries of the study region

The waters surrounding Ahus and Andra Islands support a highly diverse fish fauna. A total of 665 individual fish species were recorded from the waters surrounding Manus Island during survey work by TNC in 2006 (Allen 2009). Subsequently, fishing is an important activity for the people of Ahus and Andra Islands. Socio-economic survey work conducted at Andra as part of the PROCFish surveys by SPC in 2006 revealed that 50% of households are dependent on fisheries as a primary income, while the remaining 50% are dependent on fisheries as a secondary income (Friedman et al. 2008). Per capita consumption of fresh fish was found to be approximately 36 kg/person/year (Friedman et al. 2009). Fishing methods vary among habitats. Most frequently, handlines and spears are used to catch fish on the sheltered coastal reefs, deep-bottom lining and trolling are the main methods used on the outer reef, and handlining and deep-bottom lining techniques are used in the lagoon. Fishing typically always involves a boat (100% of households on

Andra own a boat); mostly paddling canoes (Friedman et al. 2008). Fishing on Andra is performed by both males and females (Friedman et al. 2008). Composition of catches generally varies with the habitat fished, but catches are typically dominated by the families Acanthuridae, Carangidae, Haemulidae, Lethrinidae, Mullidae and Scaridae (Friedman et al. 2008).

By comparison, consumption of invertebrates (edible meat weight only) was found to be considerably lower, at approximately 6.5 kg/person/year (Friedman et al. 2009). On Andra, subsistence catches are mainly focused on giant clams (*Tridacna* spp.) and octopus (*Octopus* sp.), while the gastropods *Turbo crassus*, *Lambis lambis* and *Cypraea tigris* and the urchin *Tripneustes gratilla* are of secondary importance (Friedman et al. 2008). Invertebrates are mainly harvested by women gleaning on reef-top habitats (Friedman et al. 2008). During open seasons, harvesting of sea cucumbers and trochus (*Tectus niloticus*) plays an important role in generating income. During one open season, the average catch (dry weight) of beche-de-mer per family on Andra was reported to be 100-150 kg, totalling 8.5–12.75 t (dry weight), while a total harvest of 11 t of trochus shell was reported for one two-day open season (Friedman et al. 2008).

Lime production for betel nut chewing is a significant source of income for the Andra community. Lime powder is made from hard corals (predominantly *Acropora* species), which are harvested from the reefs surrounding Andra Island (Figure 4). Lime powder is sold at the Lorengau market or to nearby villages. Branching *Porites* species are also harvested and crushed to make paths (B. Moore, *pers. obs*.).

Figure 4 *Acropora* spp. corals collected for lime production on Andra Island.

Habitat Definition and Selection

Coral reefs are highly complex and diverse ecosystems. The NASA Millennium Coral Reef Mapping Project (MCRMP) has identified and classified coral reefs of the world in about 1000 categories. These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the purposes of the baseline field surveys at Ahus and Andra Islands, three general reef types were categorised:

1) lagoon-reef: patch reef or finger of reef stemming from main reef body that is inside a lagoon or pseudo-lagoon;
2) back-reef: inner/lagoon side of outer reef/main reef body; and
3) outer-reef: ocean-side of fringing or barrier reefs.

A Comparative Approach Only

The data collected provides a quantitative baseline that will be analysed after future monitoring events to examine temporal changes in coastal habitat and fishery resources. It should be stressed that due to the comparative design of the project, the methodologies used, and the number of sites and habitats examined, the data provided in this report should only be used in a comparative manner to explore differences in coastal fisheries productivity over time. These data should not be considered as indicative of the actual available fisheries resources.

3. Monitoring of Water Temperature

Methodologies

To monitor water temperature, two RBR TR-1060 temperature loggers were deployed at the Ahus Island site in August 2011: with one logger deployed on the outer-reef and one on the back-reef. The loggers were calibrated to an accuracy of ±0.002ºC and programmed to record temperature every five minutes. For security reasons both loggers were housed in a PVC tube with holes to allow flow of water and encased in a concrete block. These blocks were then secured to the sea floor using rebars. Both loggers were deployed at a depth of approximately 10 m (Table 7). The collected data will be stored on SPC servers and made available to networks of researchers, governmental services and conservation non-government organizations (NGOs).

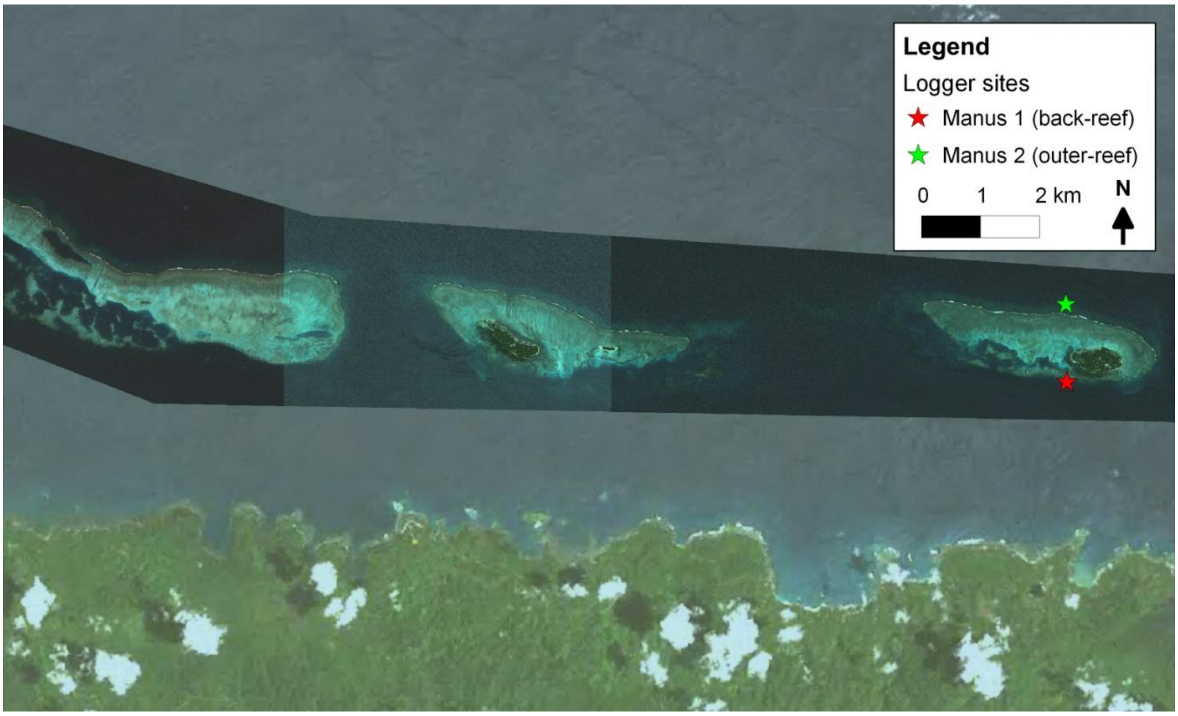


Figure 5 Location of water temperature loggers deployed at the study site

Table 7 Details of temperature loggers deployed at Ahus Island.

Details	Manus 1	Manus 2
Deployment date	01/08/2011	01/08/2011
Location	Ahus Island, Manus Province	Ahus Island, Manus Province
Habitat	Back-reef	Outer-reef
Longitude (E)	147.096533	147.096366
Latitude (S)	1.945	1.9318166
Depth	10 m	10 m

Results

The logger on the back-reef of Ahus Island recorded water temperatures from its installation on the 1st August until the 20th December 2011, while the logger installed on the outer-reef recorded water temperatures from 1st August to 22nd November 2011, before a fault caused the batteries to fail in both loggers. Both loggers demonstrated an increase in water temperature from August to November-December, consistent with seasonal patterns (Figure 6). In general, mean daily water temperatures were slightly higher on the outer-reef than the back-reef (Figure 6). Both loggers have been replaced with a newer model (Seabird SBE 56), which is expected to have considerably longer battery power.

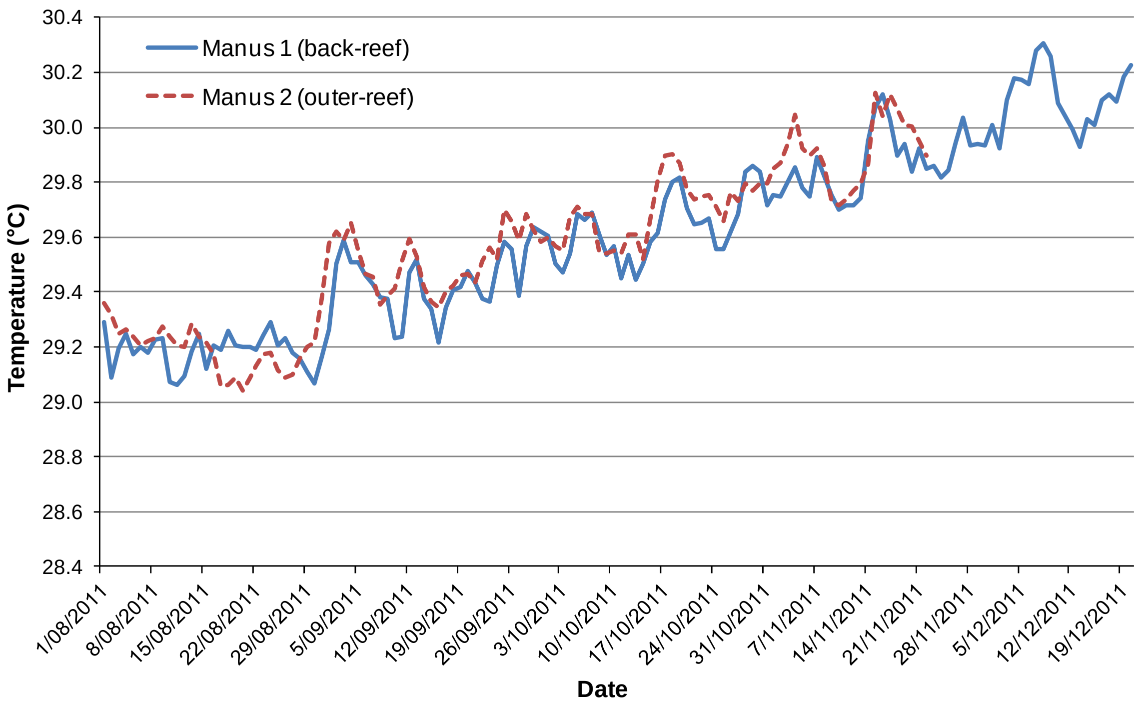


Figure 6 **Mean daily water temperatures recorded at Ahus Island, Manus Province, August to December 2011.**

4. Benthic Habitat Assessment

Methodologies

Data collection

For the assessments of benthic habitat and finfish resources, two survey stations were established at each of the Ahus and Andra Island sites. Within each station, benthic habitat assessments focused on three habitats: back-reefs, lagoon-reefs and outer-reefs (Figure 7), with a target of three replicate 50 m transects planned in each habitat for each station. To assess benthic habitats, up to 50 photographs of the benthos were taken per transect (with one photo taken approximately every metre) using a housed underwater camera and a quadrat frame measuring an area of 0.25 m^2. Photos were taken approximately 1 m above the benthos. Transects were laid parallel to the reef. A GPS position was recorded at the beginning of each replicate transect. In general, the same transects were used for both the benthic habitat and finfish assessments.

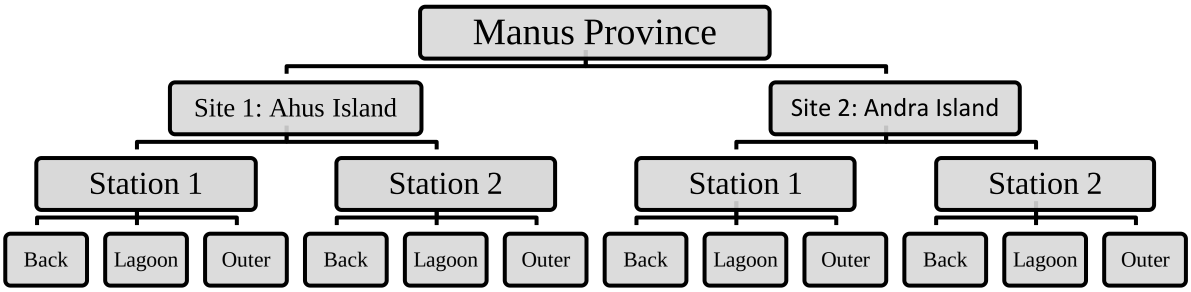


Figure 7 Survey design of the benthic habitat and finfish assessments in Manus Province, PNG. Three replicate 50m transects were planned in each back-, lagoon- or outer-reef habitat.

Data processing and analysis

The habitat photographs were analyzed using SPC software (available online: http://www.spc.int/CoastalFisheries/CPC/BrowseCPC), which is similar to the Coral Point Count (CPC) analysis software by Kohler and Gill (2006). Using this software, five randomly generated points were created on the downloaded photographs. The substrate under each point was identified based on the following substrate categories:

1. Hard coral – sum of the different types of hard coral, identified to genus level[1];
2. Other invertebrates – sum of invertebrate types including *Anemones*, *Ascidians*, *Cup sponge*, *Discosoma*, *Dysidea sponge*, *Gorgonians*, *Olive sponge*, *Terpios sponge*, *Other sponges*, *Soft coral*, *Zoanthids*, and *Other invertebrates* (other invertebrates not included in this list);

[1] Corals of the genus *Porites* were further divided into *Porites* (branching and encrusting forms), *Porites-rus* and *Porites*-massive categories.

3. Macroalgae – sum of different types of macroalgae *Asparagopsis*, *Blue-green algae*, *Boodlea*, *Bryopsis*, *Chlorodesmis*, *Caulerpa*, *Dicotyota*, *Dictosphyrea*, *Galaxura*, *Halimeda*, *Liagora*, *Lobophora*, *Mastophora*, *Microdictyton*, *Neomeris*, *Padina*, *Sargassum*, *Schizothrix*, *Turbinaria*, *Tydemania*, *Ulva*, and *Other macroalgae* (other macroalgae not included in this list);
4. Branching coralline algae – *Amphiroa*, *Jania*, *Branching coralline general*;
5. Crustose coralline algae;
6. Fleshy coralline algae;
7. Turf algae;
8. Seagrass – sum of seagrass genera *Enhalus*, *Halodule*, *Halophila*, *Syringodium*, *Thalassia*, *Thalassodendron*;
9. Chrysophyte;
10. Sand – 0.1 mm < hard particles < 30 mm;
11. Rubble – carbonated structures of heterogeneous sizes, broken and removed from their original locations; and
12. Pavement.

In addition, the status of corals (live, recently dead or bleached) was noted for each coral genera data point. Recently dead coral was defined as coral with exposed skeletons with visible corallites and no polyps present, while bleached coral was defined as white coral with polyps still present. Resulting data were then summarized as percentages and extracted to MS Excel. To assess broad-scale patterns in benthic habitat among sites and habitats, principle component analysis (PCA) was conducted on log(x+1) transformed mean percent cover values of each major substrate category, using Primer 6. To explore differences among sites and habitats, coverage data of each major benthic category in each individual transect were square-root transformed to reduce heterogeneity of variances and analysed by two-way analysis of variance (ANOVA) using Statistica 7.1, with site (Ahus and Andra) and habitat (back-reef, lagoon-reef, and outer-reef) as fixed factors in the analysis. Tukey-Kramer post-hoc pairwise tests were used to identify specific differences between factors at $P = 0.05$. Where transformed data failed Cochran's test for homogeneity of variances ($P < 0.05$), an increased level of significance of $P = 0.01$ was used. Summary graphs of mean percentage cover (± SE) were generated to further explore patterns of each major substrate category by habitat.

Results

Survey coverage

A total of 29 benthic habitat assessment transects were completed across the back-, lagoon- and outer-reef habitats, with 11 transects completed in the Ahus site and 18 transects completed in the Andra site (Figure 8; Table 8). Due to logistical issues and poor weather one outer-reef and no lagoon-reef transects could not be completed at the Ahus site. A list of GPS positions for each benthic habitat assessment transect is presented as Appendix 1.

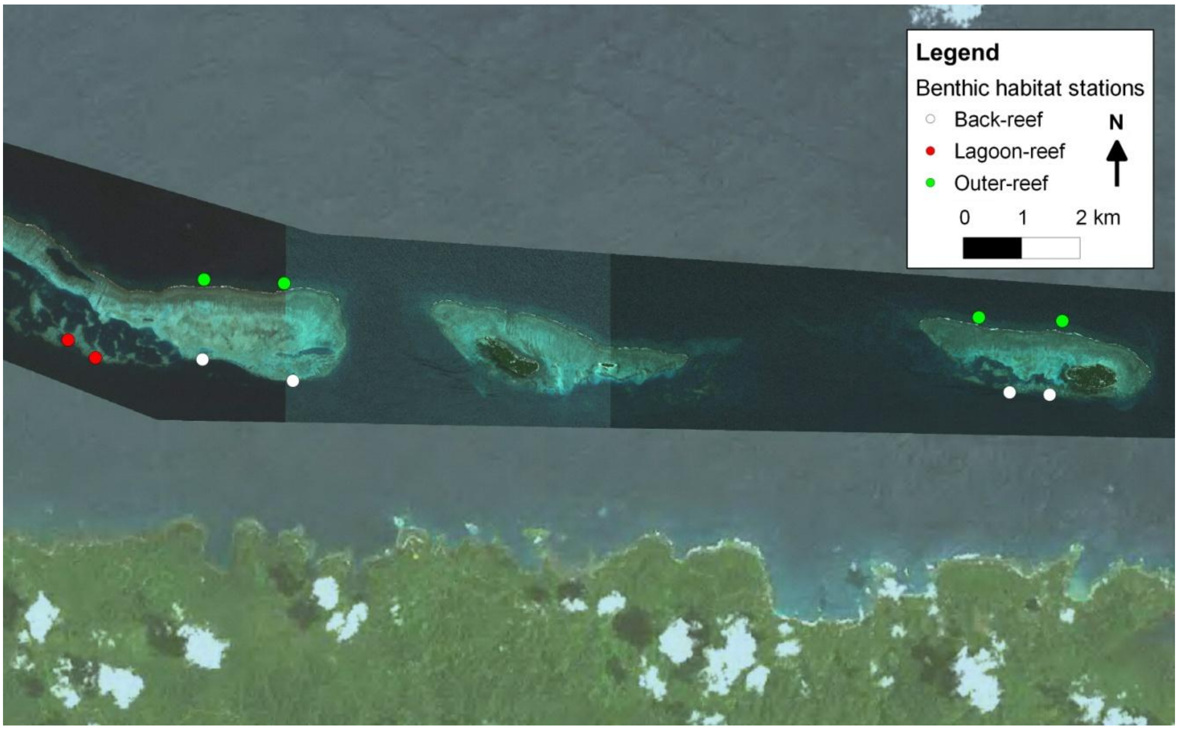


Figure 8 Location of benthic habitat assessment stations established in Ahus and Andra Islands, 2012.

Table 8 Summary of benthic habitat assessment transects at Ahus and Andra monitoring stations, 2012.

Site	Station	Habitat	No. of transects
Ahus	Ahus 1	Back-reef	3
		Lagoon-reef	0
		Outer-reef	2
	Ahus 2	Back-reef	3
		Lagoon-reef	0
		Outer-reef	3
Andra	Andra 1	Back-reef	3
		Lagoon-reef	3
		Outer-reef	3
	Andra 2	Back-reef	3
		Lagoon-reef	3
		Outer-reef	3

Back-reef habitats

Back-reef habitats of Ahus and Andra appeared largely similar in terms of cover of hard corals, other invertebrates, turf algae and rubble (Figure 9; Figure 10). The back-reefs at Ahus had a greater cover of macroalgae than those at Andra (P = 0.001), in particular *Halimeda* and blue-green algae (cyanobacteria), while back-reefs at Andra had a significantly greater cover of sand (P = 0.006) (Figure 10). Soft corals were relatively abundant on the back-reefs of both sites, representing 13.4±2.9% and 11.1±1.7% of overall cover at Ahus and Andra, respectively.

Hard coral diversity at the back-reef habitats was relatively high, with a total of 24 types of hard coral recorded at the Ahus site, and 25 types of hard coral recorded at Andra (Figure 10). Hard coral cover was moderate at both sites (approximately 20%). In terms of cover, *Porites*-massive and *Acropora* were the most common hard corals at both sites, representing 6.3±1.0% and 2.7±0.8% of overall cover at Ahus, and 6.2±1.7 and 2.1+0.3 of overall cover at Andra, respectively. Fire coral (*Millepora* spp.) was relatively common at the Andra site, representing 5.2+1.9% of overall cover (Figure 10). At Ahus, the cover of bleached corals was low, constituting 0.031±0.03% of overall mean cover of hard corals, while no bleached corals were observed on the back-reefs of Andra. The cover of recently dead corals was low at both sites, representing 0.5±0.4 and 0.7±0.3% of overall cover at Ahus and Andra, respectively

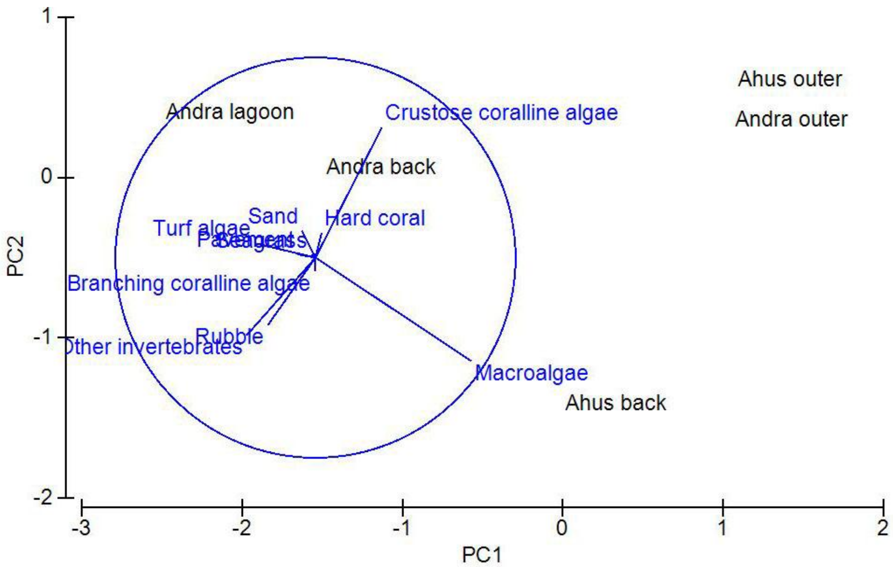


Figure 9 **Principle Component Analysis (PCA) of each major benthic substrate category for each site. Sites separate along a gradient of macroalgae versus turf algae (PC1) and rubble versus hard coral and crustose coralline algae (PC2).**

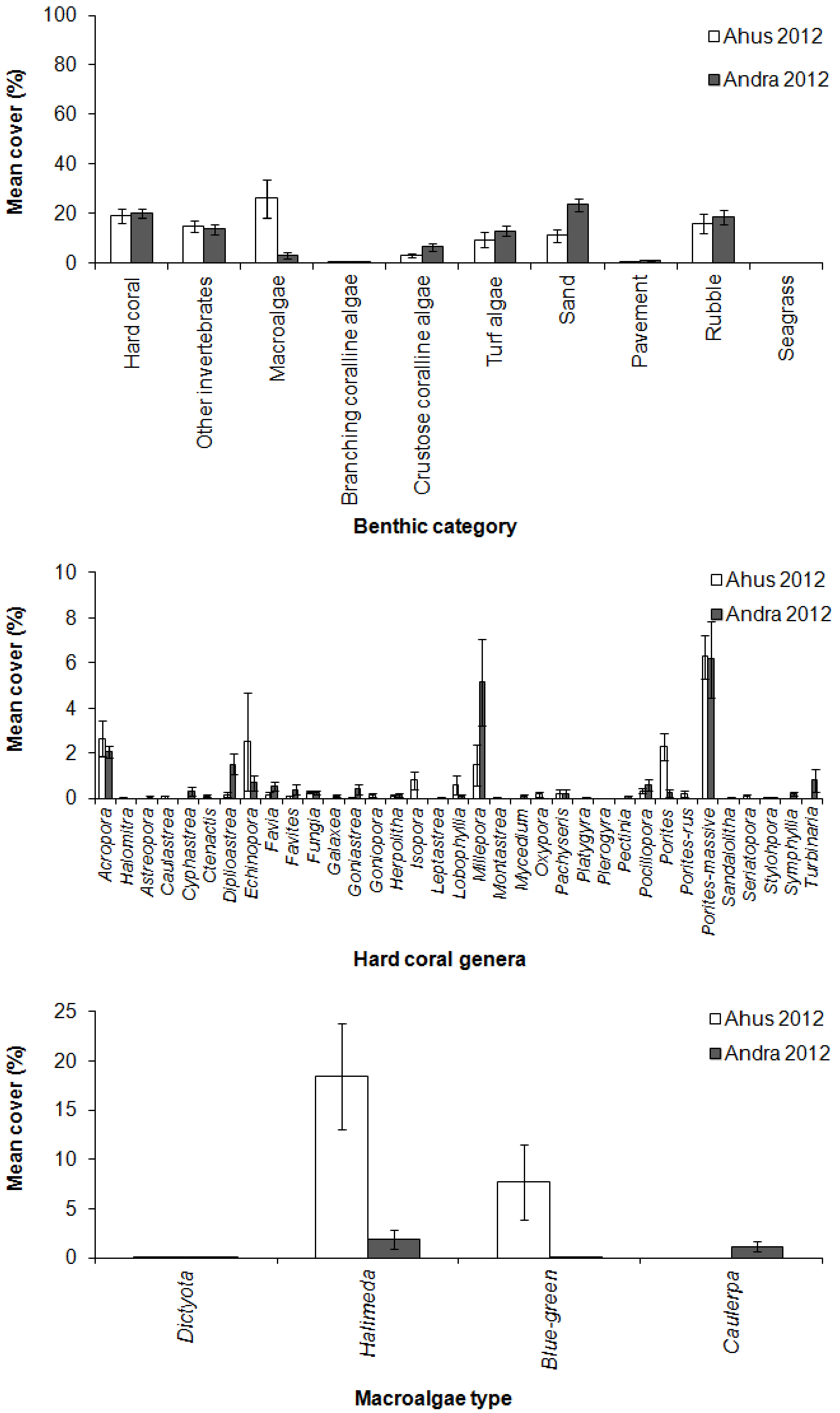


Figure 10 **Mean cover (± SE) of each major benthic category (top), hard coral type (middle) and macroalgae type (bottom) present at back-reef habitats during benthic habitat assessments at the Ahus and Andra monitoring sites, 2012.**

Lagoon-reef habitats

Lagoon-reef habitats of Andra appeared largely similar to the back-reefs habitats of this site, with a moderate cover (approximately 20%) of hard corals, sand and rubble, and low cover of macroalgae (Figure 9; Figure 11). Lagoon-reefs habitats of Andra had the highest percent cover of turf algae of any habitat and site, constituting 25.9±2.1% of overall cover (Figure 11). Consistent with back-reefs, soft corals were relatively common at the lagoon-reef habitats of Andra, representing 14.2±2.9% of overall cover.

As with back-reef habitats, hard coral diversity on the lagoon-reef habitats was relatively high, with a total of 25 types of hard coral recorded from the lagoon-reef habitats of this site (Figure 11). In terms of cover, *Porites*-massive was the most common hard coral, representing 7.5±3.7% of overall cover (Figure 11). The overall cover of recently dead corals was low, with recently dead corals constituting 0.9±0.3% of overall mean hard coral cover. No bleached corals were recorded from the lagoon-reef habitats of Andra.

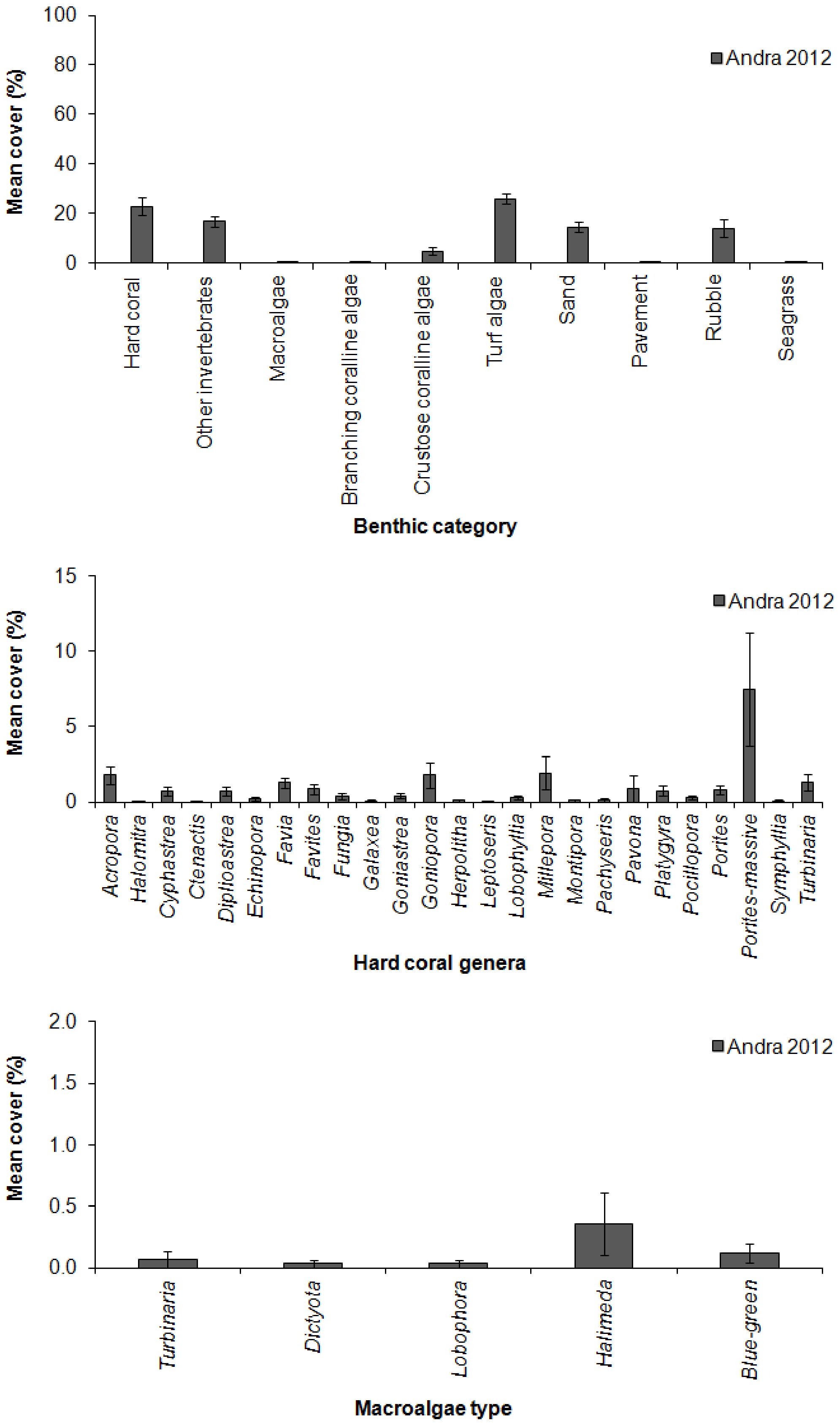


Figure 11 **Mean cover (± SE) of each major benthic category (top), hard coral type (middle) and macroalgae type (bottom) present at lagoon-reef habitats during benthic habitat assessments at the Andra monitoring site, 2012.**

Outer-reef habitats

Outer-reef habitats of both the Ahus and Andra monitoring stations differed from back- and lagoon-reef habitats by the presence of a relatively high percent cover of crustose coralline algae and lower cover of other invertebrates (in particular soft corals) (Figure 9; Figure 12). No significant differences were observed in the cover of major habitat categories among the outer-reefs of Ahus and Andra (Figure 12). In contrast to the back- and lagoon-reef habitats, the cover of soft corals was low at both sites, representing 0.9±0.2% and 1.7±0.6% of overall cover at Ahus and Andra, respectively.

A total of 24 types of hard coral were recorded from the outer-reef habitats at Ahus, while 19 types of hard coral were recorded from the outer-reef habitats of Andra (Figure 12). In terms of cover, *Acropora*, *Pocillopora* and *Porites* were the most common hard coral genera at both sites, representing 7.8±1.9%, 3.4±0.7% and 3.6±0.9% of overall cover at Ahus, and 8.3±1.3%, and 5.1±1.8% and 2.7±0.6% of overall cover at Andra, respectively. No recently dead corals were observed in the outer-reef habitats of Ahus, while the cover of recently dead corals at Andra was low (0.03±0.03%). The cover of bleached corals was low at both sites, constituting 0.04±0.04% and 0.1±0.1% of the overall mean cover of hard corals at Ahus and Andra, respectively.

Macroalgae cover on the outer-reefs of both sites was moderate, comprising 21.9±1.7% and 24.0±2.9% of cover at Ahus and Andra, respectively. *Halimeda* was the dominant macroalgae at both sites (Figure 12).

