EXPEDITION REPORT

28 Aug to 13 Sep, 2018

ElysiumEpic.org

A carbon neutral expedition supported by

CITY DEVELOPMENTS LIMITED

OCEAN GEOGRAPHIC

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OVERVIEW

The Elysium Heart of the Coral Triangle expedition stems from its explorers' shared understanding that climate change is intimately related to ocean change. The oceans play an essential role in regulating global climate and regional temperature, and are crucial for controlling the carbon, oxygen, and water cycles of the planet. The oceans are a vital part of the complex geophysical and biochemical systems that support life on Earth.

The exchanges of cold and warm water that take place in the Antarctic's Southern Ocean and the seas of the Arctic are key drivers of thermohaline circulation throughout all the oceans across the globe, and thermohaline circulation in turn plays a fundamental role in controlling the world's climate. There is strong evidence that, due to impacts on our atmosphere stemming from the emission of greenhouse gases, significant changes are taking place in the chemical composition of the oceans. Those changes are affecting the oceans' pH levels and productivity, and are impairing the ability of ocean life to survive and thrive. Impacts on the well-being of ocean life are beginning to affect other forms of life as well. These issues are vital signs, telling us that our planet is in distress.

Human impact on the ocean is increasing every year with global climate change and acidification reducing ocean productivity, overdevelopment and pollution contaminating the sea, and an increasing demand for food causing over-harvesting of the world's fisheries. Addressing these issues requires a combination of exploration and quantitative analysis to understand the underlying processes controlling diversity and productivity of marine life.

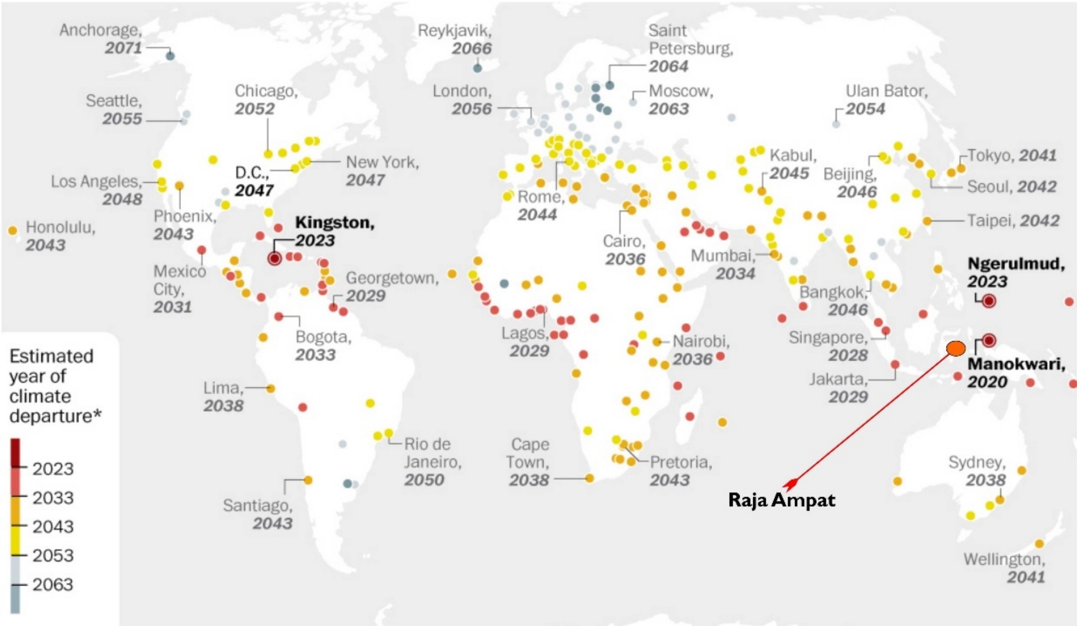


Fig A

Climate departure in the tropics is expected to take place in 2020. A study by a panel of 15 scientists explains is as, "a new index of the year when the climate of a given location moves to a state continuously outside the bounds of historical variability under alternative greenhouse gas emissions scenarios." Climate Departure is a point of no return – where abnormal becomes normal. Unprecedented climates will occur earliest in the tropics and among low-income countries, highlighting the vulnerability of global biodiversity, coral reefs, and governmental capacity to respond to the impacts of climate change. The findings shed light on the urgency of mitigating greenhouse gas emissions if climates potentially harmful to biodiversity and society are to be prevented. This landmark article co-authored by 15 climate scientists explains how species extinctions will soar faster and earlier in the tropics, further driving home the point of how critical it is for us to protect coral reefs, especially those in the Coral Triangle in every way possible.

Our utmost concern is the Bird's Head Peninsula region, comprising the northwestern end of the island of New Guinea. To the east is Cenderawasih Bay, and to the south is Bintuni Bay. To the west, across the Dampier Strait, is the island of Waigeo in Raja Ampat, with Batanta Island lying just off the northwest tip. To the south of the region is the deep Banda Sea. See Fig A – arrow directed to Raja Ampat, next to Manokwari. **THIS IS PLANET EARTH'S EPICENTRE OF MARINE BIO-DIVERSITY – THE HEART OF THE CORAL TRIANGLE.**

In the heartland of this region is the crown jewel of coral reefs - Raja Ampat. The exceptional level of biodiversity here has been well-recognized since the 1850s when famed naturalist and evolutionary biologist Alfred Russel Wallace travelled through the Malay Archipelago (Singapore, Malaysia, and Indonesia) collecting specimens and studying natural history. His keen observations of the significant zoological differences in species between Asia and Australia led to the designation of the Wallace Line: a boundary that delineates Australian and Southeast Asian fauna. While his discoveries pertained to terrestrial ecosystems, it is undeniable that he would have been equally stunned by the range of marine life had he been able to study it in the same way.

Encompassing around 4.5 million hectares of land and sea, the archipelago is home to more than 1,400 species of fish, 553 species of reef-building corals, and 25 species of mangrove. Scientists affirmed Raja Ampat as the home to the world's highest known diversity of hard corals for an area of its size, as well as 13 species of marine mammals – including dugongs, whales, and dolphins. The Bird's Head Peninsula also includes the Pacific's most important Leatherback Turtle nesting site.

The unprecedented level of biodiversity in the Bird's Head Peninsula can be more than partially attributed to the deep-water basins that surround the entire Coral Triangle. These basins have served as a barrier to environmental change throughout a substantial part of Earth's geological history, shielding the Coral Triangle region from encroaching glaciers during our planet's ice ages.

Since cooling was mitigated by the protection of deep-water trenches, there was never a temperature-induced reduction in species diversity, meaning that life has continued to proliferate for millions of years. Conversely, these trenches also protect the Coral Triangle and Raja Ampat in particular, from rising temperatures. But even with this incredible natural barrier, climate change is beginning to take hold.

Signs of coral bleaching sighted during expedition

It is clear that the region is now under threat. While the area has been previously stressed from overfishing and highly destructive fishing techniques, climate change is now the force capable of inflicting the most severe trauma. The effects of climate change in the form of rising water temperatures, sea levels and ocean acidity are distressing coral reef habitats with increasing mass coral bleaching and mortality occurrences. Without mitigation, scientists estimate that we could lose up to 70% of remaining coral reefs in the next 50 years.

In addition, the ability of the region's coastal environments to feed people will decline by 80%, and the livelihoods of around 100 million people will have been lost or severely impacted. Under the present trajectory of unfettered growth in greenhouse gas emissions, many parts of the Coral Triangle will be largely unliveable by the end of this century.

Due to the urgency to document diversity and density of the state of our ocean's richest coral frontier, the focus of expedition in 2018 was to create a report card of the Raja Ampat environ, the heart of marine biodiversity. With the use of arts and science, the expedition aims to foster appreciation, education, and bring about deeper awareness and understanding of the impacts of climate change on coral reef environments. Our purpose is to encapsulate the beauty and diversity of the Heart of the Coral Triangle in one volume before it changes. Coral reefs around the world are suffering, hence our efforts are directed to reduce the extent of the damage and to protect what remains.

The Strategy

The members of the Elysium Heart of the Coral Triangle and all affiliated agents and organizations will embark on a systematic global awareness campaign, using a variety of publications and activities, to increase public and governmental understanding of climate change and ocean change in the polar region. A crucial goal is to explain that ocean change is a key element of climate change, and addressing the serious changes occurring in our oceans must be a part of addressing climate change if we are going to achieve the most beneficial outcomes. The strategy was to convene a team of some of the world's best image makers and scientists to document the vibrant heart of the Coral Triangle from above and below into one exquisite collection.

Positioning Statement

ELYSIUM – ARTISTS FOR THE CORAL TRIANGLE engages the world's finest artists, photographers, scientists, and writers to produce a benchmark record of the flora, fauna and vista of the HEART of marine biodiversity in a perspective no one has ever seen before.

The Vision

The product of this imaging epic shall inspire, invigorate and serve as a call for action to preserve and protect the final frontier of the world's richest coral province.

MSY Damai

MV GAIA Love

MSY Mola Mola

Expedition Platforms & Route

MSY Mola Mola : Cenderawasih Bay to Dampier Strait (Raja Ampat) – Sorong
MSY Damai II: Banda Sea to Misool (Raja Ampat South) – Sorong
MY GAIA LOVE: Triton Bay, Misool, Dampier Strait - Sorong

All expedition members were scheduled to meet in Jakarta before beginning their respective journeys on three separate routes. After 11 days of exploring and documenting the region, the team convened in Sorong for a two-day debrief.

Science - Targets

The Coral Triangle is the world's centre of marine life, with more species living in this area than anywhere else on the planet. It sparkles as the biological treasure chest of our planet, with many of its mysteries and species yet to be discovered.

Baseline documentation of 15 selected sites – five per vessel
transect survey of live coral coverage
number of hard coral species in each site
number of soft coral species in each site
number of ornamental fish species in each site

Sea surface sampling of micro plastic at nine sites – three sites per vessel
During the expedition we will deploy a manta net from the side of each using a spinnaker boom, lines and karabiner set up.

Blue and black water survey – five sites per vessel
During the expedition, we will be conducting blue water (day) and black water (night) documentation of species found in this zone. We will conduct sampling and photographic documentation of species in open-ocean environs.

Fish Biomass Survey – five sites per vessel
These surveys shall be conducted using the underwater visual census method; buddy teams will lay out 30m transect tapes and then swim along them identifying relevant fish observed within 2m on either side of the tape. Each fish is identified to species-level and its length is recorded. After each transect, the team will conduct a roving survey. This involves identifying any species of grouper, jacks, butterflyfishes, snappers, or sweetlips that can be seen whilst swimming along for a set distance. These methods enable an understanding of the abundance and biomass of selected fish species at each surveyed site.

Manta Habitats
Mantas are found in at least five known sites within the expedition route; our aim is to build a representative picture of these environments.

Assessment – damaged reefs
The expedition comprised of both aerial and underwater photographic and visual survey of reefs affected by illegal fishing methods and warm temperatures. Research shall focus on fish diversity and biomass, coral coverage, and impacts from marine tourism.

The Expedition

By Michael AW (FI’ 08)

Preamble

We were equipped with state-of-the-art cameras in SEACAM housings and broadcast quality video equipment, neuston nets for survey of micro plastic, two units of CCROV 100-metre depth 4K capable ROV (remote operated vehicle), Fourth Element wetsuits, high powered Scubalamp LED lights, and the entire expedition was made carbon neutral by CDL (City Development Limited). Unlike the two previous Elysium expeditions to the Antarctic in 2010 and the Arctic in 2015, where we were operating in the outermost regions of civilisation in extreme weather conditions, this time we had on our side the best time of the year in the tropics, and were operating in close proximity to villages within range of cellular services. So, what could possibly go wrong?

Well, things started to go wrong three months before the expedition commenced. Of the three expedition vessels, the most reliable, MSY SEAHORSE (a liveaboard I have used more than 10 times since 2008), was sold. Fortunately, the owner honoured our arrangement by swiftly offering us a replacement – the still under construction, brand new, yet to be furnished, MSY Mola Mola. I was assured that all would be good as the ship would be completed early and would have undergone sea trials and at least three cruises in the Raja Ampat region before our expedition.

Disaster struck on 6th August: a magnitude-6.9 quake hit the northern part of Lombok, triggering a tsunami that careened an unattended Mola Mola into a reef, broke her keel, and mangled her propeller shaft. By then, she had only six weeks for repair before heading off for her maiden voyage with us. This sounded like a bad idea, but with payment made in full for the charter, the only option open was to pray and cross our fingers and toes.

29th September 2018

By 08:00 hours, 29th September morning, all expedition members and equipment promptly arrived at the Swiss Belle Airport Hotel in Jakarta. However, 19 pieces of 12,000 lumens Scubalamp V6 Pro did not. We needed these lights for our blackwater operation. Several calls and WhatsApp messages later, Jessie Shaw brought in five pieces from Singapore and Tae Peng from Prestige Scuba flew in with 12 pieces from Kuala Lumpur. It was far from ideal, but sufficient to get the job done.

Other than this glitch, everything else went as planned. Team leaders Cassandra Dragon, Andrea Jaschek and Jayne Jenkins, hosted meetings with their respective team members and principal scientists. Paul Muir PhD, Charlotte Young and Renato Araujo staged sampling methodology for corals, microplastic and fish surveys. Even Brett Lobwein, our tech whiz kid managed to successfully test drive the CCROV in the hotel pool. Miraculously, everyone's luggage arrived. Once mission briefings and logistics were finalised, the three teams, Alpha, Whiskey and Echo, began their preparation to fly out the same evening to board their assigned expedition vessels.

To cover the vast expanse of Raja Ampat and her adjacent seas, MSY Damai departed from Saumaki, headed North, crossing the Banda Sea sampling and surveying its way into Misool, then continued the survey of South and Central Raja Ampat. GAIA Love departed from Ambon, then followed an easterly course towards the Banda Islands, before heading north towards Raja Ampat, to explore the western region of Misool and some signature sites of Cape Kri and Fam Islands. The route for the MSY Mola Mola was perhaps the most exciting of the three. Starting from Nabire, the plan was to head north to document the whale sharks at Kwatisore, then proceed with a survey of two atolls of Cenderawasih Bay before a two-day sail to document the reefs of North Raja Ampat. Cenderawasih Bay was once described by the legendary Shark Lady, Valerie Taylor, as the Galapagos of the East. It was not to be.

At 2 pm, I received a call from Cici Armayn, cruise director for Mola Mola. The new vessel was underpowered, ambling at 4 knots, crossing a fiery Banda Sea. It was still about three days out of Nabire, the boarding gateway for Team Echo! A decision had to be made if the team should proceed as planned, with a possible loss of three survey days, or instead start the expedition from Sorong, and focus mainly within Raja Ampat vicinity. Discarding Cenderawasih Bay was a very difficult decision, but it could be a wise one. I left the decision to Andre Jaschek, team leader of Echo, upon boarding the brand new sluggish Mola Mola.

Promptly at 20:30 hrs, I commandeered three tourist buses to send the three teams to the domestic terminal for flights to their respective departure cites. I boarded the plane with team members of Alpha on the flight to Ambon, alongside David Doubilet, Jennifer Hayes, Charlotte Young, team leader Cassandra Dragon, and the principal investigator for coral Dr Paul Muir. As the plane lifted off runway 7R25L, I looked around for Paul, scanning the entire aircraft. Paul was not on board. Had he boarded the wrong plane? Cassandra, team leader for Alpha confirmed he was last seen at dinner. Did we leave him behind? Did he suffer a heart attack in the airport rest room? Not a good idea to lose a principal scientist at the start of the expedition. Turning the plane around was not an option and we had no way to contact him whilst in flight! It was one long agonizing overnight flight.

06:00, 30 September, we touched down at Ambon Pattimura Airport. Seated alone near the conveyor belt, was a tall male in blue jeans, with an Einstein hairdo, smiling docilely as we approached. Our delinquent scientist had decided to catch an earlier flight without telling his team leader or any of his teammates! Relieved, and with all Alpha team members accounted for, the Elysium expedition officially began. We started with a mad dash to shoot the mystical Holy Grail of fish - the psychedelic Ambon frogfish (*Histiophryne psychedelica)* sighted by the GAIA's crew the day before we arrived. Of course, that fish successfully eluded all 18 of us. Fortunately, I already had a picture of one in the bag during a reconnaissance trip the year before.

Over the next 12 days, we encountered the fury of the Banda Sea as we sailed towards Raja Ampat. On the morning we dived the first site at Raja Ampat, Tank Rock at Fiabacet. I descended into a sea of a zillion Silverside baitfish *(Atheriniformes sp.)* and I knew immediately we would have a successful expedition. We nailed it, right on the best time of the year to explore Raja Ampat. During the crossing over waters greater than 200 metres deep, we managed to do six blackwater explorations. On the third attempt in deep water south of Wayil, we returned with the first ever pictures of the Mesopelagic deep water Polka dot Ribbonfish (*Desmodema polystictum*) in the Indonesian sea.

The blue water mangrove area at the north west of Misool is taboo to many liveaboard vessels due to two crocodile-related accidents in previous years. We were determined to include this very special habitat where expansive coral meadows are found just beneath the foliage of mangrove forests. With diligent reconnaissance for those amphibious reptiles, we efficaciously deployed our photographic and video teams for an afternoon survey. Everyone returned in one piece.

In Banda Neira, Charlotte Young and her team successfully conducted the first microplastic trawl in the region. Over the course of the expedition through the islands, the Alpha team accomplished eight microplastic trawls, four fish surveys led by Jennifer Hayes, and 18 coral transects led by Paul Muir. By the time we pulled into the harbour of Sorong on 11th of October for a two-day debrief, team GAIA had completed 33 dives across a 7065-nautical mile voyage, consumed 960 eggs, 200 kilograms of rice, 90 chickens, and 105 kilograms of watermelons. No one was injured, no cameras lost, all our toes and fingers accounted for.

Team Echo, hampered by the sluggish expedition vessel, completed their mission with astounding success. Upon boarding the vessel on 30th September, after consulting with the team and Cici, Andreas Jaschek made the decision to drop Cenderawasih Bay and confine their expedition within the Raja Ampat islands. It was a good call, as in the days that followed, the team discovered that MSY Mola Mola was not quite a waterproof vessel-- water leaked into both the cabins and common areas. Nevertheless, their team spirit was far from dampened with the combination of passion and commitment to the success of the mission. It brought out the best from each individual and as a unit, they excelled.

I was duly impressed when I visited the team in Misool. I did not hear a single complaint, no one whined, no one whimpered. Every single person was enthused with the outcome of the survey and dives. Even with a flooded camera and housing, Alex Rose (FN ’17), team leader for fish surveys, was busy sorting out the species documented from the evening transect whilst several other were preparing for a black water dive at 10 pm, undeterred by the choppy sea and windy night. Team Echo completed their mission with 34 dives, six microplastic trawls, 10 transects for corals, and five fish surveys. If there was an award for excellence and camaraderie, team Echo would have won hands down.

Expedition vessel Damai, carrying team Whisky, was a stark contrast to that of MSY Mola Mola and team Echo. Damai is a five-star boutique class vessel affording superlative luxury and service for those on board to achieve their mission objectives in comfort. Of the three, team Whisky was the most pampered and privileged. They got free massages on board, free flow of alcohol and even had a school of hammerhead sharks during their check-out dive. On 2nd October, day two of the expedition, team Whiskey arrived on a halcyon morning at Manuk to document the world's second biggest congregation of sea snakes. Snakes were found in blue water, in every crevice and cranny. On day three, the Damai began crossing the rough Banda Sea, similarly encountered by the GAIA Love and Mola Mola. But for Team Whisky, this inconvenience brought upon a surprise blessing. Beneath a blue equatorial sky, the team literally bumped into two of our planet's biggest animals - the Blue and Fin whales. The whales cooperated, giving the Damai time to deploy dive tenders for the team to acquire footage from the air, at sea level and underwater as well.