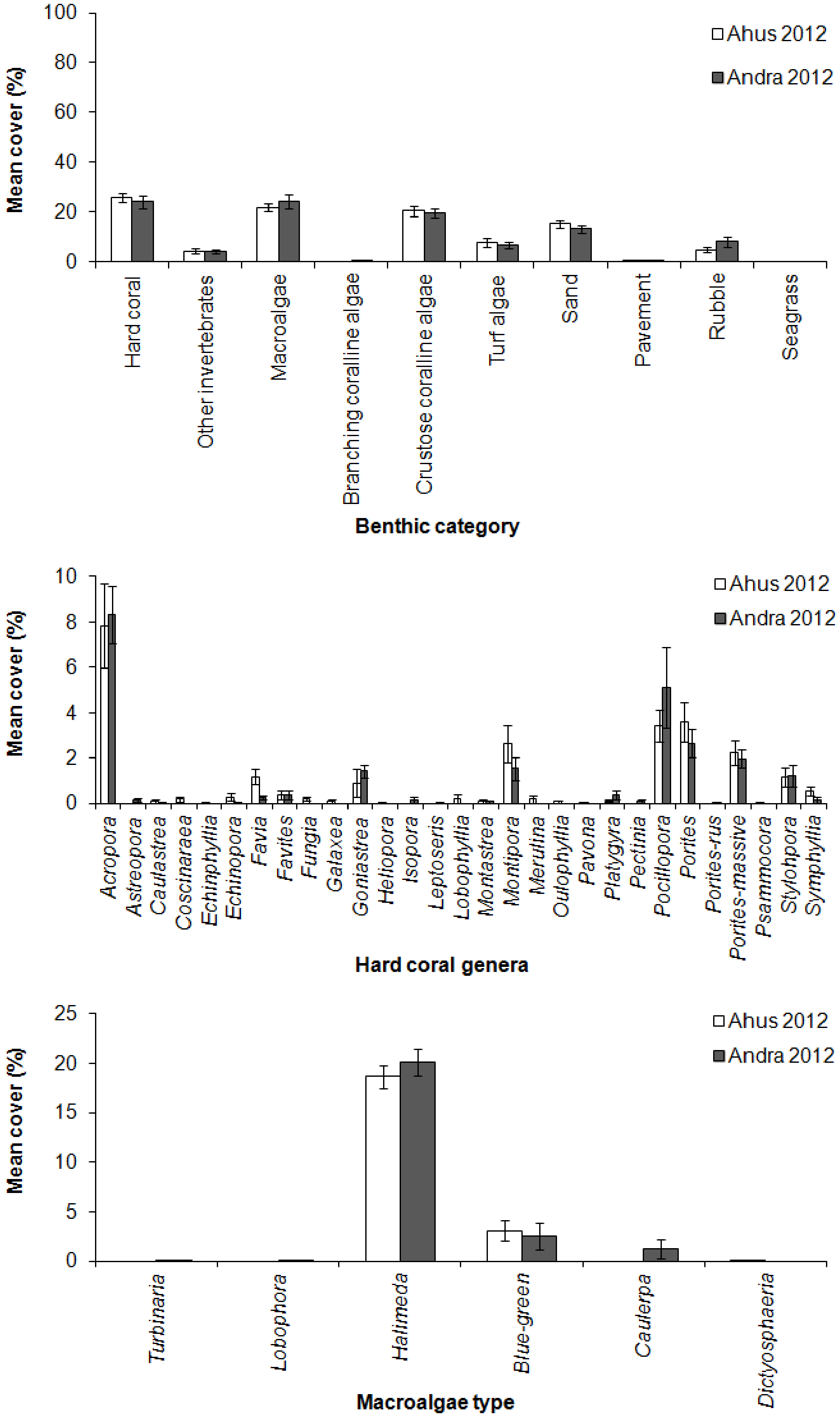


Figure 12 **Mean cover (± SE) of each major benthic category (top), hard coral type (middle) and macroalgae type (bottom) present at outer-reef habitats during benthic habitat assessments at the Ahus and Andra monitoring sites, 2012.**

5. Finfish Surveys

Methods and Materials

Data collection

Finfish surveys

Fish on reef habitats were surveyed using distance-sampling underwater visual census (D-UVC) techniques. As per the benthic habitat assessments, three replicate 50 m transects were planned to be surveyed in the back-reef, lagoon-reef and outer-reef habitats at each of two stations within the Ahus and Andra Island sites (Figure 7). Each transect census was completed by two SCUBA divers who recorded the species name, abundance and total length (TL) of all fish observed (Appendix 2). The distance of the fish from the transect line was also recorded (Figure 13). Two distance measurements were recorded for a school of fish belonging to the same species and size (the distance from the transect tape to the nearest individual (D1) and the distance from the transect tape to the furthest individual (D2), while for individual fish only one distance was recorded (D1) (Figure 13). Regular review of identification books and cross-checks between divers after the dive ensured that accurate and consistent data were collected. Where possible, transects in the Andra sites were positioned in the same locations as those surveyed during the PROCFish surveys of Friedman et al. (2008), to allow for comparison of results among survey events.

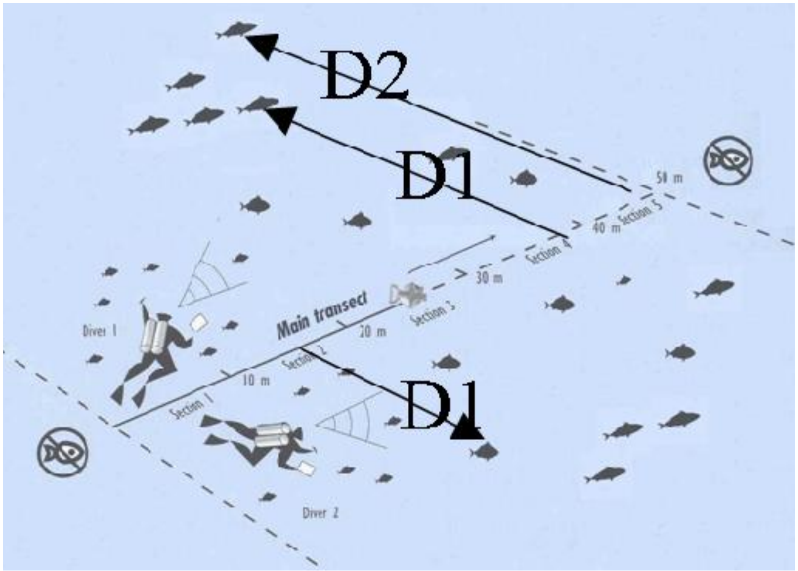


Figure 13 Diagram portraying the D-UVC method.

Habitats supporting finfish

Habitats supporting finfish were documented after the finfish survey using a modified version of the medium scale approach of Clua et al (2006). This component uses a separate form (Appendix 3) from that of the finfish assessment, consisting of information on depth, habitat complexity, oceanic influence and an array of substrate parameters (percentage coverage of certain substrate type) within five 10 x 10 m quadrats (one for each 10 m of transect) on each side of the 50 metre transect.

The substrate types were grouped into the following six categories:

1. Soft substrate (% cover) — sum of substrate components *silt* (sediment particles < 0.1 mainly on covering other substrate types like coral and algae), *mud*, and *sand* and *gravel* (0.1 mm < hard particles < 30 mm);
2. Hard substrate (% cover) — sum of hard substrate categories including *hard coral status* and hard *abiotic*;
3. Abiotic (% cover) — sum of substrate components *rocky substratum* (slab) (flat rock with no relief), *silt*, *mud*, *sand*, *rubbles* (carbonated structures of heterogeneous sizes, broken and removed from their original locations), *gravels and small boulders* (< 30 cm), *large boulders* (< 1m) and *rocks* (> 1m);
4. Hard corals status (% cover) – sum of substrate components *live coral*, *bleaching coral* (dead white corals) and *long dead algae covered coral* (dead carbonated edifices that are still in place and retain a general coral shape covered in algae);
5. Hard coral growth form (% cover) — sum of substrate component live coral consisting of *encrusting coral*, *massive coral*, *sub-massive coral*, *digitate coral*, *branching coral*, *foliose coral* and *tabulate coral*;
6. Others – % cover of *soft coral*, *sponge*, *plants and algae*, *silt covering coral* and *cyanophycae* (blue-green algae). The *plants and algae* category is divided into *macroalge*, *turf algae*, *calcareous algae*, *encrusting algae* (crustose coralline algae) and *seagrass* components.

Data analysis

Finfish surveys

In this report, the status of finfish resources has been characterised using the following parameters:

1) richness – the number of families, genera and species counted in D-UVC transects;
2) diversity – total number of observed species per habitat and site divided by the number of transects conducted in each individual habitat and site;
3) community structure – overall mean density and biomass compared among habitats and sites (based on all observations within 5 m from the transect line);
4) mean density (fish/m^2) – estimated from fish abundance in D-UVC, calculated at both a family, trophic group and individual species level;
5) mean biomass (g/m^2) – obtained by combining densities, size, and weight–size ratios, calculated at both a family, trophic group and individual species level;
6) weighted mean size (cm total length) – direct record of fish size by D-UVC, calculated at both a family, trophic group and individual species level;

7) weighted mean size ratio (%) – the ratio between fish size and maximum reported size of the species, calculated at both a family, trophic group and individual species level. This ratio can range from nearly zero when fish are very small to 100% when a given fish has reached the maximum size reported for the species;
8) trophic structure – density, size and biomass of trophic groups compared among habitats and sites. Trophic groups were based on accounts from published literature. Each species was classified into one of five broad trophic groups: 1) carnivore (feed predominantly on zoobenthos), 2) herbivore (feed predominantly on plants and algae), 3) piscivore (feed predominantly on nekton, other fish and cephalopods), 4) planktivore (feed predominantly on zooplankton), and 5) detritivore (feed predominantly on detritus). More details on fish diet can be found online at:
   http://www.fishbase.org/manual/english/FishbaseThe_FOOD_ITEMS_Table.htm.

To account for differences in visibility among sites and habitats, only fish recorded within five metres of the transect line were included in the analysis. While all observed finfish species were recorded, including both commercial and non-commercial species, for the purposes of this report results of analyses of density, biomass, size, size ratio, and trophic structure are presented based on data for 18 selected families, namely Acanthuridae, Balistidae, Chaetodontidae, Ephippidae, Haemulidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Pomacanthidae, Pomacentridae, Scaridae, Serranidae, Siganidae and Zanclidae. These families were selected as they comprise the dominant finfish families of tropical reefs (and are thus most likely to indicate changes where they occur), and constitute species with a wide variety of trophic and habitat requirements. Other families abundant on reefs, such as Blennidae and Gobiidae, were not analysed due to the difficulties in enumerating these cryptic species.

Given the baseline nature of this report, relationships between environmental parameters and finfish resources have not been fully explored. Rather, the finfish resources are described and compared amongst habitats within sites and between the Ahus and Andra sites. To explore differences among sites and reef environments, habitat category data and density, biomass, mean size and mean size ratio data of each of the 18 indicator families and five trophic groups in each individual transect were square-root transformed to reduce heterogeneity of variances and analysed by two-way analysis of variance (ANOVA) using Statistica 7.1, with site (Ahus and Andra) and habitat (back-reef and outer-reef) as fixed factors in the analysis. A square-root transformation was used as preliminary analyses revealed it provided the greatest homogeneity of variances as compared to other transformation methods (e.g. log(x+1), 4th-root). Tukey-Kramer post-hoc pairwise tests were used to identify specific differences between factors at $P = 0.05$. Where transformed data failed Cochran's test for homogeneity of variances ($P < 0.05$), an increased level of significance of $P = 0.01$ was used. In addition, density and biomass data from the Andra transects were compared against those collected during the PROCFish surveys in this region in 2006 (Friedman et al. 2008; Figure 14) by habitat using one-way ANOVA. While the PROCFish project collected data relating to species of interest to fisheries only, precluding comparisons of overall density and biomass and comparisons among trophic groups against the current study, data of commonly recorded families (Acanthuridae, Balistidae, Chaetodontidae, Holocentridae, Kyphosidae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Scaridae, Siganidae and Zanclidae) can nevertheless be compared, providing an important starting point from which to explore changes over time.

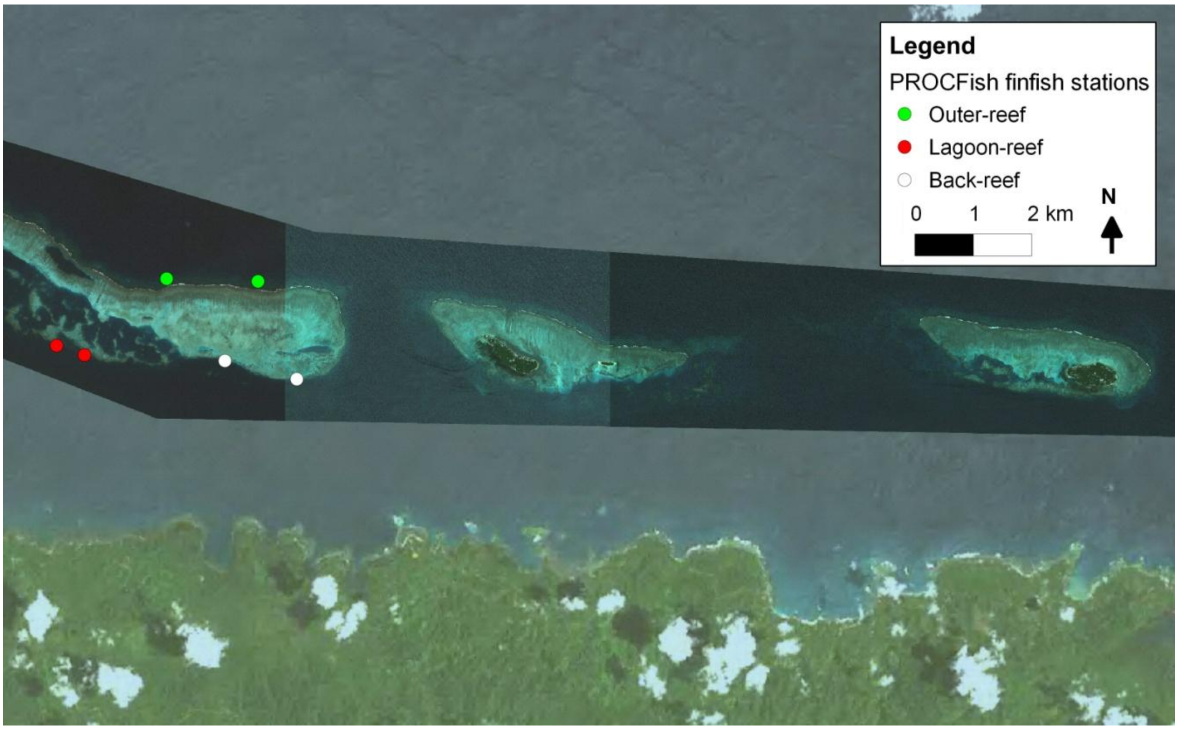


Figure 14 Location of PROCFish finfish survey sites at Andra used to compare against data collected during the current (2012) study.

Results

Coverage

A total of 29 D-UVC transects were completed across the back-, lagoon- and outer-reef habitats, with 11 transects completed in the Ahus site and 18 transects completed in the Andra site (Figure 15; Table 9). Due to logistical issues and poor weather one outer-reef and no lagoon-reef transects could not be completed at the Ahus site. A list of GPS positions for each D-UVC transect is presented as Appendix 4.

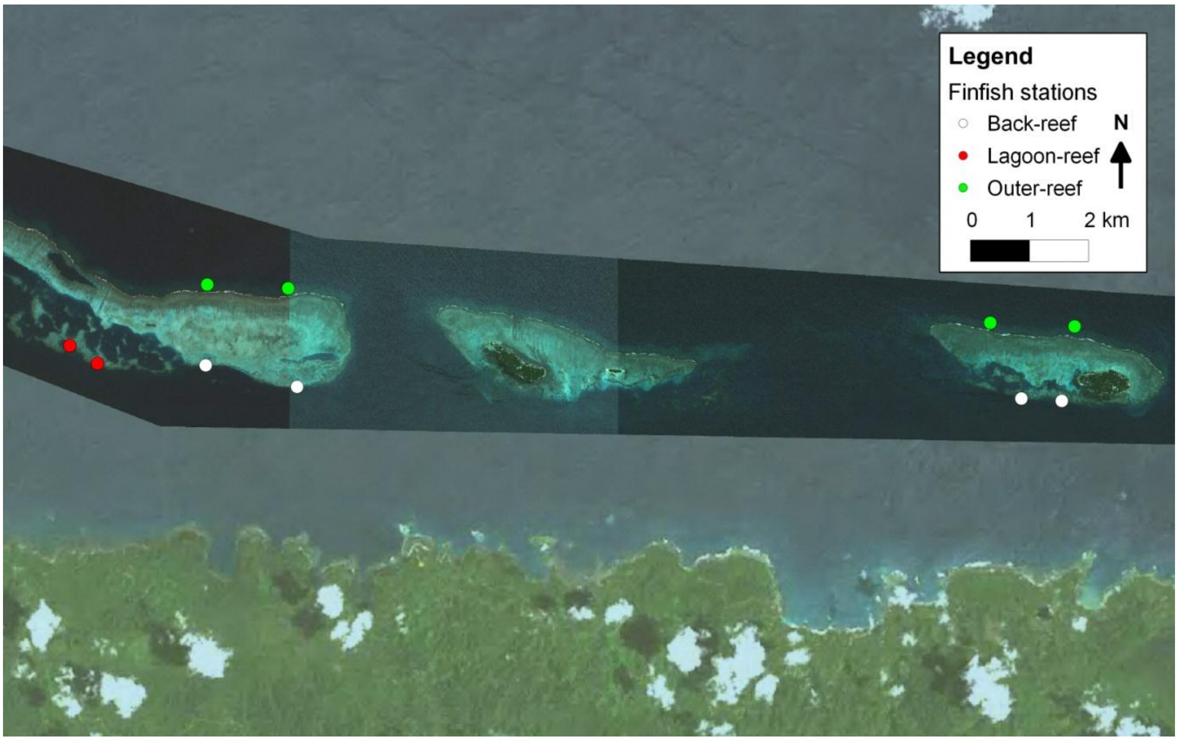


Figure 15 Location of finfish assessment stations established in Ahus and Andra Islands, 2012.

Table 9 Summary of distance underwater visual census (D-UVC) transects among habitats for Ahus and Andra monitoring sites.

Site	Station	Habitat	No. of transects
Ahus	Ahus 1	Back-reef	3
		Lagoon-reef	0
		Outer-reef	2
	Ahus 2	Back-reef	3
		Lagoon-reef	0
		Outer-reef	3
Andra	Andra 1	Back-reef	3
		Lagoon-reef	3
		Outer-reef	3
	Andra 2	Back-reef	3
		Lagoon-reef	3
		Outer-reef	3

Finfish surveys

Overall

A total of 28 families, 79 genera, 204 species and 14,748 individual fish were recorded from the 29 D-UVC transects. Of these, 22 families, 60 genera, 132 species and 5,391 individual fish were recorded from the Ahus monitoring stations, while 25 families, 71 genera, 177 species and 9,357 individual fish were recorded from the Andra monitoring stations (see Appendices 5–8 for a full list of families and species recorded at both the Ahus and Andra sites). Species diversity was typically highest within back- and lagoon-reef habitats, and lowest within outer-reef habitats (Table 10). Within the Ahus site, overall mean density appeared higher within the back-reef compared to the outer-reef habitats (Figure 16). Similarly at Andra, overall mean density of back-reef habitats appeared higher than the outer-reefs, while no difference was evident between the lagoon-reefs and any other habitat. No differences were evident in mean biomass amongst habitats at either site. Similarly, no differences in overall mean density or mean biomass were apparent among the Ahus and Andra sites for any habitat (Figure 16; Figure 17).

Table 10 Total number of families, genera and species, and diversity of finfish observed at the back-, lagoon- and outer-reef habitats of Ahus and Andra monitoring stations, 2012.

Parameter	Back-reef		Lagoon-reef		Outer-reef	
	Ahus	Andra	Ahus	Andra	Ahus	Andra
No. of families	20	20	-	23	16	19
No. of genera	16	50	-	54	43	52
No. of species	115	118	-	121	84	106
Diversity	19.2	19.7	-	20.2	16.8	17.7

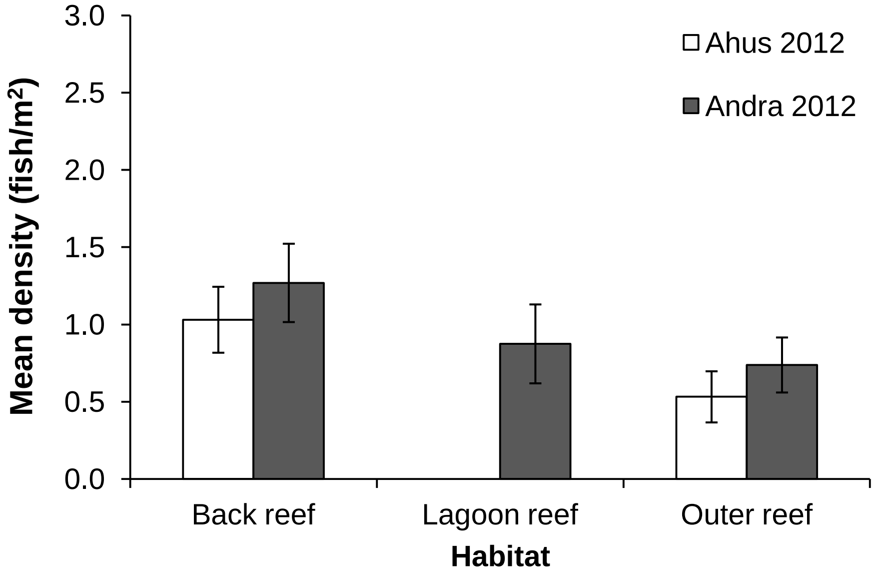


Figure 16 **Overall mean density of finfish (± SE) within back, lagoon and outer-reef habitats within the Ahus and Andra monitoring sites, 2012.**

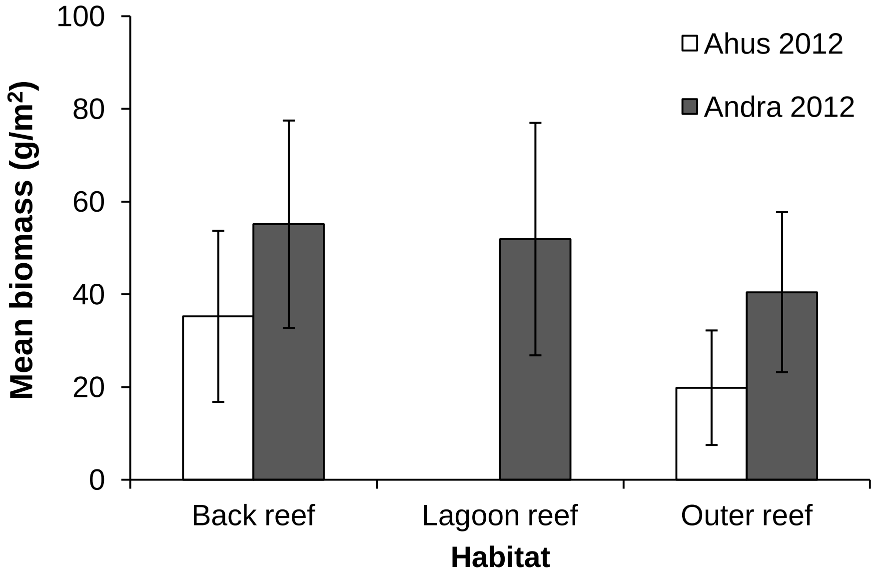


Figure 17 **Overall mean biomass of finfish (± SE) within back, lagoon and outer-reef habitats within the Ahus and Andra monitoring sites, 2012.**

Back-reef habitats

Habitats supporting finfish

Back-reefs habitats where D-UVC transects were established at both sites were largely characterised by hard corals (both live and dead), sand and rubble (Figure 18). Live hard coral cover was relatively high at both sites, representing 37.8±7.2% and 33.6±5.8% of overall cover at Ahus and Andra, respectively. Of the corals present, massive and branching corals were the most common growth forms present at both sites (Figure 18). No significant differences were observed in the depth, topography, or complexity of the D-UVC transects among on the back-reefs of Ahus and Andra stations (P > 0.05). Of the substrate categories, only the cover of calcareous algae (P = 0.007), and cyanophycae (P < 0.001) differed among sites, with back-reefs at Ahus having a greater percent cover of these variables than those at Andra (Figure 18).

Finfish surveys

A total of 20 families, 53 genera, 115 species and 3,361 individual fish were recorded from back-reef habitats of the Ahus monitoring stations, while 20 families, 50 genera, 118 species and 4,013 individuals were recorded from back-reef habitats of the Andra monitoring stations (Table 10). Of the 18 selected 'indicator' families, Pomacentridae were observed in the highest mean densities within the back-reef habitats of both the Ahus (0.737±0.130 fish/m^2, comprising 71.5% of mean density at this site) and Andra sites (0.879±0.111 fish/m^2, 69.2% of mean density), followed by Acanthuridae (0.087±0.006 and 0.086±0.019 fish/m^2 at Ahus and Andra, respectively) and Labridae (0.092±0.018 and 0.061±0.016 fish/m^2 at Ahus and Andra, respectively) (Figure 19). Mean densities of Chaetodontidae, Holocentridae and Lethrinidae were significantly greater within the back-reefs at Andra stations than those at Ahus ($P \leq 0.008$) (Figure 19). The individual species of the 18 indicator families observed in the highest mean densities within the back-reef habitats of Ahus were the pomacentrids *Amblyglyphidodon curacao*, *Pomacentrus moluccensis*, *Chromis ambionensis*, *Chromis ternatensis* and *Neoglyphidodon nigroris* (Table 11). Similarly, the individual species observed in the highest mean densities within the back-reefs of Andra were the pomacentrids *A. curacao*, *P. moluccensis*, *Chromis margaritifer*, *Dascyllus reticulatus* and *Chromis xanthura* (Table 11).

In accordance with their high density, Pomacentridae had the greatest biomass at the back-reefs of Ahus (7.385±1.882 g/m^2, representing 20.9% of the observed mean biomass of this site), followed by the families Acanthuridae (6.814±2.105 g/m^2, 19.3% of observed mean biomass), Scaridae (3.154±01.145 g/m^2, 8.9% of observed mean biomass) and Mullidae (2.110±1.214 g/m^2, 6.0% of observed mean biomass) (Figure 19). At the back-reef habitats of Andra, Pomacentridae had the greatest biomass (12.956±3.369 g/m^2, representing 23.5% of the observed mean biomass of this site), followed by the families Acanthuridae (9.635±4.205 g/m^2, representing 17.5% of the observed mean biomass of this site), Scaridae (5.624±2.103 g/m^2, 10.2% of observed mean biomass) and Holocentridae (5.605±2.167 g/m^2, 10.2% of observed mean biomass) (Figure 19). Mean biomass of Holocentridae was significantly higher on the back-reefs of the Andra stations compared to those at Ahus (P = 0.002). The individual species of the 18 indicator families that had the greatest biomass within the back-reef habitats of Ahus were the acanthurid *Ctenochaetus striatus*, the scarid *Chlorurus sordidus*, the pomacentrids *Amblyglyphidodon curacao* and *Chromis ternatensis* and the mullid *Parupeneus bifasciatus* (Table 12). The individual species with the greatest biomass within the back-reef habitats of Andra were the pomacentrid *Amblyglyphidodon curacao*, the holocentrid *Myripristis murdjan*, the scarid *Scarus oviceps*, the lethrinid *Monotaxis grandoculis* and the acanthurid *Ctenchaetus striatus* (Table 12).

The mean size of Labridae was significantly greater at back-reef habitats of Andra stations than those at Ahus (P = 0.011). No significant differences were apparent in mean size ratio of any of the 18 indicator families among sites.

In terms of trophic structure, planktivores were observed in the highest mean densities within the back-reef habitats of both the Ahus (0.572±0.114 fish/m^2) and Andra sites (0.735±0.120 fish/m^2), followed by herbivores (0.302±0.026 and 0.306±0.046 fish/m^2 at Ahus and Andra, respectively). Few piscivores, and no detritivores, were observed at either site (Figure 20). The dominant trophic groups in terms of biomass in the back-reef habitats of both Ahus and Andra were herbivores, with mean biomasses of 12.733±3.777 g/m^2 and 17.581±5.033 g/m^2 at Ahus and Andra, respectively. No significant differences were observed in mean density, biomass, size or mean size ratio of any trophic group among the back-reef habitats of Ahus and Andra.

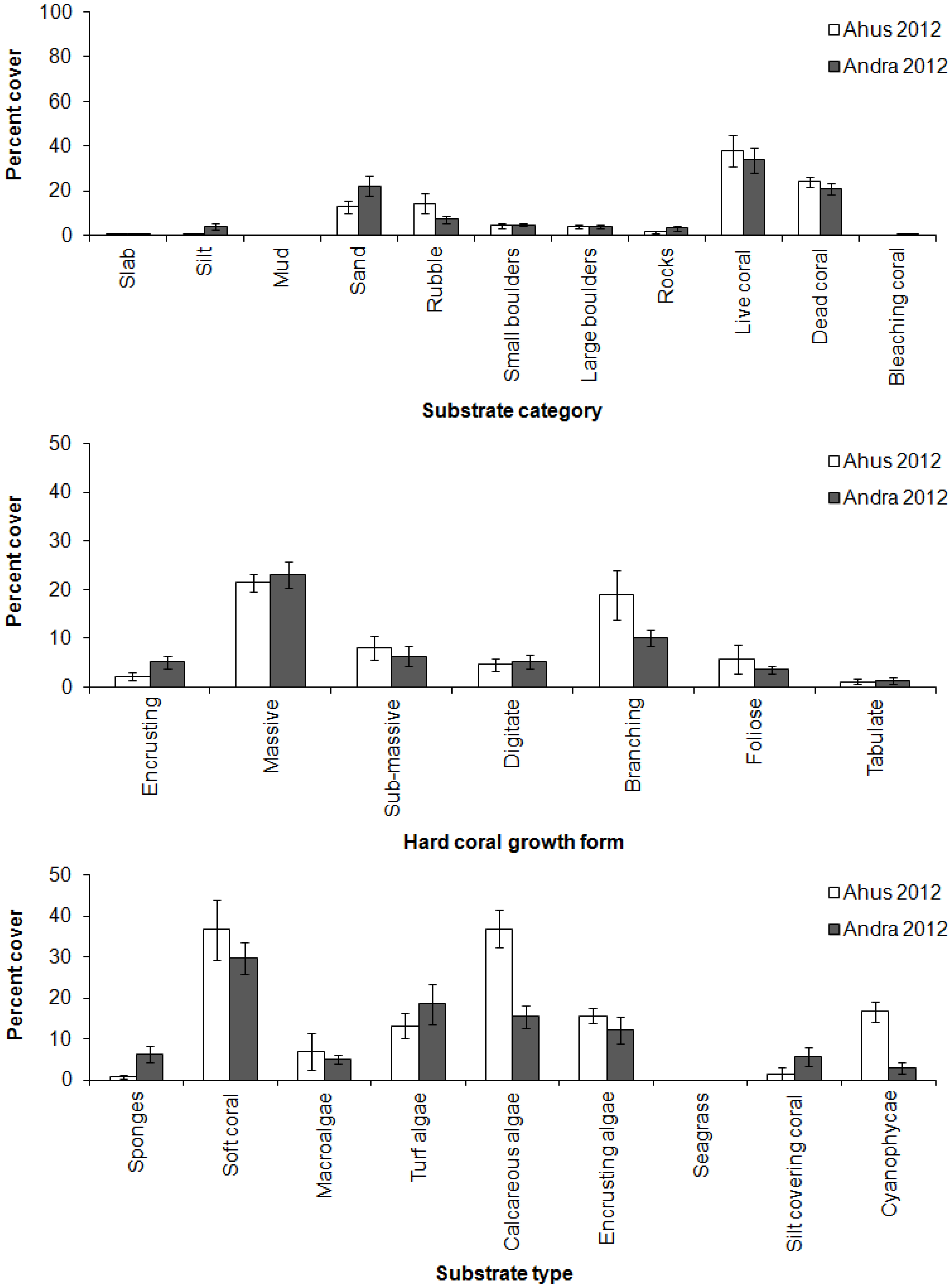


Figure 18 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at back-reef habitats during finfish surveys at Ahus and Andra monitoring stations, 2012.**

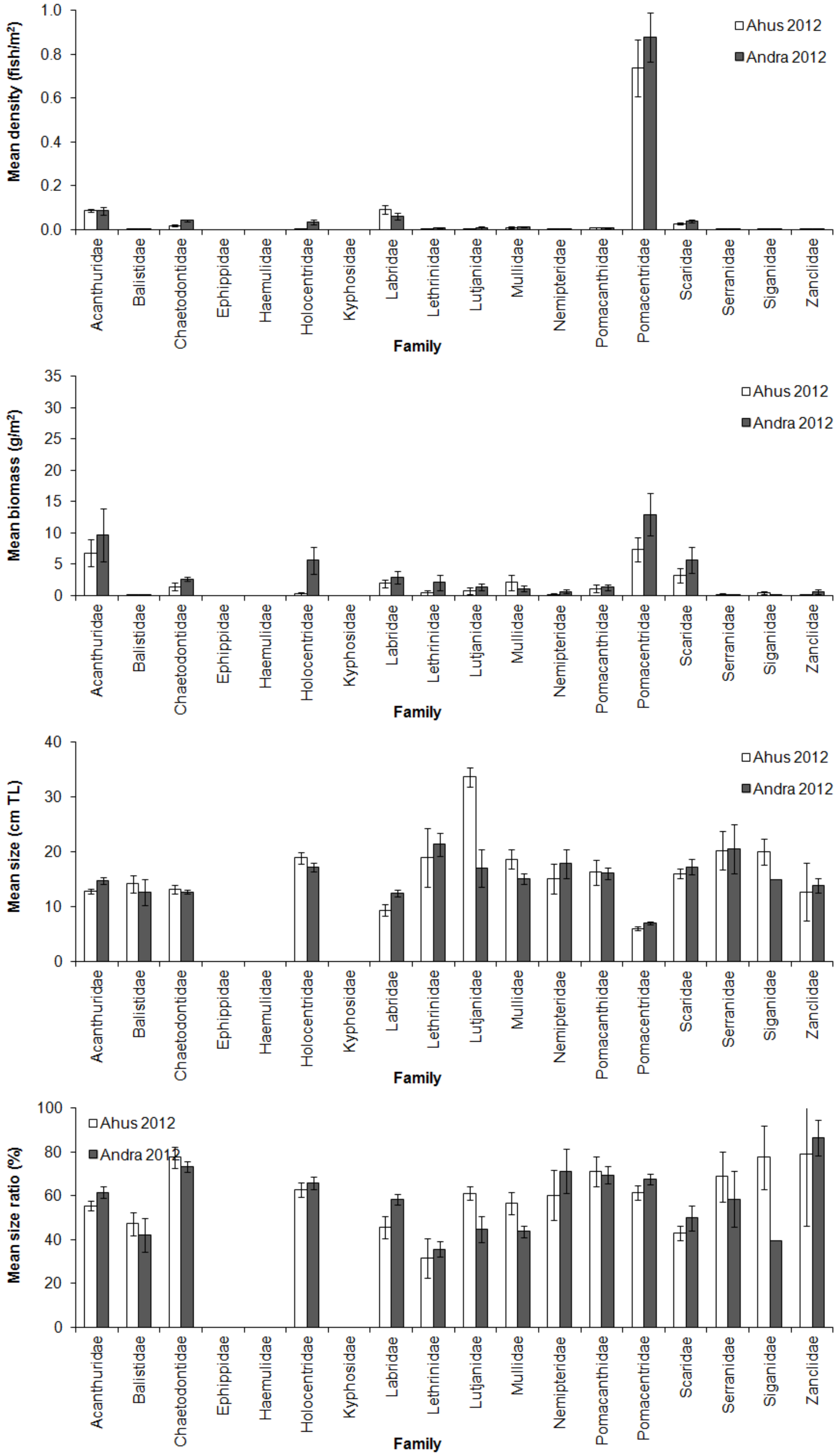


Figure 19 Profile of finfish indicator families in back-reef habitats of Ahus and Andra monitoring stations, 2012.

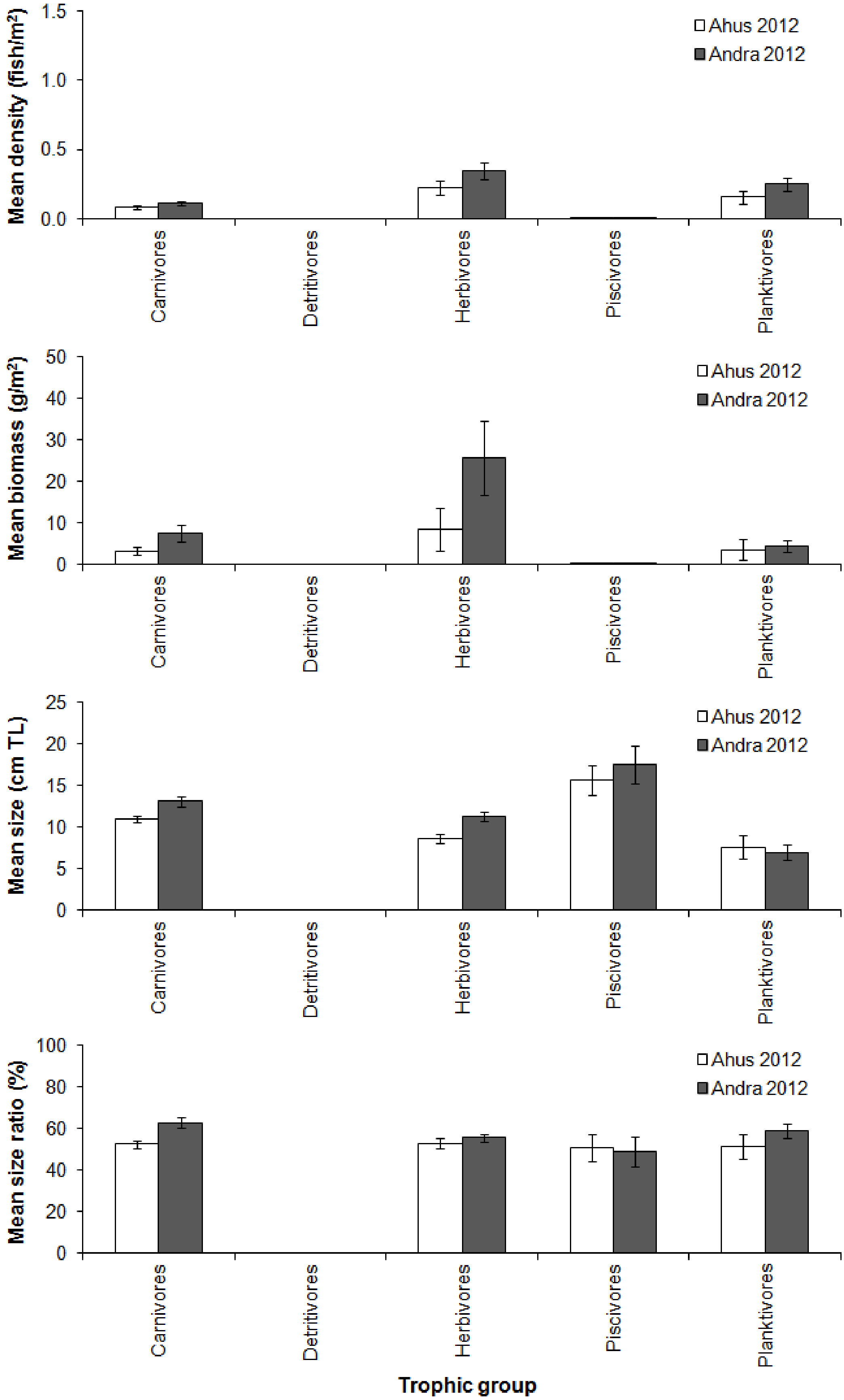


Figure 20 Profile of finfish by trophic level in back-reef habitats of Ahus and Andra monitoring stations, 2012.

Table 11 Finfish species observed in the highest densities in back-reef habitats of Ahus and Andra monitoring sites, 2012. See Appendix 7 and 8 for a full list of densities of individual fish species observed at the Ahus and Andra sites.

Site	Species	Family	Density (fish/m^2±SE)
Ahus	*Amblyglyphidodon curacao*	Pomacentridae	0.219±0.042
	Pomacentrus moluccensis	Pomacentridae	0.109±0.0.21
	Chromis amboinensis	Pomacentridae	0.100±0.081
	Chromis ternatensis	Pomacentridae	0.086±0.049
	Neoglyphidodon nigroris	Pomacentridae	0.050±0.012
Andra	*Amblyglyphidodon curacao*	Pomacentridae	0.486±0.090
	Pomacentrus moluccensis	Pomacentridae	0.079±0.026
	Chromis margaritifer	Pomacentridae	0.051±0.024
	Dascyllus reticulatus	Pomacentridae	0.035±0.018
	Chromis xanthura	Pomacentridae	0.034±0.020

Table 12 Finfish species with the highest biomass in back-reef habitats of Ahus and Andra monitoring sites, 2012. See Appendix 7 and 8 for a full list of biomass of individual fish species observed at the Ahus and Andra sites.

Site	Species	Family	Biomass (g/m^2±SE)
Ahus	*Ctenochaetus striatus*	Acanthuridae	3.280±1.192
	Chlorurus sordidus	Scaridae	2.197±1.115
	Amblyglyphidodon curacao	Pomacentridae	2.052±0.486
	Chromis amboinensis	Pomacentridae	1.518±1.382
	Parupeneus bifasciatus	Mullidae	1.483±1.099
Andra	*Amblyglyphidodon curacao*	Pomacentridae	8.052±2.633
	Myripristis murdjan	Holocentridae	4.362±1.505
	Scarus oviceps	Scaridae	2.653±2.396
	Monotaxis grandoculis	Lethrinidae	2.126±1.235
	Ctenchaetus striatus	Acanthuridae	2.095±0.919

Comparisons with PROCFish (2006) surveys

Both the density and biomass of finfish resources observed on back-reef habitats of Andra during the current (2012) survey generally appeared lower than that observed during the PROCFish surveys of 2006 (Figure 21). Observed mean densities of Acanthuridae, Chaetodontidae, Lethrinidae and Scaridae, and mean biomassses of Acanthuridae, Lethrinidae and Scaridae, were significantly lower at back-reef habitats during the curerent surveys than the PROCFish (2006) survey ($P < 0.05$) (Figure 21). In additon, a significant increase in the cover of sand, rubble, small and large boulders, and calcareous algae (primarily *Halimeda* spp.) and a significant decrease of unvegetated hard substrate (slab) and dead coral was observed between the PROCFish surveys of 2006 and the current (2012) survey ($P < 0.05$) (Figure 22). It should be noted that due to differences in survey design it was not possible to compare the exact same location among surveys (PROCFish surveys typically established one transect per station, whereas the current survey established three transects per station), thus these results may be confounded in part by location differences. Further monitoring is required to determine whether these differences are consistent over time.

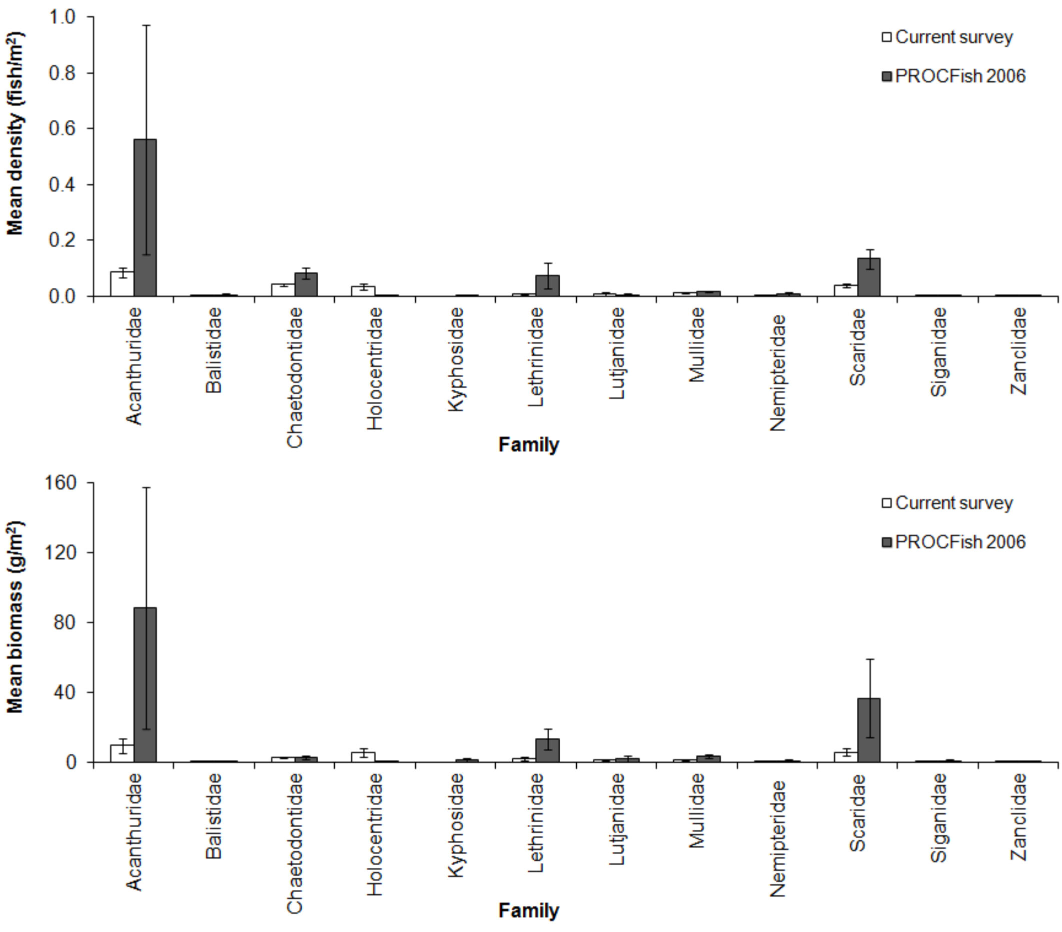


Figure 21 **Comparison of mean density (top) and biomass (bottom) of families recorded from back-reef habitats of Andra in the current (2012) study and during PROCFish surveys in 2006 (± SE).**

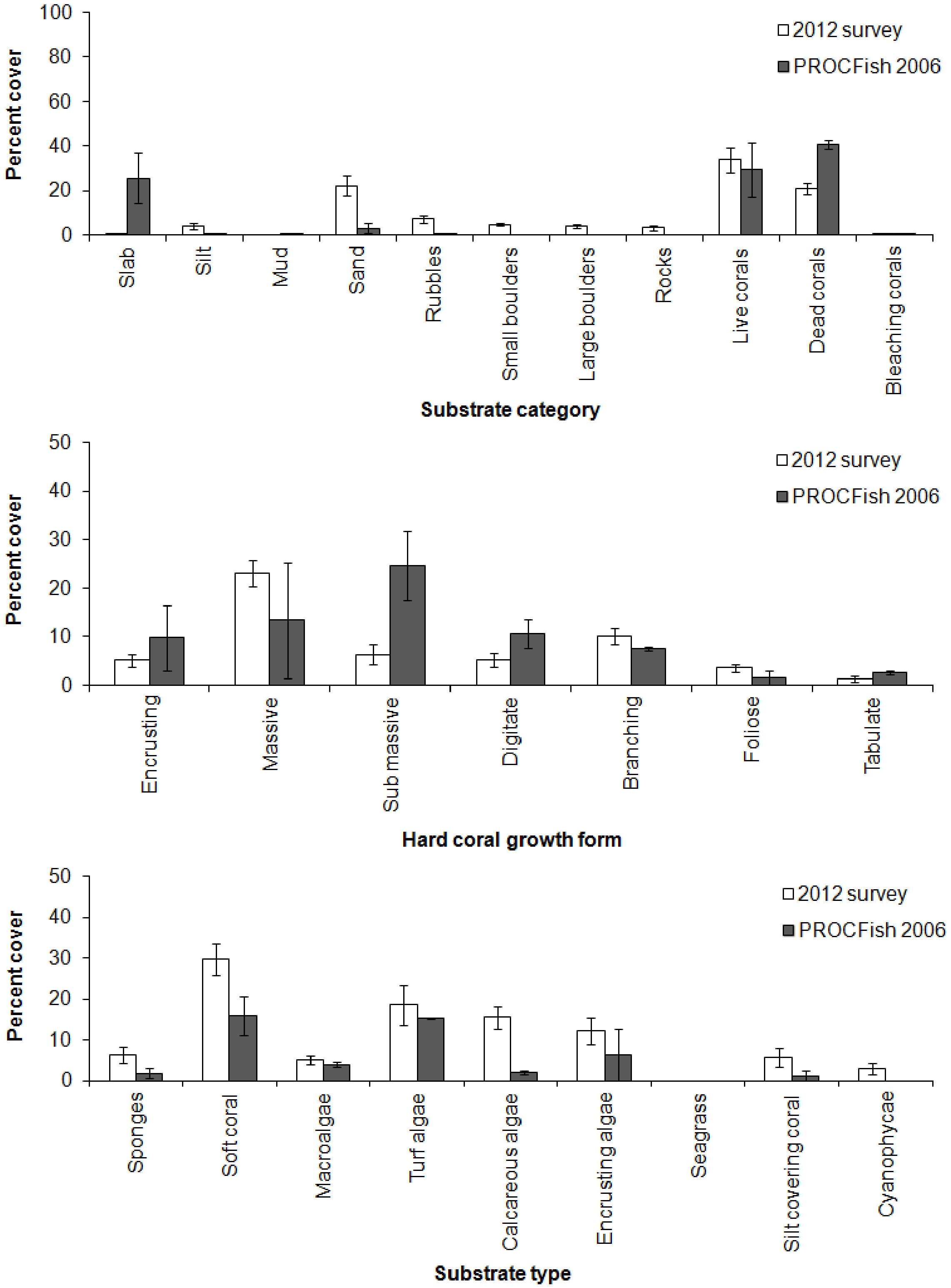


Figure 22 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at back-reef habitats of Andra stations in the cuurrent (2012) study and during PROCFish surveys in 2006.**

Lagoon-reef habitats

Habitats supporting finfish

Due to logistical issues and poor weather at the time of survey, finfish resources and their supporting habitats were surveyed at the lagoon-reefs of Andra only. Lagoon-reefs habitats where D-UVC transects were established at the Andra site were largely characterised by hard corals (both live and dead) and sand (Figure 23). Live hard coral cover was relatively high, constituting 35.4±5.6% of overall cover. Of the corals present, massives were the most prevalent growth form (Figure 23). Similarly, cover of soft corals and turf algae was relatively high (24.9±2.8 and 22.7±3.6%, respectively) (Figure 23).

Finfish surveys

A total of 23 families, 54 genera, 121 species and 2,817 individual fish were recorded from lagoon-reef habitats of the Andra monitoring stations (Table 10). Of the 18 selected 'indicator' families, Pomacentridae were observed in the highest mean densities within the lagoon-reef habitats of Andra, with 0.478±0.094 fish/m^2 constituting 54.6% of the observed mean density, followed by Acanthuridae (0.153±0.062 fish/m^2, 17.5% of observed mean density) and Scaridae (0.058±0.014 fish/m^2, 6.6% of observed mean density) (Figure 24). The individual species observed in the highest mean densities within the lagoon-reef habitats of Andra were the pomacentrids *Amblyglyphidodon curacao*, *Chromis viridis*, *Pomacentrus moluccensis*, *Ctenochaetus striatus* and *Chromis ternatensis* (Table 13).

For lagoon-reef habitats of Andra, members of the Acanthuridae had the greatest biomass (21.558±10.720 g/m^2, comprising 41.5% of the observed mean biomass), followed by members of the families Scaridae (9.077±3.720 g/m^2, 17.5% of observed mean biomass) and Pomacentridae (6.753±1.625 g/m^2, 13.0% of observed mean biomass). Individual species that had the greatest mean biomass within the lagoon-reef habitats of Andra were the acanthurids *Ctenochaetus striatus*, *Acanthurus lineatus* and *Acanthurus nigrofuscus*, the scarid *Scarus dimidiatus* and the pomacentrid *Amblyglyphidodon curacao* (Table 14).

In terms of trophic structure, planktivores (0.354±0.071 fish/m^2) occurred in the greatest mean density within the lagoon-reef habitats of Andra, followed by herbivores (0.345±0.108 fish/m^2). Similarly, herbivores (33.410±14.277 g/m^2) had the greatest biomass at lagoon-reefs of Andra, resulting from the relatively high biomass of Acanthuridae (Figure 25).

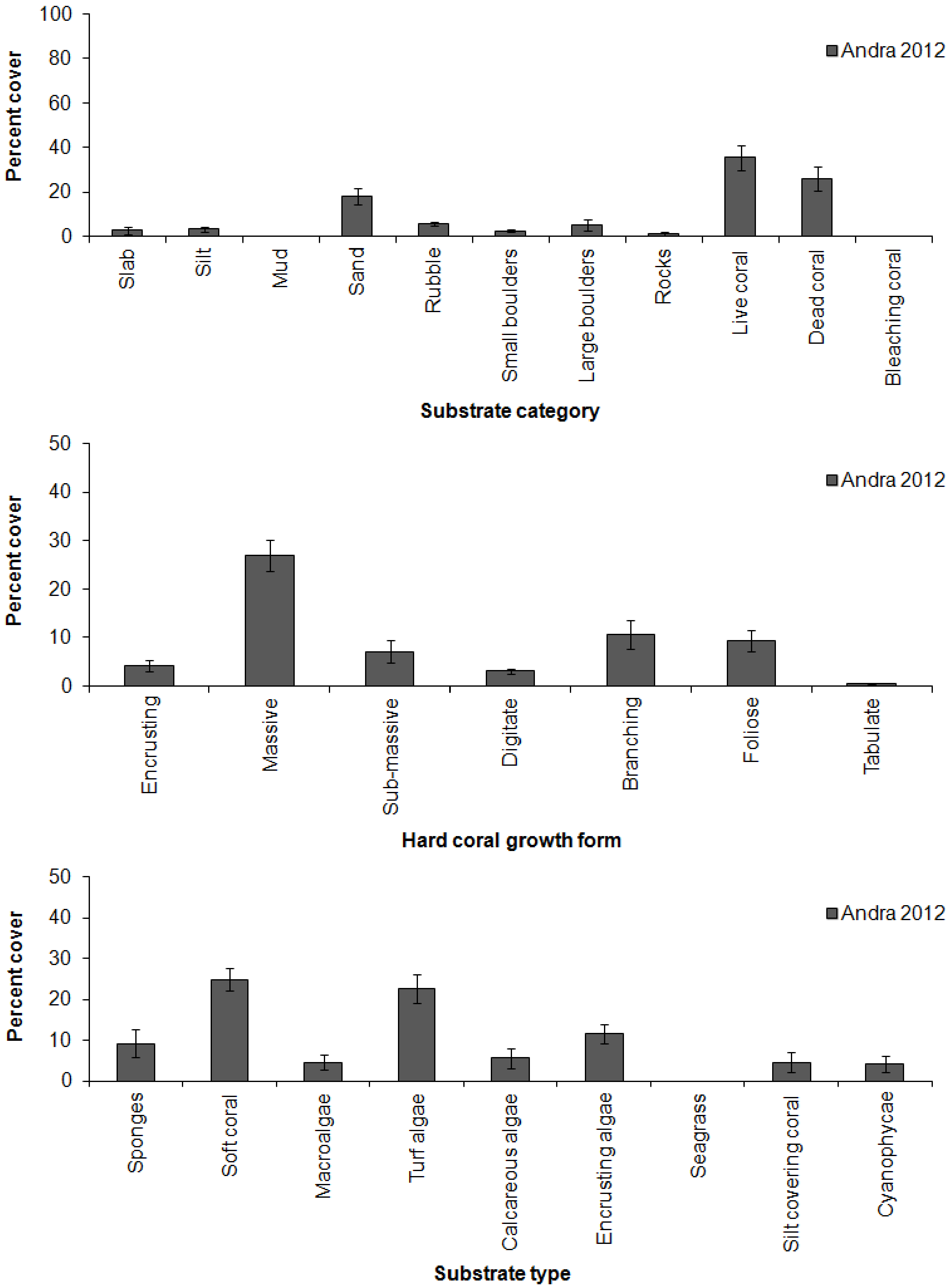


Figure 23 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at lagoon-reef habitats during finfish surveys at Andra monitoring stations, 2012.**

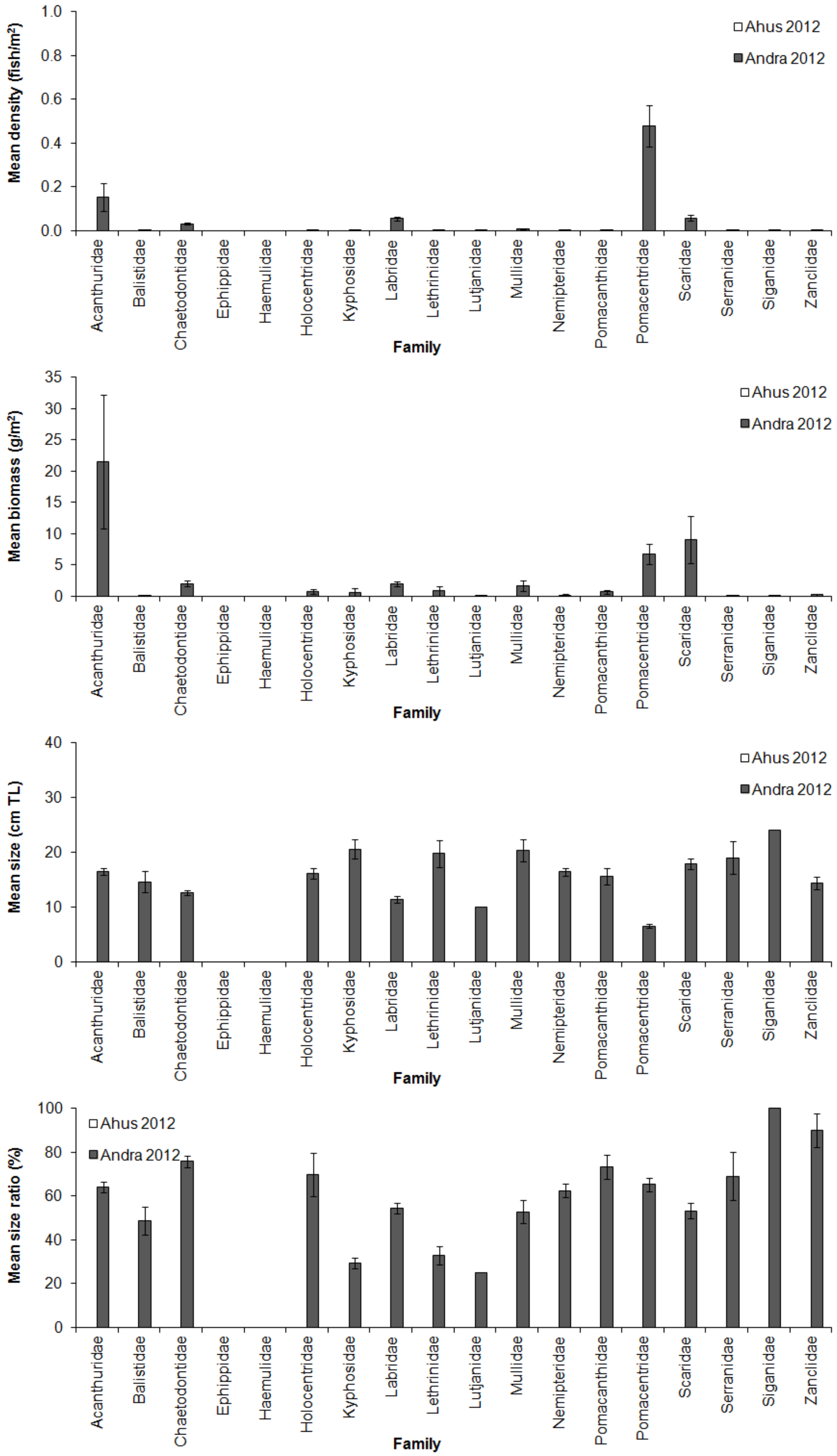


Figure 24 **Profile of finfish indicator families in lagoon-reef habitats of Andra monitoring stations, 2012.**

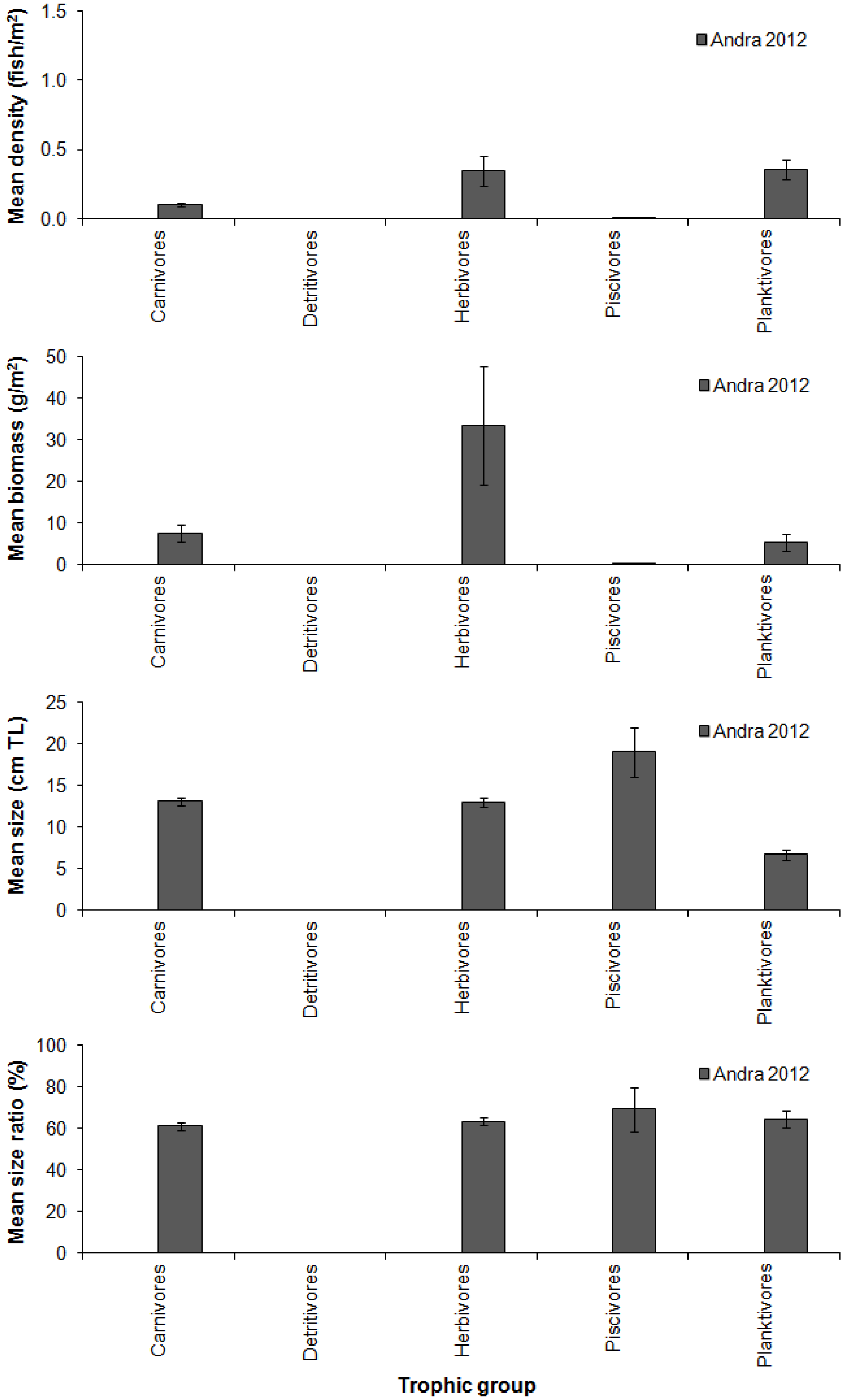


Figure 25 **Profile of finfish by trophic level in lagoon-reef habitats of Andra monitoring stations, 2012.**

Table 13 Finfish species observed in highest densities in lagoon-reef habitats of Andra 2012. See Appendix 7 and 8 for a full list of densities of individual fish species observed at Ahus and Andra monitoring sites.

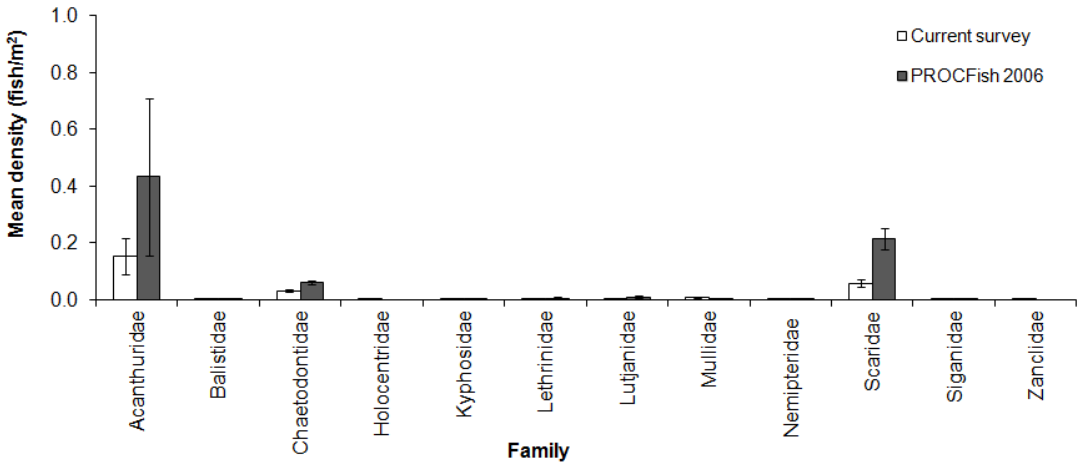
Site	Species	Family	Density (fish/m^2±SE)
Andra	*Amblyglyphidodon curacao*	Pomacentridae	0.185±0.035
	Chromis viridis	Pomacentridae	0.082±0.047
	Pomacentrus moluccensis	Pomacentridae	0.074±0.038
	Ctenochaetus striatus	Acanthuridae	0.063±0.028
	Chromis ternatensis	Pomacentridae	0.036±0.010

Table 14 Finfish species with the highest biomass in lagoon-reef habitats of Andra, 2012. See Appendix 7 and 8 for a full list of biomass of individual fish species observed at Ahus and Andra monitoring sites.