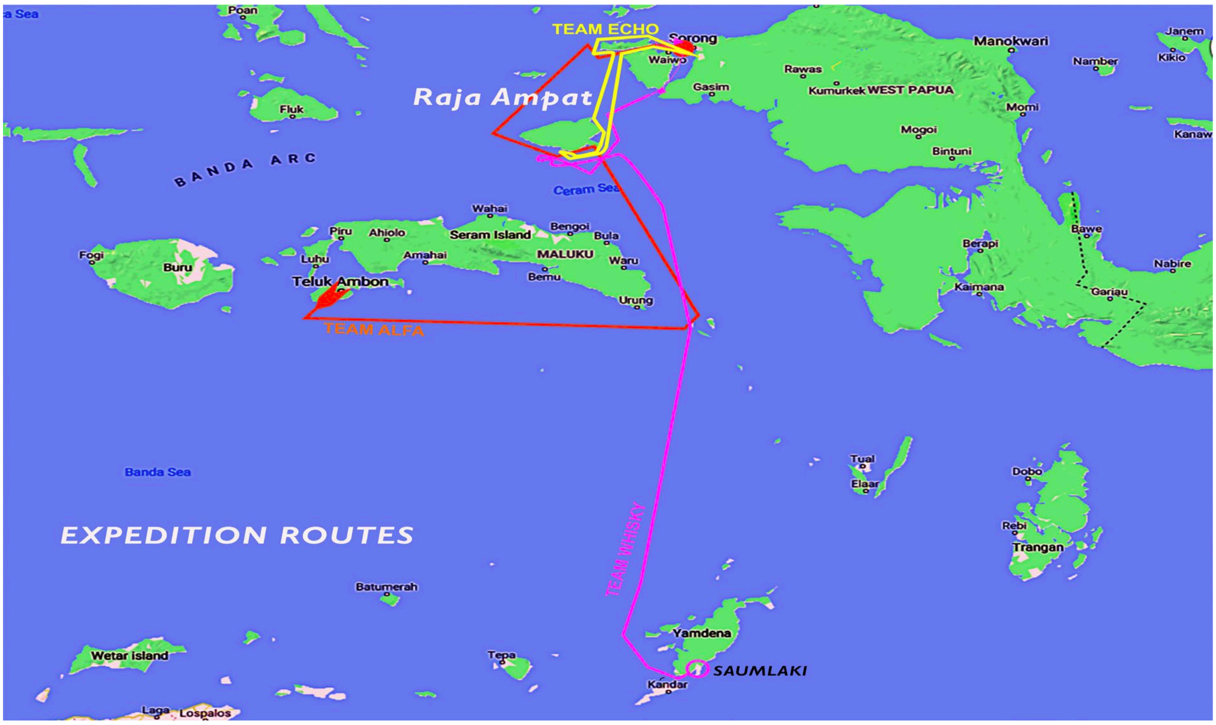
The mission plan for team Whisky also included exploring the best kept secret of Raja Ampat, the Goa Keramat jellyfish lake. Team Whisky was bequeathed with unique opportunities that were not presented to the other teams. Perhaps it is passion that drove the team to opt for one last dive at Sawandarek jetty, instead of joining the rest for the expedition official group picture on the last day of expedition. I was relieved to find out that they too successfully completed their mission with 32 dives, 14 fish surveys, five microplastic trawls and six coral surveys. Team Echo arrived at the Swiss Belle Hotel long after team Alpha and Echo.

From this expedition, we have created a comprehensive and compelling artistic portrait of the heart of the Coral Triangle, and documented its current ecological well being scientifically. We hope the fruits of our labour comprised of a magnificent collection of sights, sounds, and information will be treasured by future generations, and bring the beauty of this crucial region to the attention of the world, inspire action to mitigate climate change, and yield vital baseline data for measuring future effects on the Coral Triangle.

The return of the Elysium flag by Captain Dani of GAIA LOVE to Michael AW, project director at Sorong

Executive Summary

1. Successfully conducted the first multi-disciplinary art and science baseline survey of its kind in Raja Ampat with 49 expedition members of 15 nationalities.
2. First to conduct 99 dives, 40 line intersect transects for corals, 16 trawls for micro plastic and 23 fish surveys over 12 days with three expedition vessels in Raja Ampat.
3. First expedition to conduct black water dives in Raja Ampat.
4. First to sight and capture pictures of the Polka dot Ribbonfish (*Desmodema polystictum*) in Indonesian water.
5. First to document presence of Paper nautilus Argonauta in Raja Ampat's waters.
6. Twenty-one sites surveyed.
7. Hard coral cover varied from 3.5% to 97.7% and averaged 34% over the 40 transects surveyed.
8. High levels of plankton and particulate material were noted at many sites and have been reported for the region. These are likely to be related to upwelling from deep ocean currents impinging against the many islands of the region.
9. 94% of trawls conducted contained some form of plastic debris, with 6% yielding none.
10. The most abundant form of plastic found in trawls was filaments, with an overall 285 individual pieces identified.
11. Team Echo collected more plastic (n=306) than the other two teams during their trawls, followed by Team Alpha (n=144). The least amount of plastic was found by Damai II (n=94).
12. The most polluted area sampled was Manta Sandy (n=76) (S0 34.798 E130 32.534) located in the Mioskoon area of Raja Ampat, west of Sorong, New Guinea. The second most polluted site was Sardine Reef (n=75) (S0 32.066 E130 42.977).
13. A total of 16 trawls were successfully conducted with neustron net for micro plastic.
14. Damselfishes (Pomacentridae) were the most abundant fishes found throughout Raja Ampat and the Banda Sea, comprising over 83,000 individuals per hectare. They were followed closely by fusiliers (Caesionidae) and cardinalfishes (Apogonidae), with almost 50,000, and over 40,000 ind. ha^{-1}, respectively.
15. High biodiversity, high fish biomass and an important contribution from planktivores are some of the features that summarise Raja Ampat's coral reef fish assemblages. Regional species richness seems to increase more steeply with sampling effort here in the Coral Triangle compared to the adjacent species-rich Great Barrier Reef.
16. A total of 347 species were identified in the 19 fish counts.



Results

1. **A Report Card of the Health of Raja Ampat.**
2. **Images and research procured from the expedition will be assembled to produce a limited-edition photographic book, video documentaries, and photographic index.**
3. **A series of exhibitions worldwide with the premiere in China scheduled for Beijing 22 April, Shanghai, 25 April, Chengdu 27 April, and Shenzhen 30 April 2019.**

Science Report: Microplastics

Principal Investigator: Charlotte Young

The present study looks to investigate the extent of plastic pollution in The Coral Triangle, specifically Raja Ampat. Through the use of surface sample trawls we will document the abundance of different plastic types above coral reefs and in open ocean environments. Analysis of plastic pollution will allow us the opportunity to better understand how this area is affected by plastic in the context of global plastic mitigation and management. This project applies tried and tested methods which have been readily used in marine plastic studies.

Plastic Pollution: Indonesia

Indonesia is considered the second largest contributor to marine plastic pollution behind China (Jambeck et al., 2015). This can be contributed to the lack of effective waste management practises and the necessary infrastructure to deal with plastic waste produced. Rivers are a common form of waste disposal and Indonesia's rivers rank within the top 20 most polluted in the world (Lebreton et al., 2017). According to the Indonesian ministry, around 175,000 tons of plastic waste is produced each day. Although some effort has been made by the government officials to address Indonesian's waste crisis, many efforts have been hampered by the lack of effective management and appropriate funding.

Raja Ampat, The Coral Triangle

The Coral Triangle forms part of Indonesia, Papua New Guinea, Malaysia, Timor Leste and the Solomon Islands. Raja Ampat forms part of Indonesia and is considered part of the region which makes up the 'marine biodiversity hotspot' of the world. This area is home to over 1300 recorded fish and 600 documented coral species making it uniquely diverse in the context of global marine biodiversity. As a result this region has been nicknamed a 'species factory' and boasts an abundance of life throughout all its recognised habitats.

Indonesia is one of the most densely populated areas in the world, however, Raja Ampat is substantially less populated in comparison with a total of 49,048 inhabitants as of the 2014 census. Plastic pollution in this region is poorly understood with limited studies assessing this contaminant throughout coral reef and open ocean habitats. This makes it an area of extreme priority to assess as data will provide invaluable information on the distribution and accumulation of plastic throughout Indonesian waters and in relation to biologically important regions such as Raja Ampat.

Methods

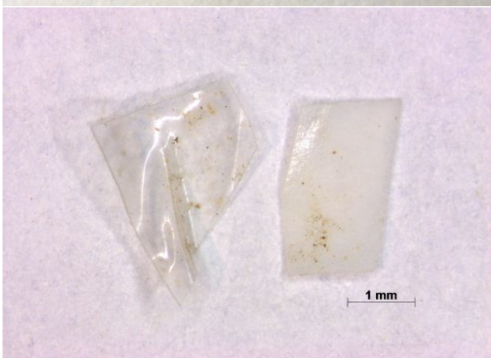
With the use of Neuston nets, surface sample trawls were conducted above coral reefs and in open ocean environments at 16 sites throughout Raja Ampat. Target sites were chosen randomly based on the organised routes of each vessel and conducted in-between dives. Target areas, dive sites and GPS coordinates were recorded for each trawl (Table 1.) and a note about the duration of each made.

Vessel	Target Location	Site Name	GPS
GAIA	Ambon	Ambon Bay	S3 41.788 E128 06.384
	Banda Neira	Lampu Hijau	S4 30.330 E129 53.213
	Banda Neira	Tangung Noret	S4 33.243 E129 40.034
	Koon	Too Many Fish	S3 55.475 E131 12.832
	Misool	Wayil	S2 11.728 E130 25.784
	Misool	Wayil	S2 11.666 E130 26.085
	Misool	Blue Water	S1 49.038 E129 38.390
	Yangelfo	Yangelfo	S0 30.472 E130 27.250
Mola Mola	Dampier Straight	Sardine Reef	S0 32.066 E130 42.977
	Mioskoon	Manta Sandy	S0 34.798 E130 32.534
	Misool	Neptunes Fan Sea	S2 13.037 E130 27.007
	Misool	Melissa's Garden	S0 35.390 E130 18.909
	Wayag	Rich Rock	N0 09.844 E130 00.663
Damai II	Manuka	Manuka	S5 31.924 E130 17.736
	Misool	Tank Rock	S2.13.011 E130 33.766
	Misool	Magic Mountain	S2 13.376 E130 33.549
	Lenmankana	Three Sisters	S1 58.153 E130 33.709
	Batanta	Batanta	S0 55.042 E130 36.090

Table 1. List of locations and dive sites where trawls were conducted.

Trawls lasted on average between 15-30 minutes, based on weather conditions and the amount of debris accumulating in the nets. Nets were then washed down with freshwater from the outside of the net to concentrate all debris in the cod- end. The sample was then poured over a 300μm stainless steel sieve and natural debris was removed, washed with ethanol and discarded from the sample. The remaining debris was then concentrated in one area of the sieve and washed in to a sample bottle for lab analysis.

Samples were individually filtered using Whatmann (Grade 1) 55mm filter paper and then viewed under a microscope for microplastic identification and analysis. Plastic debris identified was separated in to categories as outlined by Viršek et al., 2016 (Table 2.). Plastic pieces were then transferred from the sample in to a separate petri dish for visual analysis.

Type	Notes	Picture
1. Fragment	Rigid, thick, sharp crooked edges and irregular shape. Variety of different colours.	
2. Films	Irregular shapes, thin, flexible and usually transparent.	
3. Pellets	Irregular, round shapes, normally bigger in size (<5 mm). Usually flat on one side. Various colours.	

Sorting the plastic on back deck of MV GAIA Love

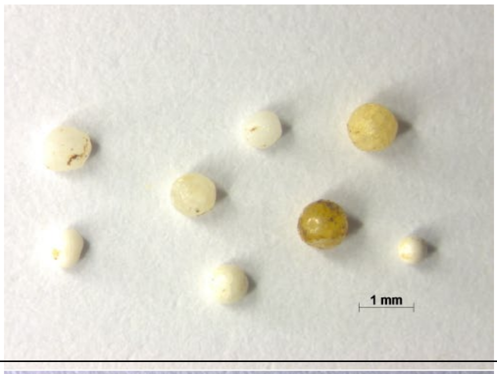
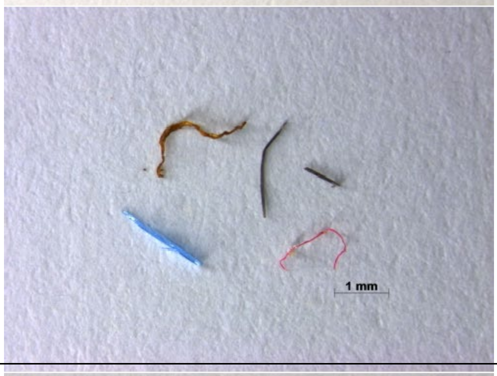
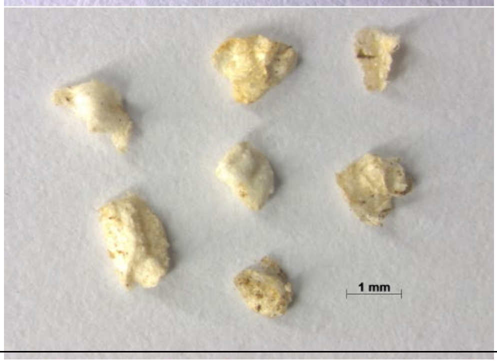
4. Granules	Regular, round shape. Usually a smaller (<1 mm). They appear in natural colours (white, beige, brown).	
5. Filaments	Short or long, with different thicknesses and colours.	
6. Foams	Soft, irregular shape and white to yellow in colour.	

Table 2. Categories for plastic identification.

Results

94% of trawls conducted contained some form of plastic debris, with 6% yielding none. Most plastic in samples was derived from land-based practises including consumer products such as packaging, bottles and waste from industry. At least one piece of all outlined plastic types was identified, ranging from fragments and films to filaments and foams. The most abundant form of plastic found in trawls were filaments, with an overall 285 individual pieces identified (Table 3). The second most abundant form were fragments (n=114) and the least abundant form were pellets (n=1). Overall, more plastic was collected in near shore habitats (n=388) than offshore (n=156), however, distribution of plastic appears random and no quantitative assessments can be drawn about its abundance.

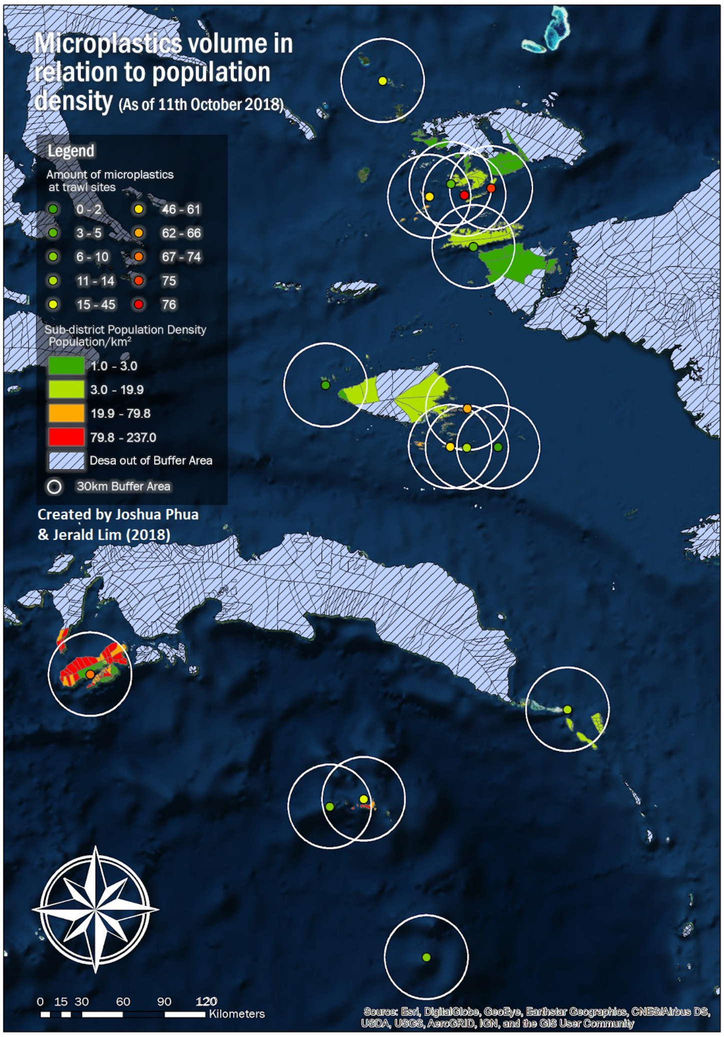


Figure 1. Microplastic volume in relation to population density. Created by Joshua Phua and Jerald Lim (2018).

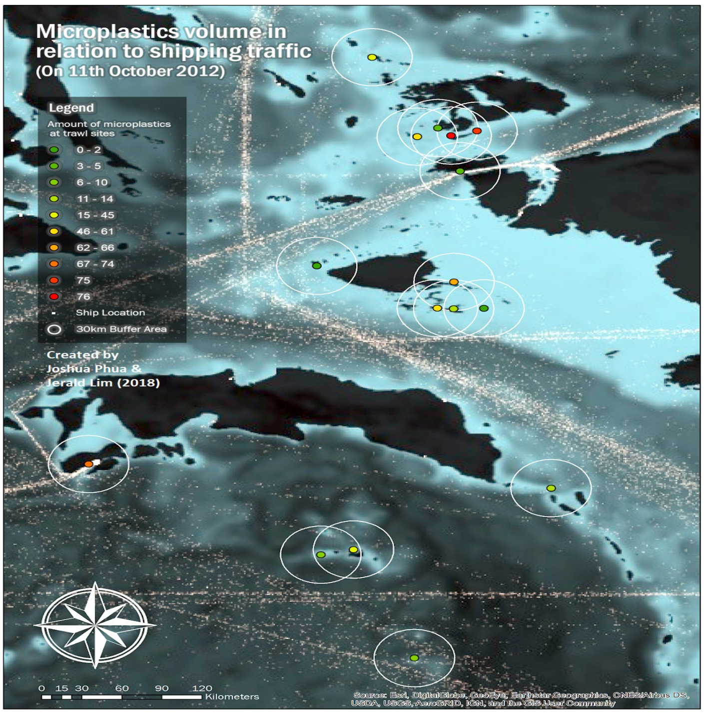


Figure 2. Microplastic volumes in relation to shipping traffic routes. Created by Joshua Phua and Jerald Lim (2018).

Microplastic volumes were mapped in ArcGIS in relation to population density (Figure. 1) and boat traffic (Figure. 2). A standardized 30km buffer area was placed around each sample site and data for population density and boat traffic within this limit were included in statistical analysis. This goal of this step was to test for the effects of multiple demographic variables against concentrations of microplastics and hypothesized that population density would have the greatest effect. Linear regressions yielded no significant differences and showed that none of the independent variables significantly explained the concentrations of microplastics identified at sample sites. Therefore the hypothesis can neither be accepted nor rejected. Multiple different regressions were attempted (heteroscedastic, homoscedastic, robust, non-robust) to no avail. As such, these observations cannot be taken as the final authority on the subject (For full results see *Appendix 1*) (Phua and Lim, 2018).

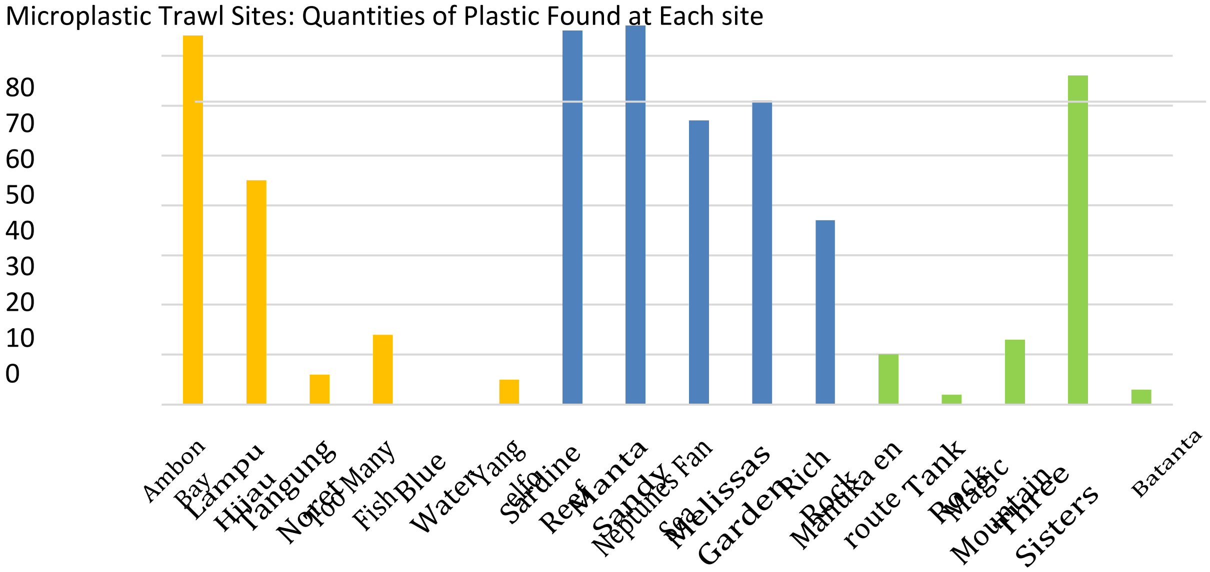
Overall the Mola Mola vessel collected more plastic (n=306) than the other two vessels during their trawls, followed by GAIA (n=144). The least amount of plastic was found by Damai II (n=94). The most abundant form of plastic present in GAIA and Mola Mola trawls were filaments, however, fragments were the most abundant form of plastic found in Damai II samples.

Plastic Type	GAIA	MOLA	DAMAI	Overall Total
Fragments	26	43	45	114
Films	30	47	13	90
Pellets	0	0	1	1
Granules	8	0	4	12
Filaments	68	187	30	285
Foams	12	29	1	42

Table 3. Total quantities of different plastic types found by each vessel.

The most polluted area sampled was Manta Sandy (n=76) (S0 34.798 E130 32.534) located in the Mioskoon area of Raja Ampat, west of Sorong, New Guinea. The second most polluted site was Sardine Reef (n=75) (S0 32.066 E130 42.977), closely followed by Ambon Bay (n=74). Other areas were also significantly affected, however, not all sites yielded high volumes. One site sampled yielded no plastic at all (Blue Water; S1 49.038 E129 38.390).

Microplastic Trawl Sites: Quantities of Plastic Found at Each site



Graph 1. Quantities of plastic found at each site. Yellow – GAIA trawls. Blue – Mola Mola Trawls. Green – Damai II trawls.

Discussion

Plastic pollution is now considered to be ubiquitously spread from the poles to the equator. This work confirms that Raja Ampat is now affected by plastic pollution similarly to other parts of the ocean. The majority of plastic found can be linked to land based practises making this a likely source of pollution in this area (Table. 3). However, further analysis is needed to confirm the molecular components and structures of the debris found to confirm its nature and true source.

As found by other studies, the most abundant form of plastic identified in trawls were filaments (Table. 2). This type of plastic can be derived from a number of different land and marine based sources. In 2011 washing machines were identified as a source of microfibre pollution to the ocean and it is widely accepted that fishing gear readily emits fibres through day to day fishing practises. Based on visual observation, filaments in trawls were predominantly characteristic of those derived from clothes, however, more in-depth analysis would be needed to confirm this.

The abundance of plastic found in trawls followed no clear pattern, although more plastic was identified in near shore habitats. The non-significant result of the linear regressions mean we cannot accept nor reject the theory that population density influences the volume of plastic pollution at the study sites, however, the result may be a consequence of a number of factors such as the number of replicates. A total of 16 trawls were conducted, a relatively low number in comparison to other studies, meaning that the dataset collected may not have been representative enough to truly answer the question. Future studies should look to sample more sites and also repeat trawls at sites to obtain average values for the study site.

Raja Ampat is characterised by fast moving and rapidly changing currents which could explain the widespread and random distribution of plastic, however, ocean currents were not incorporated in to the experimental design. In general, near shore habitats housed small local populations although overall population densities in all areas sampled were relatively low in comparison to neighbouring islands (Figure 1). Despite the low population densities, the presence of humans may explain why more plastic was present in near shore habitats as overall these sites were closer to potential sources of plastic waste.

Much of the Coral Triangle encompasses popular boat transport routes connecting Indonesia to West Papua and other smaller islands dotted throughout the archipelago. This contributes to a significant number of boats passing through this region on a daily basis (Figure. 2). Although no significant correlation between sites and boat traffic was found, it may explain some part of the random distribution observed in our results. Boats provide an opportunity for plastic waste to enter the marine environment in areas otherwise considered to be remote or absent of human presence. However, the inclusion of data from within a 30km area around sample sites results in a considerable overlap in data used to analyse study sites. As a result, the non-significant result may be partially influenced by this although a more in depth assessment would needed to better answer this question.

Interestingly, the most polluted site (Manta Sandy) was not the closest site to civilisation (Ambon Bay) and is considered a sparsely populated site with a low population density within a 30km radius (3.0-19.9 population/km^2). Manta Sandy is also widely known to be a cleaning station where species such as manta visit. Recent studies have shown that filter feeding marine megafauna such a Mobula Rays have a high potential to ingest microplastics suspended in the water column

(Germanov, et al., 2018), making this a concerning finding. Although further assessment would be needed, this suggests that areas of high importance to biodiversity may be substantially impacted by microplastic, and, as a result, the species which frequent these waters are exposed to large proportions of this pollution. Given our findings it should be of paramount concern to local officials and policy makers to consider the implementation of better waste management strategies throughout The Coral Triangle so that the free flow of plastic in to the marine environment can be stemmed. Another important step would be the introduction of educational and outreach projects in both urban and rural communities so that people habits change and they understand the significance of their actions. However, ultimately a global shift towards non-disposable, plastic alternatives needs to be adopted worldwide so that the volume of plastic waste produced annually is curbed and thus its potential to end up in the ocean reduced.