Site	Species	Family	Biomass (g/m^2±SE)
Andra	*Ctenochaetus striatus*	Acanthuridae	7.372±4.036
	Acanthurus lineatus	Acanthuridae	6.419±3.695
	Scarus dimidiatus	Scaridae	4.737±3.558
	Acanthurus nigrofuscus	Acanthuridae	3.656±2.612
	Amblyglyphidodon curacao	Pomacentridae	3.240±1.160

Comparisons with PROCFish (2006) surveys

As with back-reef habitats, both the density and biomass of finfish resources observed on lagoon-reef habitats of Andra during the current (2012) study generally appeared lower than that observed during the PROCFish surveys of 2006 (Figure 26). Observed mean densities of Chaetodontidae, Lutjanidae and Scaridae, and mean biomass of Lutjanidae and Scaridae, were significantly lower during the current survey than the PROCFish (2006) survey ($P < 0.05$) (Figure 26). In additon, a significant increase in the cover of silt and small boulders, and a significant decrease of unvegetated hard substrate (slab) was observed between the PROCFish surveys of 2006 and the current (2012) survey ($P < 0.05$) (Figure 27). As with back-reef habitats it should be noted that due to differences in survey design it was not possible to compare the exact same location among surveys (PROCFish surveys typically established one transect per station, whereas the current survey established three transects per station), thus these results may be confounded in part by location differences. Further monitoring is required to determine whether these differences are consistent over time.



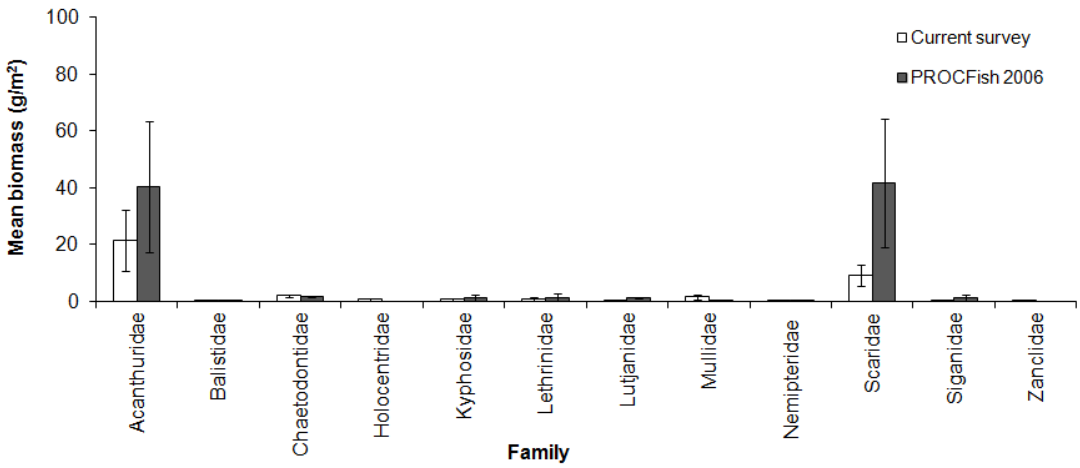


Figure 26 **Comparison of mean density (top) and biomass (bottom) of families recorded from lagoon-reef habitats of Andra in the current study and during PROCFish surveys in 2006 (± SE).**

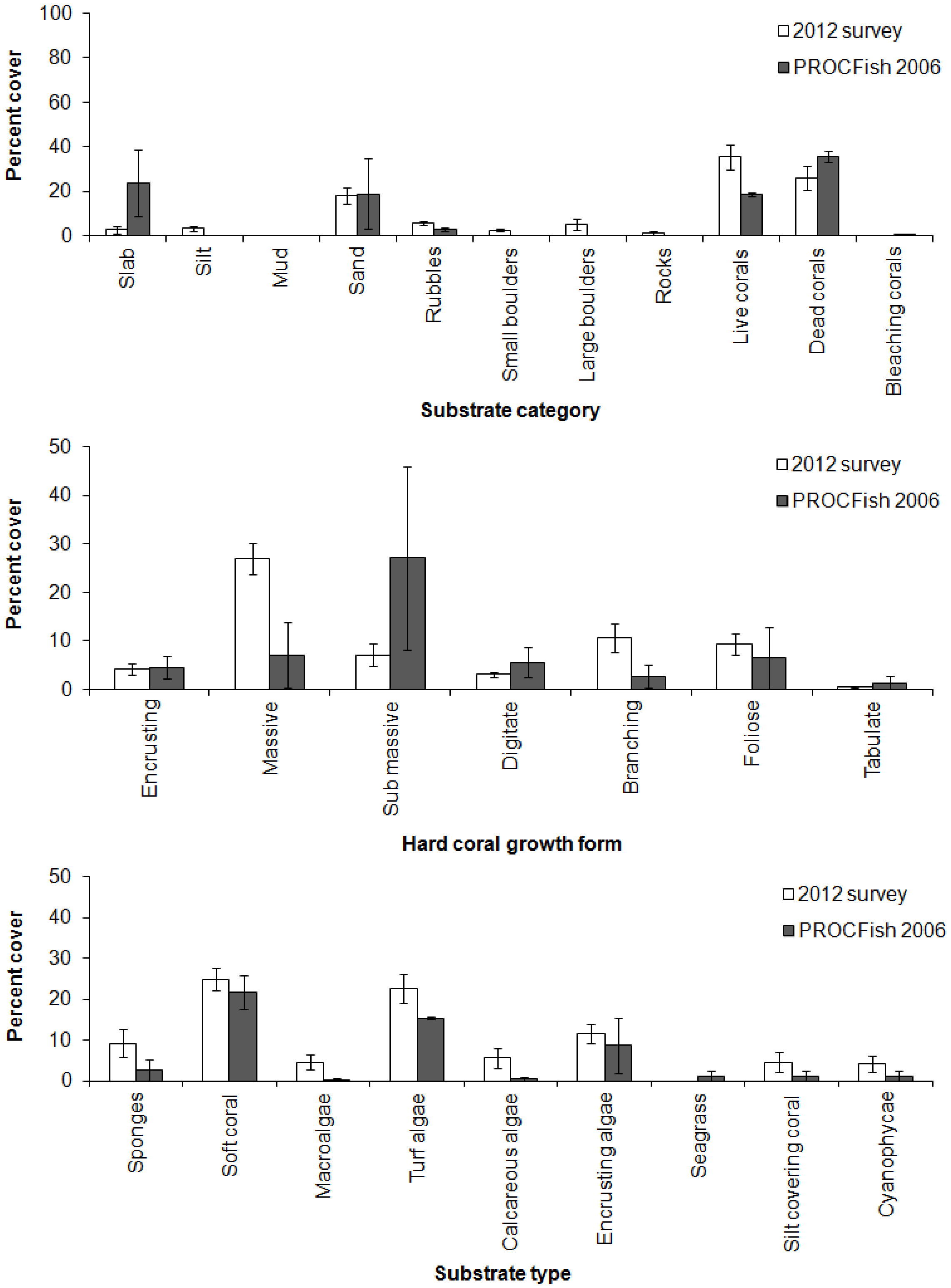


Figure 27 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at lagoon-reef habitats of Andra stations in the current (2012) study and during PROCFish surveys in 2006.**

Outer-reef habitats

Habitats supporting finfish

Of the three habitat types, outer-reef habitats had the greatest mean percent cover of hard substrate, and consequently the lowest percent of soft substrate. Live hard coral cover was relatively high at both sites, representing 43.5±8.6% and 43.9±5.0% of overall cover at Ahus and Andra, respectively (Figure 28). The cover of calcareous algae (primarily *Halimeda* spp.) was similarly high, representing 34.5±6.7 and 32.5±3.6% of overall cover at Ahus and Andra, respectively. All coral growth forms were recorded from the outer-reef habitats, with no one particular growth form dominating at either site (Figure 28). Overall, the outer-reef habitats where finfish surveys were conducted at Ahus and Andra were largely similar. Only the cover of cyanophycae (blue-green algae) differed among sites (P = 0.002), with outer-reefs of Ahus having a significantly greater cover of cyanophycae than those at Andra (Figure 23).

Finfish surveys

A total of 20 families, 50 genera, 118 species and 4,013 individual fishes were recorded from outer-reef habitats of the Ahus monitoring stations, while 16 families, 43 genera, 84 species and 2,030 individual fishes were recorded from outer-reef habitats of the Andra monitoring stations (Table 10). At Ahus, Pomacentridae occurred in the highest densities (0.224±0.023 fish/m^2, 42.2% of observed mean density), followed by members of the Labridae (0.104±0.044 fish/m^2, 19.5% of observed mean density) and Acanthuridae (0.076±0.023 fish/m^2, 14.4% of observed mean density). Similarly, at Andra, members of the Pomacentridae occurred in the highest densities (0.346±0.059 fish/m^2, 46.9% of overall density), followed by members of the Acanthuridae (0.170±0.040 fish/m^2, 23.1% of mean density) and Labridae (0.074±0.021 fish/m^2, 10.0% of overall density) (Figure 29). The mean density of Scaridae was significantly higher at the outer-reefs of the Andra stations than those at Ahus (P = 0.017) (Figure 29). The individual species from the 18 indicator families observed in the highest mean densities within the outer-reef habitats of Ahus were the pomacentrids *Pomacentrus coelestis*, *Chromis xanthura* and *Pomacentrus bankanensis*, the labrid *Thalassoma amblycephalum* and the acanthurid *Ctenochaetus striatus* (Table 15). The individual species observed in the highest densities within the outer-reef habitats of Andra was the pomacentrids *Chromis maragritifer*, *Chromis xanthura* and *Pomacentrus coelestis,* the acanthurid *Ctenochaetus striatus* and the scarid *Chlorurus sordidus* (Table 15).

Mean biomass on outer-reefs of both Ahus and Andra was lower than back- or lagoon-reefs (Figure 17). For outer-reef habitats of Ahus, the family Acanthuridae had the greatest biomass (6.853±4.593 g/m^2, comprising 34.5% of the observed mean biomass), followed the families Labridae (2.081±0.743 g/m^2, 10.5% of observed mean biomass) and Pomacentridae (1.878±0.641 g/m^2, 9.5% of observed mean biomass). Similarly at Andra, members of the Acanthuridae had the greatest biomass (19.224±7.129 g/m^2, 47.5% of observed mean biomass), followed by Scaridae (5.216±1.727 g/m^2, 12.9% of observed mean biomass) and Pomacentridae (3.189±1.167 g/m^2, 7.9% of observed mean biomass) (Figure 29). The mean biomass of Scaridae was significantly higher at outer-reef stations of Andra than those at Ahus ($P < 0.039$) (Figure 29). The individual species that had the greatest mean biomass within the outer-reef habitats of Ahus were the acanthurids *Ctenochaetus striatus*, *Acanthurus nigricans* and *Acanthurus nigroris*, the balistid *Odonus niger*, and the pomacentrid *Chromis xanthura* (Table 16). The individual species that had the greatest mean biomass within the outer-reef habitats of Andra were the acanthurids *Ctenochaetus striatus*, *Acanthurus nigrofuscus*, *Acanthurus grammoptilus*, and *Acanthurus nigricans*, and the scarid *Chlorurus sordidus* (Table 16). A full list of biomass by family and individual species can be found in Appendices 5–8.

No significant differences were apparent in mean size or mean size ratio of any of the 18 indicator families among outer-reef habitats of the Ahus and Andra sites (Figure 29).

In terms of trophic group, herbivores occurred in the greatest mean density at the outer-reef habitats of Ahus, with 0.224±0.050 fish/m^2, followed by planktivores (0.157±0.048 fish/m^2) (Table 15). Similarly, herbivores (0.348±0.061 fish/m^2) and planktivores (0.252±0.047 fish/m^2) occurred in the greatest mean densities at outer-reef stations of Andra. Consistent with their relatively high densities, herbivores (8.526±5.251 g/m^2) and planktivores (3.570±2.439 g/m^2) had the greatest biomass on the outer-reefs of the Ahus site, while herbivores (25.672±8.916 g/m^2 and carnivores (7.549±2.089 g/m^2) had the greatest biomass at Andra. The mean density and mean biomass of piscivores was low at both sites (Figure 30). No significant differences were observed in mean density, biomass or size ratio of any trophic group among the outer-reef habitats of Ahus and Andra (Figure 30). The mean size of herbivores was significantly larger at outer-reef stations at Andra compared to those at Ahus ($P = 0.038$).

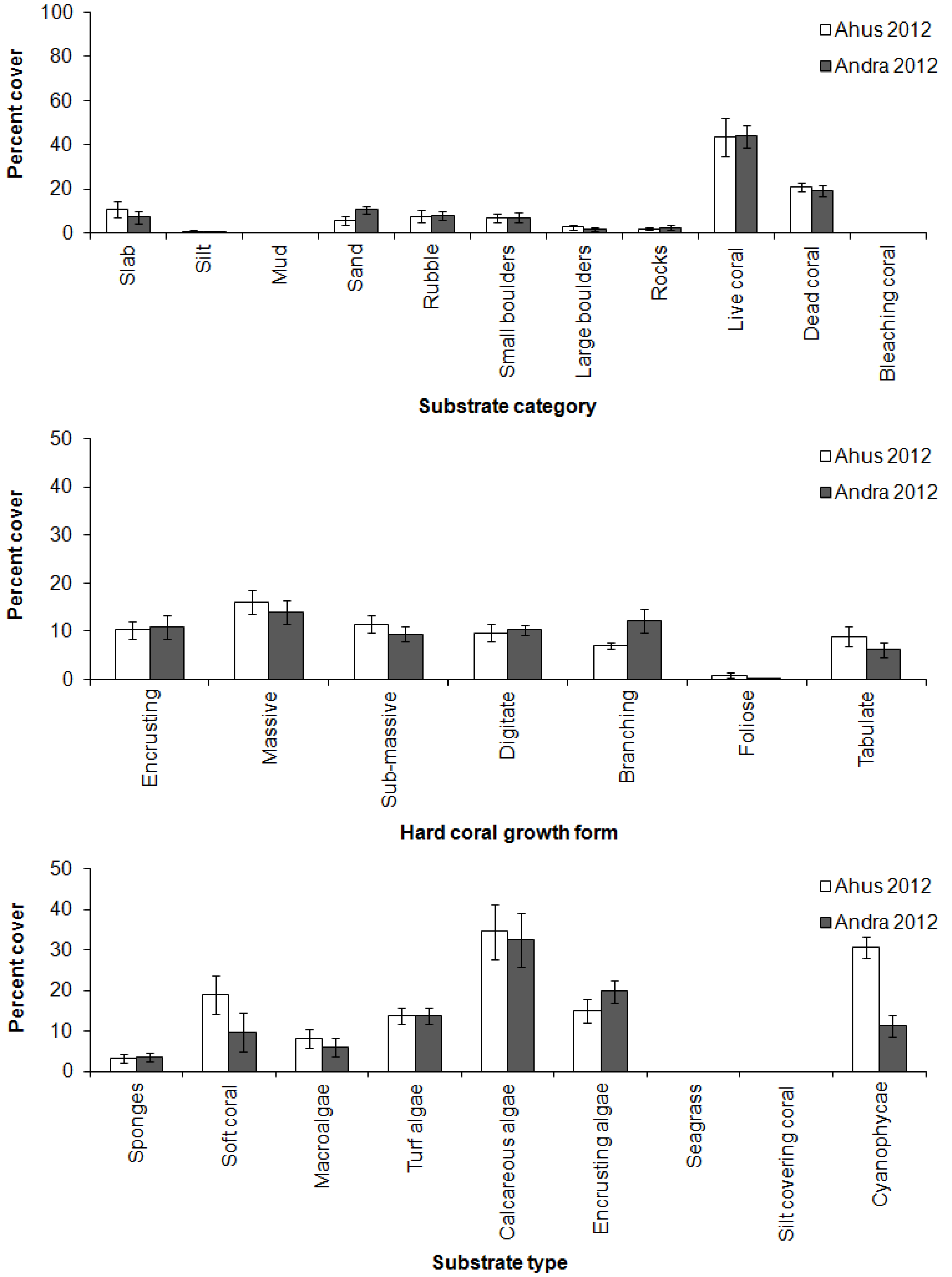


Figure 28 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at outer-reef habitats during finfish surveys at Ahus and Andra monitoring stations, 2012.**

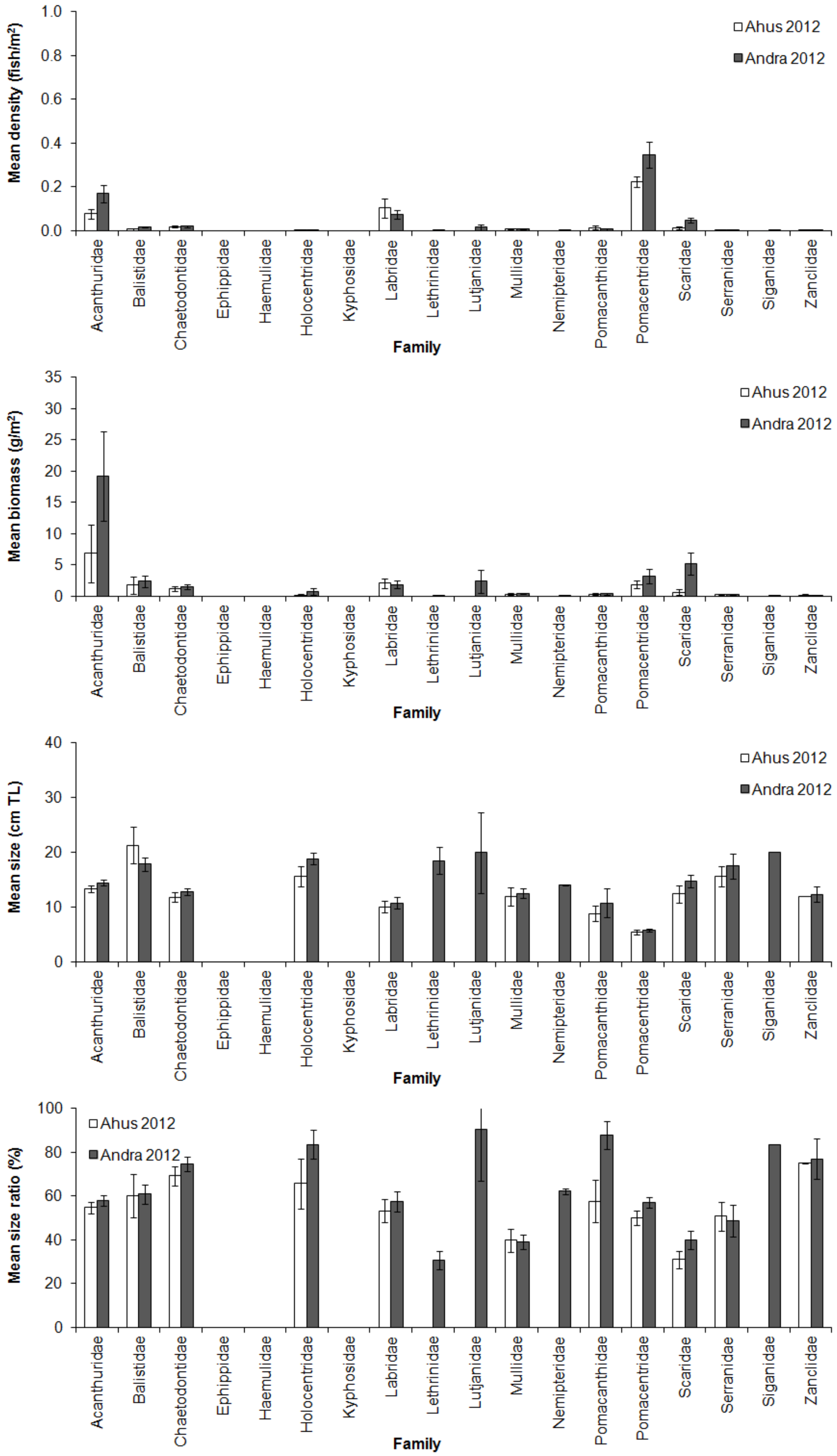


Figure 29 **Profile of finfish indicator families in outer-reef habitats of Ahus and Andra monitoring stations, 2012.**

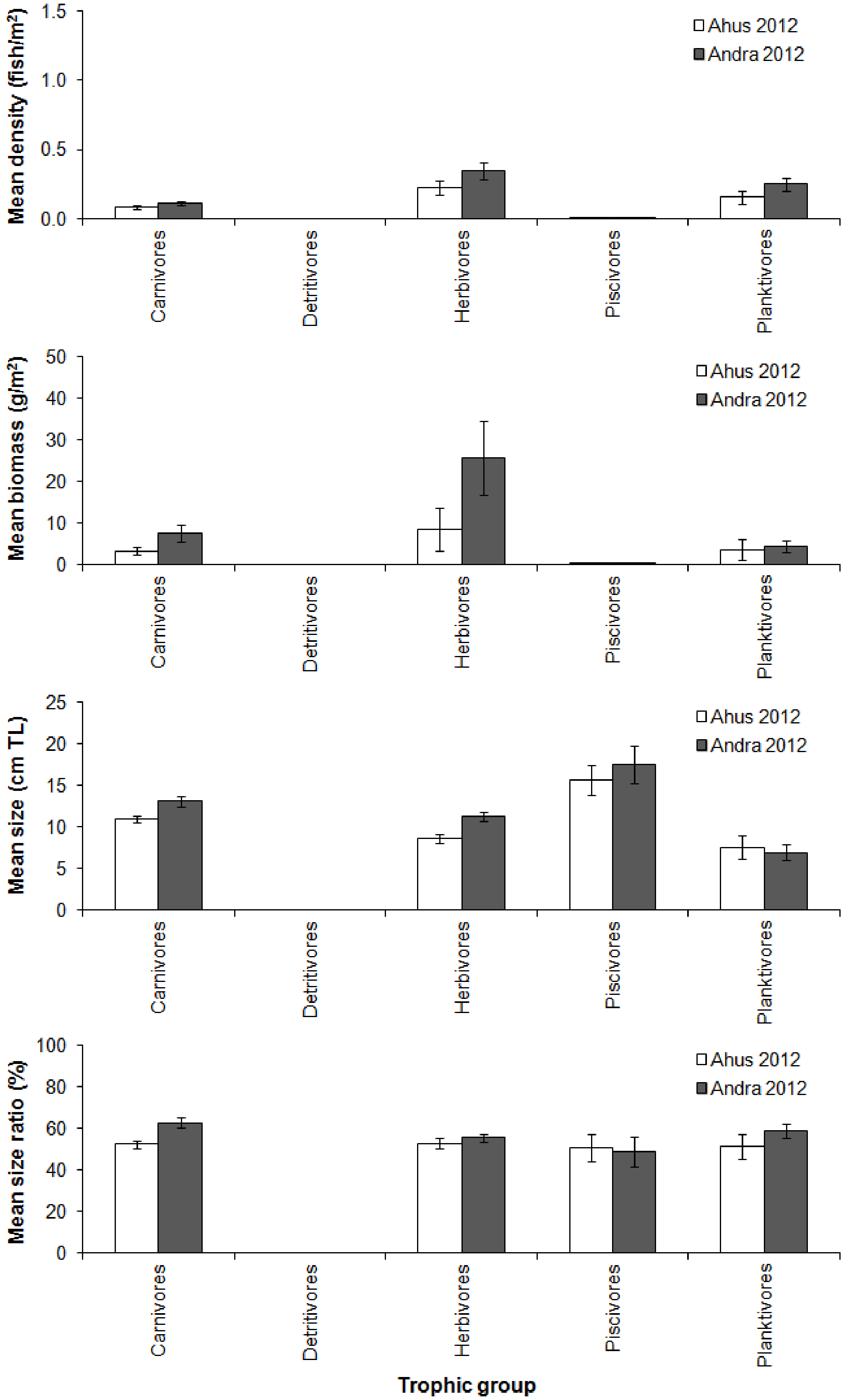


Figure 30 **Profile of finfish by trophic level in outer-reef habitats of Ahus and Andra monitoring stations, 2012.**

Table 15 Finfish species observed in highest densities in outer-reef habitats of Ahus and Andra monitoring sites, 2012. See Appendix 7 and 8 for a full list of densities of individual fish species observed at the Ahus and Andra sites.

Site	Species	Family	Density (fish/m^2±SE)
Ahus	*Pomacentrus coelestis*	Pomacentridae	0.069±0.017
	Chromis xanthura	Pomacentridae	0.056±0.027
	Thalassoma amblycephalum	Labridae	0.048±0.048
	Ctenochaetus striatus	Acanthuridae	0.031±0.013
	Pomacentrus bankanensis	Pomacentridae	0.029±0.007
Andra	*Chromis margaritifer*	Pomacentridae	0.140±0.026
	Ctenochaetus striatus	Acanthuridae	0.085±0.025
	Chromis xanthura	Pomacentridae	0.049±0.014
	Pomacentrus coelestis	Pomacentridae	0.048±0.014
	Chlorurus sordidus	Scaridae	0.036±0.012

Table 16 Finfish species with the highest biomass in outer-reef habitats of Ahus and Andra monitoring sites, 2012. See Appendix 7 and 8 for a full list of biomass of individual fish species observed at the Ahus and Andra sites.

Site	Species	Family	Biomass (g/m^2±SE)
Ahus	*Ctenochaetus striatus*	Acanthuridae	2.939±2.346
	Acanthurus nigricans	Acanthuridae	1.922±0.823
	Odonus niger	Balistidae	1.262±1.262
	Acanthurus nigroris	Acanthuridae	1.138±0.694
	Chromis xanthura	Pomacentridae	0.871±0.567
Andra	*Ctenochaetus striatus*	Acanthuridae	7.389±2.234
	Acanthurus nigrofuscus	Acanthuridae	3.545±2.264
	Acanthurus grammoptilus	Acanthuridae	3.256±3.256
	Chlorurus sordidus	Scaridae	2.581±0.744
	Acanthurus nigricans	Acanthuridae	2.121±1.173

Comparisons with PROCFish (2006) surveys

Observed mean densites of Acanthuridae, Chaetodontidae, Scaridae and Siganidae, and mean biomass of Acanthuridae, Scaridae and Siganidae, were significantly higher during the PROCFish (2006) surveys than the current (2012) survey (P < 0.05) (Figure 31). In addition, significant increases in the cover of sand, small boulders, calcareous algae and cyanophycae (blue-green algae), and significant decreases in the cover of unvegetated hard substrate (slab) and dead coral, were observed between the PROCFish surveys of 2006 and the current (2012) survey (P < 0.05) (Figure 32). As with back-reef habitats, the increase in calcareous algae and decreases in uvegetaeted hard substrate likely relates to the reductions of the herbivorous fish familes Acanthuridae and Scaridae observed between the two surveys. It should be noted that due to differences in survey design it was not possible to compare the exact same location among surveys (PROCFish surveys typically established one transect per station, whereas the current survey established three transects per station), thus these results may be confounded in part by location differences. Further monitoring is required to determine whether these differences are consistent over time.

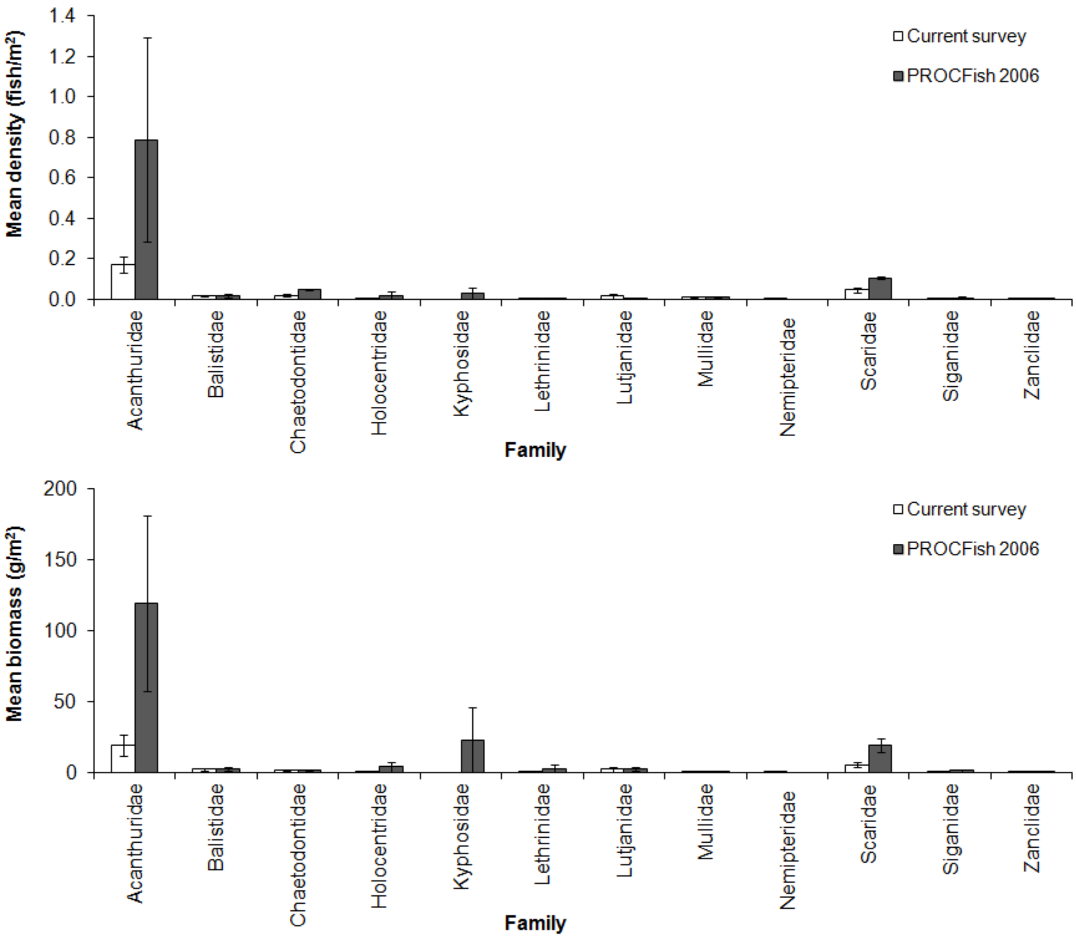


Figure 31 **Comparison of mean density (top) and biomass (bottom) of families recorded from outer-reef habitats of Andra in the current study and during PROCFish surveys in 2006 (± SE).**

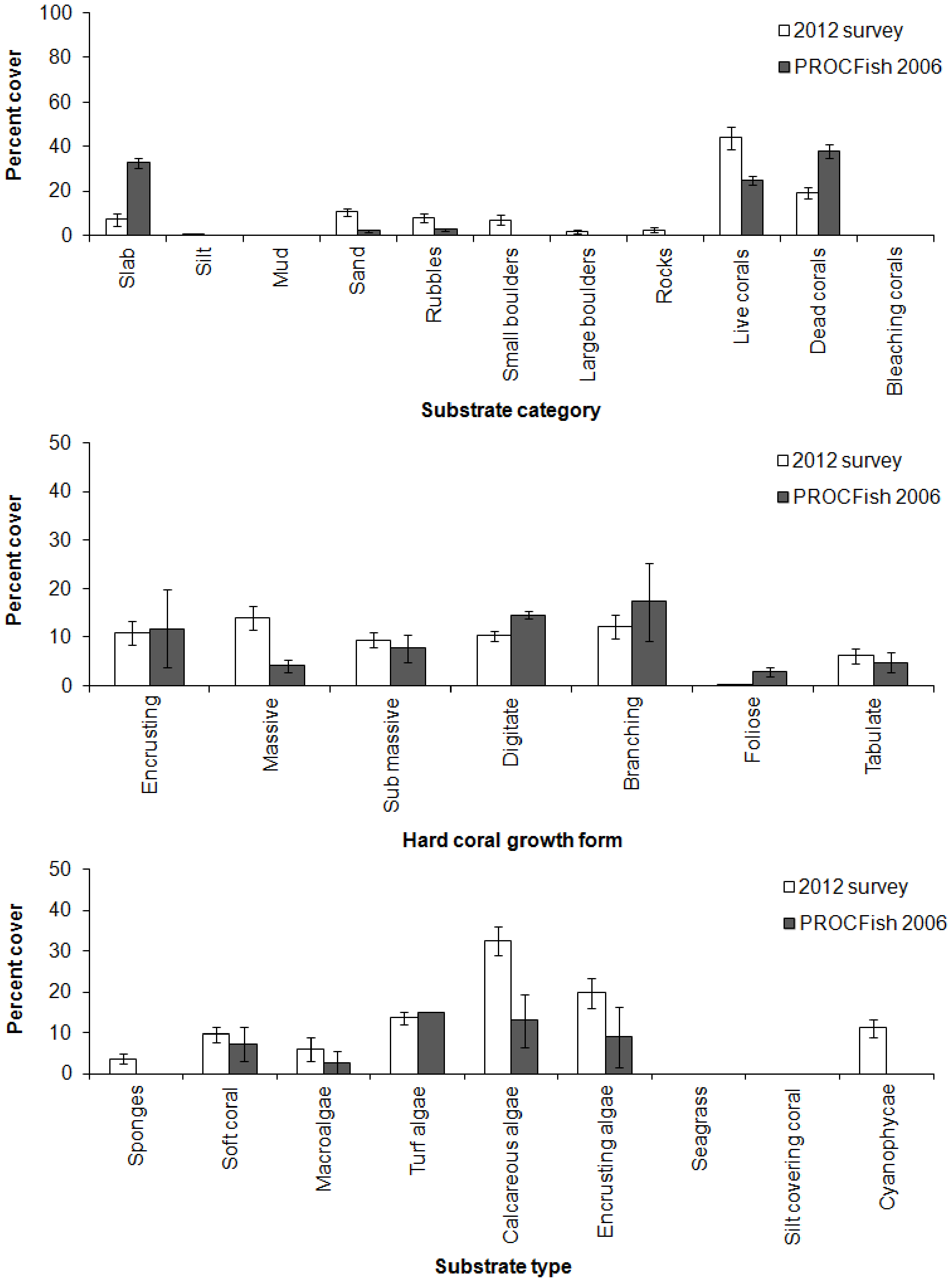


Figure 32 **Mean cover (± SE) of each major substrate category (top), hard coral growth form (middle) and 'other' substrate type (bottom) present at outer-reef habitats of Andra stations in the current (2012) study and during PROCFish surveys in 2006.**

6. Invertebrate Surveys

Methods and Materials

Data collection

Invertebrates

Two survey methods were used to assess the abundance, size and condition of invertebrate resources and their habitat across reef zones. Manta tows were used to provide a broad-scale assessment of invertebrate resources associated with reef areas. In this assessment, a snorkeller was towed behind a boat with a manta board for recording the abundance of large sedentary invertebrates (e.g. sea cucumbers) at an average speed of approximately 4 km/hour (Figure 33). Hand tally counters were also mounted on the manta board to assist with enumerating the common species on site. The snorkeller's observation belt was two metres wide and tows were conducted in depths typically ranging from one to ten metres. Each tow replicate was 300 m in length and was calibrated using the odometer function within the trip computer option of a Garmin 76Map GPS. Six 300 m manta tow replicates were conducted within each station, with the start and end GPS positions of each tow recorded to an accuracy of within ten metres.