Appendix

Regression Results

```
. regress plastic_per_tr shipping_pix fishing_hours income gov_ex pop lit_rate per_ash, robust

Linear regression                               Number of obs     =         14
                                                F(6, 6)           =          .
                                                Prob > F          =          .
                                                R-squared         =     0.6150
                                                Root MSE          =     28.908

--------------------------------------------------------------------------------
               |               Robust
plastic_per~l  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
  shipping_pix |  -.0096188    .0261159    -0.37   0.725     -.073522    .0542845
 fishing_hours |   .0971577    .7043965     0.14   0.895    -1.626439    1.820754
        income |  -.0000537    .0000424    -1.27   0.253    -.0001576    .0000501
        gov_ex |   .0000531    .0000421     1.26   0.254    -.0000498     .000156
           pop |   .0152382    .0123147     1.24   0.262    -.0148949    .0453712
      lit_rate |  -15.57036    9.727028    -1.60   0.161    -39.37154    8.230819
       per_ash |   65.44692    189.3553     0.35   0.741    -397.8889    528.7827
         _cons |   1515.035    945.5512     1.60   0.160    -798.6457    3828.715
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Science Report: Reef Condition and Coral Biodiversity

By Paul Muir PhD *Coral Principal Investigator*

Raja Ampat in eastern Indonesia is located in the "Coral triangle", the region of highest reef-coral biodiversity in the world (Veron 2000). This region extends across much of Indonesia and the Philippines and contains the greatest number of coral species, many of which are found only in small parts of the region (Veron 2000, Wallace 1999). The coral diversity is not well studied and Raja Ampat in particular has received only one or two preliminary studies. Only recently, several new coral species were discovered in the Cenderawasih Bay area (Wallace et al. 2007), and many more species are likely to be undiscovered. The lack of biodiversity data is of concern as eastern Indonesia is subject to increasing human pressures, both local (development, tourism, population growth) and global (bleaching, ocean acidification associated with climate change). Many reef areas around the world have been severely degraded in the previous few decades so there is a pressing need to record existing biodiversity in poorly documented areas and to better understand reef systems so that efforts can be made to halt these declines.

In the face of severe declines of coral reefs around the world, the deep-reef or mesophotic reef (depths 30-160m) are under scrutiny as a potential refuge area for corals. The main impacts from climate change on coral reefs to date are thermal bleaching and tropical storms and both of these impacts decrease with depth. Surviving deep corals may therefore provide a 'backup' for many species, slowing local extinctions and providing larvae that may reseed devastated shallow reefs. Despite this potentially critical role, deep corals remain virtually undocumented across much of the Indo-Pacific and in particular for Indonesia. Deeper reef areas also have unusual and extreme conditions and are likely to have many undiscovered species and diversity.
To preserve biodiversity we must first understand what is there to protect, and to preserve reefs we must understand their current state and condition. To this end, the "Elysium Coral Triangle Expedition" was conducted in the Raja Ampat area from 29/10/2018 to 12/10/2018 to survey the biodiversity of fish and corals, to look for new species, record the state of the reefs and document current impacts of concern.

Methods

Three vessels and teams conducted a total of 40 line intersect transects at 21 sites across the region (Fig.1, Table 1) from 30th October to 10th December, 2018. At each site, transect tapes either 25 or 50 m length were laid across the reef at two depths: 15-20 m and 5-10 m. Transects were then videoed using high resolution cameras and the corals and other biota that intersected the tape recorded with high resolution DSLR photography. The nature of the reef structure, reef slope, rugosity and presence of crown of thorns starfish, sick coral, litter or fishing gear at the site were also recorded. Approximately three thousand images and macro images and 150 minutes of video were captured and used to identify each hard coral, soft coral, invertebrate, plant or other substrate type that intersected the transect tape. Identification was to genus and where possible, species.

For a thorough assessment of biodiversity of hard corals, timed swim surveys were conducted at 27 sites by the author. Surveys extended to 40 m depth and the hard coral species present noted and 'vouchered' using high-resolution macro images. Approximately 2300 images were captured, and along with the images from transects, will provide the species composition of hard corals at each site, possible new species and some of the first data for Indonesia on the hard corals of the mesophotic zone (>30 m depth). There is currently great interest in the species present in the mesophotic zone of coral reefs as greater depths provide some protection for corals from bleaching and extreme storm events. Bleaching and extreme storms are widely predicted to increase in future due to increasing sea temperatures and so mesophotic reefs are likely to play an important role in the resilience of reefs. We also planned to examine coral diversity from 40 to 100 m depth using two CCROV remote operated vehicles, but technical issues precluded their use at this time.

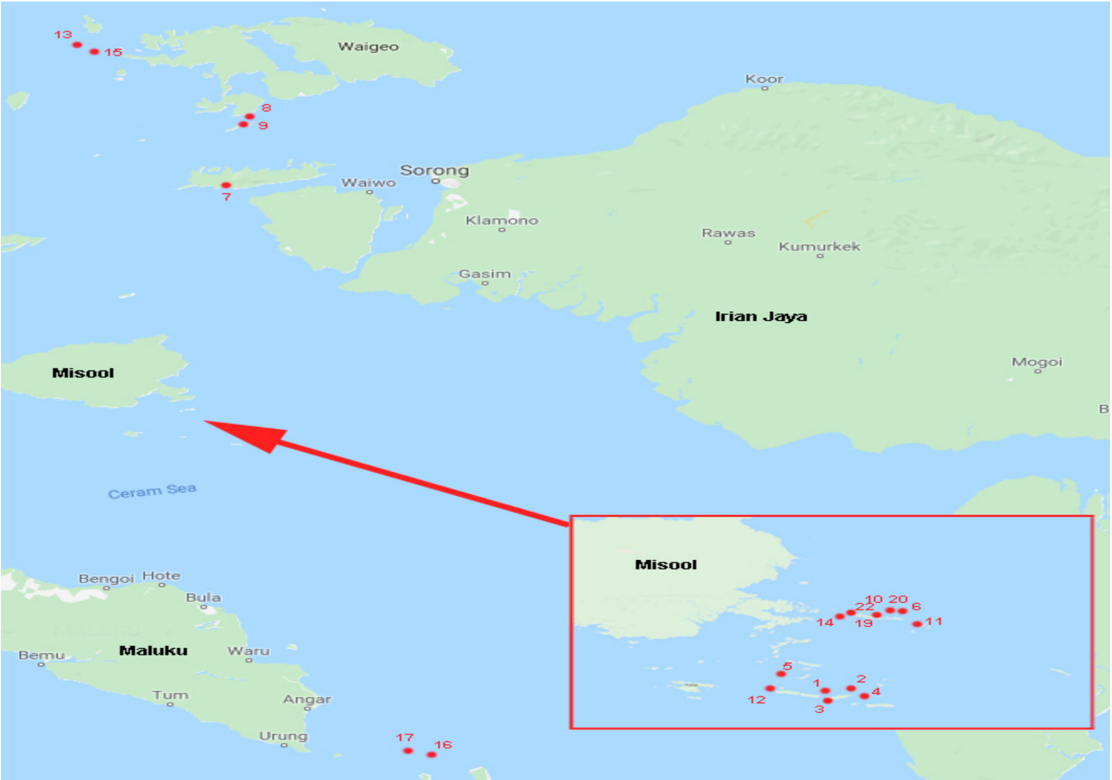

Figure 1. Location of study sites in Raja Ampat, Eastern Indonesia.

RESULTS and DISCUSSION

Overall coral cover

Hard coral cover varied from 3.5% to 97.7% and averaged 34% over the 40 transects surveyed (Table 2, Figure 2). Six transects from four sites showed very high (>70%) cover. These were distributed across the region and included “Lava Flow”, “Yenuba Jetty”, Sawandarak Jetty” and “Three Sisters” (Table 3 & 4). High coral cover transects occurred at both deep (15-20 m) and shallow (5-10 m) depths. Only five transects showed hard coral cover less than 10% and like the high cover transects, showed little geographic or bathymetric trends, occurring at Misool, Maluku and Waigeo and at both deep and shallow depths.

The cover of hard corals detected was high relative to other regions and likely reflects the geographical location and lack of major human impacts. . The region is largely a protected area, within the Raja Ampat National Park and not subject to overfishing, blast fishing, runoff from agriculture and industry and other human pressures. The population is relatively small and mainly living in a traditional manner that creates very low impacts relative to “developed” population centres. Indeed, one of the sites of highest hard coral cover was immediately adjacent to Sandarawak village (Figure 2, Tables 3 & 4). The region is also outside of the latitudes that are normally affected by cyclones, which greatly reduces the significant impacts often found in many reef systems. The presence of very deep waters immediately adjacent to many of the sites is also likely to have a protective value, regulating against unusually high temperatures and lowered salinities from freshwater runoff. Equatorial regions also have highest diversity of corals (and many other organisms) and high coral diversity may also contribute to the high coral cover. Finally, the influence of the Pacific-flow-through current that runs through much of the eastern Indonesian archipelago is likely to provide conditions optimal for coral growth.

Soft coral cover ranged from 0 to 58% and averaged 13% (Figure 2, Table 2). Many sites showed only low cover: 19 sites had less than 10% soft coral cover (Figure 2, Tables 3 & 4). High soft coral cover, particularly in shallow sites as seen here, is somewhat unusual in healthy coral reef systems.

Soft corals such as Sarcophyton can often dominate reefs that have been damaged and have low hard coral cover, but in this case the soft corals were extremely diverse and the hard corals healthy. The high cover of soft corals seen at many sites across the region is more likely to be natural and a result of the unusual conditions in Raja Ampat. Strong water currents between the many islands and high levels of plankton and particulate material in the water column would favour soft corals that derive much of their nutrition from these sources. High levels of plankton and particulate material were noted at many sites and have been reported for the region. These are likely to be related to upwelling from deep ocean currents impinging against the many islands of the region.

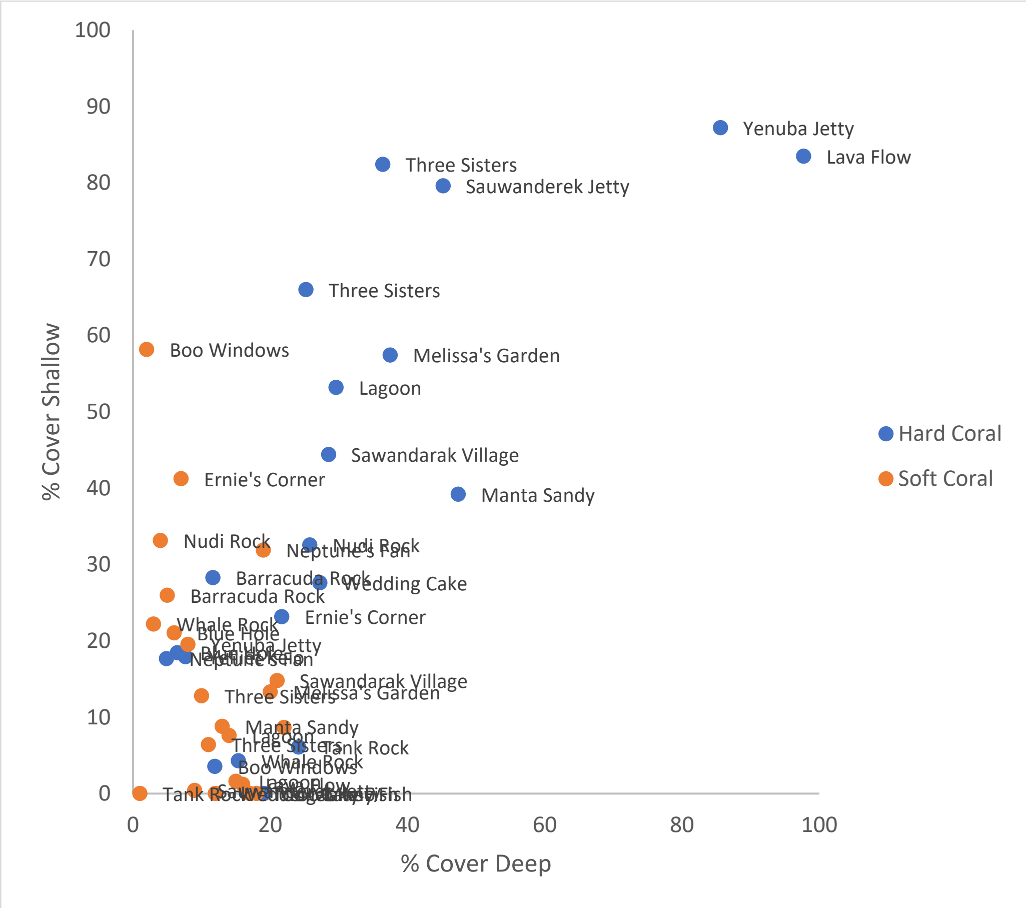

Figure 2. Coral cover at shallow (5-10 m) and deep (15-20 m) depths for each transect.

Interaction between Soft and Hard Corals

Most large tropical Indo-Pacific reef systems are dominated by hard corals in shallow (<30 m) depths, with only a small proportional cover of soft corals. Soft corals can dominate in deeper waters (>30 m), turbid waters or areas subjected impacts, but generally not in the clear-water conditions that favour their 'hard cousins'. In Raja Ampat the presence of numerous sites with high cover of both hard and soft corals at shallow depths was somewhat unusual. Certainly, sites with the highest level of soft coral cover had low hard coral cover, and vice versa, consistent with each group favouring a different set of conditions (Figure 2). However, many sites had a moderately high cover of both groups (Figure 2), resulting in reefs with very high biodiversity. The prevalence of these unusual 'mixed' reefs is possibly related to the unusual conditions present in the region. Deep, nutrient rich waters upwelling around numerous islands and the Pacific-flow-through current likely provide high levels of nutrients in the water column and strong currents, but the low latitudes allow high levels of light necessary for good hard coral growth. This aspect requires further study, particularly water quality data and surveys of deeper (> 30 m) depths where soft corals normally reach their highest abundance.

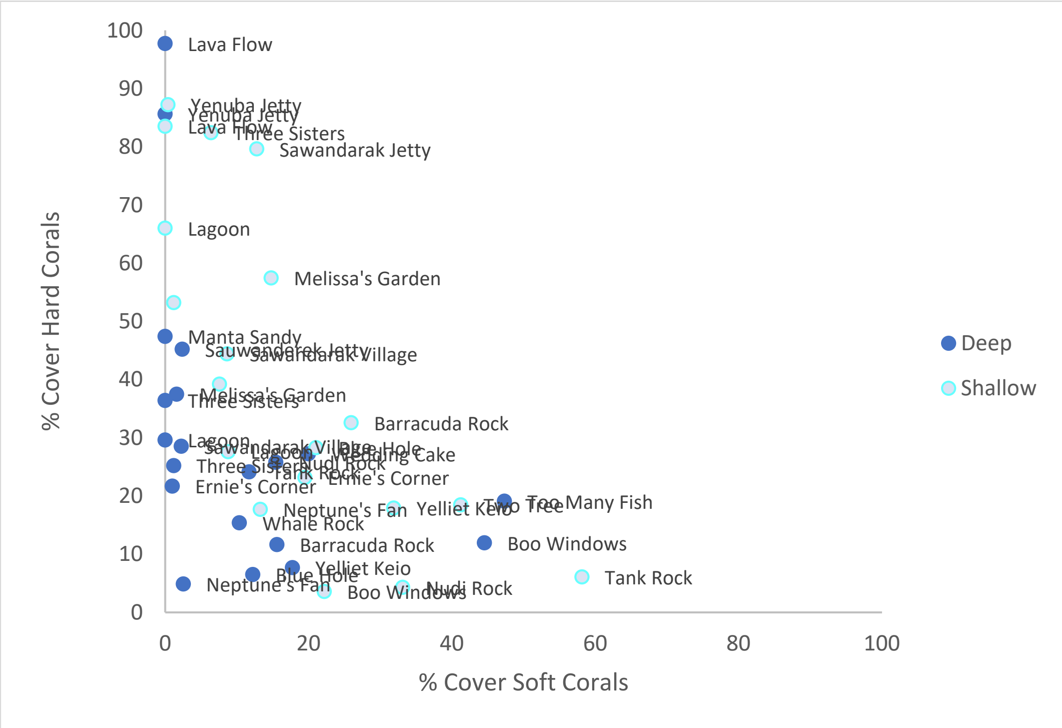

Figure 3. Sites with highest cover of hard corals tended to have very low cover of soft corals and those with highest soft coral cover tended to have low hard coral cover.

Depth Effects

Sites with high hard coral cover on deep reef (15-20 m) transects also tended to also have higher hard coral cover in the shallows (5-10 m) (Figure 3), however, soft corals showed no such trend, with highest cover mainly restricted to shallow transects (Figure 3). This suggests that hard coral populations are regulated by site effects such as water clarity and sediment type, while soft coral populations are more dependent upon fine scale factors such as currents and reef slope. The higher soft coral cover for shallow transects that was seen at many sites (Figure 3) is unusual and unexpected: these organisms are not restricted by light and tend to prefer deeper depths in many other reef systems.

Other Fauna and Flora

Benthic invertebrates such as sponges, ascidians and echinoderms made only a minor contribution to cover (4.3% overall, Tables 2-4). Similarly algae and crustose coralline algae made only a minor contribution to benthic cover at the majority of sites (mean 5.4%), although for some sites crustose coralline algae cover was moderately high, with total algal cover reaching 29.2% at one site. The very minor contribution of macroalgae to the reef cover suggest a good herbivore population and a low level of dissolved inorganic nutrients, consistent with the reefs being in a remote and protected system.

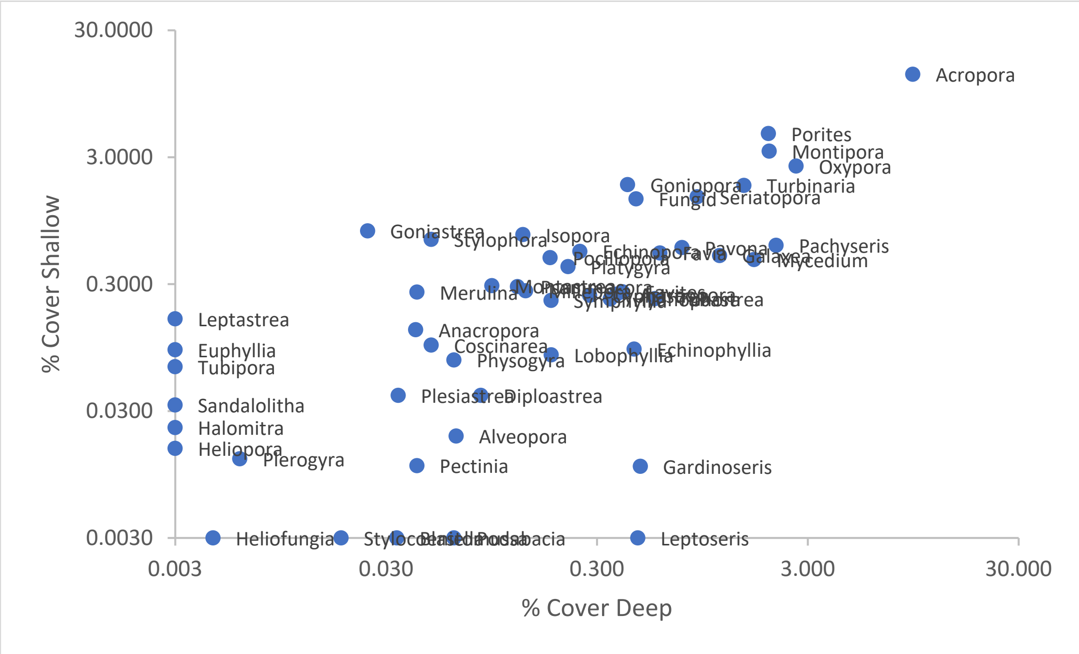

Figure 4. Hard coral genera and their average cover at shallow (5-10 m) and deep (15-20 m) depths. D

Hard Coral Diversity

Fifty-two hard coral genera were detected on the line intersect transects, the most dominant being *Acropora*, with an average cover of 11% (Table 5). The *Acropora* group dominates healthy reefs across the Indo-Pacific and is often one of the first groups to be adversely affected by natural and human-related impacts. The group once dominated the Caribbean reefs, but an estimated 90% have been lost during the last few decades, almost certainly related to increasing human impacts. *Acropora* cover was slightly lower in deeper sites, similar to patterns seen across the Indo-Pacific. The next most dominant groups were the *Porites* and *Montipora, Goniopora* and *Turbinaria* which again is similar to patterns seen across the Indo-Pacific. However, the other dominant genera were unusual: *Oxypora, Pachyseris, Mycedium, Pavona* are generally associated with deeper waters (> 30 m depth) and this is consistent with the finding for soft corals that also are normally more abundant in deeper waters. The percent cover was similar between depths, although some species were restricted to deeper sites (*Leptoseris, Podabacia, Heliofungia, Stylocoeniella, Blastomoussa*). The genera *Leptastrea, Euphyllia, Tubipora, Sandalolitha, Halomitra* and *Heliopora* were restricted to shallow transects, although these groups were found deeper in the targeted biodiversity surveys (see below).

Deep-Reef Diversity

Surveys of deep-reef coral diversity were only possible at 6 sites from 30-40m depth due to technical issues with the ROVs. Analysis is continuing with 55 species recorded to date, including the rare species *Acropora pichoni* at 40 m depth (Figure 1). Clearly more surveys, including ROV surveys, are required to assess the deep-reef coral fauna of the region. While only 55 species were recorded in the upper mesophotic zone, this is a significant finding given that very few deep corals were reported for the area prior to the expedition.

Damage to Reef

The cover of dead hard coral varied from 0 to 23% and averaged only 1.9% over all transects (Table 2, Figure 2). Only one transect showed more that 10% dead coral cover: “Lagoon”, Waigeo at 23%. This percentage is not outside of what would be considered normal variation on reef sites, although it would be worthwhile finding the cause for this dead coral at the site.

Species Composition: Hard Corals
Preliminary analysis of coral biodiversity surveys showed very high diversity for many sites, with 320 species identified to date. Over 2300 high resolution macro images were captured from 21 sites and are currently being analysed. Several rare and endemic species were recorded, including *Acropora plumosa, A. jacquelinae, A. simplex, A. pichoni A. indonesia* (see Figures 5-10). A small number of very unusual corals that cannot be identified at this stage are being studied as possible new species (Figure 10).

CONCLUSIONS
Overall, the reefs surveyed at Raja Ampat were in good condition with evidence of only slight human impacts at a small proportion of sites. Sites showed very little dead coral, coral bleaching, disease or predation by *Acanthaster plancii* (crown of thorns seastar). One site had three *A. planci* (Figure 7), well within the natural range expected for healthy reef systems. The abundance of vulnerable hard coral genera (e.g. *Acropora*) and lack of macroalgal cover on transects is also consistent with a healthy reef system. Small quantities of plastic rubbish or tangled fishing line were observed at only a small proportion of sites. At one site a small number of *Porites* colonies had feeding scars from the gastropod *Coralliophila violacea* (Figure 8), but this is likely to be within that expected for healthy systems.

The final results for the hard coral species composition are still to be analysed but these, along with many of the rests presented here will published in peer reviewed scientific journals. With this report and the photographic material, the results will provide an enduring record of coral diversity and reef condition for a range of sites around Raja Ampat in 2018. While this is not 'baseline', there is very little obvious human impact in the region and apparently no significant coral bleaching impacts in recent times. Therefore, future surveys can determine if there are changes in the reefs which may happen slowly over a long period of time and be imperceptible or unable to be proven to managers and political decision makers. Declines to reef systems can occur slowly over many generations and thus imperceptible without a comprehensive baseline dataset. The reef declines in the Caribbean, with 90% loss of the main coral genus *Acropora* provides a chilling reminder of what can happen to large reef systems with increased human impacts. In addition, the rare coral species documented are particularly worthy of attention as their restricted geographic range makes them more vulnerable to extinction.

Figure 5. *Acropora pichoni,* a rare species found here at 40-45 m depth at one site.

Figure 6. *Acropora indonesia,* a species only found in parts of the coral triangle.

Figure 7. *Acropora simplex,* a rare species with a small geographic range, potentially vulnerable to extinction.

Figure 8.. *Acropora plumosa,* another rare and potentially vulnerable coral, here found at a small number of sites in Raja Ampat.

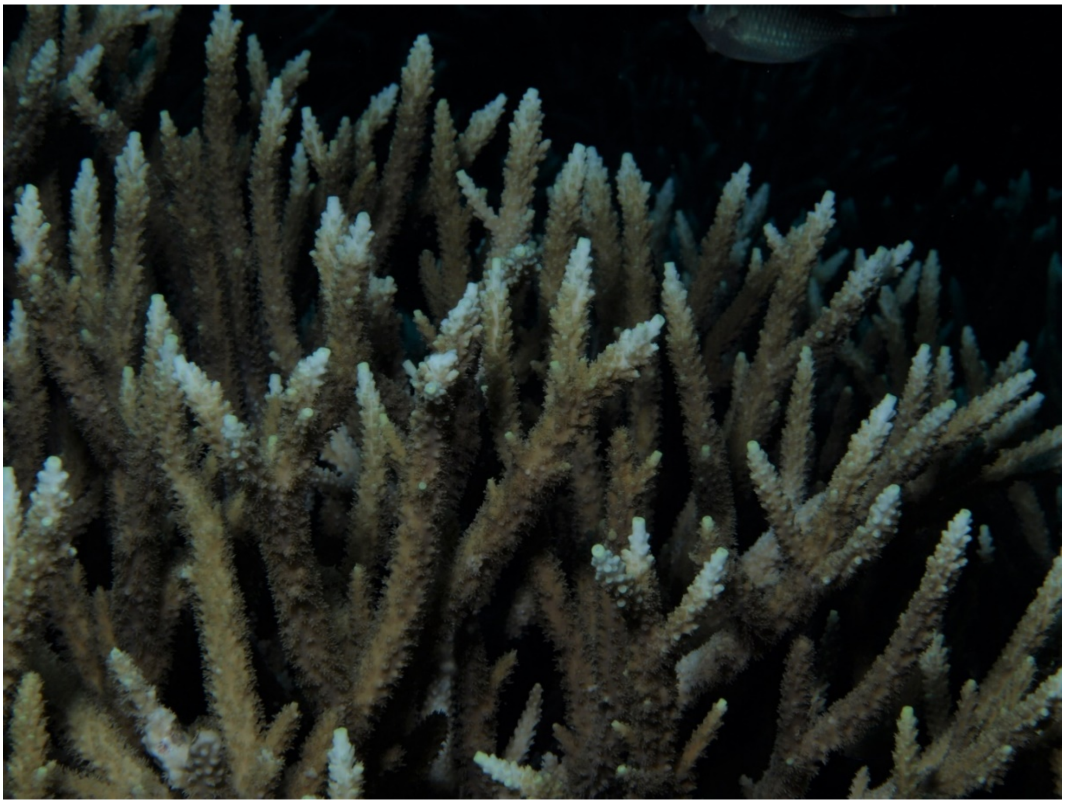

Figure 9. *Acropora halmaherae,* a rare fine-branching staghorn coral found at one of the sites.

Figure 10. One of several species that were so unusual that they cannot be identified at this stage.

TABLES

Site No.	Site Name	Latitude	Longitude	Reef Slope	Rugosity	Area
1	Tank Rock	2° 13.134'S	130° 34.063'E			Misool
2	Boo Windows	2° 13.295'S	130° 36.700'E	High	Medium	Misool
3	Whale Rock	2° 13.163'S	130° 33.552'E			Misool
4	Nudi Rock	2° 13.103'S	130° 33.936'E	Moderate	Medium	Misool
5	Barracuda Rock	2° 11.721'S	130° 25.647'E	Low	Medium	Misool
6	Blue Hole	2° 0.260'S	130° 38.638'E	Low	Medium	Misool
7	Ernie's Corner	0° 54.378'S	130° 34.168'E	Low	Low	Waigeo
8	Yenuba Jetty	0° 34.184'S	130° 39.472'E	Moderate	Med-Low	Waigeo
9	Sauwanderek Jetty	0° 35.577'S	130° 36.378'E	Moderate	Moderate	Waigeo
10	Three Sisters	2° 00.117'S	130° 37.956'E	High	Med-Low	Misool
11	Three Sisters	2° 00.125'S	130° 37.956'E	High	Med-Low	Misool
12	Wedding Cake	2° 12.418'S	130° 25.239'E	Moderate	Moderate	Misool
13	Manta Sandy	0° 10.032'S	130° 00.860'E	High	Mild	Waigeo
14	Lagoon, Misool	2° 11.967'S	130° 25.022'E	High	Medium	Misool
15	Lagoon, Waigeo	0° 10.083'S	130° 00.970'E	Moderate	Medium	Waigeo
16	Lava Flow	3° 55.472'S	131° 12.632'E	Low	Low	Maluku
17	Too Many Fish	3° 55.68'S	131° 12.741'E	High	High	Maluku
18	Yelliet Keio	2° 13.115'S	130° 34.437'E	Moderate	Medium	Misool
19	Neptune's Fan	2° 12.801'S	130° 27.3206'E	Moderate	Medium	Misool
20	Melissa's Garden	0° 35.39'S	130° 18.909'E	Low	Med-Low	Misool
21	Sawandarak Village	0° 35.49'S	130° 36.317'E	Low	Med-Low	Misool

Table 1. Details of study sites surveyed at Raja Ampat.

GROUPS	Overall Mean	SD	Maximum	Minimum	Deep Mean	Shallow Mean
Sand/Rock	40.73	23.43	91.12	0.76	47.64	33.82
Other Animals	4.29	4.34	14.92	0.00	4.72	4.31
Plants	5.42	7.01	29.20	0.00	5.80	4.75
Soft Corals	13.37	14.75	58.16	0.00	9.89	16.43
Dead Coral	1.90	4.56	23.60	0.00	1.39	2.35
Hard Corals	34.81	26.08	97.72	3.56	30.78	39.18

Table 2. Overall summary of benthic cover results from 40 line intersect transects across 21 sites. Deep transects were conducted at 15-20 m depth and shallow at 5-10 m.

Site	Sand/ Rock	Other Animals	Plants	Soft Corals	Dead Coral	Hard Corals
Tank Rock	6.60	14.92	17.52	58.16	0.00	6.08
Boo Windows	52.04	5.20	17.24	22.20	0.00	3.56
Whale Rock	48.80	8.54	8.12	33.14	0.88	4.28
Nudi Rock	31.40	8.88	3.48	25.96	0.88	32.56
Barracuda Rock	44.00	4.72	5.80	21.04	1.04	28.28
Blue Hole	26.40	7.68	5.76	41.24	0.48	18.44
Ernie's Corner	46.68	1.80	8.60	19.52	0.24	23.16
Yenuba Jetty	11.20	0.00	0.00	0.40	2.40	87.20
Sauwanderek Jetty	4.00	3.60	0.00	12.80	0.00	79.60
Three Sisters	1.60	9.60	0.00	6.40	0.00	82.40
Three Sisters	12.40	0.00	14.00	0.00	7.60	66.00
Wedding Cake	53.20	1.20	13.20	8.80	0.00	27.60
Manta Sandy	28.00	1.60	0.00	7.60	23.60	39.20
Lagoon	87.20	0.00	0.00	1.60	0.00	11.20
Lagoon	38.00	0.40	0.00	1.20	4.80	53.20
Lava Flow	15.50	0.24	0.76	0.00	0.00	83.48
Yelliet Keio	49.69	0.51	0.00	31.89	0.00	17.91
Neptune's Fan	67.24	1.80	0.00	13.29	0.00	17.67
Melissa's Garden	8.65	13.42	0.00	14.80	5.10	57.44
Sawandarak Village	43.75	2.00	0.60	8.64	0.00	44.40
Mean	33.82	4.31	4.75	16.43	2.35	39.18
Maximum	87.20	14.92	17.52	58.16	23.60	87.20
Minimum	1.60	0.00	0.00	0.00	0.00	3.56

Table 3. Summary of line intersect transect results for deep???? (15-20 m) depth.

Site	Sand/ Rock	Other Animals	Plants	Soft Corals	Dead Coral	Hard Corals
Tank Rock	47.20	3.60	15.40	11.72	0.00	24.12
Boo Windows	14.56	8.56	20.36	44.56	0.04	11.92
Whale Rock	64.56	3.92	5.24	10.36	0.56	15.36
Nudi Rock	44.68	5.08	7.08	15.44	1.96	25.76
Barracuda Rock	51.36	10.48	9.84	15.60	1.08	11.64
Blue Hole	66.44	6.56	5.40	12.24	2.88	6.48
Ernie's Corner	55.32	10.56	6.88	1.00	4.56	21.68
Yenuba Jetty	4.40	2.00	8.00	0.00	0.00	85.60
Sauwanderek Jetty	47.20	5.20	0.00	2.40	0.00	45.20
Three Sisters	32.80	3.60	29.20	0.00	0.00	36.40
Three Sisters	62.40	0.00	11.20	1.20	0.00	25.20

Wedding Cake	52.76	0.00	0.00	20.00	0.00	27.24
Lagoon	52.60	0.00	0.00	0.00	0.00	47.40
Lagoon	54.00	0.00	0.00	0.00	16.40	29.60
Lava Flow	0.76	0.00	1.82	0.00	0.00	97.72
Too Many Fish	24.36	9.24	0.15	47.35	0.00	19.08
Yelliet Keio	71.93	1.84	0.80	17.77	0.00	7.66
Neptune's Fan	91.12	1.45	0.00	2.56	0.00	4.87
Melissa's Garden	47.45	13.48	0.00	1.60	0.00	37.47
Sawandarak Village	67.14	0.00	0.41	2.27	1.67	28.51
Mean	47.65	4.28	6.09	10.30	1.46	30.45
Maximum	91.12	13.48	29.20	47.35	16.40	97.72
Minimum	0.76	0.00	0.00	0.00	0.00	4.87

Table 4. Summary of main substrate types for each site. Average of deep and shallow transects.

Species	**All**	**Deep**	**Shallow**
Acropora	11.39	9.45	13.49
Porites	3.23	1.95	4.59
Montipora	2.63	1.97	3.34
Oxypora	2.58	2.64	2.55
Turbinaria	1.63	1.49	1.79
Pachyseris	1.37	2.12	0.60
Seriatopora	1.17	0.89	1.46
Goniopora	1.10	0.42	1.82
Mycedium	1.07	1.66	0.46
Fungid	0.92	0.46	1.40
Galaxea	0.82	1.14	0.50
Pavona	0.67	0.76	0.58
Favia	0.56	0.59	0.52
Isopora	0.42	0.13	0.73
Tubastrea	0.40	0.56	0.23
Goniastrea	0.39	0.02	0.78
Echinopora	0.39	0.25	0.54
Stylophora	0.35	0.05	0.67
Favites	0.33	0.39	0.26
Pocillopora	0.32	0.18	0.48
Platygyra	0.31	0.22	0.41
Astreopora	0.31	0.37	0.25
Hydnophora	0.29	0.34	0.23
Echinophyllia	0.27	0.45	0.09
Cyphastrea	0.26	0.27	0.24
Gardinoseris	0.25	0.48	0.01
Leptoseris	0.24	0.47	0.00
Psammocora	0.20	0.12	0.28
Symphyllia	0.20	0.18	0.22
Millepora	0.20	0.13	0.26
Montastrea	0.19	0.09	0.29
Merulina	0.14	0.04	0.26
Lobophyllia	0.13	0.18	0.08
Anacropora	0.08	0.04	0.13
Leptastrea	0.08	0.00	0.16
Coscinarea	0.07	0.05	0.10

Physogyra	0.07	0.06	0.07
Diploastrea	0.06	0.08	0.04
Euphyllia	0.04	0.00	0.09
Alveopora	0.04	0.06	0.02
Plesiastrea	0.03	0.03	0.04
Tubipora	0.03	0.00	0.06
Podabacia	0.03	0.06	0.00
Pectinia	0.02	0.04	0.01
Blastomussa	0.02	0.03	0.00
Sandalolitha	0.01	0.00	0.03
Halomitra	0.01	0.00	0.02
Stylocoeniella	0.01	0.02	0.00
Plerogyra	0.01	0.00	0.01
Heliopora	0.01	0.00	0.01
Heliofungia	0.00	0.00	0.00

Table 5. Overall abundance of hard coral genera given as the percentage cover averaged over 40 transects and 21 sites.

Site Name	Tank Rock		Boo Windows		Whale Rock		Nudi Rock		Barracuda Rock		Blue Hole		Ernie's Corner		Yenuba Jetty		Sawandarak Jetty		Three Sisters		Thr Sist
Depth	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7
Sand	0.00	0.88	1.39	0.03	0.00	0.80	0.00	0.42	0.34	0.54	0.00	0.34	0.00	0.00	0.70	0.00	0.90	5.60	0.00	4.90	1.10
Rock	0.07	5.14	7.23	2.19	0.04	0.52	0.28	1.75	1.90	0.79	0.55	0.00	1.40	1.02	0.00	0.00	0.00	0.70	0.00	0.00	0.10
Rubble	1.58	5.78	4.39	1.42	12.16	14.82	7.57	9.00	8.76	11.51	6.05	16.27	10.27	12.81	2.10	1.10	0.10	5.50	0.40	3.30	1.90
Dead Coral	0.00	0.00	0.00	0.01	0.22	0.14	0.22	0.49	0.26	0.27	0.12	0.72	0.06	1.14	0.60	0.00	0.00	0.00	0.00	0.00	1.90
Ascidean	3.12	0.03	0.04	0.11	1.05	0.07	0.06	0.14	0.23	0.06	0.94	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crinoid	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sponge	0.58	0.84	1.06	2.03	1.08	0.91	2.10	1.03	0.90	2.55	0.98	1.52	0.44	2.58	0.00	0.50	0.90	1.30	2.40	0.90	0.00
Hydroid	0.00	0.03	0.20	0.00	0.00	0.00	0.06	0.00	0.05	0.01	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corallimorph	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant Clam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae	0.18	0.52	1.09	2.38	0.26	0.66	0.00	0.48	1.31	0.22	0.14	0.12	2.12	0.83	0.00	0.00	0.00	0.00	0.00	7.30	3.50
CCA	4.20	3.33	3.22	2.71	1.77	0.65	0.87	1.29	0.14	2.24	1.30	1.23	0.03	0.89	0.00	2.00	0.00	0.00	0.00	0.00	0.00
Soft Coral	14.54	2.93	5.55	11.14	8.29	2.59	6.49	3.86	5.26	3.90	10.31	3.06	4.88	0.25	0.10	0.00	3.20	0.60	1.60	0.00	0.00
Acropora	0.73	0.20	0.00	0.11	0.00	0.04	0.00	0.00	1.08	0.00	0.00	0.00	1.75	0.21	1.20	0.00	9.10	1.70	10.10	0.00	0.00
Anacropora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00
Alveopora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astreopora	0.00	0.13	0.09	0.00	0.43	0.12	0.12	0.00	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blastomussa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coscinaraea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.10
Cyphastrea	0.00	0.12	0.09	0.00	0.08	0.00	0.00	0.00	0.11	0.15	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70
Diploastrea	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Echinophyllia	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00

Echinopora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	1.50	0.00	0.00	0.10
Euphyllia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Favia	0.00	0.17	0.10	0.00	0.00	0.20	0.15	0.27	0.00	0.00	0.00	0.00	0.43	2.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Favites	0.00	0.17	0.13	0.11	0.00	0.00	0.00	0.15	0.00	0.44	0.02	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.10
Fungid	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.90	0.40	0.70	1.00	3.90	0.10	1.50
Galaxea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.30	1.20	0.20	2.20	0.00
Gardinoseris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.38	0.00	0.00	0.00	1.60	0.00	0.00	0.00
Goniastrea	0.06	0.00	0.01	0.01	0.00	0.00	0.22	0.00	0.21	0.08	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	1.00	0.00	1.40
Goniopora	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	11.30	0.00	0.00	0.00	0.00	0.00	0.00
Halomitra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heliofungia	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heliopora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydnophora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.04	0.76	0.00	0.05	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00
Isopora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptastrea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
Leptoseris	0.00	0.16	0.00	0.00	0.00	0.02	0.00	0.23	0.00	0.15	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lobophyllia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.21	0.09	0.00	0.00	0.00	0.30	0.00	0.00	0.10
Millepora	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00
Merulina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Montastrea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Montipora	0.00	0.47	0.14	0.00	0.00	0.00	0.00	0.07	2.62	0.33	0.00	0.21	0.00	0.00	6.30	0.00	0.00	1.80	0.00	1.20	0.30
Mycedium	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.10	1.00
Oxypora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00	13.40	0.00	0.00	0.70	0.00	4.30
Pachyseris	0.00	2.15	0.10	0.00	0.00	0.16	0.00	0.22	0.14	0.43	0.63	0.00	0.00	0.18	0.00	5.20	0.00	0.10	0.00	4.10	2.20
Pavona	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pectinia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Physogyra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.39	0.00	0.00	0.00	0.07	0.06	0.07
Platygyra	0.25	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.50	0.24	0.00	0.00	0.20	0.55	0.10	0.30	0.31	0.22	0.41
Plerogyra	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Plesiastrea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.03	0.03	0.04
Pocillopora	0.20	0.25	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.06	1.00	0.00	0.00	0.10	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.20	0.00	0.08	0.00	0.05	0.00	0.15	0.20	0.00	0.32	0.18	0.48
Podabacia	0.00	0.03	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.00
Porites	0.06	1.66	0.00	1.05	0.32	0.76	5.41	0.71	1.28	0.80	0.05	0.69	1.81	0.72	0.00	0.00	1.00	0.00	3.10	1.20	1.70	1.10	3.20	1.30	0.80	0.05	0.50	3.70	0.00	0.00	0.33	0.88	0.00	3.99	0.00	0.73	1.35	0.73	0.40	0.00	3.23	1.95	4.59
Psammocora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.20	0.12	0.28
Sandalolitha	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
Seriatopora	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.30	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.18	1.06	0.00	0.00	0.10	0.03	3.71	5.83	0.33	0.40	1.17	0.89	1.46
Stylocoeniella	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00
Stylophora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.05	0.67
Symphyllia	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.09	0.07	0.05	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.20	0.00	0.00	0.00	0.30	1.03	0.10	0.00	0.20	0.18	0.22
Tubastrea	0.22	0.00	0.05	0.00	0.04	0.00	0.02	1.01	0.00	0.00	0.09	0.13	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.40	0.56	0.23
Tubipora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.03	0.00	0.06
Turbinaria	0.00	0.23	0.08	1.36	0.00	2.18	2.03	3.33	0.00	0.12	2.73	0.00	0.00	0.00	0.30	0.00	0.00	0.10	0.00	0.00	0.40	1.10	0.00	0.50	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.95	0.00	0.00	0.00	3.36	0.68	0.75	1.63	1.49	1.79
TOTA	**25**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**24**	**2**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**5**	**4**			

L	**.8**	**5.5**	**5.1**	**5.0**	**5.9**	**5.0**	**5.8**	**5.0**	**6.2**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**5.3**	**5.0**	**5.0**	**5.0**	**5.0**	**5.5**	**5.0**	**5.0**	**6.0**	**5.0**	**5.0**	**5.0**	**5.0**	**.4**	**5.0**	**0.2**	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**9.7**	**0.0**	**9.7**			
GROUPS	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	S	**S**	**D**	**D**	**S**	**D**	**D**	**S**	**D**	**S**	**D**	**S**	**D**	**S**	**MEAN**	**SD**	**Max**