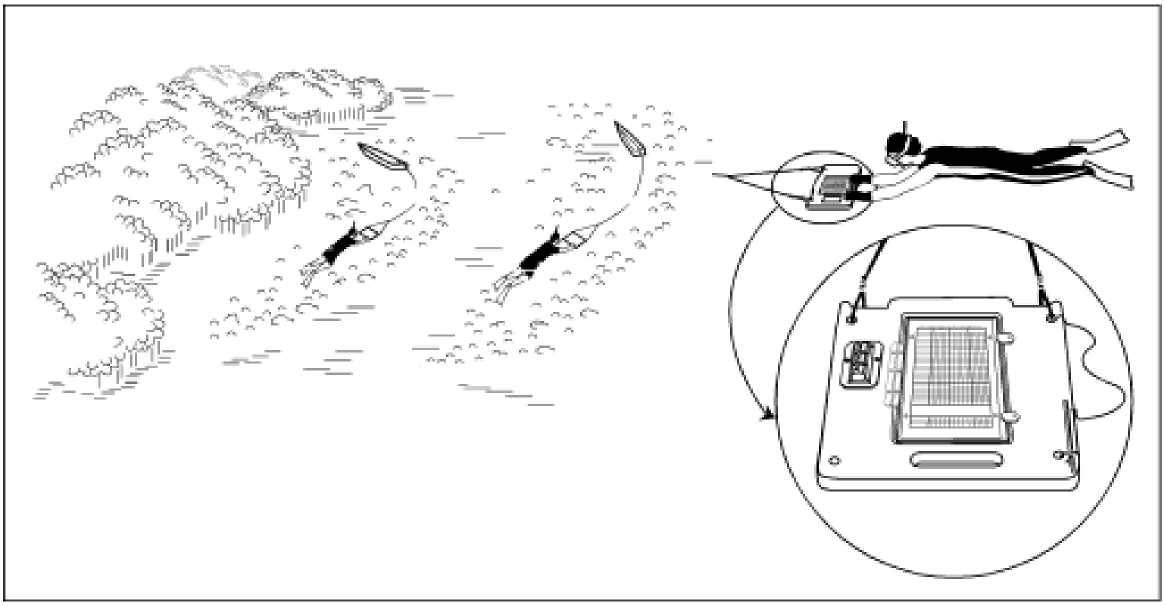


Figure 33 Broad-scale method: manta tow survey

To assess the abundance, size and condition of reef-associated invertebrate resources and their habitat at finer-spatial scales, reef-benthos transects (RBT) were conducted. Reef-benthos transects were conducted by two snorkelers equipped with measuring instruments attached to their record boards (slates) for recording the abundance and size of invertebrate species. For some species, such as sea urchins (e.g. *Echinometra sp*.), only abundance was recorded due to difficulty in measuring the size of these organisms. Each transect was 40 metres long with a one metre wide observation belt, conducted in depths ranging from one to three metres. The two snorkellers conducted three transects each, totalling six 40 m transects for each RBT station (Figure 34). The GPS position of each station was recorded in the centre of the station.

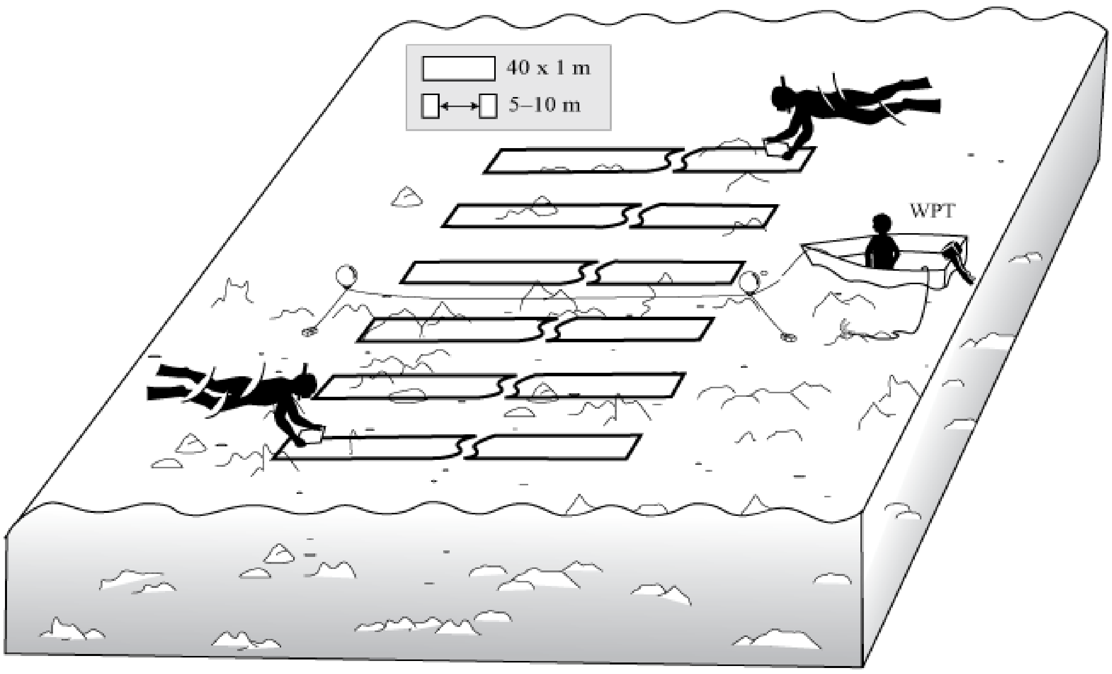


Figure 34 Fine-scale method: reef-benthos transects

Habitats supporting invertebrates

Both manta tows and reef benthos transects used the same survey form (Appendix 9) which also includes a section for substrate cover record (medium scale approach). Habitat is recorded in seven broad categories:

1. Relief and complexity
   - Relief – describes average height variation for hard and soft benthos (scale 1–5, with 1 = low relief and 5 = high relief);
   - Complexity – describes average surface variation for substrates (relative to places for animals to find shelter; scale 1–5, with 1= low complexity and 5 = high complexity);
2. Ocean influence – describes the distance and influence of area to open sea (scale 1–5, with 1 = low ocean influence and 5 = high ocean influence);
3. Depth – average depth of the surveyed area (in metres);
4. Substrate categories (totalling to 100%):
   - Soft sediments including (1) *mud*, (2) *mud and sand*, (3) *sand* and (4) *coarse sand*;
   - (5) *rubble* - small fragments of coral between 0.5 and 15 cm;
   - (6) *boulders* - detached big pieces of coral stone more than 30 cm;
   - (7) c*onsolidated rubble* - cemented pieces of coral and limestone debris,
   - (8) *pavement* - solid fixed flat limestone;

    - (9) *coral live* any live hard coral; and
    - (10) *coral dead* any dead carbonated edifices that are still in place and retain a general coral shape;
5. Other substrate types (recorded in occurrences not totalling 100%)
    - (11) s*oft coral*;
    - (12) *sponges*; and,
    - (13) *fungids*;
    - (14) *crustose coralline algae*;
    - (15) *coralline algae* (e.g. *Halimeda*);
    - (16) *other algae* - includes all fleshy macroalgae not having calcium carbonate deposits; and
    - (17) *seagrass* (e.g. *Halophila*);
6. Epiphytes and silt
    - Epiphytes – describes the coverage of filamentous algae such as turf algae on hard substrate (scale 1–5, with 1 = no cover and 5 = high cover);
    - Silt – easily suspended fine particles (scale 1–5, as 1 = no silt and 5 = high silt);
7. Bleaching - the percentage of bleached live coral.

Data analysis

In this report, the status of invertebrate resources has been characterised using the following parameters:

1) richness – the number of families and species counted in each survey method;
2) diversity – total number of observed species per habitat and site divided by the number of stations;
3) mean density (individuals/ha);
4) mean size (mm).

As with the finfish analyses, relationships between environmental parameters and invertebrate resources have not been fully explored in this baseline report. To explore differences in invertebrate densities and their habitats among sites, density data for each individual invertebrate species, and habitat categorical data, of each transect was square-root transformed to reduce heterogeneity of variances and analysed by ANOVA, using Statistica 7.1. Manta tow data were analysed using two-way ANOVA at $P = 0.05$, with site (Ahus and Andra) and habitat (back-reef and outer-reef) as fixed factors in the analysis, while RBT data were analysed using one-way ANOVA, with site as a fixed factor in the analysis. While Cochran's C tests revealed that homogeneity of data was not always achieved, results of the ANOVA were still considered valid for both manta tow and RBT data as the designs for these surveys were balanced (Underwood 1997). Additionally, density data from the current study were compared against that collected during the PROCFish surveys in the region in 2006 (Friedman et al. 2008) for both manta tow and RBT methodologies using one-way ANOVA. While the PROCFish study collected data across the region in general, including the passages and back reefs of Ahus and Andra Islands and the coastal fringing reefs of Manus Island (see Friedman et al. 2008), only data from similar habitats were used in these comparison (Figure 35). Tukey-Kramer post-hoc pairwise tests were used to identify specific differences between factors of the manta tow data at $P = 0.05$.

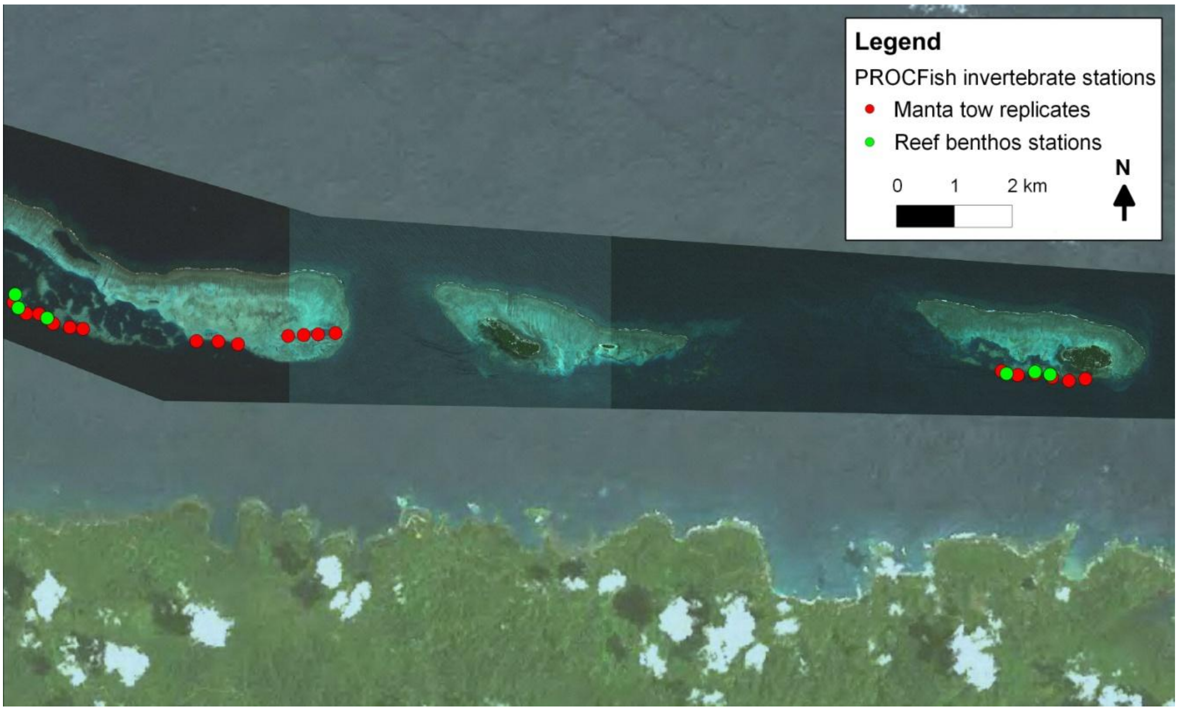


Figure 35 Location of PROCFish invertebrate survey sites at Ahus and Andra Islands used to compare against data collected during the current (2012) study.

Results

Manta tow

Survey coverage

A total of eight manta tow stations were established, with four manta tows conducted in each of the Ahus and Andra sites (Figure 36; Table 17). At each site, two manta tow stations were completed on each of the back- and outer-reefs. GPS positions of all manta tow replicates are tabulated in Appendix 10.

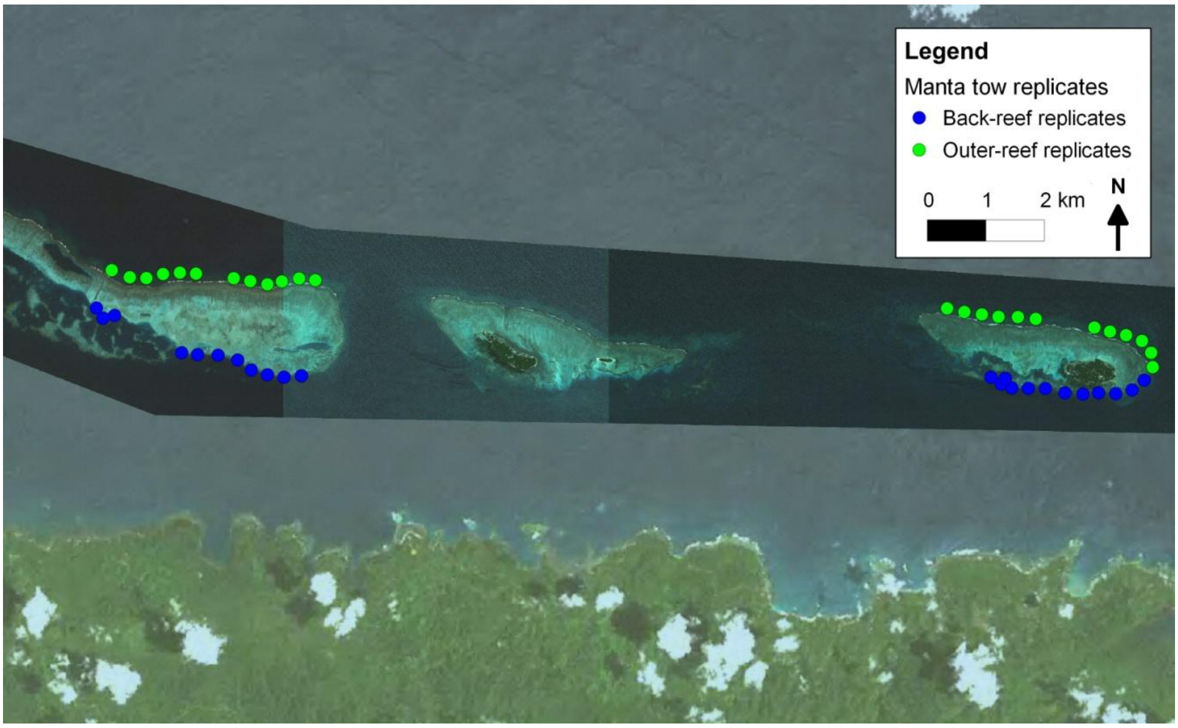


Figure 36 Locations of manta tow replicates established at the Ahus and Andra monitoring stations, 2012.

Table 17 Summary of manta tow stations established at the Ahus and Andra monitoring sites, 2012.

Site	Habitat	Number of stations	Number of replicates	Area surveyed (m^2)
Ahus	Back-reef	2	12	7,200
	Outer-reef	2	12	7,200
Andra	Back-reef	2	12	7,200
	Outer-reef	2	12	7,200

Back-reefs

Habitats supporting invertebrates

Habitats where the manta tow surveys were conducted on the back-reefs varied among survey sites. The substrate of Ahus stations was dominated by sand, while Andra stations were dominated by live coral (Figure 37). Back-reef habitats where manta tows were conducted at Ahus had significantly high cover of sand, coralline algae (primarily *Halimeda* spp.), crustose coralline algae, other algae and soft coral, and lower cover of live coral, than those at the Andra stations (Figure 37). A full list of percent cover of each habitat variable recorded during the manta tow surveys is presented as Appendix 11.

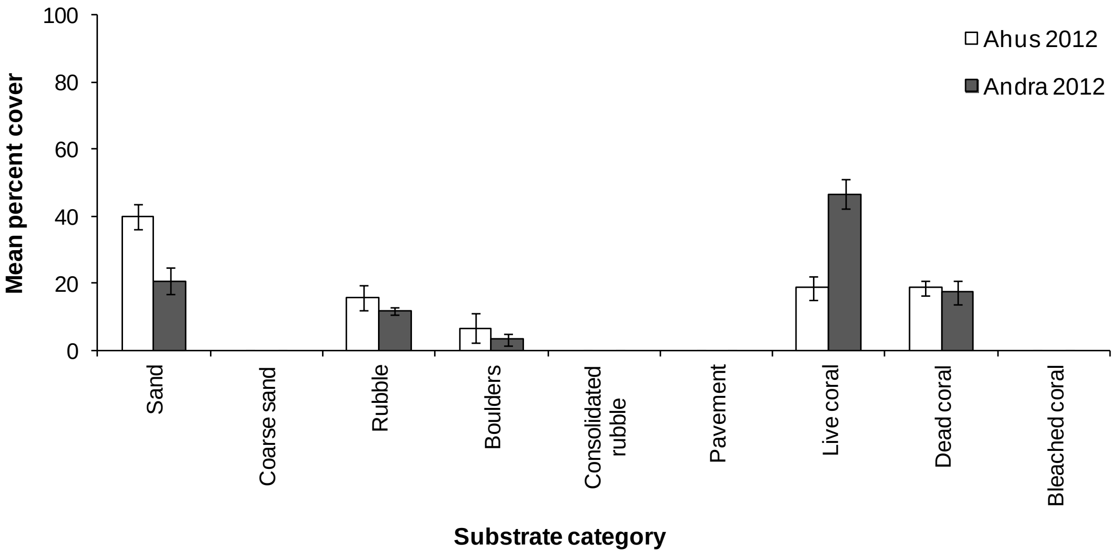


Figure 37 Mean percent cover (± SE) of each major substrate category of manta tow survey stations established on the back-reefs of Ahus and Andra, 2012.

Invertebrate surveys

A total of 16 species were recorded during the manta tow surveys on the back-reef habitats, with 10 species observed on the back-reefs of Ahus and 13 species observed on the back-reefs of Andra. A slightly greater diversity was observed on the back-reef habitats of Andra, where an average of 6.5 species were recorded per station, compared to 5 at Ahus (Table 18). Mean densities of observed invertebrate species were typically low at both sites (Figure 38). Individual species observed in the highest mean densities during the manta tow surveys on back-reef habitats at Ahus included the sea cucumbers *Holothuria atra* (48.61±23.61 individuals/ha) and *Bohadschia argus* (16.67±13.89 individuals/ha) and the starfish *Linckia laevigata* (29.17±29.17 individuals/ha), while at Andra *L. laevigata* (159.72±45.83 individuals/ha), *H. atra* (30.56±8.33) and *Thelenota anax* (23.61±23.61 individuals/ha) were observed in the highest densities. The mean densities of the sea cucumbers *Bohadschia vitiensis*, *Holothuria edulis* and *Pearsonothuria graeffei*, the starfish *L. laevigata*, and the giant clam *Tridacna maxima* were significantly higher on back-reefs habitats of Andra than Ahus ($P < 0.05$) (Figure 41). A single individual of trochus, *Tectus niloticus*[2], was observed at the Ahus site. No crown-of-thorns starfish, *Acanthaster planci*, were observed during the manta tow surveys on the back-reefs of

[2] This species was formerly known as *Trochus niloticus*

either site. A full list of densities of individual species observed during the manta tow surveys on the back-reefs of each site is presented as Appendix 12.

Table 18 Total number of genera and species, and diversity, of invertebrates observed during manta tow surveys at Ahus and Andra monitoring stations, 2012.

Parameter	Back-reef		Outer-reef	
	Ahus	Andra	Ahus	Andra
No. of genera	7	9	4	8
No. of species	10	13	5	8
Diversity	5.0	6.5	2.5	4

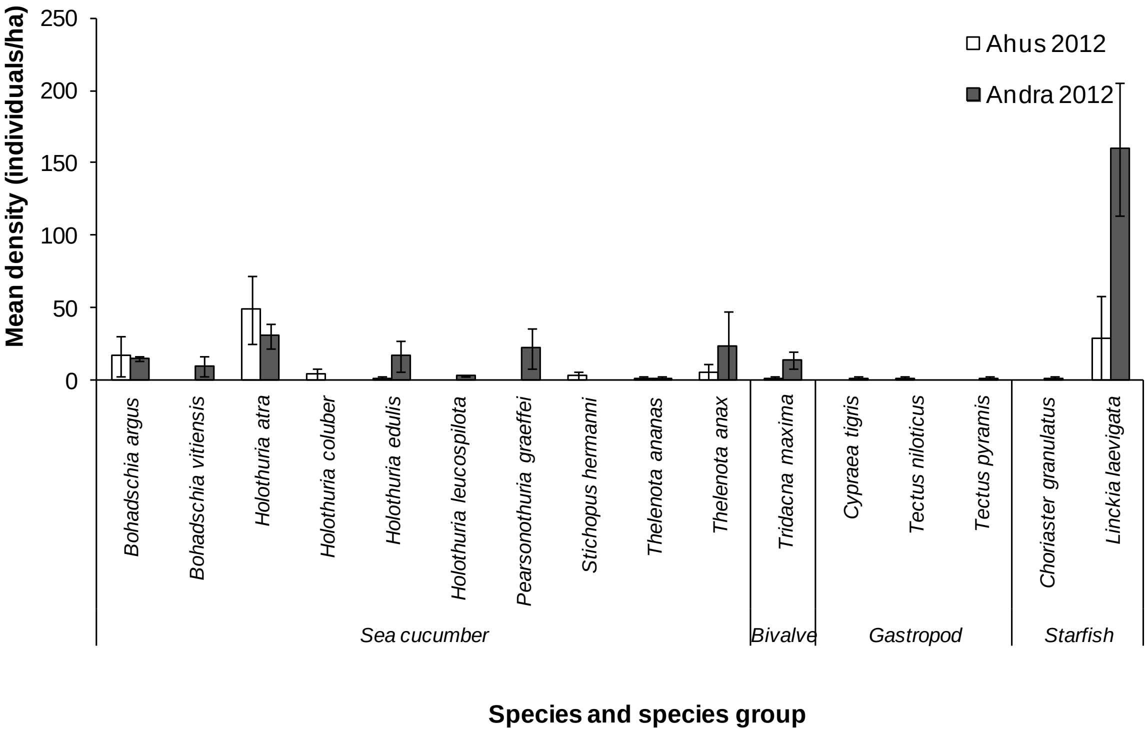


Figure 38 Overall mean density of invertebrate species (± SE) observed at back-reef habitats during manta tow assessments at Ahus and Andra, 2012.

Comparison with PROCFish (2006) surveys

Mean densities of the sea cucumber *Bohadschia argus*, the starfish *Protoreaster nodosus* and the clam *Tridacna maxima* on the back-reefs of Ahus were significantly lower during the current (2012) study than the PROCFish (2006) survey (P < 0.05) (Figure 39). Similarly, mean densities of *B. argus*, *P. nodosus* and the clam *Tridacna crocea* observed during manta tow surveys on the back-reefs of Andra were significantly lower in the current study compared to the PROCFish survey. In contrast, mean densities of *Holothuria atra* on the back-reefs of Ahus and *Pearsonothuria graeffei* on the back-reefs of Andra were significantly higher in the current (2012) study than the PROCFish survey (P < 0.05)

(Figure 39). It should be noted that while these surveys were conducted in the same general habitats, they were not conducted at the same locations, and as such these results may be at least partially influenced by spatial differences among locations. Further monitoring is required to determine whether these differences are consistent over time.

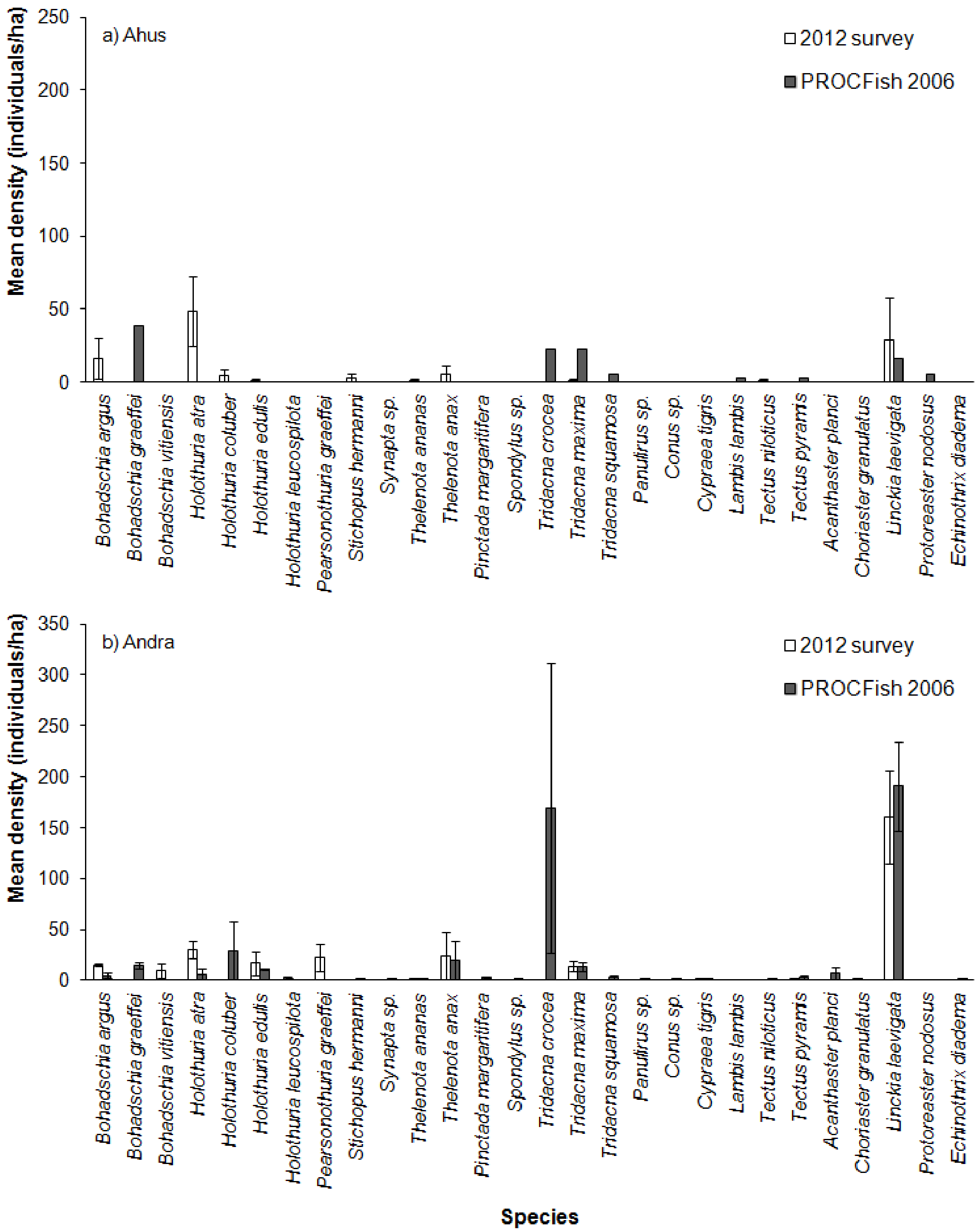


Figure 39 **Comparison of mean density (±SE) of invertebrates recorded from back-reef habitats during manta tow surveys at a) Ahus and b) Andra in the current (2012) and PROCFish (2006) surveys.**

Outer-reefs

Habitats supporting invertebrates

Outer-reef habitats were manta tow stations were established were largely characterised by high cover of live coral and pavement (Figure 40). Habitats where manta tows were conducted on the outer-reefs of Ahus were less complex, had slightly higher percent cover of boulders and 'other' algae, and lower percent cover of crustose coralline algae than those at Andra ($P < 0.05$). A full list of percent cover of each habitat variable recorded during the manta tow surveys is presented as Appendix 11.

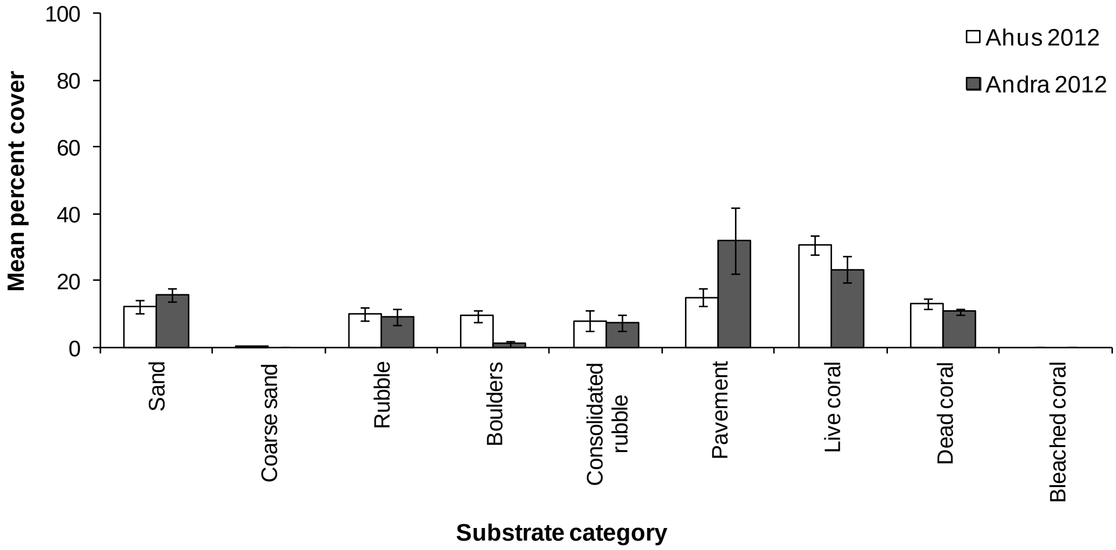


Figure 40 Mean percent cover (± SE) of each major substrate category of manta tow survey stations established on the outer-reefs of Ahus and Andra, 2012.

Invertebrate surveys

A total of 11 species were recorded during the manta tow surveys on the outer-reefs of Ahus and Andra. Species diversity was low at both sites, with 4.0 species recorded per station on the outer-reefs of Andra, and 2.5 species recorded per station on the outer-reefs of Ahus (Table 18). Similarly, mean densities of observed invertebrate species were typically low at both sites (Figure 41). No significant differences in mean density were observed for any species among the outer-reefs of the Ahus and Andra sites (Figure 41). No trochus (*T. niloticus*) or crown-of-thorns starfish (*A. planci*) were observed during the manta tow surveys on the outer-reefs of either site. A full list of densities of individual species observed during the manta tow surveys on the outer-reefs of each site is presented as Appendix 13.