Sand/Rock	6.600	47.20	52.04	14.56	48.80	64.56	31.40	44.68	44.00	51.36	26.40	66.44	46.68	55.32	11.20	4.40	4.00	47.20	1.60	32.80	12.40	62.40	53.20	52.76	28.00	52.60	87.20	38.00	54.00	0.76	15.50	24.36	71.93	49.69	91.12	67.24	47.45	8.65	67.14	43.75	**40.7**	**23.4**	**91.1**
Invertebrates	14.92	3.60	5.20	8.56	8.54	3.92	8.88	5.08	4.72	10.48	7.68	6.56	1.80	10.56	0.00	2.00	3.60	5.20	9.60	3.60	0.00	0.00	1.20	0.00	1.60	0.00	0.00	0.400	0.00	0.00	0.24	9.24	1.84	0.51	1.45	1.80	13.48	13.42	0.00	2.00	**4.3**	**4.3**	**14.9**
Plants	17.52	15.40	17.24	20.36	8.12	5.24	3.48	7.08	5.80	9.84	5.76	5.40	8.60	6.88	0.00	8.00	0.00	0.00	0.00	29.20	14.00	11.20	13.20	0.00	0.00	0.00	0.00	0.000	0.00	1.82	0.76	0.15	0.80	0.00	0.00	0.00	0.00	0.00	0.41	0.60	**5.4**	**7.0**	**29.2**
Soft Corals	58.16	11.72	22.20	44.56	33.14	10.36	25.96	15.44	21.04	15.60	41.24	12.24	19.52	1.00	0.40	0.00	12.80	2.40	6.40	0.00	0.00	1.20	8.80	20.00	7.60	0.00	1.60	1.200	0.00	0.00	0.00	47.35	17.77	31.89	2.56	13.29	1.60	14.80	2.27	8.64	**13.4**	**14.7**	**58.2**
Dead Coral	0.000	0.00	0.00	0.04	0.88	0.56	0.88	1.96	1.04	1.08	0.48	2.88	0.24	4.56	2.40	0.00	0.00	0.00	0.00	0.00	7.60	0.00	0.00	0.00	23.60	0.00	0.00	4.800	16.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10	1.67	0.00	**1.9**	**4.6**	**23.6**
Hard Corals	6.08	24.12	3.56	11.92	4.28	15.36	32.56	25.76	28.28	11.64	18.44	6.48	23.16	21.68	87.20	85.60	79.60	45.20	82.40	36.40	66.00	25.20	27.60	27.24	39.20	47.40	11.20	53.20	29.60	97.72	83.48	19.08	7.66	17.91	4.87	17.67	37.47	57.44	28.51	44.40	**34.8**	**26.1**	**97.7**

Table 5 Main site data summary.

Science Report: Coral Reef Fish

By Renato Morais, *Fish team Principal Investigator*

Outline

This report provides an analysis of the coral reef fishes assemblages of Raja Ampat based on output data from the 2018 Elysium Heart of the Coral Triangle Expedition. The area investigated included sites in the Banda Sea, and in the southern and northern parts of the Raja Ampat region, in the Maluku and West Papua Provinces of eastern Indonesia. Coral reef fish assemblages were characterised with underwater visual surveys while SCUBA diving with the aim to produce a baseline of fish biodiversity and biomass in the area.

Introduction

The Coral Triangle has been identified as the most biodiverse marine region of the Planet (e.g. Allen, 2008; Bellwood et al., 2005; Briggs, 2007). The Coral Triangle has a critical role as a centre of both origination and accumulation of marine species (Bowen et al., 2013), which is believed to have existed for at least the past 20 million years (Renema et al., 2008). As a result, the biodiversity of marine organisms, such as corals, varies more than an order of magnitude from the Coral Triangle toward peripheral regions such as the Southwestern and Eastern Atlantic and Eastern Pacific (Veron et al., 2015). Coral reef fishes are no different, depicting varying species composition and increasing biodiversity as one moves toward the Coral Triangle (Kulbicki et al., 2013; Parravicini et al., 2013). The total number of fish species varies depending on the limits used to define the taxa analysed (e.g. shore fishes, reef fishes, coastal fishes), but ranges from 1,500 to over 2,000 species (e.g. Allen and Erdmann, 2009; Randall, 1998). Within the larger Coral Triangle seascape, the Bird’s Head Peninsula, or Raja Ampat, has been pointed out as the potential centre of the centre of biodiversity (Allen, 2008; Allen and Erdmann, 2009). Although the Banda Sea is not officially part of the Bird’s Head Peninsula or Raja Ampat, it will be referred to as part of these regions for simplicity.

Only relatively recently has a comprehensive and systematic species list of reef fishes from Raja Ampat been compiled, stemming from almost a decade of surveys (Allen and Erdmann, 2009; McKenna et al., 2002). Although some level of endemism exists, the vast majority of species is widely distributed throughout the Coral Triangle and adjacent regions (Allen and Erdmann, 2009). This is not unexpected given one of the very features that allows Raja Ampat to be particularly megadiverse: its high degree of connectivity with other biogeographical regions. This led Allen and Erdmann to state that the Bird's Head Peninsula is a biogeographical 'melting pot', combining elements from the Melanesian Archipelago, wider Indonesia and the Timor and Arafura Seas (Allen and Erdmann, 2009). Its unmatched habitat diversity, stemming from a complex geologic past, is distributed over a complex mosaic of islands encompassing different levels of wave exposure, current flow, shelf widths and turbidity (DeVantier et al., 2009).

Ecological knowledge of fish assemblages in the Raja Ampat region exists mainly in the form of technical reports to NGOs such as The Nature Conservancy and Conservation International (e.g. DeVantier et al., 2009; McKenna et al., 2002). A particularly fruitful source of information is the comprehensive report series by the Fisheries Centre from the University of British Columbia in Canada. These reports culminate with a detailed ecosystem model (Ecopath with Ecosim) of Raja Ampat that includes quantitative data on reef fish assemblages (Ainsworth et al., 2008b). This ecosystem model has been used along with a series of policy reports to guide conservation planning in the region (Ainsworth et al., 2008a; Grantham et al., 2013; Varkey et al., 2010). These reports focus on applied ecological questions from fisheries and/or conservation perspectives, with pure ecological knowledge of the coral reef fish assemblages of the region is still scarce. The quantitative fish assemblage data used in Ainsworth et al. (2008b), for example, pertains to a limited number of families composing critical trophic groups, and were collected at the family level. Here we report on a series of fish surveys undertaken at 19 sites in the Banda Sea and Raja Ampat regions. Although spatially limited, this species-level dataset reveals important ecological information absent from the literature and suggests future directions if research on the topic is to be continued in the region.

Fish survey method

Each underwater fish survey involved a four-step procedure that was executed by a single diver with the guide of a standard 50m-long tape. Each step encompassed different surveyed areas and targeted different sets of fishes. Each fish detected at each step was identified, whenever possible to species level (but at least to genus level), and had its size determined (Total length, TL, in cm).

The first phase of the survey (Figure 1) occurred over a 50m-long by 5m-wide transect, and targeted large species (> 25cm TL) that are normally mobile and wary. These fishes are likely to be heavily affected by the diver and whose abundance could not be reliably estimated after the diver passes. These fishes include: most sharks and rays (but not cryptic epaulette sharks and others alike), parrotfishes (Labridae, Scarini), surgeonfishes (Acanthuridae), jacks (Carangidae), fusiliers (Caesionidae), snappers (Lutjanidae), emperors (Lethrinidae), groupers (Epinephelidae), sweetlips (Haemulidae), rabbitfishes (Siganidae), as well as other less common families provided that the fishes are larger than >25cm and widely exposed in the water column.

The second phase (Figure 1) occurred over a 30m-long by 5m-wide transect, and targeted smaller species (from 10 to 25 cm TL) that are either moderately mobile or moderately wary. These fishes are likely to be affected by the presence of the diver in the previous step, but are unlikely to roam away from the surveyed area in that time frame. These fishes include wrasses (Labridae), goatfishes (Mullidae), breams (Nemipteridae), squirrelfishes (Holocentridae), and also all fishes from the previously referred families that are between 10 and 25 cm TL. This step also includes individuals from larger species that are not necessarily immediately affected by the diver presence, such as triggerfishes (Balistidae), porcupines (Diodontidae), pufferfishes (Tetraodontidae) and moray eels.

The third phase (Figure 1) occurred over a transect that is 30m-long by 1m-wide. This step targeted small fishes with 10 cm TL or smaller in the water column, in proximity to, or associated with the bottom, but not inside crevices and holes. This step mainly surveys abundant and species rich groups such as small damselfishes (Pomacentridae), wrasses (Labridae), anthias (Serranidae), and some cardinalfishes (Apogonidae), but also includes juveniles of all other families mentioned so far. Finally, the fourth and final phase (Figure 1) also involved a 30m-long by 1m-wide transect, and targeted very small fishes associated to, or hidden in, holes and crevices of the bottom. The main families assessed at this point are small cryptobenthic reef fishes such as hawkfishes (Cirrhithidae), dottybacks (Pseudochromidae), gobies (Gobiidae), blennies (Blenniidae), triplefins (Tripterygiidae) and cardinalfishes (Apogonidae). However, very cryptical, but not necessarily small, scorpionfishes and stonefishes (Scorpaenidae and Synanceiidae). Visual identification of many of these fishes, especially the cryptobenthic ones, is extremely challenging, and was not always possible.

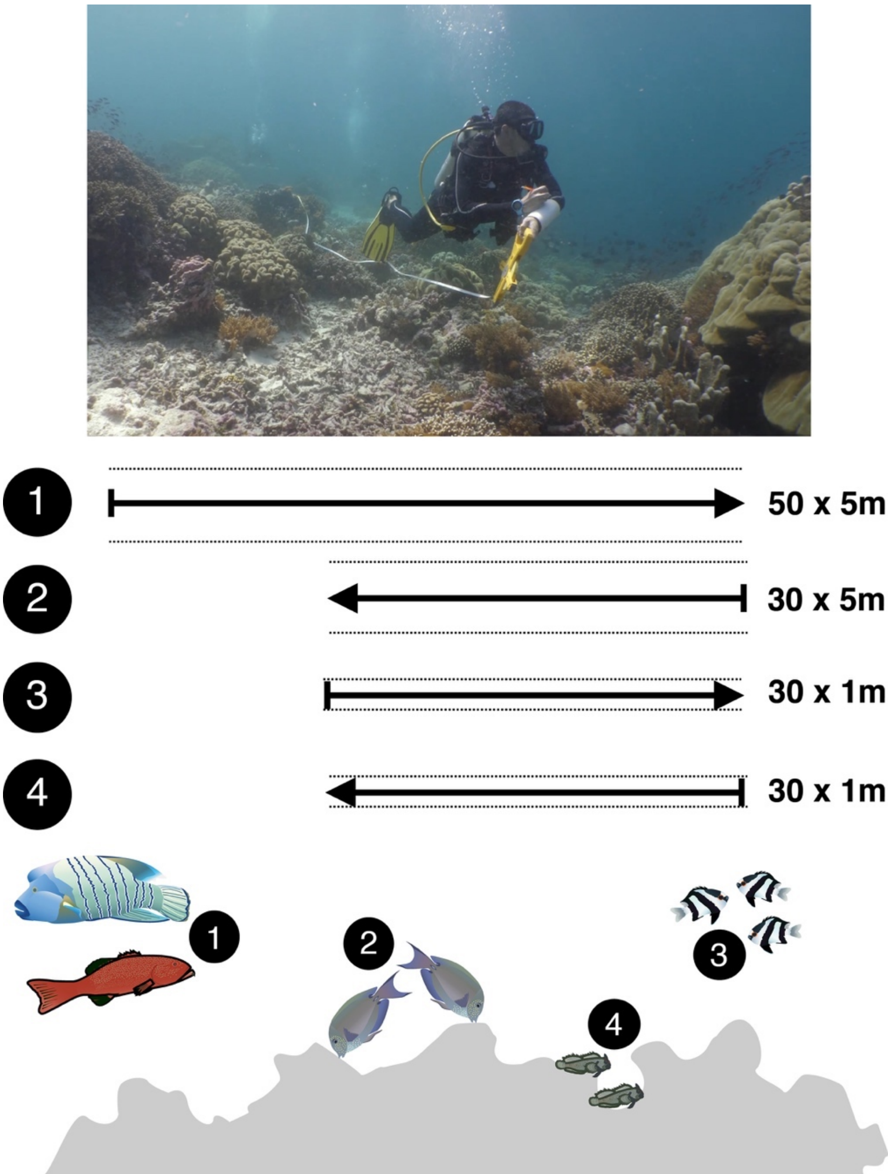

Figure 1: The underwater visual procedure employed to survey coral reef fish assemblages in the present work. Numbers match the phases explained in the main text in both the diagram and the reef section showing the target fish groups. Fish figures by Joanna Woerner, Kim Kraeer, Lucy Van Essen-Fishman and Tracey Saxby (Integration and Application Network). Image by Sabrina Inderbitzi.

A total of 19 sites in the Banda Sea and Raja Ampat were surveyed for the 2018 Elysium Heart of the Coral Triangle Expedition. Table 1 below depicts the coordinates of each of the sites sampled, as well as the person responsible for the data collection.

Table 1: Sites surveyed during the 2018 Elysium Heart of the Coral Triangle expedition, with coordinates (in decimal degrees) and data collector.

Locality	Site	lat	lon	Collector	Sample
Banda Sea	Nills Desperadum - North West Corner	-6.608	129.77915	Renato Morais	T01
Banda Sea	Manuk island - North West	-5.5428167	130.297917	Renato Morais	T02
Banda Sea	Manuk island - North East	-5.54005	130.30305	Renato Morais	T03
Raja Ampat	Misool - Tank Rock	-2.2189333	130.567717	Renato Morais	T04
Raja Ampat	Misool - Boo Windows	-2.2215833	130.610333	Renato Morais	T05
Raja Ampat	Misool - Whale Rock	-2.2193833	130.5592	Renato Morais	T06
Raja Ampat	Misool - Nudi Rock	-2.2183833	130.5656	Renato Morais	T07
Raja Ampat	Misool - Four Kings Bay	-2.119607	130.250220	Alex Rose	T08
Raja Ampat	Farondi - Three Sisters	-2.0028333	130.6396	Renato Morais	T09
Raja Ampat	Farondi - Coral Bay	-1.998622	120.639127	Alex Rose	T10
Raja Ampat	Farondi - Blue Hole	-2.0043333	130.643967	Renato Morais	T11
Raja Ampat	Farondi - Two Trees	-2.0280667	130.73425	Renato Morais	T12
Raja Ampat	Farondi - Three Sisters	-2.0028333	130.6396	Renato Morais	T13
Raja Ampat	Batanta - Southeast (Ernie's Corner)	-0.910488	130.571332	Renato Morais	T14
Raja Ampat	Batanta - Southeast (Ernie's Corner)	-0.910488	130.571332	Renato Morais	T15
Raja Ampat	Batanta - Unnamed	-0.908700	130.651092	AlexRose	T16
Raja Ampat	Dampier Strait - Cape Kri	-0.558799	130.688415	Renato Morais	T17
Raja Ampat	Dampier Strait – Yenbuba Jetty	-0.570133	130.660981	Alex Rose	T18
Raja Ampat	Pulau Wayag	0.168050	130.016167	Juan Romero	T19

Methods for data analysis

Patterns in the biodiversity, abundance and the standing biomass of coral reef fishes of Raja Ampat are the focus of this report. Coral reef fishes are herein defined following Bellwood and Wainwright (2002). Data from the four surveying steps described previously were combined into a single unit (thereby a 'survey') by using the method described in Morais and Bellwood (2019). Another set of surveys using the exact same underwater visual count method by the same observer (R. Morais) was used to provide a reference point with which to contrast the Raja Ampat data for biodiversity patterns. This data was obtained from Lizard Island, in the Great Barrier Reef (GBR) of Australia, a species-rich region that is adjacent to (but outside) the Coral Triangle. The regional fish species richness of the two regions (GBR and Raja Ampat) was compared using sample-based rarefaction curves (Gotelli and Colwell, 2001). Because fish species identification varies strongly among observers (Bernard et al., 2013; Williams et al., 2006), this was achieved by using data from a single observer only (R. Morais). Average sample species richness (species density) was compared between the two regions with a simple Gaussian linear model (t test). The species abundance relationships of these two regions were compared by plotting them side-by-side, and the average fish abundance was compared by using a Poisson generalised linear model (Z test).

The potential variability in the species composition (which species are present and their abundances) among different sub-regions within the Raja Ampat seascape (Banda Sea, southern and norther Raja), was evaluated using a non-metric Multidimensional Scaling (nMDS) and an Analysis of Similarity (ANOSIM). The nMDS produces a two-dimensional representation of the relationship among surveys, with points close to one another representing similar assemblages, and points far from one another representing distinct assemblages. The ANOSIM is a permutation test that allows to test if surveys from a sub-region are more similar among themselves compared to surveys from other sub-regions. We also tested whether potential differences in species composition were related to environmental variables using a permutation test of correlations (envfit). The environmental variables investigated were depth, water temperature, current intensity and topographic complexity, all measured or estimated for each survey. Depth and water temperature were obtained from the dive computer. Current intensity was qualitatively estimated as nill, low, moderate or strong. Topographic complexity was obtained by a second diver using a modified version of the 'chain method' (using a weighed rope instead) to assess the rugosity of the substrate (Morais and Bellwood, 2019; Wilson et al., 2007).

Fish standing biomass was estimated by transforming length data, as obtained from the surveys, to weight for each individual fish. This was achieved by using length-weight regression coefficients compiled for each species from FishBase (Froese and Pauly, 2018). Individual weights were aggregated to sum up the standing biomass of each species. Standing biomass if hereafter referred as 'biomass' for simplicity. Patterns of biomass were then evaluated by fish family, trophic group and individual body size. Seven trophic groups were considered: herbivores-detritivores, herbivores-macroalgivores, omnivores, planktivores, invertivores of sessile organisms, invertivores of mobile organisms and piscivores, following Morais and Bellwood (2018). Individual body size was transformed from length values to six length classes to ease the detection of patterns, being these: 0 to 7 cm TL, 8 to 15 cm TL, 16 to 30 cm TL, 31 to 50 cm TL, 51 to 80 cm TL and larger than 80 cm TL.

Biodiversity patterns

In total, 347 species were identified in the 19 fish counts. Contrasting the regional species richness between Raja Ampat and Lizard Island (Great Barrier Reef) showed similar species accumulation trajectories (Figure 2), although the curve from Raja tended to increase faster after five samples. This suggests that more new species are found in consecutive surveys in Raja Ampat compared to the GBR, although this difference was small. The species density, however, did not differ between the two regions: 52-54 species can be found, on average, in an area of 100m^2 of reef at both regions.

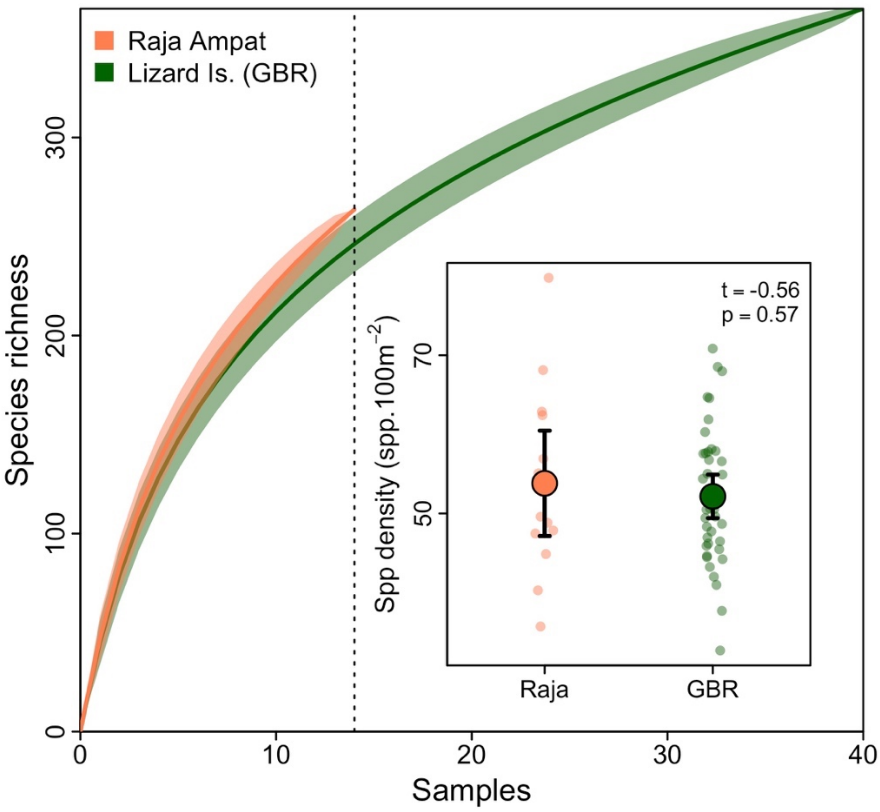

Figure 2: Contrasting coral reef fish biodiversity patterns between Raja Ampat and a Great Barrier Reef location (Lizard Island). Larger plot shows sample-based species rarefaction curves, with each line being the average trajectory and the shaded areas representing the confidence interval (95%) of these trajectories. The inset shows the survey-level species density, where each small dot is a survey, larger dots are mean values and the intervals are confidence intervals (95%). The legend in the upper right of the inset shows the test statistics. It should be interpreted as: no differences in average species density were found between regions.

Ordering the species detected in the counts by their respective abundances showed substantially different patterns between regions (Figure 3). The most abundant species were clearly more abundant in Raja Ampat compared to the GBR location. Whereas the abundance abruptly dropped in the GBR from the first to the second species, this decline in the abundance was more gradual in Raja Ampat. This pattern was particularly strong for the first 10 species and existed at least for the 70-80 most abundant species. As a result, the overall fish abundance was much higher in Raja Ampat than on the GBR location: almost 2,500 individuals would be expected, on average, in a reef area of 100m^2 at Raja Ampat, while only about 1,200 would be expected at an equivalent area at the GBR location.

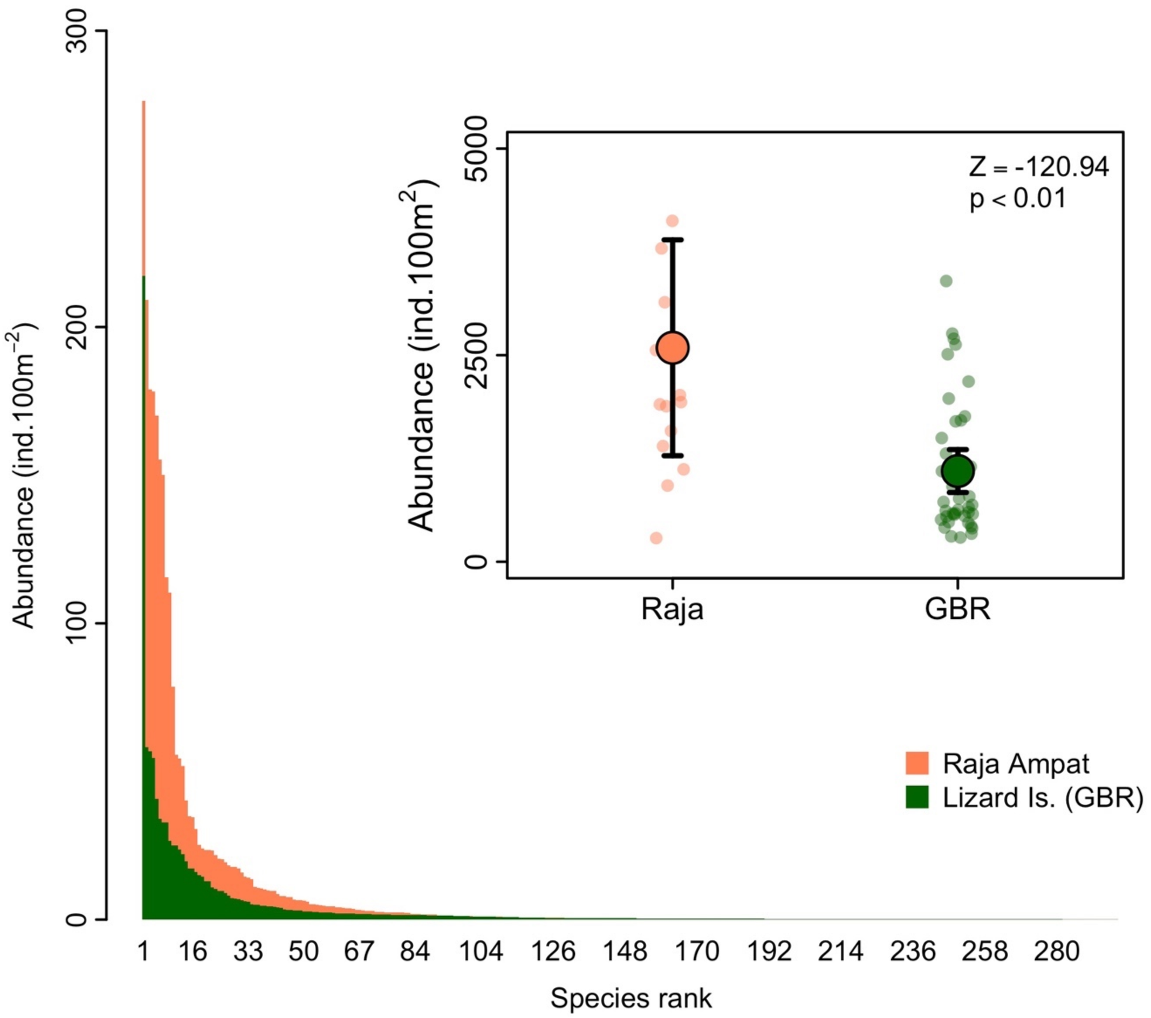

Figure 3: Coral reef fish species abundance relationships in Raja Ampat and the Great Barrier Reef (Lizard Island). The larger plot shows species ordered by their respective abundances in both regions and reveals that all of the most abundant species were more abundant in Raja Ampat than in the GBR location. The inset shows survey-level abundance patterns. where each small dot is a survey, larger dots are mean values and the intervals are confidence intervals (95%). The legend in the upper left of the inset shows the test statistics. It should be interpreted as: average abundance is different between regions.

Raja Ampat taxonomic composition patterns

Overall, damselfishes (Pomacentridae) were the most abundant fishes found throughout Raja Ampat and the Banda Sea, comprising over 83,000 individuals per hectare (Figure 4). They were followed closely by fusiliers (Caesionidae) and cardinalfishes (Apogonidae), with almost 50,000, and over 40,000 ind. ha^{-1}, respectively.

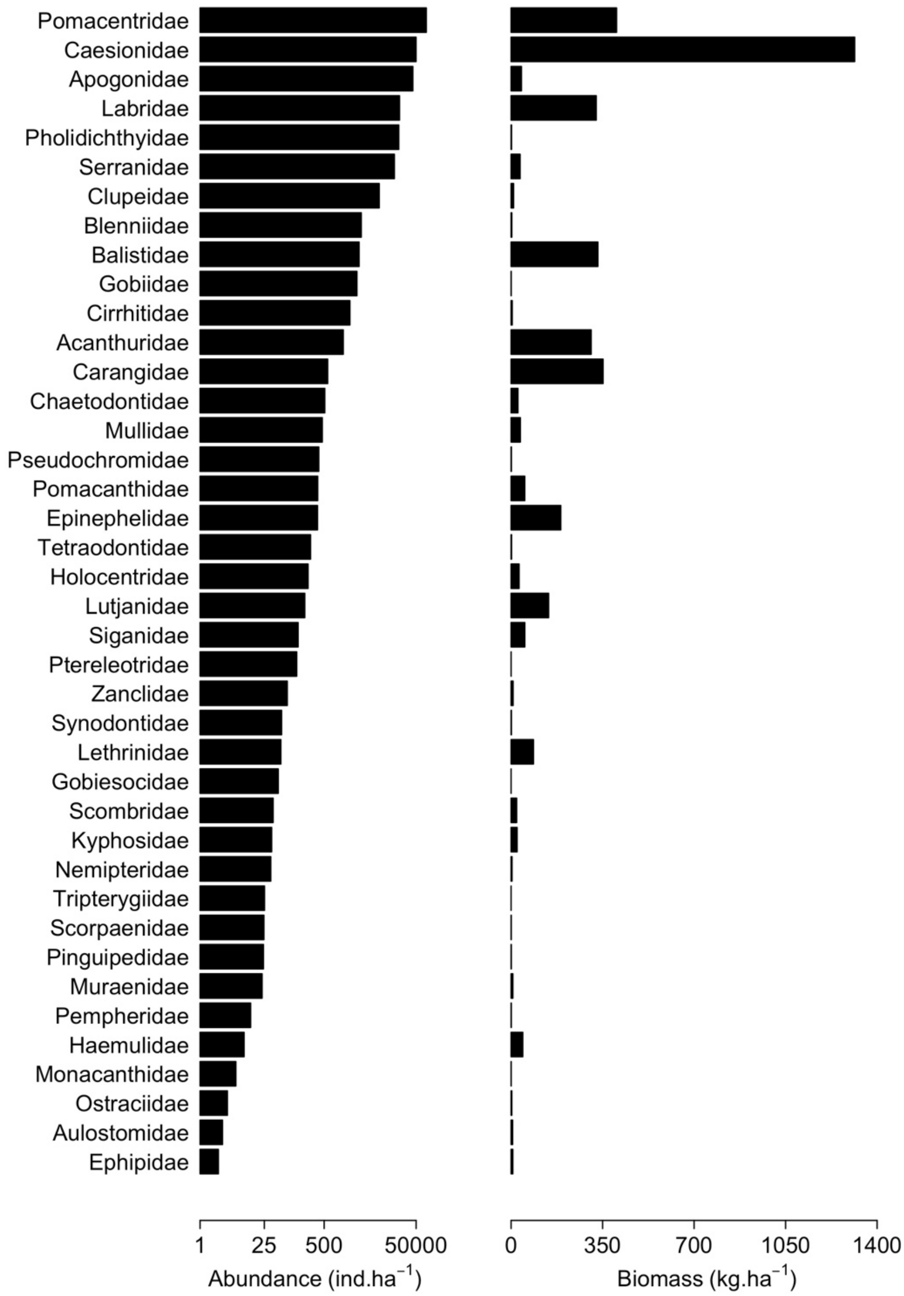
Pomacentridae
Caesionidae
Apogonidae
Labridae
Pholidichthyidae
Serranidae
Clupeidae
Blenniidae
Balistidae
Gobiidae
Cirrhitidae
Acanthuridae
Carangidae
Chaetodontidae
Mullidae
Pseudochromidae
Pomacanthidae
Epinephelidae
Tetraodontidae
Holocentridae
Lutjanidae
Siganidae
Ptereleotridae
Zanclidae
Synodontidae
Lethrinidae
Gobiesocidae
Scombridae
Kyphosidae
Nemipteridae
Tripterygiidae
Scorpaenidae
Pinguipedidae
Muraenidae
Pempheridae
Haemulidae
Monacanthidae
Ostraciidae
Aulostomidae
Ephipidae
1 25 500 50000
Abundance (ind.ha^{-1})
0 350 700 1050 1400
Biomass (kg.ha^{-1})

Figure 4: Patterns in the abundance and biomass of different coral reef fish families in Raja Ampat. Note that, to facilitate visualizing the least abundant families, the scale is not proportional in the abundance plot. The scale is proportion on the biomass plot.

Wrasses and parrotfishes (Labridae), convict blennies (Pholidichthyidae) and anthias (Serranidae) all comprised over 15,000 ind. ha^{-1}, and baitfish comprised almost 8,000 ind. ha^{-1} (Clupeidae, Figure 4). In terms of total biomass, however, fusiliers had by far the largest contribution (Figure 4), with 1,313 ± 33 kg ha^{-1} (mean ± std. dev.). Fusiliers were followed by damselfishes, with less than a third of their biomass (403 ± 5 kg ha^{-1}), jacks and trevallies (Carangidae, 355 ± 40 kg ha^{-1}), wrasses and parrotfishes (338 ± 106 kg ha^{-1}), triggerfishes (Balistidae, 330 ± 24 kg ha^{-1}) and unicornfishes and surgeonfishes (Acanthuridae, 314 ± 53 kg ha^{-1}). Groupers (Epinephelidae, 179 ± 59 kg ha^{-1}) and snappers (Lutjanidae, 138 ± 33 kg ha^{-1}) were the only other families comprising more than 100 kg ha^{-1}.

As hypothesized, species composition varied between the Banda Sea, southern and northern Raja Ampat (ANOSIM R = 0.56; $p < 0.001$; Figure 5). Although the number of samples is relatively small, the surveys of each sub-region tended to cluster, and to be separated from those of other sub-regions.

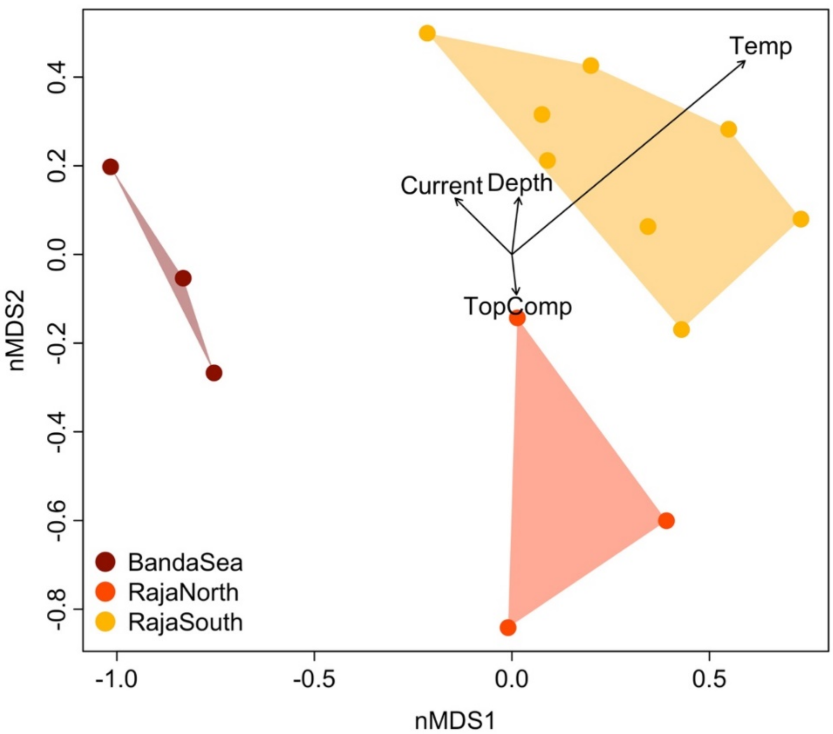

Figure 5: Patterns of coral reef fish species among surveyed sub-regions in the Raja Ampat seascape. Dots that are closer are more similar in species composition and dots that are farther are more different. Coloured polygons delimit each sub-region, with each dot representing one survey. Arrows represent the environmental variables: depth, current, water temperature (Temp) and topographic complexity (TopComp). The longer the arrow, the more it is influential in the pattern observed.

From the environmental variables tested, only temperature was significantly correlated to species composition patterns (Table 2). Figure 5 shows that surveys in the northern and southern part of Raja Ampat were positively correlated to temperature and, thus, had higher temperatures than the Banda Sea. Although latitudes are higher in the Banda Sea (Table 1), the sites investigated were only 300-400 km away from Raja Ampat, likely insufficient for the abrupt differences detected in temperature and species composition. The investigated sites in the Banda Sea, however, were located in isolated oceanic islands, and, as such, likely more exposed to the upwelling of cooler, deeper waters.

Table 2: Summary of permutation tests of correlation between environmental variables and coral reef fish assemblage composition in Raja Ampat. p-values smaller or = 0.05 indicate significant effect of variables. The R^2 values are proportional to the correlation between species composition and the variables.

Variable	R^2	p-value
Topographic complexity	0.112	0.530
Depth	0.157	0.406
Current intensity	0.205	0.241
Water temperature	0.875	0.002

Patterns in the standing biomass of families, trophic groups and size classes

The mean fish biomass was very similar in the three investigated sub-regions (Figure 6), ranging only from 3,508 kg ha^{-1} in the northern Raja Ampat to 3,766 kg ha^{-1} in the Banda Sea and 4,087 kg ha^{-1} in the southern Raja Ampat. However, there was considerable variability among surveys, especially in the northern Raja and, to a lesser degree in the southern Raja (Figure 6). This was driven by the extreme high biomass values occurred in two samples of these regions. Given the previous observation that different fish assemblages occur on each of the sub-regions investigated, a deeper evaluation of taxonomic (family), trophic and size structure was carried out for each sub-region (Figure 7, Figure 8 and Figure 9).

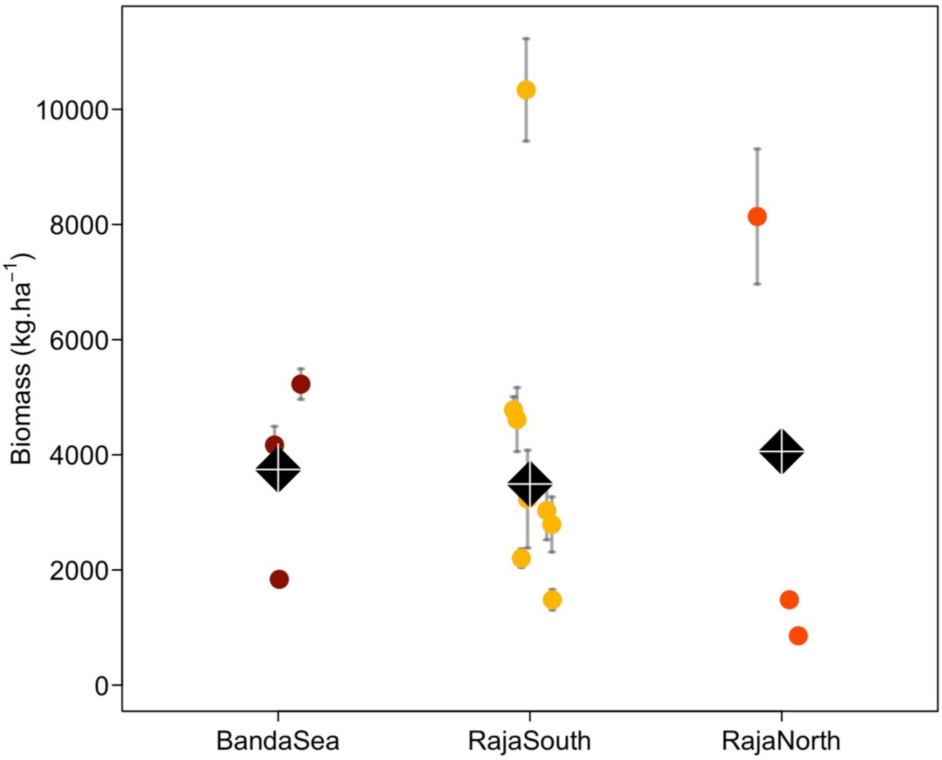

Figure 6: Patterns of total coral reef fish biomass among the surveyed sub-regions of Raja Ampat. Coloured dots represent each survey, with intervals representing uncertainty in the values that arise due to the resampling procedure used to incorporate multiple phases in one single survey unit (see Morais and Bellwood 2019 for details). Black diamonds with white internal crosses represent the mean biomass of each sub-region.

Some common features can be identified from the separate analyses of the taxonomic (family-level), trophic and size biomass structure in the sub-regions. First, fusiliers (Caesionidae) composed the largest biomass in the three sub-regions. The amount of biomass that they comprised, on average, in each sub-region, was remarkably similar: 1,359 ± 74 kg ha^{-1} in the Banda Sea, 1,298 ± 36 kg ha^{-1} in the southern Raja Ampat and 1,308 ± 71 kg ha^{-1} in the northern Raja Ampat. Second, planktivores composed most of the biomass in all three sub-regions, much likely due to the fusiliers. This was also consistent, ranging from 1,896 ± 102 kg ha^{-1} in the Banda Sea, to 2,007 ± 75 kg ha^{-1} in the northern Raja Ampat and 2,316 ± 94 kg ha^{-1} in the southern Raja Ampat. Finally, the size class of fishes between 16 and 30 cm TL also composed most of the biomass, once more likely due to the representability of fusiliers in this size class.

In the Banda Sea, triggerfishes (Balistidae) were the second-most representative family in terms of biomass, with 848 ± 43 kg ha^{-1} (Figure 7). Omnivores composed a higher biomass here compared to the other sub-regions, possibly driven by dense schools of the black triggerfish (*Melichthys niger)* and the pinktail triggerfish (*M. vidua*). In terms of size structure, no fishes larger than 80 cm TL were detected in the Banda Sea; and even fishes larger than 50 cm TL composed only a negligible part of the biomass (Figure 7).

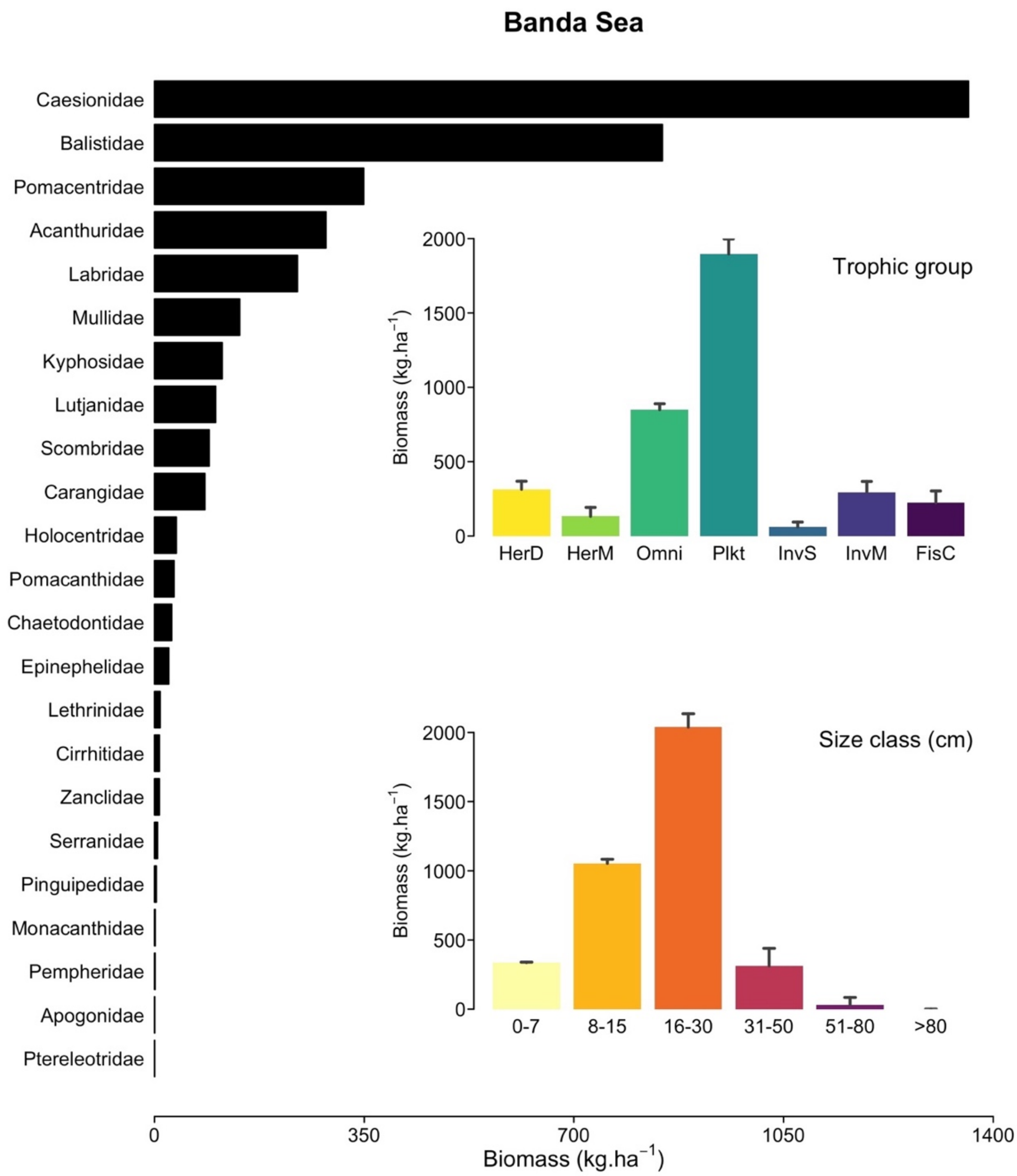

Figure 7: Taxonomic (family), trophic and size class patterns of coral reef fish standing biomass in the Banda Sea. Only 23 families are depicted, although 25 were detected in the surveys of this sub-region.

In the southern Raja Ampat, jack and trevallies (Carangidae) were the second-most representative family in terms of biomass, with 561 ± 75 kg ha^{-1} (Figure 8). Piscivores composed a higher biomass here compared to the other sub-regions, possibly driven by schools of the orangespotted trevally (*Carangoides bajad)*. Similar to the Banda Sea, no fishes larger than 80 cm TL were detected in the surveys of southern Raja Ampat, although fishes larger than 50 cm TL composed a non-negligible part of the total biomass (Figure 8).

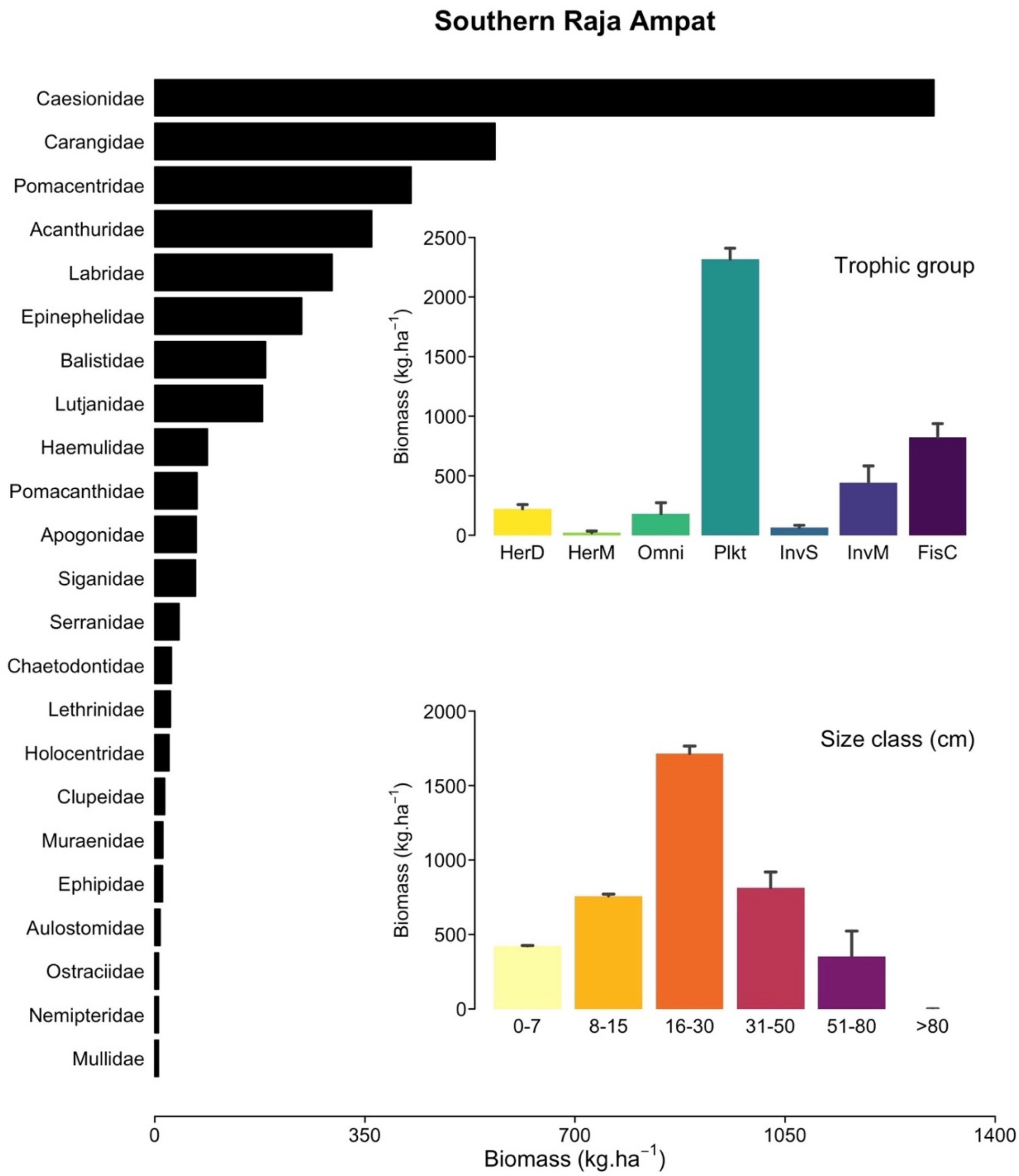

Figure 8: Taxonomic (family), trophic and size class patterns of coral reef fish standing biomass in the southern Raja Ampat. Only 23 families are depicted, although 36 were detected in the surveys of this sub-region.

In the northern Raja Ampat, wrasses and parrotfishes (Labridae) were the second-most representative family in terms of biomass, with 593 ± 366 kg ha^{-1} (Figure 9). However, the very high variability likely reflects the divergence in species composition among samples evident on Figure 5. Herbivores-detrivores composed a higher biomass here compared to the other sub-regions, potentially due to schools of the rivulated parrotfish (*Scarus rivulatus)*. This was the only sub-region where fishes larger than 80 cm TL were detected in the surveys, mainly large bumphead parrotfish (*Bolbometopon muricatum*).

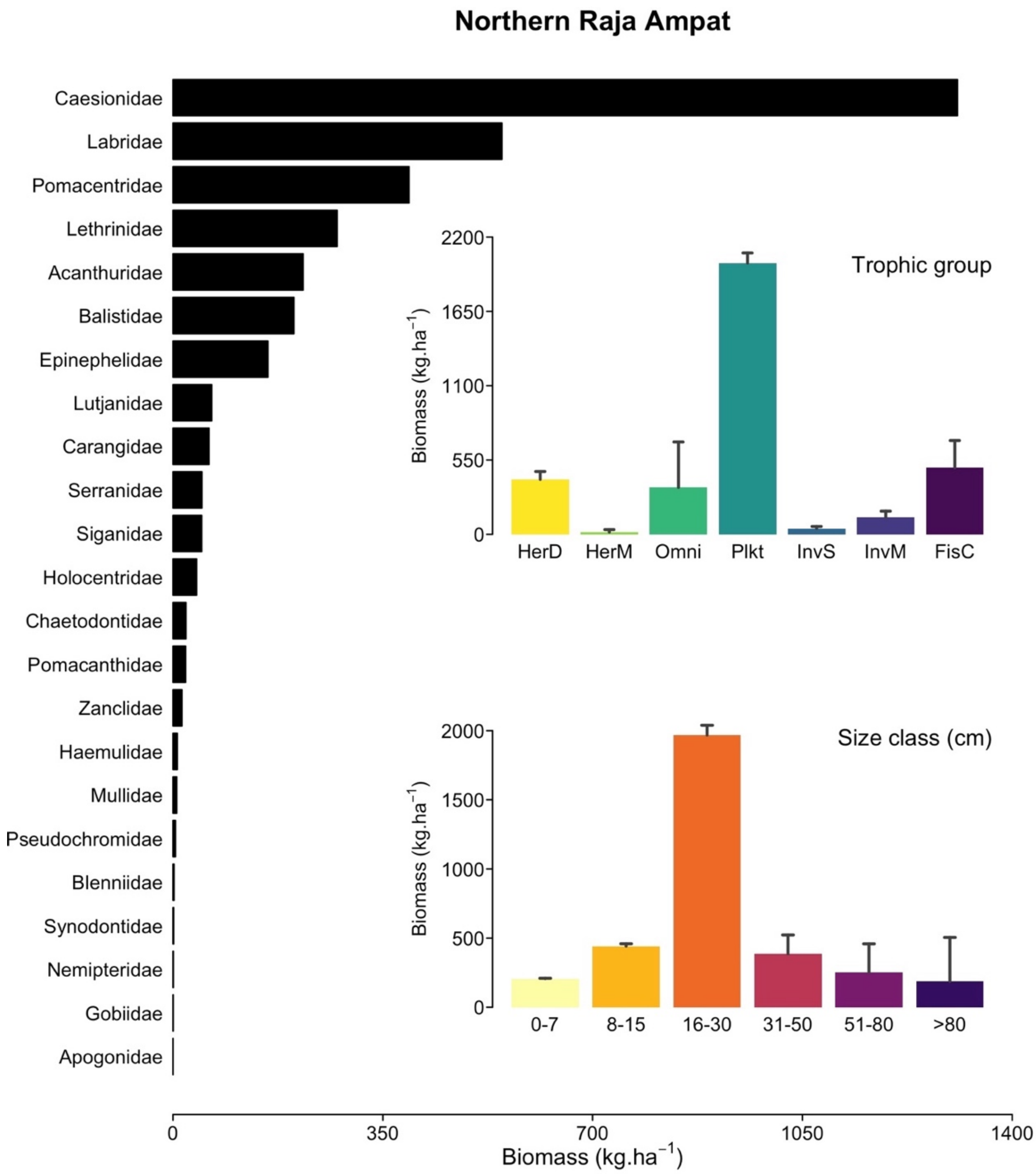

Figure 9: Taxonomic (family), trophic and size class patterns of coral reef fish standing biomass in the northern Raja Ampat. Only 23 families were detected in the surveys of this sub-region.

Remarks and general future perspectives

High biodiversity, high fish biomass and an important contribution from planktivores are some of the features that summarise Raja Ampat's coral reef fish assemblages. Regional species richness seems to increase more steeply with sampling effort here in the Coral Triangle compared to the adjacent species-rich Great Barrier Reef, a similar pattern as found by Barneche et al. (2019). Also, the average total fish biomass in the three surveyed sub-regions (3.5 to 4 ton.ha^{-1}) is at a similar magnitude as has been described for isolated coral reefs in the Pacific Ocean with no, or only limited, human population and exploitation (e.g. D'agata et al., 2016; Friedlander and DeMartini, 2002; Sandin et al., 2008). Furthermore, the high abundance of planktivores matches expectations that currents are a significant provider of nutrients and food to coral reefs here. Although current intensity was not a factor distinguishing fish assemblages among surveys within the region, it is likely that the strong currents observed have a stronger role in determining fish assemblages here when compared to other regions. The is further supported by benthic organisms that significantly rely on plankton to their nutrition, such as gorgonians, very abundant. Taken together, these findings suggest that Raja Ampat's reefs are thriving ecosystems, highly valuable both from the perspective of their biodiversity and the abundance of life that they are able to sustain.

However, some quantitative evidence arising from the data collected in this expedition suggests caution in the evaluation of how healthy fish assemblages in Raja Ampat are. For example, we noticed some indicators traditionally associated with continued fishing activities, such as the relatively low abundance of large-bodied fishes and low abundance of large predatory fishes, such as big groupers, giant trevallies and, especially sharks (Cinner et al., 2018; D'agata et al., 2016; Robinson et al., 2017). Three possible explanations exist to this pattern. First, it is possible that these represent natural conditions for the reefs here investigated that do not match the traditional perception of what a truly healthy reef should be. This is supported by recent research showcasing how different combinations of benthic and fish assemblages can exist in both healthy and degraded coral reefs (e.g. Donovan et al., 2018). Second, it is possible that reef communities have not yet recovered from destructive or unsustainable fishing practices known to have occurred in Raja Ampat in the recent past (e.g. Ainsworth et al., 2008a; Varkey et al., 2010). And third, it is possible that destructive or unsustainable fishing activities continue to happen throughout the archipelago, maintaining a constant state of relatively low abundance of large predatory fishes. Further research attempting to evaluate these scenarios is urgently needed and would ideally involve a comprehensive spatial and temporal sampling coverage. Furthermore, data collect in this expedition can serve as a baseline against which to evaluate potential future data collections initiatives.

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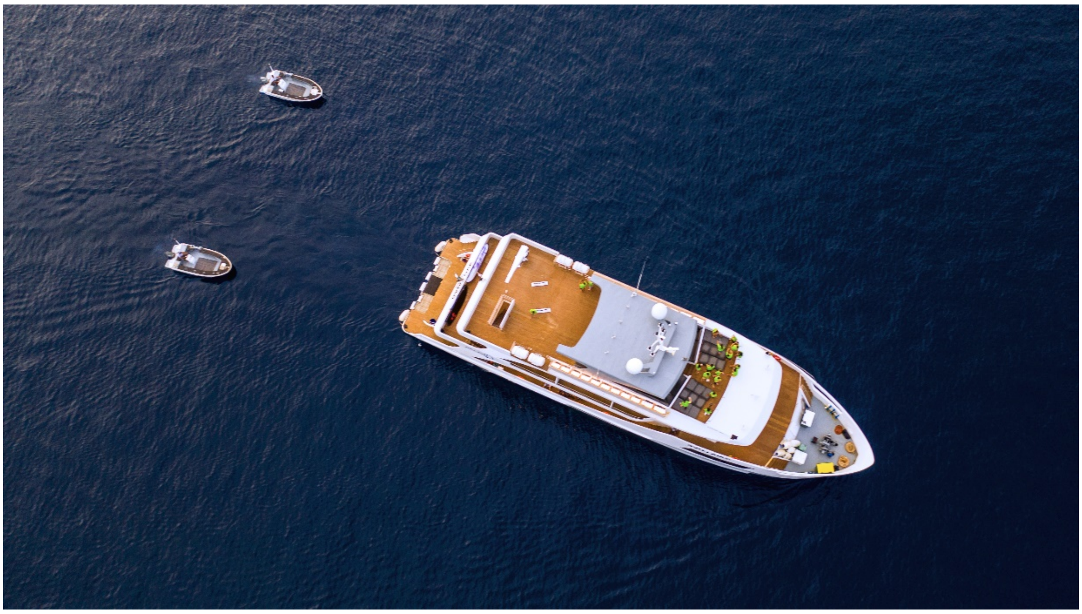


Summary from Team Alpha - MV GAIA LOVE

By: Anna Oposa

Team Alpha
Jessie Shaw : Kiki Tokizawa : Quinan Zhang : Tyler Wang : Paul Muir : Michael AW : Arica Hilton :
Rui Wang : Jennifer Hayes : David Doubilet : Cassandra Dragon : Kitty Trandoann :
Emily Chan : Charlotte Young : Anna Opposo : Richard Meng : Stuart Ireland : Lim Yew Kuan : Fabian Schorp

The opportunity to dive in Raja Ampat was a dream come true. As a marine key biodiversity area at the heart of the Coral Triangle, it can only be described in superlatives: the most biodiverse, the craziest currents, and the clearest visibility. No two dives were alike, even if we dove at the same site or same areas.