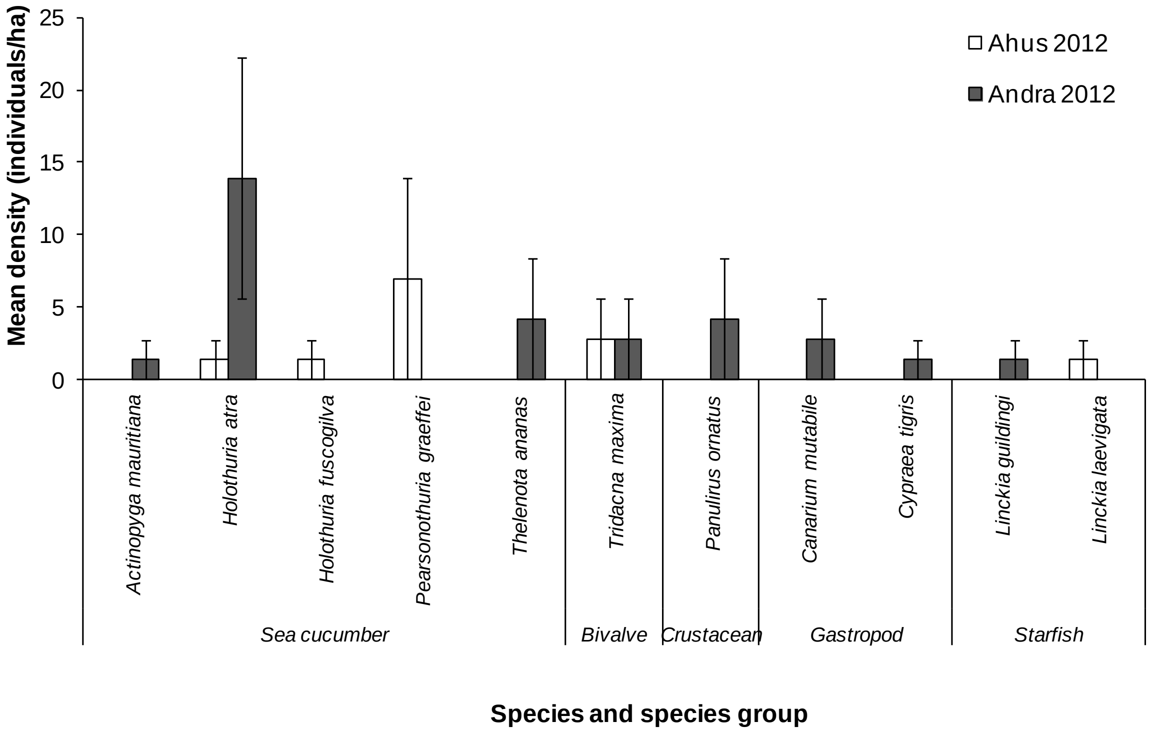


Figure 41 **Overall mean density of invertebrate species (± SE) observed at outer-reef habitats during manta tow assessments at Ahus and Andra, 2012.**

Reef-benthos transects

Coverage

Six RBT stations (6 x 40 m transects) were established in each of the Ahus and Andra sites (Figure 42; Table 19). GPS positions of all RBT stations are tabulated in Appendix 14.

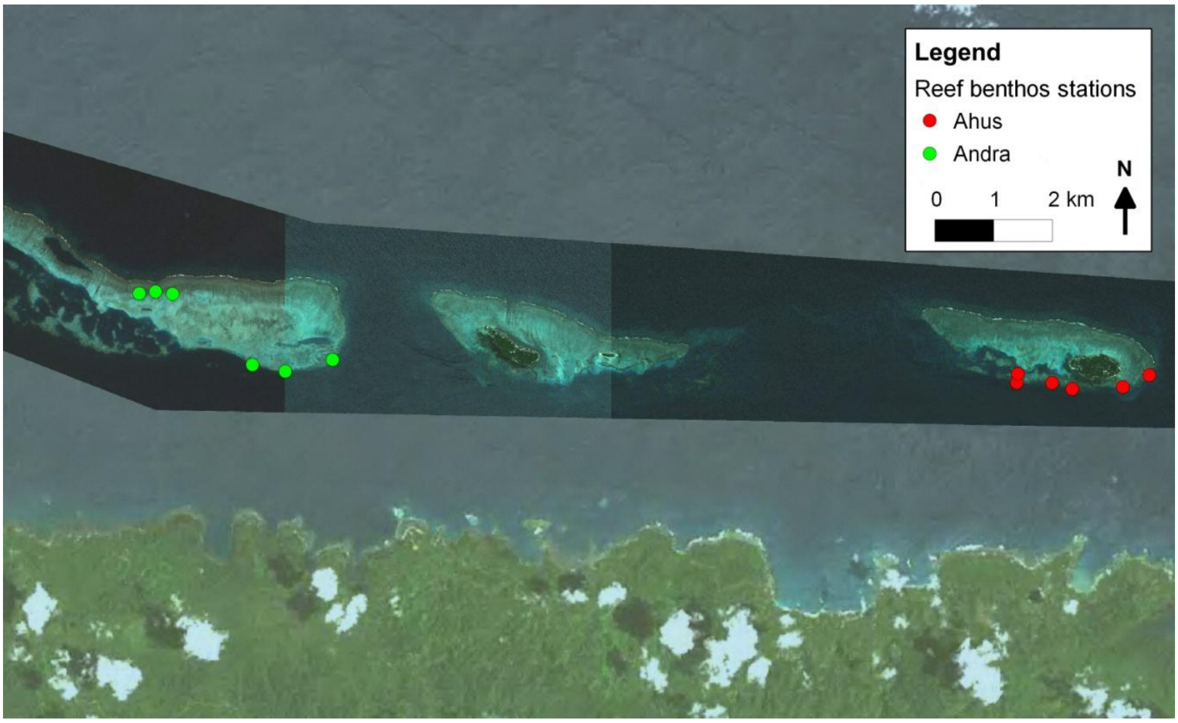


Figure 42 Locations of reef-benthos transect (RBT) stations established at the Ahus and Andra monitoring sites, 2012. Six 40 m replicate transects were completed at each RBT station.

Table 19 Summary of reef-benthos transect stations established within the Ahus and Andra monitoring sites, 2012

Site	Number of stations	Number of replicates	Area surveyed (m^2)
Ahus	6	36	1,440
Andra	6	36	1,440

Habitats supporting invertebrates

The habitat where RBT stations were established at both the Ahus and Andra sites was dominated by live and dead coral, sand and rubble (Figure 43). Habitats where RBT stations were established at the Ahus site had a slightly greater relief and complexity, and a higher percent cover of coarse sand, consolidated rubble, pavement, dead coral, crustose coralline algae, 'other' algae and soft coral than those at Andra. In contrast, the cover of sand, seagrass and sponges were higher at Andra stations ($P < 0.05$). A full list of percent cover of each habitat variable recorded during the RBT surveys as presented as Appendix 15.

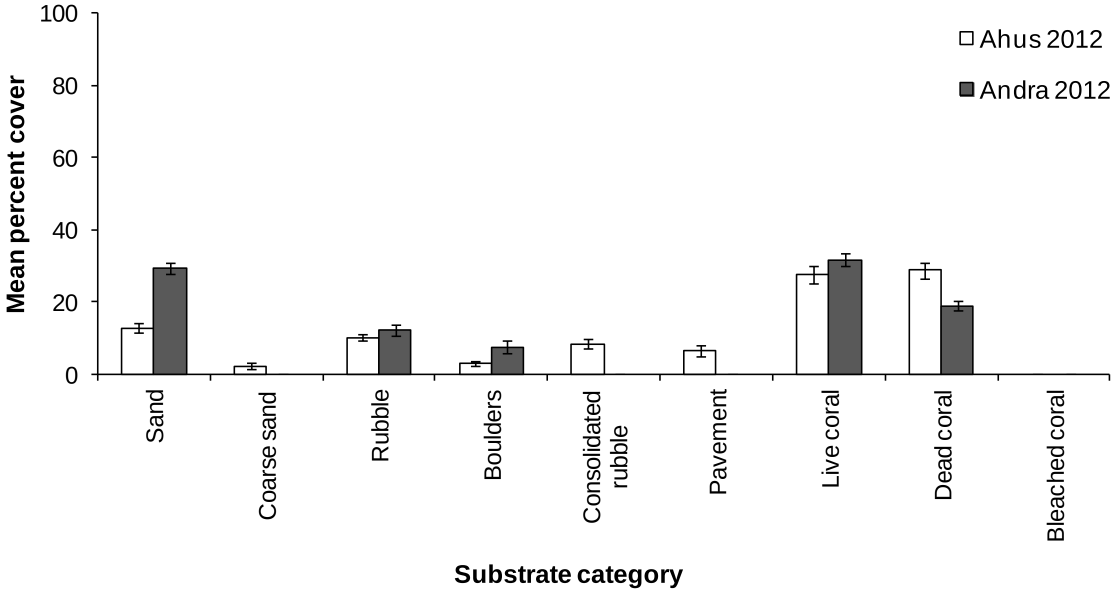


Figure 43 Mean percent cover (± SE) of each major substrate category at reef-benthos transect stations at Ahus and Andra stations, 2012.

Invertebrate surveys

A total of 36 species were recorded during the reef-benthos surveys, with 23 species recorded from Ahus and 26 species recorded from Andra. Individual species observed in the highest mean densities during the RBT surveys at Ahus included the starfish *Linckia laevigata* (673.61±161.52 individuals/ha), the giant clam *Tridacna maxima* (145.83±129.88 individuals/ha) and the trochus *Tectus niloticus* (152.78±71.90 individuals/ha) while at Andra the urchin *Echinometra mathaei* (354.17±190.86 individuals/ha), the giant clam *T. maxima* (270.83±95.47 individuals/ha) and the sea cucumber *Holothuria atra* (263.89±125.31) were observed in the highest density. The mean densities of crown-of-thorns starfish, *Acanthaster planci*, and the gastropods *Conus vexillum* and *Tectus niloticus* were significantly higher at Ahus than Andra ($P < 0.001$), while the mean densities of the urchin *Echinometra mathaei*, the sea cucumbers *Holothuria atra* and *H. edulis*, the gastropod *Monetaria moneta* and the giant clam *Tridacna maxima* were significantly higher at Andra than Ahus ($P < 0.05$) (Figure 44). Numbers of trochus (*Tectus niloticus*) observed in the RBT surveys at both the Ahus and Andra sites were well below the benchmark of 500 individual/ha that indicates a healthy stock (Figure 44) (Tardy et al. 2009). A full list of densities of individual species observed during the RBT surveys at each site is presented as Appendix 16. Few differences in mean size were evident for species common to both the Ahus and Andra monitoring sites, with only the mean size of *Tridacna maxima* appearing slightly larger at Ahus (Table 20).

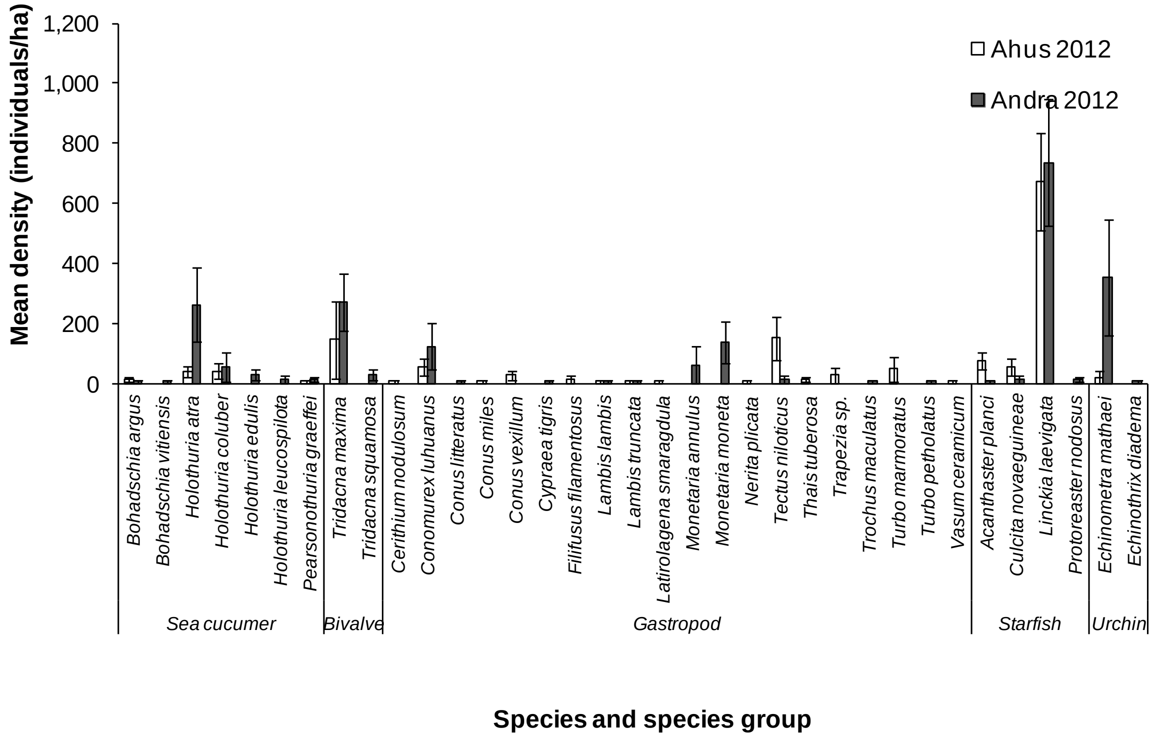


Figure 44 Overall mean density of invertebrate species (± SE) observed during reef-benthos transects at Ahus and Andra, 2012.

Table 20 Mean size (± SE) of measured invertebrates during reef-benthos transects at Ahus and Andra, 2012. Only species with ≥ 5 individuals measured at any one site are presented.

Group	Species	Mean size (mm)	
		Laura	Majuro
Sea cucumber	*Holothuria atra*	180.0±29.7	165.9±10.1
Bivalve	*Tridacna maxima*	195.0±5.0	106.3±4.4
Gastropod	*Conomurex luhuanus*	48.0±5.6	52.0±3.4
Gastropod	*Tectus niloticus*	50.1±9.3	140.0±75.0

Comparisons with PROCFish (2007) surveys

At Ahus, mean densities of the sea cucumber *Bohadschia graeffei* and the gastropods *Tectus pyramis* and *Turbo chrysostomus* observed during RBT surveys in the current study were significantly lower than those observed during the PROCFish surveys (P < 0.05) (Appendix 17). Similarly, mean densities of the sea cucumber *Stichopus chloronotus*, the bivalve *Tridacna crocea*, and the gastropods *Conus miles*, *C. vexillum* and *Conus* sp. observed during RBT surveys on the back-reef of Andra were significantly lower in the current study compared to the PROCFish survey, while mean densities of *Holothuria atra* and *Monetaria moneta* significantly higher in the current (2012) study than the PROCFish survey (P < 0.05) (Appendix 17). As with the manta tow surveys, it should be noted that while these surveys were conducted in the same general habitats, they were not conducted at the same locations, and as such these results may be at least partially influenced by spatial differences among locations. Further monitoring is required to determine whether these differences are consistent over time.

7. Capacity Building

One of the key objectives of the project is to train local Fisheries Officers in undertaking monitoring programs and resource assessments. The training includes planning logistics, safety protocols, site selection criteria, species identification, survey methods and other preparations required for conducting resource assessments. This is to build local capacity before conducting the baseline assessment and to provide staff with the skills so regular re-assessments of the pilot sites can be carried out in the future.

A week of training was conducted before the actual baseline assessment of both finfish and invertebrate surveys. A total of five officers were trained: four from NFA and one from Manus Provincial Fisheries Department (Table 21). The training initially consisted of classroom sessions where assessment methods and survey forms were explained in detail and slideshows of species photos were presented for identification. This was followed by field activities where the trainees practiced a method, as well as species identification. Only when the results of the trainees were consistent with senior project staff were the trainees able to participate in the baseline assessment.

Table 21 List of trainees who participated in the baseline assessment

Name	Title	Organisation
Ian Liviko	Management Officer	NFA
Robinson Liu	Marine Aquarium Officer	NFA
Malakai Komai	Fisheries Officer	NFA/NFC
Lorel Dandava	Marine Aquarium Officer	MIMRA
Kanawi Pomat	Fisheries Officer	Manus Provincial Fisheries

8. Recommendations for Future Monitoring

The following recommendations are proposed for future monitoring events:

- Due to logistical difficulties and poor weather at the time of survey, no lagoon-reef transects were completed at the Ahus monitoring site. As a priority, these transects should be established during the re-survey event.

- Depth has been routinely demonstrated to be a significant factor influencing the distribution and abundance of fish and corals (Pittman and Brown 2011; Green 1996; Veron 1986). To avoid pseudoreplication issues associated with replicates being at different depths, it is recommended that depth be standardised among transects within a habitat during future monitoring events where possible (e.g. 10 m of outer-reef environments).

- The substantial differences observed in densities and biomass of those finfish families common to the current study and the PROCFish survey is of considerable concern, as it indicates a significant reduction in finfish populations over a short-term period. To ensure that these contrasting results, and results of future surveys, were not a result of differences in observer skill or experience, the use of non-observer based monitoring techniques, such as videography, in conjunction with the D-UVC surveys are recommended.

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Appendix 1 GPS positions of benthic habitat assessments

Station ID	Habitat	Transect name	Longitude (E)	Latitude (S)
Ahus 1	Back-reef	T10	147.086733	1.94345
	Back-reef	T11	147.087267	1.943917
	Back-reef	T12	147.087617	1.943933
	Outer-reef	T1	147.081267	1.930883
	Outer-reef	T2	147.081633	1.930983
	Outer-reef	T3	147.08235	1.9311
Ahus 2	Back-reef	T7	147.094467	1.944333
	Back-reef	T8	147.094133	1.94425
	Back-reef	T9	147.093683	1.944133
	Outer-reef	T4	147.096633	1.931717
	Outer-reef	T6	147.097433	1.931367
Andra 1	Back-reef	T22	146.948533	1.9383
	Back-reef	T23	146.948983	1.938283
	Back-reef	T24	146.94945	1.9383
	Lagoon-reef	T25	146.925883	1.934333
	Lagoon-reef	T26	146.92615	1.93465
	Lagoon-reef	T27	146.92645	1.934967
	Outer-reef	T13	146.948933	1.9247
	Outer-reef	T14	146.949217	1.924633
	Outer-reef	T15	146.949717	1.924633
Andra 2	Back-reef	T19	146.964033	1.94205
	Back-reef	T20	146.96435	1.941983
	Back-reef	T21	146.964933	1.94195
	Lagoon-reef	T28	146.931133	1.938
	Lagoon-reef	T29	146.931467	1.938533
	Lagoon-reef	T30	146.93195	1.9386
	Outer-reef	T16	146.963433	1.925267
	Outer-reef	T17	146.964117	1.92525
	Outer-reef	T18	146.964483	1.925

Appendix 2 Finfish distance-sampling underwater visual census (D-UVC) survey form

Campaign |______________________| Site |__________________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|’ Long.|__|__|__|°|__|__|,|__|__|__|’ Left ☐ Right ☐

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

Appendix 3 Form used to assess habitats supporting finfish

Campaign |________________| **Site** |__________________________| **Diver** |__|__| **Transect** |__|__|__|

D |__|__|/|__|__|/20|__|__| **Lat.**|__|__|°|__|__|,|__|__|__|' **Long.**|__|__|__|°|__|__|,|__|__|__|' **WT** |__|__|__|

Start time: |__|__| :|__|__| End time: |__|__| :|__|__| Secchi disc visibility |__|__| m Left ☐ Right ☐

Primary reef: Coastal ☐ Lagoon ☐ Back ☐ Outer ☐ **Secondary Reef:** Coastal ☐ Lagoon ☐ Back ☐ Outer ☐

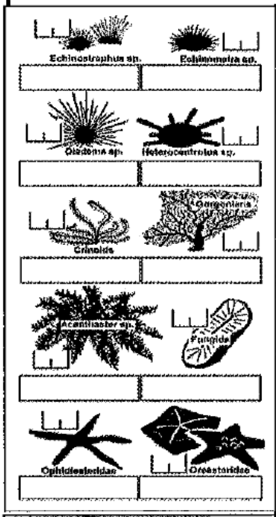
	current	oceanic influence	terrigenous influence
none	☐	☐	☐
medium	☐	☐	☐
strong	☐	☐	☐

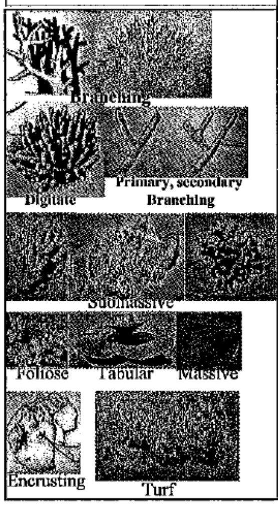
draw profile including estimate of slope in degree
Flat ☐ Floor ☐
Gentle slope ☐ Steep slope ☐

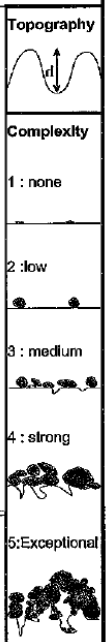
Remarks:

	Quadrat limits	0	10	20	30	40	50 %
	Depth of transect line (m)						
	Slope only: Depth of crest (m)						
	Slope only: Depth of floor (m)						
	Line of sight visibility (m)						
	Topography (1-5)						
	Complexity (1-5)						
1st layer	Hard substrate						100
	Soft substrate						
2nd layer	(1) Abiotic						100
	(2) Hard corals (dead & live)						
(1) Abiotic	Rocky substratum (Slab)						100
	Silt						
	Mud						
	Sand						
	Rubbles						
	Gravels, small boulders (< 30 cm)						
	Large boulders (< 1m)						
	Rocks (> 1m)						
(2a) Hard coral status	Live						100
	Bleaching						
	Long dead algae covered						
(2b) Hard coral shape	Encrusting						100
	Massive						
	Sub-massive						
	Digitate						
	Branch						
	Foliose						
	Tabulate						
3rd layer: other	Sponge						
	Soft coral						
3rd layer: Plant & algae	Macro-algae (soft to touch)						
	Turf (filaments)						
	Calcareous algae (hard to touch)						
	Encrusting algae (Crustose coralline)						
	Seagrass						
3rd layer:	Silt covering coral						
3rd layer:	Cyanophycae						

Branching : has secondary branching
Digitate : no secondary branching
Hard coral (dead & live) **:** Coral attached to substrate with an identifiable shape (otherwise it's abiotic)
Rubble : any piece or whole coral colony of any size that is not attached to substrate
Topography (regardless of surface orientation): 1 : no relief, 2 : low (h<1m), 3: medium (1<h<2m) 4: strong (2<h<3m), 5: exceptional (h>3m)
Complexity (quantity and diversity of holes and cavities): 1: none, 2: low, 3: medium, 4: strong, 5:exceptional
% measured over line of sight visibility







Depth :
<10m : measure it ;
>10 m : estimate as 10-15m 15-20m >20m

Crest side : Floor=transect depth

Slope side : Crest=transect depth

Appendix 4 GPS positions of finfish D-UVC transects

Station ID	Habitat	Transect name	Longitude (E)	Latitude (S)
Ahus 1	Back-reef	T10	147.086733	1.94345
	Back-reef	T11	147.087267	1.943917
	Back-reef	T12	147.087617	1.943933
	Outer-reef	T1	147.081267	1.930883
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	Outer-reef	T3	147.08235	1.9311
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	Back-reef	T8	147.094133	1.94425
	Back-reef	T9	147.093683	1.944133
	Outer-reef	T4	147.096633	1.931717
	Outer-reef	T6	147.097433	1.931367
Andra 1	Back-reef	T22	146.948533	1.9383
	Back-reef	T23	146.948983	1.938283
	Back-reef	T24	146.94945	1.9383
	Lagoon-reef	T25	146.925883	1.934333
	Lagoon-reef	T26	146.92615	1.93465
	Lagoon-reef	T27	146.92645	1.934967
	Outer-reef	T13	146.948933	1.9247
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Andra 2	Back-reef	T19	146.964033	1.94205
	Back-reef	T20	146.96435	1.941983
	Back-reef	T21	146.964933	1.94195
	Lagoon-reef	T28	146.931133	1.938
	Lagoon-reef	T29	146.931467	1.938533
	Lagoon-reef	T30	146.93195	1.9386
	Outer-reef	T16	146.963433	1.925267
	Outer-reef	T17	146.964117	1.92525
	Outer-reef	T18	146.964483	1.925

Appendix 5 Mean density and biomass of finfish families recorded in Ahus by habitat

Habitat	Family	Density (fish/m²)	SE density	Biomass (g/m²)	SE biomass
Back-reef	Acanthuridae	0.087	0.006	6.814	2.105
Back-reef	Balistidae	0.002	0.001	0.094	0.055
Back-reef	Caesionidae	0.007	0.004	1.149	0.890
Back-reef	Carangidae	0.008	0.008	1.167	1.167
Back-reef	Chaetodontidae	0.017	0.004	1.397	0.596
Back-reef	Cirrhitidae	0.001	0.001	0.043	0.027
Back-reef	Holocentridae	0.001	0.001	0.228	0.228
Back-reef	Labridae	0.092	0.018	1.911	0.558
Back-reef	Lethrinidae	0.001	0.001	0.393	0.371
Back-reef	Lutjanidae	0.001	0.001	0.702	0.518
Back-reef	Monacanthidae	0.000	0.000	0.000	0.000
Back-reef	Mullidae	0.010	0.003	2.110	1.214
Back-reef	Nemipteridae	0.002	0.002	0.204	0.134
Back-reef	Pomacanthidae	0.007	0.003	1.130	0.594
Back-reef	Pomacentridae	0.737	0.130	7.385	1.882
Back-reef	Scaridae	0.028	0.005	3.154	1.145
Back-reef	Serranidae	0.001	0.001	0.208	0.100
Back-reef	Siganidae	0.003	0.001	0.503	0.223
Back-reef	Sphyraenidae	0.024	0.024	6.549	6.549
Back-reef	Zanclidae	0.001	0.001	0.114	0.112
Outer-reef	Acanthuridae	0.076	0.023	6.853	4.593
Outer-reef	Balistidae	0.008	0.005	1.749	1.359
Outer-reef	Caesionidae	0.040	0.029	4.067	3.315
Outer-reef	Chaetodontidae	0.018	0.005	1.159	0.383
Outer-reef	Cirrhitidae	0.010	0.004	0.112	0.037
Outer-reef	Holocentridae	0.002	0.002	0.189	0.189
Outer-reef	Labridae	0.104	0.044	2.081	0.743
Outer-reef	Microdesmidae	0.009	0.009	0.000	0.000
Outer-reef	Mullidae	0.006	0.001	0.299	0.158
Outer-reef	Pinguipedidae	0.000	0.000	0.005	0.005
Outer-reef	Pomacanthidae	0.014	0.008	0.355	0.214
Outer-reef	Pomacentridae	0.224	0.023	1.878	0.641
Outer-reef	Scaridae	0.013	0.008	0.644	0.443
Outer-reef	Serranidae	0.004	0.002	0.301	0.121
Outer-reef	Zanclidae	0.002	0.002	0.153	0.153

Appendix 6 Mean density and biomass of finfish families recorded in Andra by habitat

Habitat	Family	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back-reef	Acanthuridae	0.086	0.019	9.635	4.205
Back-reef	Apogonidae	0.033	0.033	0.406	0.406
Back-reef	Balistidae	0.001	0.001	0.039	0.025
Back-reef	Caesionidae	0.044	0.028	7.954	5.252
Back-reef	Chaetodontidae	0.041	0.004	2.627	0.308
Back-reef	Cirrhitidae	0.001	0.001	0.011	0.007
Back-reef	Holocentridae	0.035	0.012	5.605	2.167
Back-reef	Labridae	0.061	0.016	2.871	1.004
Back-reef	Lethrinidae	0.007	0.002	2.126	1.235
Back-reef	Lutjanidae	0.010	0.007	1.305	0.548
Back-reef	Microdesmidae	0.001	0.001	0.000	0.000
Back-reef	Mullidae	0.012	0.004	1.130	0.394
Back-reef	Nemipteridae	0.004	0.002	0.647	0.323
Back-reef	Pomacanthidae	0.009	0.003	1.312	0.416
Back-reef	Pomacentridae	0.879	0.111	12.956	3.369
Back-reef	Scaridae	0.039	0.008	5.624	2.103
Back-reef	Serranidae	0.001	0.000	0.106	0.083
Back-reef	Siganidae	0.000	0.000	0.021	0.021
Back-reef	Tetraodontidae	0.000	0.000	0.134	0.134
Back-reef	Zanclidae	0.005	0.003	0.608	0.367
Lagoon-reef	Acanthuridae	0.153	0.062	21.558	10.720
Lagoon-reef	Apogonidae	0.007	0.007	0.016	0.016
Lagoon-reef	Aulostomidae	0.000	0.000	0.033	0.033
Lagoon-reef	Balistidae	0.002	0.001	0.108	0.063
Lagoon-reef	Caesionidae	0.058	0.044	3.541	3.292
Lagoon-reef	Carangidae	0.001	0.000	0.698	0.458
Lagoon-reef	Chaetodontidae	0.032	0.005	1.998	0.458
Lagoon-reef	Holocentridae	0.005	0.002	0.750	0.415
Lagoon-reef	Kyphosidae	0.003	0.003	0.628	0.628
Lagoon-reef	Labridae	0.055	0.009	1.927	0.374
Lagoon-reef	Lethrinidae	0.004	0.003	0.844	0.744
Lagoon-reef	Lutjanidae	0.000	0.000	0.007	0.007
Lagoon-reef	Microdesmidae	0.001	0.001	0.000	0.000
Lagoon-reef	Mullidae	0.007	0.002	1.622	0.837
Lagoon-reef	Nemipteridae	0.002	0.001	0.198	0.109
Lagoon-reef	Pomacanthidae	0.005	0.002	0.695	0.271
Lagoon-reef	Pomacentridae	0.478	0.094	6.753	1.625
Lagoon-reef	Scaridae	0.058	0.014	9.077	3.720
Lagoon-reef	Scombridae	0.000	0.000	1.004	1.004
Lagoon-reef	Serranidae	0.001	0.000	0.070	0.051

Habitat	Family	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Lagoon-reef	Siganidae	0.000	0.000	0.098	0.098
Lagoon-reef	Tetraodontidae	0.001	0.001	0.065	0.051
Lagoon-reef	Zanclidae	0.002	0.001	0.210	0.105
Outer-reef	Acanthuridae	0.170	0.040	19.224	7.129
Outer-reef	Balistidae	0.016	0.003	2.391	0.946
Outer-reef	Caesionidae	0.007	0.007	2.260	2.169
Outer-reef	Chaetodontidae	0.021	0.004	1.468	0.379
Outer-reef	Cirrhitidae	0.008	0.003	0.132	0.049
Outer-reef	Holocentridae	0.005	0.003	0.759	0.480
Outer-reef	Labridae	0.074	0.021	1.861	0.600
Outer-reef	Lethrinidae	0.001	0.000	0.109	0.076
Outer-reef	Lutjanidae	0.016	0.014	2.407	1.875
Outer-reef	Malacanthidae	0.000	0.000	0.000	0.000
Outer-reef	Microdesmidae	0.004	0.003	0.000	0.000
Outer-reef	Mullidae	0.009	0.002	0.448	0.132
Outer-reef	Nemipteridae	0.001	0.001	0.037	0.037
Outer-reef	Pomacanthidae	0.008	0.004	0.396	0.162
Outer-reef	Pomacentridae	0.346	0.059	3.189	1.167
Outer-reef	Scaridae	0.048	0.012	5.216	1.727
Outer-reef	Serranidae	0.003	0.001	0.296	0.123
Outer-reef	Siganidae	0.001	0.001	0.111	0.111
Outer-reef	Zanclidae	0.002	0.001	0.156	0.088

Appendix 7 Mean density and biomass of all fish species recorded in Ahus by habitat

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back	Acanthuridae	*Acanthurus blochii*	0.000	0.000	0.045	0.045
Back	Acanthuridae	*Acanthurus nigricans*	0.008	0.003	0.728	0.229
Back	Acanthuridae	*Acanthurus nigrofuscus*	0.014	0.008	1.040	0.609
Back	Acanthuridae	*Acanthurus nigroris*	0.013	0.005	0.568	0.272
Back	Acanthuridae	*Acanthurus pyroferus*	0.003	0.002	0.206	0.130
Back	Acanthuridae	*Ctenochaetus striatus*	0.029	0.004	3.280	1.192
Back	Acanthuridae	*Zebrasoma scopas*	0.019	0.003	0.947	0.442
Back	Balistidae	*Balistapus undulatus*	0.002	0.001	0.094	0.055
Back	Caesionidae	*Caesio lunaris*	0.004	0.004	0.919	0.919
Back	Caesionidae	*Caesio teres*	0.004	0.003	0.230	0.182
Back	Carangidae	*Caranx tille*	0.008	0.008	1.167	1.167
Back	Chaetodontidae	*Chaetodon baronessa*	0.002	0.001	0.083	0.039
Back	Chaetodontidae	*Chaetodon ephippium*	0.001	0.001	0.221	0.221
Back	Chaetodontidae	*Chaetodon kleinii*	0.002	0.001	0.081	0.041
Back	Chaetodontidae	*Chaetodon lineolatus*	0.001	0.000	0.023	0.019
Back	Chaetodontidae	*Chaetodon lunulatus*	0.007	0.002	0.486	0.171
Back	Chaetodontidae	*Chaetodon ornatissimus*	0.001	0.001	0.081	0.064
Back	Chaetodontidae	*Chaetodon rafflesii*	0.000	0.000	0.016	0.016
Back	Chaetodontidae	*Chaetodon ulietensis*	0.000	0.000	0.003	0.003
Back	Chaetodontidae	*Chaetodon vagabundus*	0.003	0.001	0.350	0.202
Back	Chaetodontidae	*Forcipiger longirostris*	0.001	0.001	0.020	0.020
Back	Chaetodontidae	*Heniochus monoceros*	0.000	0.000	0.034	0.034
Back	Cirrhitidae	*Paracirrhites arcatus*	0.000	0.000	0.001	0.001
Back	Cirrhitidae	*Paracirrhites forsteri*	0.001	0.001	0.042	0.027
Back	Holocentridae	*Myripristis berndti*	0.001	0.001	0.228	0.228
Back	Labridae	*Anampses geographicus*	0.000	0.000	0.005	0.005
Back	Labridae	*Cheilinus fasciatus*	0.001	0.001	0.082	0.070
Back	Labridae	*Cheilinus trilobatus*	0.014	0.014	0.266	0.266
Back	Labridae	*Gomphosus varius*	0.000	0.000	0.000	0.000
Back	Labridae	*Halichoeres hortulanus*	0.003	0.001	0.196	0.130
Back	Labridae	*Halichoeres marginatus*	0.001	0.001	0.005	0.005
Back	Labridae	*Halichoeres melanurus*	0.002	0.001	0.025	0.013
Back	Labridae	*Halichoeres trimaculatus*	0.000	0.000	0.025	0.025
Back	Labridae	*Hemigymnus fasciatus*	0.001	0.001	0.194	0.194
Back	Labridae	*Hemigymnus melapterus*	0.004	0.002	0.156	0.082
Back	Labridae	*Labroides bicolor*	0.000	0.000	0.001	0.001
Back	Labridae	*Labroides dimidiatus*	0.018	0.002	0.090	0.025
Back	Labridae	*Oxycheilinus celebicus*	0.001	0.000	0.038	0.029
Back	Labridae	*Oxycheilinus unifasciatus*	0.001	0.001	0.025	0.025
Back	Labridae	*Stethojulis bandanensis*	0.003	0.002	0.039	0.025

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back	Labridae	*Stethojulis strigiventer*	0.001	0.001	0.006	0.004
Back	Labridae	*Thalassoma amblycephalum*	0.017	0.017	0.128	0.128
Back	Labridae	*Thalassoma hardwicke*	0.021	0.006	0.571	0.172
Back	Labridae	*Thalassoma lunare*	0.001	0.001	0.010	0.005
Back	Labridae	*Thalassoma lutescens*	0.000	0.000	0.039	0.039
Back	Labridae	*Thalassoma purpureum*	0.000	0.000	0.002	0.002
Back	Labridae	*Thalassoma quinquevittatum*	0.001	0.001	0.008	0.008
Back	Lethrinidae	*Monotaxis grandoculis*	0.001	0.001	0.393	0.371
Back	Lutjanidae	*Macolor niger*	0.001	0.001	0.702	0.518
Back	Monacanthidae	*Oxymonacanthus longirostris*	0.000	0.000	0.000	0.000
Back	Mullidae	*Parupeneus bifasciatus*	0.006	0.002	1.483	1.099
Back	Mullidae	*Parupeneus multifasciatus*	0.004	0.002	0.627	0.343
Back	Nemipteridae	*Pentapodus trivittatus*	0.000	0.000	0.010	0.010
Back	Nemipteridae	*Scolopsis bilineata*	0.001	0.001	0.067	0.067
Back	Nemipteridae	*Scolopsis temporalis*	0.000	0.000	0.029	0.029
Back	Nemipteridae	*Scolopsis trilineatus*	0.000	0.000	0.098	0.098
Back	Pomacanthidae	*Centropyge bicolor*	0.002	0.001	0.031	0.028
Back	Pomacanthidae	*Centropyge vrolikii*	0.000	0.000	0.004	0.004
Back	Pomacanthidae	*Pygoplites diacanthus*	0.005	0.002	1.095	0.568
Back	Pomacentridae	*Abudefduf sexfasciatus*	0.001	0.001	0.107	0.107
Back	Pomacentridae	*Amblyglyphidodon curacao*	0.219	0.042	2.052	0.486
Back	Pomacentridae	*Amblyglyphidodon leucogaster*	0.006	0.006	0.023	0.019
Back	Pomacentridae	*Amblyglyphidodon ternatensis*	0.002	0.002	0.001	0.001
Back	Pomacentridae	*Amphiprion chrysopterus*	0.002	0.002	0.018	0.012
Back	Pomacentridae	*Amphiprion clarkii*	0.008	0.002	0.115	0.027
Back	Pomacentridae	*Amphiprion melanopus*	0.001	0.001	0.037	0.037
Back	Pomacentridae	*Cheiloprion labiatus*	0.002	0.002	0.076	0.054
Back	Pomacentridae	*Chromis amboinensis*	0.100	0.081	1.518	1.382
Back	Pomacentridae	*Chromis margaritifer*	0.029	0.013	0.104	0.043
Back	Pomacentridae	*Chromis ternatensis*	0.086	0.049	0.487	0.325
Back	Pomacentridae	*Chromis viridis*	0.043	0.021	0.091	0.038
Back	Pomacentridae	*Chromis weberi*	0.010	0.010	0.008	0.008
Back	Pomacentridae	*Chromis xanthochira*	0.023	0.020	0.316	0.261
Back	Pomacentridae	*Chromis xanthura*	0.006	0.006	0.062	0.062
Back	Pomacentridae	*Chrysiptera taupou*	0.001	0.001	0.008	0.008
Back	Pomacentridae	*Chrysiptera unimaculata*	0.001	0.001	0.014	0.014
Back	Pomacentridae	*Dascyllus melanurus*	0.000	0.000	0.007	0.007
Back	Pomacentridae	*Dascyllus trimaculatus*	0.016	0.008	0.128	0.077
Back	Pomacentridae	*Dischistodus melanotus*	0.010	0.005	0.636	0.354
Back	Pomacentridae	*Neoglyphidodon melas*	0.003	0.002	0.119	0.097
Back	Pomacentridae	*Neoglyphidodon nigroris*	0.050	0.012	0.759	0.274

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back	Pomacentridae	*Plectroglyphidodon dickii*	0.001	0.001	0.043	0.043
Back	Pomacentridae	*Plectroglyphidodon lacrymatus*	0.001	0.000	0.001	0.001
Back	Pomacentridae	*Pomacentrus bankanensis*	0.002	0.001	0.028	0.021
Back	Pomacentridae	*Pomacentrus coelestis*	0.000	0.000	0.001	0.001
Back	Pomacentridae	*Pomacentrus grammorhynchus*	0.002	0.002	0.006	0.006
Back	Pomacentridae	*Pomacentrus moluccensis*	0.109	0.021	0.597	0.138
Back	Pomacentridae	*Pomacentrus simsiang*	0.002	0.002	0.008	0.008
Back	Pomacentridae	*Pomacentrus vaiuli*	0.000	0.000	0.001	0.001
Back	Pomacentridae	*Stegastes fasciolatus*	0.001	0.001	0.003	0.003
Back	Pomacentridae	*Stegastes nigricans*	0.000	0.000	0.013	0.013
Back	Scaridae	*Cetoscarus bicolor*	0.002	0.001	0.091	0.062
Back	Scaridae	*Chlorurus bleekeri*	0.002	0.001	0.102	0.067
Back	Scaridae	*Chlorurus sordidus*	0.019	0.005	2.197	1.115
Back	Scaridae	*Scarus dimidiatus*	0.004	0.002	0.530	0.215
Back	Scaridae	*Scarus oviceps*	0.001	0.001	0.203	0.129
Back	Scaridae	*Scarus quoyi*	0.000	0.000	0.023	0.023
Back	Scaridae	*Scarus schlegeli*	0.001	0.001	0.007	0.007
Back	Serranidae	*Cephalopholis cyanostigma*	0.000	0.000	0.085	0.085
Back	Serranidae	*Epinephelus merra*	0.001	0.000	0.123	0.077
Back	Siganidae	*Siganus puellus*	0.001	0.001	0.043	0.043
Back	Siganidae	*Siganus vulpinus*	0.002	0.001	0.460	0.236
Back	Sphyraenidae	*Sphyraena barracuda*	0.024	0.024	6.549	6.549
Back	Zanclidae	*Zanclus cornutus*	0.001	0.001	0.114	0.112
Outer	Acanthuridae	*Acanthurus grammoptilus*	0.001	0.001	0.571	0.571
Outer	Acanthuridae	*Acanthurus lineatus*	0.001	0.001	0.032	0.022
Outer	Acanthuridae	*Acanthurus nigricans*	0.023	0.003	1.922	0.823
Outer	Acanthuridae	*Acanthurus nigrofuscus*	0.002	0.002	0.192	0.192
Outer	Acanthuridae	*Acanthurus nigroris*	0.016	0.007	1.138	0.694
Outer	Acanthuridae	*Acanthurus triostegus*	0.000	0.000	0.016	0.016
Outer	Acanthuridae	*Ctenochaetus striatus*	0.031	0.013	2.939	2.346
Outer	Acanthuridae	*Naso lituratus*	0.002	0.002	0.035	0.035
Outer	Acanthuridae	*Zebrasoma scopas*	0.001	0.001	0.008	0.008
Outer	Balistidae	*Balistapus undulatus*	0.001	0.000	0.024	0.015
Outer	Balistidae	*Melichthys vidua*	0.002	0.001	0.312	0.285
Outer	Balistidae	*Odonus niger*	0.004	0.004	1.262	1.262
Outer	Balistidae	*Sufflamen bursa*	0.001	0.001	0.151	0.151
Outer	Caesionidae	*Caesio teres*	0.040	0.028	4.055	3.303
Outer	Caesionidae	*Pterocaesio tile*	0.001	0.001	0.013	0.013
Outer	Chaetodontidae	*Chaetodon auriga*	0.001	0.001	0.022	0.022
Outer	Chaetodontidae	*Chaetodon bennetti*	0.001	0.001	0.040	0.040
Outer	Chaetodontidae	*Chaetodon citrinellus*	0.002	0.001	0.060	0.040

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Outer	Chaetodontidae	*Chaetodon ephippium*	0.000	0.000	0.086	0.086
Outer	Chaetodontidae	*Chaetodon kleinii*	0.001	0.000	0.036	0.024
Outer	Chaetodontidae	*Chaetodon lunulatus*	0.003	0.001	0.175	0.089
Outer	Chaetodontidae	*Chaetodon ornatissimus*	0.002	0.001	0.169	0.137
Outer	Chaetodontidae	*Chaetodon rafflesii*	0.000	0.000	0.020	0.020
Outer	Chaetodontidae	*Chaetodon reticulatus*	0.001	0.001	0.039	0.039
Outer	Chaetodontidae	*Chaetodon trifascialis*	0.000	0.000	0.032	0.032
Outer	Chaetodontidae	*Chaetodon ulietensis*	0.001	0.001	0.004	0.004
Outer	Chaetodontidae	*Chaetodon vagabundus*	0.002	0.001	0.340	0.209
Outer	Chaetodontidae	*Heniochus chrysostomus*	0.002	0.001	0.113	0.109
Outer	Chaetodontidae	*Heniochus monoceros*	0.001	0.001	0.022	0.022
Outer	Cirrhitidae	*Paracirrhites arcatus*	0.009	0.003	0.078	0.025
Outer	Cirrhitidae	*Paracirrhites forsteri*	0.002	0.001	0.034	0.015
Outer	Holocentridae	*Neoniphon sammara*	0.001	0.001	0.055	0.055
Outer	Holocentridae	*Sargocentron caudimaculatum*	0.001	0.001	0.134	0.134
Outer	Labridae	*Anampses melanurus*	0.001	0.001	0.001	0.001
Outer	Labridae	*Bodianus mesothorax*	0.000	0.000	0.049	0.049
Outer	Labridae	*Cirrhilabrus punctatus*	0.001	0.001	0.030	0.030
Outer	Labridae	*Coris gaimard*	0.001	0.000	0.007	0.006
Outer	Labridae	*Gomphosus varius*	0.006	0.002	0.093	0.043
Outer	Labridae	*Halichoeres hortulanus*	0.020	0.003	0.537	0.194
Outer	Labridae	*Hemigymnus fasciatus*	0.001	0.000	0.106	0.089
Outer	Labridae	*Hemigymnus melapterus*	0.000	0.000	0.008	0.008
Outer	Labridae	*Labroides dimidiatus*	0.010	0.002	0.058	0.025
Outer	Labridae	*Stethojulis bandanensis*	0.002	0.001	0.014	0.009
Outer	Labridae	*Thalassoma amblycephalum*	0.048	0.048	0.757	0.757
Outer	Labridae	*Thalassoma hardwicke*	0.010	0.002	0.314	0.130
Outer	Labridae	*Thalassoma lunare*	0.000	0.000	0.006	0.006
Outer	Labridae	*Thalassoma lutescens*	0.000	0.000	0.006	0.006
Outer	Labridae	*Thalassoma purpureum*	0.002	0.002	0.025	0.025
Outer	Labridae	*Thalassoma quinquevittatum*	0.003	0.002	0.070	0.058
Outer	Microdesmidae	*Ptereleotris evides*	0.009	0.009	0.000	0.000
Outer	Mullidae	*Parupeneus multifasciatus*	0.006	0.001	0.299	0.158
Outer	Pinguipedidae	*Parapercis clathrata*	0.000	0.000	0.005	0.005
Outer	Pomacanthidae	*Centropyge bicolor*	0.013	0.009	0.294	0.218
Outer	Pomacanthidae	*Centropyge vrolikii*	0.000	0.000	0.011	0.011
Outer	Pomacanthidae	*Pygoplites diacanthus*	0.001	0.000	0.049	0.036
Outer	Pomacentridae	*Amphiprion chrysopterus*	0.001	0.001	0.127	0.127
Outer	Pomacentridae	*Amphiprion clarkii*	0.001	0.001	0.017	0.017
Outer	Pomacentridae	*Chromis amboinensis*	0.001	0.001	0.009	0.009
Outer	Pomacentridae	*Chromis margaritifer*	0.028	0.014	0.087	0.030

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Outer	Pomacentridae	*Chromis ternatensis*	0.005	0.005	0.018	0.018
Outer	Pomacentridae	*Chromis xanthura*	0.056	0.027	0.871	0.567
Outer	Pomacentridae	*Chrysiptera taupou*	0.001	0.001	0.009	0.009
Outer	Pomacentridae	*Chrysiptera unimaculata*	0.005	0.004	0.047	0.031
Outer	Pomacentridae	*Dascyllus reticulatus*	0.001	0.001	0.001	0.001
Outer	Pomacentridae	*Neoglyphidodon nigroris*	0.002	0.001	0.025	0.023
Outer	Pomacentridae	*Plectroglyphidodon dickii*	0.012	0.005	0.085	0.031
Outer	Pomacentridae	*Plectroglyphidodon lacrymatus*	0.002	0.001	0.017	0.010
Outer	Pomacentridae	*Pomacentrus auriventris*	0.005	0.005	0.004	0.004
Outer	Pomacentridae	*Pomacentrus bankanensis*	0.029	0.007	0.206	0.067
Outer	Pomacentridae	*Pomacentrus coelestis*	0.069	0.017	0.309	0.153
Outer	Pomacentridae	*Pomacentrus grammorhynchus*	0.000	0.000	0.004	0.004
Outer	Pomacentridae	*Pomacentrus lepidogenys*	0.001	0.001	0.009	0.009
Outer	Pomacentridae	*Pomacentrus moluccensis*	0.003	0.003	0.030	0.030
Outer	Pomacentridae	*Pomacentrus pavo*	0.003	0.003	0.002	0.002
Outer	Scaridae	*Chlorurus sordidus*	0.013	0.008	0.644	0.443
Outer	Serranidae	*Cephalopholis argus*	0.002	0.001	0.128	0.085
Outer	Serranidae	*Cephalopholis urodeta*	0.003	0.002	0.173	0.135
Outer	Zanclidae	*Zanclus cornutus*	0.002	0.002	0.153	0.153

Appendix 8 Mean density and biomass of all fish recorded in Andra by habitat

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back	Acanthuridae	*Acanthurus lineatus*	0.007	0.007	1.537	1.537
Back	Acanthuridae	*Acanthurus nigricans*	0.008	0.004	0.610	0.350
Back	Acanthuridae	*Acanthurus nigricauda*	0.000	0.000	0.053	0.053
Back	Acanthuridae	*Acanthurus nigrofuscus*	0.018	0.012	2.073	1.728
Back	Acanthuridae	*Acanthurus nigroris*	0.006	0.003	0.663	0.340
Back	Acanthuridae	*Acanthurus pyroferus*	0.010	0.002	1.549	0.534
Back	Acanthuridae	*Ctenochaetus striatus*	0.019	0.005	2.095	0.919
Back	Acanthuridae	*Zebrasoma scopas*	0.018	0.004	1.055	0.235
Back	Apogonidae	*Apogon cyanosoma*	0.033	0.033	0.406	0.406
Back	Balistidae	*Balistapus undulatus*	0.001	0.001	0.039	0.025
Back	Caesionidae	*Caesio caerulaurea*	0.021	0.021	0.703	0.703
Back	Caesionidae	*Caesio cuning*	0.007	0.006	2.143	2.046
Back	Caesionidae	*Caesio teres*	0.014	0.013	4.386	4.361
Back	Caesionidae	*Pterocaesio tile*	0.002	0.002	0.722	0.722
Back	Chaetodontidae	*Chaetodon auriga*	0.000	0.000	0.065	0.065
Back	Chaetodontidae	*Chaetodon baronessa*	0.001	0.001	0.071	0.060
Back	Chaetodontidae	*Chaetodon bennetti*	0.001	0.001	0.109	0.053
Back	Chaetodontidae	*Chaetodon citrinellus*	0.002	0.001	0.047	0.029
Back	Chaetodontidae	*Chaetodon ephippium*	0.001	0.001	0.104	0.104
Back	Chaetodontidae	*Chaetodon kleinii*	0.003	0.001	0.121	0.057
Back	Chaetodontidae	*Chaetodon lineolatus*	0.001	0.001	0.011	0.011
Back	Chaetodontidae	*Chaetodon lunulatus*	0.007	0.001	0.383	0.078
Back	Chaetodontidae	*Chaetodon melannotus*	0.000	0.000	0.028	0.028
Back	Chaetodontidae	*Chaetodon meyeri*	0.001	0.001	0.102	0.102
Back	Chaetodontidae	*Chaetodon ocellicaudus*	0.003	0.001	0.135	0.080
Back	Chaetodontidae	*Chaetodon ornatissimus*	0.002	0.001	0.197	0.086
Back	Chaetodontidae	*Chaetodon rafflesii*	0.001	0.001	0.007	0.007
Back	Chaetodontidae	*Chaetodon trifascialis*	0.001	0.001	0.016	0.016
Back	Chaetodontidae	*Chaetodon ulietensis*	0.002	0.001	0.106	0.051
Back	Chaetodontidae	*Chaetodon vagabundus*	0.009	0.002	0.566	0.105
Back	Chaetodontidae	*Forcipiger flavissimus*	0.001	0.000	0.022	0.012
Back	Chaetodontidae	*Heniochus chrysostomus*	0.002	0.001	0.162	0.104
Back	Chaetodontidae	*Heniochus monoceros*	0.001	0.001	0.054	0.054
Back	Chaetodontidae	*Heniochus varius*	0.003	0.002	0.319	0.188
Back	Cirrhitidae	*Paracirrhites forsteri*	0.001	0.001	0.011	0.007
Back	Holocentridae	*Myripristis berndti*	0.001	0.001	0.140	0.107
Back	Holocentridae	*Myripristis botche*	0.001	0.001	0.334	0.334
Back	Holocentridae	*Myripristis kuntee*	0.004	0.003	0.459	0.366
Back	Holocentridae	*Myripristis murdjan*	0.026	0.008	4.362	1.505
Back	Holocentridae	*Neoniphon sammara*	0.003	0.003	0.311	0.311
Back	Labridae	*Bodianus mesothorax*	0.001	0.000	0.021	0.015

Habitat	Family	Species	Density (fish/m²)	SE density	Biomass (g/m²)	SE biomass
Back	Labridae	*Cheilinus fasciatus*	0.006	0.002	1.102	0.304
Back	Labridae	*Cheilinus trilobatus*	0.001	0.001	0.022	0.022
Back	Labridae	*Epibulus insidiator*	0.000	0.000	0.023	0.023
Back	Labridae	*Gomphosus varius*	0.001	0.000	0.006	0.004
Back	Labridae	*Halichoeres binotopsis*	0.000	0.000	0.003	0.003
Back	Labridae	*Halichoeres hortulanus*	0.003	0.001	0.195	0.135
Back	Labridae	*Halichoeres marginatus*	0.000	0.000	0.030	0.030
Back	Labridae	*Halichoeres melanurus*	0.004	0.001	0.063	0.023
Back	Labridae	*Hemigymnus fasciatus*	0.000	0.000	0.007	0.007
Back	Labridae	*Hemigymnus melapterus*	0.002	0.001	0.127	0.055
Back	Labridae	*Labroides bicolor*	0.000	0.000	0.000	0.000
Back	Labridae	*Labroides dimidiatus*	0.011	0.003	0.068	0.019
Back	Labridae	*Oxycheilinus unifasciatus*	0.000	0.000	0.005	0.005
Back	Labridae	*Stethojulis bandanensis*	0.001	0.001	0.022	0.014
Back	Labridae	*Thalassoma hardwicke*	0.023	0.011	0.891	0.441
Back	Labridae	*Thalassoma lunare*	0.005	0.003	0.216	0.139
Back	Labridae	*Thalassoma purpureum*	0.001	0.000	0.062	0.044
Back	Labridae	*Thalassoma quinquevittatum*	0.000	0.000	0.005	0.005
Back	Labridae	*Thalassoma trilobatum*	0.000	0.000	0.003	0.003
Back	Lethrinidae	*Monotaxis grandoculis*	0.007	0.002	2.126	1.235
Back	Lutjanidae	*Lutjanus fulviflammus*	0.007	0.007	0.417	0.417
Back	Lutjanidae	*Lutjanus fulvus*	0.002	0.001	0.488	0.226
Back	Lutjanidae	*Lutjanus gibbus*	0.000	0.000	0.254	0.254
Back	Lutjanidae	*Macolor niger*	0.000	0.000	0.147	0.147
Back	Microdesmidae	*Ptereleotris evides*	0.001	0.001	0.000	0.000
Back	Mullidae	*Parupeneus barberinoides*	0.000	0.000	0.006	0.006
Back	Mullidae	*Parupeneus barberinus*	0.002	0.001	0.229	0.079
Back	Mullidae	*Parupeneus bifasciatus*	0.005	0.002	0.656	0.284
Back	Mullidae	*Parupeneus multifasciatus*	0.004	0.001	0.233	0.071
Back	Mullidae	*Upeneus moluccensis*	0.000	0.000	0.006	0.006
Back	Nemipteridae	*Scolopsis bilineata*	0.003	0.002	0.345	0.294
Back	Nemipteridae	*Scolopsis margaritifer*	0.002	0.001	0.303	0.228
Back	Pomacanthidae	*Centropyge vrolikii*	0.001	0.001	0.033	0.028
Back	Pomacanthidae	*Pomacanthus xanthometopon*	0.000	0.000	0.078	0.078
Back	Pomacanthidae	*Pygoplites diacanthus*	0.008	0.002	1.201	0.346
Back	Pomacentridae	*Acanthochromis polyacanthus*	0.010	0.005	0.267	0.186
Back	Pomacentridae	*Amblyglyphidodon curacao*	0.486	0.090	8.052	2.633
Back	Pomacentridae	*Amblyglyphidodon leucogaster*	0.001	0.001	0.008	0.008
Back	Pomacentridae	*Amphiprion clarkii*	0.003	0.003	0.017	0.017
Back	Pomacentridae	*Amphiprion percula*	0.000	0.000	0.005	0.005
Back	Pomacentridae	*Chromis amboinensis*	0.027	0.019	0.289	0.208
Back	Pomacentridae	*Chromis margaritifer*	0.051	0.024	0.426	0.199
Back	Pomacentridae	*Chromis ternatensis*	0.033	0.025	0.392	0.260

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Back	Pomacentridae	*Chromis viridis*	0.001	0.001	0.007	0.007
Back	Pomacentridae	*Chromis xanthura*	0.034	0.020	0.995	0.872
Back	Pomacentridae	*Chrysiptera biocellata*	0.001	0.001	0.000	0.000
Back	Pomacentridae	*Chrysiptera rex*	0.001	0.001	0.004	0.004
Back	Pomacentridae	*Chrysiptera traceyi*	0.002	0.002	0.002	0.002
Back	Pomacentridae	*Chrysiptera unimaculata*	0.005	0.005	0.010	0.010
Back	Pomacentridae	*Dascyllus reticulatus*	0.035	0.018	0.264	0.137
Back	Pomacentridae	*Dascyllus trimaculatus*	0.000	0.000	0.001	0.001
Back	Pomacentridae	*Dischistodus melanotus*	0.004	0.003	0.181	0.174
Back	Pomacentridae	*Neoglyphidodon melas*	0.020	0.015	0.314	0.114
Back	Pomacentridae	*Neoglyphidodon nigroris*	0.024	0.006	0.326	0.107
Back	Pomacentridae	*Pomacentrus bankanensis*	0.019	0.011	0.330	0.215
Back	Pomacentridae	*Pomacentrus coelestis*	0.014	0.007	0.062	0.047
Back	Pomacentridae	*Pomacentrus moluccensis*	0.079	0.026	0.713	0.275
Back	Pomacentridae	*Pomacentrus pavo*	0.027	0.020	0.234	0.132
Back	Pomacentridae	*Pomacentrus simsiang*	0.000	0.000	0.000	0.000
Back	Pomacentridae	*Stegastes nigricans*	0.001	0.001	0.057	0.057
Back	Scaridae	*Cetoscarus bicolor*	0.002	0.002	0.140	0.087
Back	Scaridae	*Chlorurus bleekeri*	0.002	0.002	0.278	0.199
Back	Scaridae	*Chlorurus sordidus*	0.017	0.006	1.442	0.606
Back	Scaridae	*Scarus dimidiatus*	0.006	0.002	0.878	0.353
Back	Scaridae	*Scarus frenatus*	0.001	0.001	0.011	0.011
Back	Scaridae	*Scarus niger*	0.000	0.000	0.023	0.023
Back	Scaridae	*Scarus oviceps*	0.009	0.007	2.653	2.396
Back	Scaridae	*Scarus schlegeli*	0.001	0.000	0.028	0.023
Back	Scaridae	*Scarus tricolor*	0.001	0.000	0.171	0.145
Back	Serranidae	*Cephalopholis cyanostigma*	0.001	0.000	0.106	0.083
Back	Siganidae	*Siganus puellus*	0.000	0.000	0.021	0.021
Back	Tetraodontidae	*Arothron nigropunctatus*	0.000	0.000	0.134	0.134
Back	Zanclidae	*Zanclus cornutus*	0.005	0.003	0.608	0.367
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.026	0.015	6.419	3.695
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.007	0.002	0.599	0.211
Lagoon	Acanthuridae	*Acanthurus nigrofuscus*	0.029	0.020	3.656	2.612
Lagoon	Acanthuridae	*Acanthurus nigroris*	0.006	0.005	1.629	1.366
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.002	0.001	0.098	0.052
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.000	0.000	0.053	0.053
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.063	0.028	7.372	4.036
Lagoon	Acanthuridae	*Naso lituratus*	0.001	0.000	0.277	0.186
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.018	0.005	1.417	0.608
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.001	0.000	0.040	0.026
Lagoon	Apogonidae	*Cheilodipterus quinquelineatus*	0.007	0.007	0.016	0.016
Lagoon	Aulostomidae	*Aulostomus chinensis*	0.000	0.000	0.033	0.033
Lagoon	Balistidae	*Balistapus undulatus*	0.002	0.001	0.108	0.063

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Lagoon	Caesionidae	*Caesio cuning*	0.033	0.033	3.215	3.215
Lagoon	Caesionidae	*Caesio teres*	0.025	0.012	0.326	0.193
Lagoon	Carangidae	*Carangoides plagiotaenia*	0.000	0.000	0.428	0.428
Lagoon	Carangidae	*Caranx sexfasciatus*	0.000	0.000	0.270	0.270
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.000	0.000	0.009	0.009
Lagoon	Chaetodontidae	*Chaetodon baronessa*	0.001	0.001	0.092	0.063
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.001	0.001	0.016	0.016
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.000	0.000	0.052	0.052
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.003	0.002	0.102	0.066
Lagoon	Chaetodontidae	*Chaetodon lineolatus*	0.001	0.001	0.084	0.084
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.013	0.001	0.703	0.117
Lagoon	Chaetodontidae	*Chaetodon octofasciatus*	0.001	0.001	0.033	0.033
Lagoon	Chaetodontidae	*Chaetodon ornatissimus*	0.002	0.001	0.104	0.061
Lagoon	Chaetodontidae	*Chaetodon rafflesii*	0.000	0.000	0.004	0.004
Lagoon	Chaetodontidae	*Chaetodon reticulatus*	0.001	0.000	0.046	0.036
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.001	0.001	0.092	0.092
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.001	0.001	0.046	0.033
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.006	0.002	0.455	0.150
Lagoon	Chaetodontidae	*Heniochus chrysostomus*	0.000	0.000	0.018	0.018
Lagoon	Chaetodontidae	*Heniochus varius*	0.001	0.001	0.144	0.122
Lagoon	Holocentridae	*Myripristis berndti*	0.001	0.001	0.102	0.102
Lagoon	Holocentridae	*Myripristis kuntee*	0.002	0.002	0.447	0.447
Lagoon	Holocentridae	*Myripristis murdjan*	0.002	0.001	0.201	0.102
Lagoon	Kyphosidae	*Kyphosus bigibbus*	0.003	0.003	0.628	0.628
Lagoon	Labridae	*Cheilinus chlorourus*	0.001	0.001	0.035	0.035
Lagoon	Labridae	*Cheilinus fasciatus*	0.005	0.001	0.604	0.245
Lagoon	Labridae	*Coris gaimard*	0.000	0.000	0.004	0.004
Lagoon	Labridae	*Gomphosus varius*	0.001	0.001	0.034	0.029
Lagoon	Labridae	*Halichoeres hortulanus*	0.003	0.002	0.080	0.062
Lagoon	Labridae	*Halichoeres melanurus*	0.006	0.003	0.085	0.052
Lagoon	Labridae	*Halichoeres richmondi*	0.000	0.000	0.003	0.003
Lagoon	Labridae	*Hemigymnus melapterus*	0.002	0.001	0.125	0.044
Lagoon	Labridae	*Labroides bicolor*	0.000	0.000	0.002	0.002
Lagoon	Labridae	*Labroides dimidiatus*	0.008	0.002	0.039	0.015
Lagoon	Labridae	*Thalassoma hardwicke*	0.025	0.006	0.832	0.235
Lagoon	Labridae	*Thalassoma lunare*	0.002	0.001	0.055	0.033
Lagoon	Labridae	*Thalassoma purpureum*	0.001	0.001	0.023	0.015
Lagoon	Labridae	*Thalassoma quinquevittatum*	0.000	0.000	0.005	0.005
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.004	0.003	0.844	0.744
Lagoon	Lutjanidae	*Lutjanus fulvus*	0.000	0.000	0.007	0.007
Lagoon	Microdesmidae	*Ptereleotris evides*	0.001	0.001	0.000	0.000
Lagoon	Mullidae	*Mulloidichthys flavolineatus*	0.001	0.001	0.742	0.742
Lagoon	Mullidae	*Parupeneus barberinus*	0.002	0.001	0.337	0.269

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Lagoon	Mullidae	*Parupeneus bifasciatus*	0.003	0.002	0.417	0.205
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.001	0.001	0.126	0.126
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.000	0.000	0.025	0.025
Lagoon	Nemipteridae	*Scolopsis lineatus*	0.000	0.000	0.025	0.025
Lagoon	Nemipteridae	*Scolopsis margaritifer*	0.002	0.001	0.148	0.111
Lagoon	Pomacanthidae	*Centropyge flavissimus*	0.000	0.000	0.005	0.005
Lagoon	Pomacanthidae	*Centropyge vrolikii*	0.001	0.001	0.028	0.028
Lagoon	Pomacanthidae	*Chaetodontoplus mesoleucus*	0.000	0.000	0.037	0.037
Lagoon	Pomacanthidae	*Pomacanthus navarchus*	0.001	0.001	0.194	0.194
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.003	0.001	0.430	0.189
Lagoon	Pomacentridae	*Amblyglyphidodon curacao*	0.185	0.035	3.240	1.160
Lagoon	Pomacentridae	*Amphiprion clarkii*	0.001	0.001	0.010	0.010
Lagoon	Pomacentridae	*Amphiprion perideraion*	0.001	0.001	0.010	0.010
Lagoon	Pomacentridae	*Chromis atripectoralis*	0.007	0.007	0.025	0.025
Lagoon	Pomacentridae	*Chromis margaritifer*	0.014	0.011	0.061	0.049
Lagoon	Pomacentridae	*Chromis ternatensis*	0.036	0.010	0.255	0.129
Lagoon	Pomacentridae	*Chromis viridis*	0.082	0.047	1.061	0.989
Lagoon	Pomacentridae	*Chromis xanthura*	0.002	0.001	0.039	0.034
Lagoon	Pomacentridae	*Chrysiptera biocellata*	0.002	0.002	0.002	0.002
Lagoon	Pomacentridae	*Chrysiptera rex*	0.000	0.000	0.000	0.000
Lagoon	Pomacentridae	*Chrysiptera rollandi*	0.001	0.001	0.003	0.002
Lagoon	Pomacentridae	*Chrysiptera taupou*	0.001	0.001	0.002	0.002
Lagoon	Pomacentridae	*Chrysiptera traceyi*	0.003	0.003	0.006	0.006
Lagoon	Pomacentridae	*Chrysiptera unimaculata*	0.004	0.004	0.036	0.036
Lagoon	Pomacentridae	*Dascyllus aruanus*	0.002	0.002	0.010	0.008
Lagoon	Pomacentridae	*Dascyllus melanurus*	0.002	0.001	0.005	0.002
Lagoon	Pomacentridae	*Dascyllus reticulatus*	0.001	0.001	0.003	0.003
Lagoon	Pomacentridae	*Dischistodus melanotus*	0.010	0.009	0.492	0.438
Lagoon	Pomacentridae	*Dischistodus prosopotaenia*	0.002	0.002	0.067	0.055
Lagoon	Pomacentridae	*Neoglyphidodon bonang*	0.000	0.000	0.002	0.002
Lagoon	Pomacentridae	*Neoglyphidodon melas*	0.009	0.003	0.564	0.214
Lagoon	Pomacentridae	*Neoglyphidodon nigroris*	0.008	0.002	0.111	0.052
Lagoon	Pomacentridae	*Plectroglyphidodon dickii*	0.000	0.000	0.015	0.015
Lagoon	Pomacentridae	*Plectroglyphidodon johnstonianus*	0.001	0.001	0.008	0.008
Lagoon	Pomacentridae	*Plectroglyphidodon lacrymatus*	0.001	0.001	0.059	0.059
Lagoon	Pomacentridae	*Pomacentrus bankanensis*	0.001	0.001	0.035	0.019
Lagoon	Pomacentridae	*Pomacentrus coelestis*	0.006	0.003	0.025	0.016
Lagoon	Pomacentridae	*Pomacentrus moluccensis*	0.074	0.038	0.339	0.179
Lagoon	Pomacentridae	*Pomacentrus pavo*	0.015	0.008	0.017	0.006
Lagoon	Pomacentridae	*Pomacentrus simsiang*	0.001	0.001	0.023	0.021
Lagoon	Pomacentridae	*Stegastes nigricans*	0.004	0.003	0.230	0.204
Lagoon	Scaridae	*Cetoscarus bicolor*	0.001	0.001	0.281	0.236
Lagoon	Scaridae	*Chlorurus bleekeri*	0.002	0.002	0.236	0.236

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Lagoon	Scaridae	*Chlorurus sordidus*	0.017	0.003	1.421	0.332
Lagoon	Scaridae	*Hipposcarus longiceps*	0.001	0.001	0.495	0.495
Lagoon	Scaridae	*Scarus dimidiatus*	0.027	0.015	4.737	3.558
Lagoon	Scaridae	*Scarus forsteni*	0.001	0.001	0.070	0.070
Lagoon	Scaridae	*Scarus oviceps*	0.005	0.002	1.385	0.781
Lagoon	Scaridae	*Scarus schlegeli*	0.000	0.000	0.206	0.206
Lagoon	Scaridae	*Scarus spinus*	0.000	0.000	0.106	0.106
Lagoon	Scaridae	*Scarus tricolor*	0.002	0.002	0.140	0.140
Lagoon	Scombridae	*Scomberomorus commerson*	0.000	0.000	1.004	1.004
Lagoon	Serranidae	*Epinephelus merra*	0.001	0.000	0.070	0.051
Lagoon	Siganidae	*Siganus vulpinus*	0.000	0.000	0.098	0.098
Lagoon	Tetraodontidae	*Arothron nigropunctatus*	0.000	0.000	0.052	0.052
Lagoon	Tetraodontidae	*Canthigaster papua*	0.001	0.001	0.014	0.014
Lagoon	Zanclidae	*Zanclus cornutus*	0.002	0.001	0.210	0.105
Outer	Acanthuridae	*Acanthurus achilles*	0.005	0.005	0.893	0.893
Outer	Acanthuridae	*Acanthurus auranticavus*	0.000	0.000	0.015	0.015
Outer	Acanthuridae	*Acanthurus grammoptilus*	0.009	0.009	3.256	3.256
Outer	Acanthuridae	*Acanthurus lineatus*	0.002	0.002	0.183	0.183
Outer	Acanthuridae	*Acanthurus nigricans*	0.025	0.006	2.121	1.173
Outer	Acanthuridae	*Acanthurus nigricauda*	0.002	0.001	0.298	0.212
Outer	Acanthuridae	*Acanthurus nigrofuscus*	0.026	0.017	3.545	2.264
Outer	Acanthuridae	*Acanthurus nigroris*	0.003	0.002	0.122	0.106
Outer	Acanthuridae	*Acanthurus pyroferus*	0.007	0.002	0.868	0.566
Outer	Acanthuridae	*Ctenochaetus striatus*	0.085	0.025	7.389	2.234
Outer	Acanthuridae	*Naso vlamingii*	0.003	0.003	0.231	0.231
Outer	Acanthuridae	*Zebrasoma scopas*	0.004	0.002	0.302	0.112
Outer	Balistidae	*Balistapus undulatus*	0.007	0.002	0.493	0.243
Outer	Balistidae	*Balistoides conspicillum*	0.000	0.000	0.021	0.021
Outer	Balistidae	*Melichthys vidua*	0.005	0.003	1.125	0.803
Outer	Balistidae	*Sufflamen bursa*	0.001	0.000	0.074	0.049
Outer	Balistidae	*Sufflamen chrysopterus*	0.003	0.002	0.678	0.642
Outer	Caesionidae	*Caesio cuning*	0.000	0.000	0.077	0.077
Outer	Caesionidae	*Caesio teres*	0.007	0.007	2.183	2.183
Outer	Chaetodontidae	*Chaetodon baronessa*	0.000	0.000	0.007	0.007
Outer	Chaetodontidae	*Chaetodon citrinellus*	0.003	0.001	0.100	0.036
Outer	Chaetodontidae	*Chaetodon ephippium*	0.000	0.000	0.052	0.052
Outer	Chaetodontidae	*Chaetodon kleinii*	0.003	0.001	0.104	0.047
Outer	Chaetodontidae	*Chaetodon lineolatus*	0.000	0.000	0.003	0.003
Outer	Chaetodontidae	*Chaetodon lunulatus*	0.004	0.002	0.245	0.111
Outer	Chaetodontidae	*Chaetodon meyeri*	0.001	0.001	0.067	0.050
Outer	Chaetodontidae	*Chaetodon ornatissimus*	0.001	0.001	0.029	0.020
Outer	Chaetodontidae	*Chaetodon rafflesii*	0.001	0.001	0.020	0.020
Outer	Chaetodontidae	*Chaetodon vagabundus*	0.005	0.002	0.647	0.311

Habitat	**Family**	**Species**	**Density (fish/m²)**	**SE density**	**Biomass (g/m²)**	**SE biomass**
Outer	Chaetodontidae	*Forcipiger flavissimus*	0.000	0.000	0.071	0.071
Outer	Chaetodontidae	*Forcipiger longirostris*	0.001	0.001	0.059	0.038
Outer	Chaetodontidae	*Heniochus chrysostomus*	0.001	0.001	0.036	0.036
Outer	Chaetodontidae	*Heniochus varius*	0.000	0.000	0.029	0.029
Outer	Cirrhitidae	*Paracirrhites arcatus*	0.005	0.002	0.069	0.020
Outer	Cirrhitidae	*Paracirrhites forsteri*	0.003	0.001	0.062	0.035
Outer	Holocentridae	*Neoniphon sammara*	0.001	0.001	0.158	0.158
Outer	Holocentridae	*Sargocentron caudimaculatum*	0.004	0.002	0.600	0.340
Outer	Labridae	*Anampses melanurus*	0.001	0.001	0.008	0.008
Outer	Labridae	*Anampses meleagrides*	0.000	0.000	0.005	0.005
Outer	Labridae	*Bodianus mesothorax*	0.001	0.000	0.020	0.013
Outer	Labridae	*Cheilinus chlorourus*	0.000	0.000	0.052	0.052
Outer	Labridae	*Coris gaimard*	0.001	0.000	0.009	0.007
Outer	Labridae	*Gomphosus varius*	0.001	0.001	0.048	0.033
Outer	Labridae	*Halichoeres hortulanus*	0.018	0.004	0.645	0.295
Outer	Labridae	*Hemigymnus fasciatus*	0.000	0.000	0.037	0.037
Outer	Labridae	*Labroides bicolor*	0.001	0.001	0.008	0.007
Outer	Labridae	*Labroides dimidiatus*	0.017	0.005	0.088	0.029
Outer	Labridae	*Labroides pectoralis*	0.000	0.000	0.001	0.001
Outer	Labridae	*Stethojulis bandanensis*	0.001	0.001	0.012	0.008
Outer	Labridae	*Thalassoma amblycephalum*	0.020	0.020	0.541	0.541
Outer	Labridae	*Thalassoma hardwicke*	0.010	0.001	0.291	0.069
Outer	Labridae	*Thalassoma lutescens*	0.001	0.001	0.079	0.079
Outer	Labridae	*Thalassoma quinquevittatum*	0.001	0.001	0.019	0.014
Outer	Lethrinidae	*Monotaxis grandoculis*	0.001	0.000	0.109	0.076
Outer	Lutjanidae	*Lutjanus biguttatus*	0.013	0.013	1.911	1.911
Outer	Lutjanidae	*Macolor niger*	0.002	0.001	0.496	0.309
Outer	Malacanthidae	*Malacanthus latovittatus*	0.000	0.000	0.000	0.000
Outer	Microdesmidae	*Nemateleotris magnifica*	0.000	0.000	0.000	0.000
Outer	Microdesmidae	*Ptereleotris evides*	0.004	0.003	0.000	0.000
Outer	Mullidae	*Parupeneus barberinus*	0.001	0.001	0.027	0.025
Outer	Mullidae	*Parupeneus bifasciatus*	0.001	0.001	0.102	0.058
Outer	Mullidae	*Parupeneus multifasciatus*	0.006	0.001	0.319	0.089
Outer	Nemipteridae	*Scolopsis bilineata*	0.000	0.000	0.020	0.020
Outer	Nemipteridae	*Scolopsis lineatus*	0.000	0.000	0.017	0.017
Outer	Pomacanthidae	*Centropyge bicolor*	0.001	0.000	0.024	0.016
Outer	Pomacanthidae	*Centropyge loriculus*	0.000	0.000	0.005	0.005
Outer	Pomacanthidae	*Centropyge vrolikii*	0.006	0.004	0.132	0.103
Outer	Pomacanthidae	*Pygoplites diacanthus*	0.001	0.001	0.234	0.151
Outer	Pomacentridae	*Amphiprion chrysopterus*	0.002	0.001	0.031	0.024
Outer	Pomacentridae	*Amphiprion clarkii*	0.001	0.001	0.021	0.017
Outer	Pomacentridae	*Chromis margaritifer*	0.140	0.026	0.867	0.307
Outer	Pomacentridae	*Chromis ternatensis*	0.014	0.009	0.162	0.107

Habitat	Family	Species	Density (fish/m^2)	SE density	Biomass (g/m^2)	SE biomass
Outer	Pomacentridae	*Chromis xanthura*	0.049	0.014	0.852	0.534
Outer	Pomacentridae	*Chrysiptera taupou*	0.016	0.013	0.066	0.042
Outer	Pomacentridae	*Chrysiptera traceyi*	0.002	0.001	0.005	0.003
Outer	Pomacentridae	*Neoglyphidodon melas*	0.003	0.003	0.028	0.028
Outer	Pomacentridae	*Plectroglyphidodon dickii*	0.020	0.005	0.362	0.147
Outer	Pomacentridae	*Plectroglyphidodon johnstonianus*	0.003	0.003	0.053	0.042
Outer	Pomacentridae	*Plectroglyphidodon lacrymatus*	0.019	0.009	0.171	0.085
Outer	Pomacentridae	*Pomacentrus bankanensis*	0.030	0.013	0.269	0.160
Outer	Pomacentridae	*Pomacentrus coelestis*	0.048	0.017	0.287	0.211
Outer	Pomacentridae	*Pomacentrus grammorhynchus*	0.001	0.001	0.007	0.007
Outer	Pomacentridae	*Stegastes nigricans*	0.001	0.001	0.008	0.008
Outer	Scaridae	*Cetoscarus bicolor*	0.001	0.001	0.031	0.023
Outer	Scaridae	*Chlorurus bleekeri*	0.001	0.001	0.061	0.061
Outer	Scaridae	*Chlorurus sordidus*	0.036	0.012	2.581	0.744
Outer	Scaridae	*Hipposcarus longiceps*	0.001	0.001	0.237	0.237
Outer	Scaridae	*Scarus altipinnis*	0.000	0.000	0.011	0.011
Outer	Scaridae	*Scarus dimidiatus*	0.002	0.001	0.203	0.104
Outer	Scaridae	*Scarus niger*	0.001	0.001	0.013	0.013
Outer	Scaridae	*Scarus oviceps*	0.005	0.002	1.483	0.657
Outer	Scaridae	*Scarus rivulatus*	0.000	0.000	0.042	0.042
Outer	Scaridae	*Scarus schlegeli*	0.000	0.000	0.024	0.024
Outer	Scaridae	*Scarus spinus*	0.002	0.001	0.529	0.415
Outer	Serranidae	*Cephalopholis argus*	0.002	0.001	0.236	0.131
Outer	Serranidae	*Cephalopholis urodeta*	0.001	0.001	0.060	0.060
Outer	Siganidae	*Siganus vulpinus*	0.001	0.001	0.111	0.111
Outer	Zanclidae	*Zanclus cornutus*	0.002	0.001	0.156	0.088

Appendix 9 Invertebrate survey form

DATE		RECORDER		Pg No	

STATION NAME																		
WPT - WIDTH																		
RELIEF / COMPLEXITY **1–5**																		
OCEAN INFLUENCE **1–5**																		
DEPTH (M)																		
% SOFT SED (M – S – CS)																		
% RUBBLE / BOULDERS																		
% CONSOL RUBBLE / PAVE																		
% CORAL *LIVE*																		
% CORAL *DEAD*																		
SOFT / SPONGE / FUNGIDS																		
ALGAE *CCA*																		
CORALLINE																		
OTHER																		
GRASS																		
EPIPHYTES **1–5** / SILT **1–5**																		
bleaching: % of																		
entered /																		

Appendix 10 GPS positions of manta tow surveys conducted at Ahus and Andra monitoring sites, 2012

Site	Habitat	Station ID	Replicate	Start Longitude (E)	Start Latitude (N)
Ahus 2012	Back-reef	Ahus 2012	1	-1.942667	147.110767
Ahus 2012	Back-reef	Ahus 2012	2	-1.94435	147.108717
Ahus 2012	Back-reef	Ahus 2012	3	-1.944967	147.105917
Ahus 2012	Back-reef	Ahus 2012	4	-1.944817	147.102967
Ahus 2012	Back-reef	Ahus 2012	5	-1.945033	147.100317
Ahus 2012	Back-reef	Ahus 2012	6	-1.944833	147.097233
Ahus 2012	Back-reef	Ahus 2012	1	-1.944067	147.0939
Ahus 2012	Back-reef	Ahus 2012	2	-1.944067	147.090967
Ahus 2012	Back-reef	Ahus 2012	3	-1.943983	147.088167
Ahus 2012	Back-reef	Ahus 2012	4	-1.943333	147.086333
Ahus 2012	Back-reef	Ahus 2012	5	-1.942167	147.084617
Ahus 2012	Back-reef	Ahus 2012	6	-1.94235	147.087033
Ahus 2012	Outer-reef	Ahus 2012	1	-1.940433	147.112233
Ahus 2012	Outer-reef	Ahus 2012	2	-1.937983	147.111967
Ahus 2012	Outer-reef	Ahus 2012	3	-1.93595	147.1104
Ahus 2012	Outer-reef	Ahus 2012	4	-1.934983	147.107683
Ahus 2012	Outer-reef	Ahus 2012	5	-1.934367	147.104933
Ahus 2012	Outer-reef	Ahus 2012	6	-1.933683	147.102267
Ahus 2012	Outer-reef	Ahus 2012	1	-1.9322	147.09225
Ahus 2012	Outer-reef	Ahus 2012	2	-1.931883	147.0892
Ahus 2012	Outer-reef	Ahus 2012	3	-1.931833	147.085883
Ahus 2012	Outer-reef	Ahus 2012	4	-1.931433	147.083033
Ahus 2012	Outer-reef	Ahus 2012	5	-1.931017	147.08005
Ahus 2012	Outer-reef	Ahus 2012	6	-1.9304	147.0771
Andra 2012	Back-reef	Andra 2012	1	-1.93035	146.931733
Andra 2012	Back-reef	Andra 2012	2	-1.932067	146.93285
Andra 2012	Back-reef	Andra 2012	3	-1.9316	146.934833
Andra 2012	Back-reef	Andra 2012	4	-1.937983	146.9463
Andra 2012	Back-reef	Andra 2012	5	-1.9383	146.949017
Andra 2012	Back-reef	Andra 2012	6	-1.9384	146.952517
Andra 2012	Back-reef	Andra 2012	1	-1.939217	146.955867
Andra 2012	Back-reef	Andra 2012	2	-1.940933	146.958183
Andra 2012	Back-reef	Andra 2012	3	-1.94175	146.96095
Andra 2012	Back-reef	Andra 2012	4	-1.94215	146.963783
Andra 2012	Back-reef	Andra 2012	5	-1.941917	146.966767
Andra 2012	Back-reef	Andra 2012	6	-1.941917	146.966767
Andra 2012	Outer-reef	Andra 2012	1	-1.925583	146.969133
Andra 2012	Outer-reef	Andra 2012	2	-1.9253	146.966367
Andra 2012	Outer-reef	Andra 2012	3	-1.9258	146.963417

Site	Habitat	Station ID	Replicate	Start Longitude (E)	Start Latitude (N)
Andra 2012	Outer-reef	Andra 2012	4	-1.9263	146.96095
Andra 2012	Outer-reef	Andra 2012	5	-1.92575	146.958017
Andra 2012	Outer-reef	Andra 2012	6	-1.92525	146.9552
Andra 2012	Outer-reef	Andra 2012	1	-1.924467	146.94875
Andra 2012	Outer-reef	Andra 2012	2	-1.924467	146.94875
Andra 2012	Outer-reef	Andra 2012	3	-1.924533	146.943117
Andra 2012	Outer-reef	Andra 2012	4	-1.925233	146.940267
Andra 2012	Outer-reef	Andra 2012	5	-1.925083	146.937433
Andra 2012	Outer-reef	Andra 2012	6	-1.923883	146.93435

Appendix 11 Mean scores (± SE) of each habitat category at the manta tow survey sites of Ahus and Andra, 2012.

Habitat category	Back-reef		Outer-reef	
	Ahus	Andra	Ahus	Andra
Depth	4.50±0.71	3.50±0.23	6.50±0.34	5.75±0.78
Relief	1.50±0.15	1.92±0.19	1.83±0.11	1.92±0.08
Complexity	2.17±0.11	2.00±0.00	1.92±0.19	2.50±0.15
Oceanic influence	1.50±0.15	1.17±0.11	2.08±0.08	3.00±0.00
Mud	0.00±0.00	0.00±0.00	0.83±0.83	0.00±0.00
Sand	40.00±3.89	20.83±3.98	12.17±2.06	15.83±1.93
Rubble	15.83±3.79	11.67±1.12	10.00±2.04	9.17±2.60
Boulders	6.67±4.49	3.33±1.88	9.58±1.79	1.25±0.90
Consolidated rubble	0.00±0.00	0.00±0.00	7.92±3.04	7.50±2.50
Pavement	0.00±0.00	0.00±0.00	15.00±2.68	32.08±9.78
Live coral	18.75±3.49	46.67±4.49	30.83±2.88	23.33±3.91
Dead coral	18.75±2.14	17.50±3.51	13.33±1.55	10.83±0.83
Bleached coral	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Crustose coralline algae	20.42±3.04	9.17±2.60	17.08±2.92	55.83±2.53
Coralline algae	32.50±5.52	2.50±2.50	19.58±2.78	28.33±1.12
Other algae	12.08±2.50	0.00±0.00	36.67±6.23	7.50±1.31
Seagrass	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Soft coral	12.92±4.54	0.00±0.00	9.17±1.49	4.17±1.49
Sponge	16.25±4.49	5.83±1.49	8.75±2.31	4.17±1.35
Fungids	1.67±0.71	4.17±2.29	4.17±1.49	0.00±0.00

Appendix 12 Mean density (± SE) of individual invertebrate species recorded during manta tow surveys within back-reef habitats of Ahus and Andra, 2012.

Group	Species	Density (individuals/ha)	
		Ahus	Andra
Sea cucumber	*Bohadschia argus*	16.67±13.89	15.28±1.39
	Bohadschia vitiensis	-	9.72±6.94
	Holothuria atra	48.61±23.61	30.56±8.33
	Holothuria coluber	4.17±4.17	-
	Holothuria edulis	1.39±1.39	16.67±11.11
	Holothuria leucospilota	-	2.78±0.00
	Pearsonothuria graeffei	-	22.22±13.89
	Stichopus hermanni	2.78±2.78	-
	Thelenota ananas	1.39±1.39	1.39±1.39
	Thelenota anax	5.56±5.56	23.61±23.61
Bivalve	*Tridacna maxima*	1.39±1.39	13.89±5.56
Gastropod	*Cypraea tigris*	-	1.39±1.39
	Tectus niloticus	1.39±1.39	-
	Tectus pyramis	-	1.39±1.39
Starfish	*Linckia laevigata*	29.17±29.17	159.72±45.83
	Choriaster granulatus	-	1.39±1.39

Appendix 13 Mean density (± SE) of individual invertebrate species recorded during manta tow surveys within outer-reef habitats of Ahus and Andra, 2012.

Group	Species	Density (individuals/ha)	
		Ahus	Andra
Sea cucumber	*Actinopyga mauritiana*	-	1.39±1.39
	Holothuria atra	1.39±1.39	13.89±8.33
	Holothuria fuscogilva	1.39±1.39	-
	Pearsonothuria graeffei	6.94±6.94	-
	Thelenota ananas	-	4.17±4.17
Bivalve	*Tridacna maxima*	2.78±2.78	2.78±2.78
Crustacean	*Panulirus ornatus*	-	4.17±4.17
Gastropod	*Canarium mutabile*[3]	-	2.78±2.78
	Cypraea tigris	-	1.39±1.39
Starfish	*Linckia guildingi*	-	1.39±1.39
	Linckia laevigata	1.39±1.39	-

[3] This species was formerly known as *Strombus mutabilis*

Appendix 14 GPS positions of reef-benthos transects conducted at Ahus and Andra, 2012

Site	Station ID	Longitude (E)	Latitude (S)
Ahus 2012	RBT 7	147.110833	1.942683
Ahus 2012	RBT 8	147.106333	1.944683
Ahus 2012	RBT 9	147.097717	1.945033
Ahus 2012	RBT 10	147.094283	1.944
Ahus 2012	RBT 11	147.088283	1.94395
Ahus 2012	RBT 12	147.088467	1.942467
Andra 2012	RBT 1	146.93895	1.928783
Andra 2012	RBT 2	146.941717	1.928483
Andra 2012	RBT 3	146.944617	1.928867
Andra 2012	RBT 4	146.9582	1.940917
Andra 2012	RBT 5	146.9638	1.94205
Andra 2012	RBT 6	146.97185	1.940067

Appendix 15 Mean scores (± SE) of each habitat category at the reef-benthos transect stations of Ahus and Andra, 2012.

Habitat category	Site	
	Ahus	Andra
Depth	1.02±0.01	1.00±0.04
Relief	1.42±0.08	1.14±0.06
Complexity	2.56±0.11	2.03±0.10
Oceanic influence	1.00±0.00	1.00±0.00
Mud	0.00±0.00	0.00±0.00
Sand	12.92±1.51	29.44±1.59
Coarse sand	2.22±0.88	0.00±0.00
Rubble	10.28±0.97	12.72±1.65
Boulders	3.06±0.80	7.64±1.65
Consolidated rubble	8.47±1.33	0.00±0.00
Pavement	6.53±1.55	0.00±0.00
Live coral	27.78±2.35	31.67±1.74
Dead coral	28.75±2.39	19.03±1.16
Bleached coral	0.00±0.00	0.00±0.00
Crustose coralline algae	28.75±3.15	14.31±2.01
Coralline algae	19.31±1.70	19.86±1.15
Other algae	13.06±1.06	7.22±1.41
Seagrass	1.81±0.41	15.28±1.18
Soft coral	9.17±1.46	2.64±0.86
Sponge	6.94±1.26	20.56±2.11
Fungids	2.22±0.58	1.81±0.69

Appendix 16 Mean density (± SE) of individual invertebrate species recorded during reef-benthos transects at Ahus and Andra, 2012.

Group	Species	Density (individuals/ha)	
		Ahus	Andra
Sea cucumber	*Bohadschia argus*	13.89±8.78	6.94±6.94
	Bohadschia vitiensis	-	6.94±6.94
	Holothuria atra	41.67±18.63	263.89±125.31
	Holothuria coluber	41.67±26.35	55.56±47.71
	Holothuria edulis	-	27.78±17.57
	Holothuria leucospilota	-	13.89±13.89
	Pearsonothuria graeffei	6.94±6.94	13.89±8.78
Bivalve	*Tridacna maxima*	145.83±129.88	270.83±95.47
	Tridacna squamosa	-	27.78±17.57
Gastropod	*Cerithium nodulosum*	6.94±6.94	-
	Conus litteratus	-	6.94±6.94
	Conus miles	6.94±6.94	-
	Conus vexillum	27.78±13.89	-
	Cypraea tigris	-	6.94±6.94
	Monetaria annulus[4]	-	62.50±62.50
	Monetaria moneta[5]	-	138.89±71.09
	Filifusus filamentosus[6]	13.89±13.89	-
	Latirolagena smaragdula	6.94±6.94	-
	Thais tuberosa	13.89±8.78	-
	Nerita plicata	6.94±6.94	-
	Conomurex luhuanus	55.56±29.79	125.00±79.06
	Lambis lambis	6.94±6.94	6.94±6.94
	Lambis truncata	6.94±6.94	6.94±6.94
	Trapezia sp.	27.78±27.78	-
	Trochus maculatus	-	6.94±6.94
	Vasum ceramicum	6.94±6.94	-
	Tectus niloticus	152.78±71.90	13.89±13.89
	Turbo marmoratus	48.61±40.85	-
	Turbo petholatus	-	6.94±6.94
Starfish	*Acanthaster planci*	76.39±29.30	6.94±6.94
	Linckia laevigata	673.61±161.52	736.11±210.45
	Culcita novaeguineae	55.56±29.79	13.89±13.89
	Protoreaster nodosus	-	13.89±8.78
Urchin	*Echinothrix diadema*	-	6.94±6.94
	Echinometra mathaei	20.83±20.83	354.17±190.86

[4] This species was formerly known as *Cypraea annulus*
[5] This species was formerly known as *Cypraea moneta*
[6] This species was formerly known as *Pleuroploca filamentosa*

Appendix 17 Comparison of mean density of invertebrate species recorded during reef-benthos transects at the Ahus and Andra monitoring sites during the current (2012) survey and PROCFish surveys in 2006.

Group	Species	Mean density (individual/ha±SE)			
		Ahus		Andra	
		PROCFish 2006	Current (2012) survey	PROCFish 2006	Current (2012) survey
Sea cucumber	*Bohadschia argus*	-	13.89±8.78	-	6.94±6.94
	Bohadschia graeffei	41.67±24.06	-	-	-
	Bohadschia vitiensis	-	-	-	6.94±6.94
	Holothuria atra	-	41.67±18.63	-	263.89±125.31
	Holothuria coluber	-	41.67±26.35	-	55.56±47.71
	Holothuria edulis	-	-	13.89±13.89	27.78±17.57
	Holothuria leucospilota	-	-	-	13.89±13.89
	Pearsonothuria graeffei	-	6.94±6.94	-	13.89±8.78
	Stichopus chloronotus	-	-	83.33±63.65	-
Bivalve	*Tridacna crocea*	55.56±55.56	-	1819.44±1181.05	-
	Tridacna maxima	55.56±13.89	145.83±129.88	291.67±48.11	270.83±95.47
	Tridacna squamosa	-	-	13.89±13.89	27.78±17.57
Crustacean	*Trapezia* sp.	-	27.78±27.78	-	-
Gastropod	*Cerithium nodulosum*	-	6.94±6.94	-	-
	Chicoreus sp.	13.89±13.89	-	-	-
	Conomurex luhuanus	-	55.56±29.79	-	125.00±79.06
	Conus litteratus	-	-	-	6.94±6.94
	Conus miles	13.89±13.89	6.94±6.94	180.56±84.48	-
	Conus sp.	27.78±27.78	-	166.67±72.17	-
	Conus vexillum	-	27.78±13.89	138.89±60.54	-
	Cypraea sp.	27.78±27.78	-	-	-
	Cypraea tigris	13.89±13.89	-	-	6.94±6.94

Group	Species	Mean density (individual/ha±SE)			
		Ahus		Andra	
		PROCFish 2006	Current (2012) survey	PROCFish 2006	Current (2012) survey
	Drupella sp.	-	-	111.11±111.11	-
	Filifuscus filamentosa	13.89±13.89	13.89±13.89	-	-
	Lambis lambis	-	6.94±6.94	-	6.94±6.94
	Lambis truncata	-	6.94±6.94	-	6.94±6.94
	Latirolagena smaragdula	-	6.94±6.94	55.56±55.56	-
	Lyncina lynx[7]	-	-	13.89±13.89	-
	Mitra mitra	-	-	13.89±13.89	-
	Monetaria annulus	-	-	-	62.50±62.50
	Monetaria moneta	-	-	-	138.89±71.09
	Nerita plicata	-	6.94±6.94	-	-
	Ovula ovum	-	-	13.89±13.89	-
	Tectus niloticus	69.44±27.78	152.78±71.90	27.78±27.78	13.89±13.89
	Tectus pyramis	180.56±84.48	-	69.44±27.78	-
	Thais sp.	13.89±13.89	-	-	-
	Thais tuberosa	-	13.89±8.78	-	-
	Trochus maculata	-	-	-	6.94±6.94
	Turbo argyrostomus	-	-	13.89±13.89	-
	Turbo chrysostomus	138.89±73.49	-	13.89±13.89	-
	Turbo marmoratus	-	48.61±40.85	-	-
	Turbo petholatus	-	-	-	6.94±6.94
	Vasum ceramicum	27.78±13.89	6.94±6.94	13.89±13.89	-
	Vasum turbinellus	27.78±27.78	-	41.67±24.06	-

[7] This species was formerly known as *Cypraea lynx*

Group	Species	Mean density (individual/ha±SE)			
		Ahus		Andra	
		PROCFish 2006	Current (2012) survey	PROCFish 2006	Current (2012) survey
Starfish	*Acanthaster planci*	41.67±24.06	76.39±29.30	41.67±24.06	6.94±6.94
	Choriaster sp.	-	-	13.89±13.89	-
	Culcita novaeguineae	41.67±24.06	55.56±29.79	41.67±0.00	13.89±13.89
	Linckia laevigata	430.56±97.22	673.61±161.52	541.67±209.72	736.11±210.45
	Ophiomastrix sp.	-	-	-	13.89±13.89
	Protoreaster nodosus	13.89±13.89	-	-	13.89±8.78
Urchin	*Echinometra mathaei*	13.89±13.89	20.83±20.83	500.00±83.33	354.17±190.86
	Echinothrix diadema	27.78±27.78	-	-	6.94±6.94