As part of the Plastics Team, I helped our Principal Scientist, Charlotte Young, conduct surveys almost daily. We were surprised – but also pleased – to find very little plastic. The results could have been affected by the season, currents, and tides, but we were nevertheless happy to report that we didn't collect a lot of plastics. Among the specimens collected, microfibers were relatively high, which made me reflect on the clothes we buy and wear, and how what is invisible to our eyes can still affect the seas. What made the journey more memorable was the mix of characters on board Gaia Love: conservationists, artists, photographers, and scientists, all united by our love for the sea. We were all storytellers and students of the seas, and I left Indonesia a bit more hopeful for the future for our blue planet.

GAIA LOVE IN NUMBERS
17 divers, 2 snorkelers, and 22 crew members
Total of 08 microplastics trawl
Total of 4 fish surveys
Total of 6 coral surveys
Total of 33 dives (7 night and 26 day dives)

FOOD AND DRINK IN NUMBERS
70 chickens & 960 eggs
38 bottles of wine & 183 cans of beer
18 kgs of coffee
200 kgs of rice
45 kg of mangoes
105 kg of watermelons
Two big bunches of bananas (consumed ASAP)

GAIA LOVE DAILY LOG
Date: September 30, 2018
Boat location: Ambon
Dive sites: Laha (Checkout - A01), Ambon Bay (Blackwater – A02)
Weather conditions: Sunny

Ambon - Laha 1	A01	S3° 42.338' E128° 06.210'	14:30	Check dive
Ambon Bay	MP01	S3° 41.788' E128° 06.384'	18:30	
Ambon Bay	A02	S3° 42.036' E128° 06.689'	18:30	Black Water

Expedition members boarded Gaia Love in the morning, right after arriving in Sorong. We were warmly welcomed by the Gaia Love crew. After breakfast, safety briefing, boat briefing, and lunch (and a bit of nap time), we were ready for our first dive.

At 14:30, dive groups headed out for a shallow (5-7m) check-out dive in Rhino City, searching for critters, and trying out gear and Four Element suits. We found frogfish, moray and ribbon eels, and unfortunately lots of rubbish: plastic bags, food packaging, and a shoe, among others.

Knowing there was more plastic around, the Plastics Team, led by Charlotte, assembled to start our first data collection. We built a DIY spinnaker boom on a dive boat, and deployed the net around the site for 15 minutes. A visual inspection of the net showed plastic bags, cups, and tiny fish. A detailed analysis will be conducted.

Then it was time for the first blackwater dive! Eight divers plunged into 25-26C water in Ambon Bay to look for creatures that come out at night.

Dinner was waiting back in Gaia Love. At dinner, we began to sail, encountering big waves throughout the night.

Date: October 1, 2018
Boat location: Sorong
Dive sites: Batu Kapal (A03), Lava Flow (A04), Lampu Hijou (A05)
Weather conditions: Sunny

Banda Neira - Batu Kapal	A03	S4° 29.197' E129° 55.806'	11:30	
Banda Neira - Lawa Flow	A04	S4° 30.330' E129° 52.812'	15:30	Coral Reef/Fish Biomass
Banda Neira -Lampu Hijau	MP02	S4° 30.317' E129° 53.213'	17:00	
Banda Neira -Lampu Hijau	A05	S4° 30.317' E129° 53.213'	19:30	Bonfire

Gaia Love skipped the morning dive to continue powering through the rolling waves. We reached the first site of the day by noon. Batu Kapal was the first site, found in the Maluku Islands, also known as the Spice Islands because nutmeg, mace, and cloves were once exclusively found there. In between dives, the Plastic Team sorted the wastes collected from Day 1.

The second site was Lava Flow, right beside Gunung Api, a volcano that erupted in 1988. The molten lava destroyed the marine life around the island, but the story had a happy ending: within five years, the hardened lava became fertile ground for recovery. Now, over 120 species of coral have been identified at the site, supporting diverse schools of reef fish. It was the perfect site for the Coral and Fish Teams to get to work!

Both teams did 50-meter transects. The Coral Team laid out two transects, one between 8-10 meters and another at 18-20 meters. The Fish Team’s transect was between 9-10 meters. A few team members were assigned to video and photo documentation, while others were in charge of identifying and counting.

The third dive was a bonfire dive, a night dive at Lampu Hijou. While divers were down under, the Plastics Team began counting and identifying the types of plastics collected. Tomorrow at 4AM, Gaia Love is scheduled to sail to Roon.

Date: October 2, 2018
Boat location: Banda Islands
Dive sites: Tanjung Noret (A06), Tanjung Noret (A07), Lava Flow (A08)
Weather conditions: Sunny with strong winds

Outer Banda - Tanjung Noret	A06	S4° 33.493' E129° 39.992'	7:30	
Outer Banda - Tanjung Noret	MP03	S4° 33.243' E129° 40.034'	9:45	
Outer Banda - Tanjung Noret	A07	S4° 33.493' E129° 39.992'	10:30	
Banda Neira - Lava Flow	A08	S4° 30.330' E129° 52.812'	14:30	

It’s hammer time! We reached the first site, Tanjung Noret, early in the morning. By 7AM, divers were on the dive deck ready to look for hammerheads.

The search did not disappoint: eight minutes into the dive, the first group saw a shiver of hammerheads between 30-32m. Other dive groups spotted hammerheads between 30-40m. Temperature dropped between 21-22C and currents were going in different directions, but no complains! Everyone was thrilled to see hammerheads. After exchanging hammerhead stories over breakfast, the microplastics team deployed the net to trawl for plastics. A rapid visual inspection revealed fewer large plastics than Ambon, but a closer count will be conducted to identify microplastics

For the second dive, we went back to the same site, Tanjung Noret, in hopes of finding hammerheads again. No sharks greeted us the second time around, but the current was calmer, the visibility was better, and there were diverse schools of fish and coral to keep all divers entertained. After lunch, we set sail back to Lava Flow to dive in the middle of the afternoon. Paul, our resident coral scientist, says the site has "very high coral cover and moderate/high diversity.” The day ended with an easy dive in Lava Flow and a beautiful sunset by the volcano Gunung Api.

Date: October 3, 2018
Boat location: Roon
Dive site: Too Many Fish (A09, A10)
Weather conditions: Sunny and cloudy

Koon - Too Many Fish	A09	S3° 55.680' E131° 12.741'	8:30	
Koon - Too Many Fish	A10	S3° 55.680' E131° 12.741'	11:30	Coral Reef & Fish Biomass
Koon - Too Many Fish	MP04	S3° 55.475' E131° 12.832'	13:15	

We arrived in Roon at 7:30AM after a bumpy crossing. During the pre-dive briefing, we were told to beware of strong currents in the dive site Too Many Fish. To everyone's surprise, the dive had only a mild current. The site lived up to its name: there were too many fish! In addition to schools of different kinds of fish, a bumphead parrotfish, and a whitetip shark, turtles were also spotted.

The second dive began in the same site at noon. We expected similar calm conditions, so the Fish and Coral Teams prepared for their respective transects. There were still too many fish, but there were also too strong currents, bringing divers to different directions. Despite the current, the Coral Team managed to place their 50-meter transect at 7 meters. Our resident coral scientist, Paul, says the site had fair to high diversity and healthy reefs.

The Fish Team had to abort their first dive due to the conditions. On their second attempt, they were able to lay the transect and conduct the survey. After the two dives, the Microplastics Team went out on a skiff to deploy the net. Our Principal Scientist, Charlotte, completed the microplastics count by the evening. We only collected five pieces of plastic: three filaments, one film, and one fragment. This was the least number of plastics among the three sites, possibly because Ruun has been our most remote site so far. This evening's night dive was cancelled due to the winds, but this means we'll reach Raja Ampat faster! Tomorrow, we arrive in Raja Ampat!

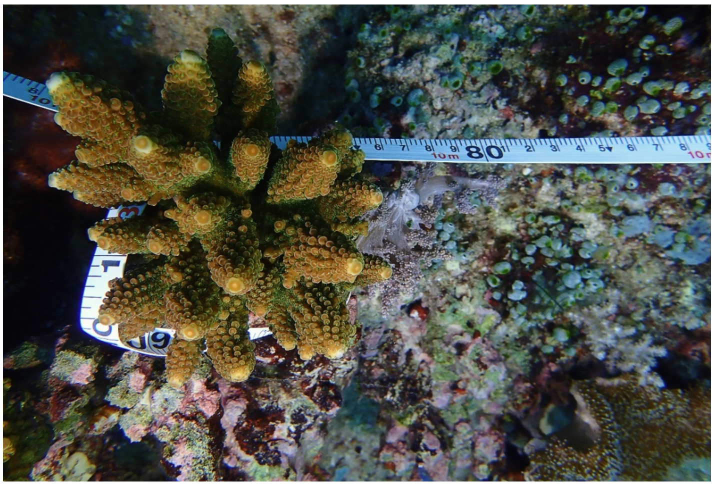
Date: October 4, 2018
Boat location: Misool, Raja Ampat
Dive site: Tank Rock (A11), Boo West (12), Yelliet Kecil (A13)
Weather conditions: Windy and cloudy

Misool - Fiabacet - Tank Rock	A11	S2° 13.136' E130° 34.063'	8:30	
Misool - Boo - Boo West	A12	S2° 13.132' E130° 34.526'	11:30	
Misool - Yelliet - Yelliet Kecil	A13	S2° 11.757' E130° 36.620'	15:30	Coral Reef & Fish Biomass
Misool - Yelliet-Yelliet Besar	A14	S2° 11.682' E130° 36.211'	19:30	Bonfire

Gaia Love now reporting from Raja Ampat! The weather during breakfast was gloomy, with dark skies and strong winds. But the weather couldn't rain on our parade - everyone on board was excited to be in Raja Ampat and even more excited to be in the water.

Our first dive was in Tank Rock at 8:30AM. Within one minute of getting in the water, a queen manta welcomed one dive group to Raja Ampat. The whole dive was a never-ending meadow of soft and hard corals and schools of fish in different sizes. We also spotted a couple of reef sharks, a pair of eagle rays, and a pair of mantas at the end of the dive. It was a haven for photographers using their wide angle lenses.

On the second dive in Boo West, there were rows of sea fans, large and small. The palette of the coral reefs ranged from yellow to pink to purple. The school of silver slides showed off as they moved rapidly as a pack.



The third dive was a working dive! The dive at Yelliet Kecil began at 1600. The Fish Team tried to put a 50-meter transect, but the topography of the reef sloped and they ran out of space, needing to adjust the entire transect another 10 meters. The Coral Team was hard at work - they recorded the hard coral diversity in the first two sites, up to 40m. They recorded one rare coral species at 45 meters. On the third site, they laid a 50-meter transect at 15-20m with video and macro photography, and another 50-meter transect between 5-10m. Paul reported that soft coral cover was high, and hard coral cover was medium.

In this site, Kitty spotted a rare albino leopard shark and was able to take a video. After cancelling night dives for the last two nights due to rough weather, the night dive for tonight finally pushed through! Tomorrow, we continue diving in Raja Ampat and resume data collection for microplastics.

Date: October 5, 2018
Boat location: Misool, Raja Ampat
Dive sites: Tank Rock (A15), Magic Mountain (A16), Neptune’s Fan Sea (A17), Under the Began (A18)
Weather conditions: Sunny

Misool - Fiabacet - Tank Rock	A15	S2° 13.136' E130° 34.063'	7:00	
Misool -Warakaraket Magic Mountain	A16	S2° 15.557' E130° 38.878'	10:30	
Misool - Wayil- Neptune's Fan Sea	A17	S2° 12.801' E130° 27.320'	15:00	Coral Reef
Misool - Wayil- Close to Barracuda	MP05	S2° 11.728' E130° 25.784'	16:45	
Misool - Wayil - Under the Bagan	A18	S2° 12.219' E130° 25.678'	19:30	Bonfire

Highlights:
It was an early day for Gaia Love! We were back in Tank Rock by 7:00. The site, just like yesterday, dazzled us with its healthy coral cover and numerous species of fish. One group saw an oceanic manta.

After breakfast, we geared up for Magic Mountain. This site was described in superlatives by divers who had been there before. Magic Mountain newbies would say that the experience lived up to the hype: visibility was about 20 meters, and there were schools and schools of yellow snappers, yellow-tailed fusilier, and silver sliders. Towards the end of the dive, when many of us were on our safety stop, an ocean manta decided to come out to play. Because of the manta, Kuan stayed underwater longer than intended and had to do a 15-minute deco stop. He ran out of air and only completed 9/15 minutes. His two dive computers went into Error, so he was advised not to dive for 48 hours.

The afternoon was a working dive for the Coral and Fish Teams. Paul, our coral scientist on board, reported a rare Acropora coral found at 40-45m depth. The species, *Acropora simplex,* is only found in Central/East Indonesia. The team also found *Acropora pichoni*. Both species are rare and restricted to a small geographical area. The third dive was in Neptune's Fan Sea. "It's a sea fan buffet," said our Cruise Director Gerry during the dive briefing. "You will see sea fans of all shapes, sizes, and colours!"

And a sea fan buffet it was. There were rows and rows of sea fans. At about 10 meters, we spotted pygmy seahorse clinging to the fan coral. It was pink - just like the seahorse in the Elysium Coral Triangle seal!
After the third dive, the Microplastics Team went out to collect data. Fifteen minutes in the water yielded jellyfish-filled water that we unfortunately couldn't use because the debris was mixed with the jellies. We returned the sample back to the sea. Other expedition members had the chance to set foot on land by staying in the beach. After dinner, several divers went out for a bonfire dive underneath a bagan. Tomorrow is another day in Raja Ampat!

Date: October 6, 2018
Boat location: Misool, Raja Ampat
Dive sites: 4 Kings (A19 and A20); Wedding Cake (A21); Black Water (A22)
Weather conditions: Sunny

Misool - Nobul - 4 Kings	A19	S2° 12.506' E130° 22.673'	6:45	
Misool - Nobul - 4 Kings	A20	S2° 12.506' E130° 22.673'	10:30	
Misool - Wayil - Wedding Cake	A21	S2° 12.283' E130° 25.165'	15:00	
Misool -Wayil	MP06	S2° 11.666' E130° 26.085'	16:50	
Misool - Wayil Black Water	A22	S2° 11.399' E130° 25.540'	19:30	BlackWater

Another beautiful day in Raja Ampat! We started 15 minutes earlier than the day before, at 6:45AM. We did our two morning dives in the same site: 4 Kings, a beautiful dive site that earned its name because of the four pinnacles. Fun fact: 4 Kings is actually the English translation of Raja (king) Ampat (four).

There were schools and schools of glass fish glimmering, forming clouds above, beneath, and around us. There were also barracudas, a giant grouper hiding under a coral, barramundis, yellow-tailed fusiliers, and jacks. The third dive in Wedding Cake was supposed to be a working dive for the Coral and Fish Teams, but the current didn't allow it. It transformed into a leisure dive for all divers, with the current coming in and out, changing our direction several times. There was a hawksbill turtle, nudibranchs, and a meadow of soft and hard coral in various colors.

The Microplastics Team went back out at 17:00. Unfortunately we collected another jar full of jellies just like yesterday, which means we are unable to use the sample. But on the flip side, the good news is that we didn't find large pieces of plastics like bags or food packaging. The weather was stable enough for a blackwater dive, setting nine divers back into the water for their fourth dive of the day!

Tomorrow is another day in Raja Ampat, with four scheduled dives, starting with Pele's Playground. Internal note: Arica and Kuan did not dive today. Arica did two dives without safety stops.

Date: October 7, 2018
Boat location: Misool, Raja Ampat
Dive sites: Pele's Playground (A23), Blue Water Mangrove (A24), Microplastics Trawl (MP07), Blackwater (A25)
Weather conditions: Dark and cloudy

Misool - Pele- Pele's Playground	A23	S2° 08.589' E130° 10.214'	7:30	
Misool - Nampale Blue Water Mangrove	A24	S1° 48.076' E129° 38.589'	15:00	
Misool - Entrance Blue Water	MP07	S1° 49.038' E129° 38.390'	17:25	
Misool - Black Water Dive	A25	S1° 46.752' E129° 32.693'	19:30	Black water

The first dive was in Pele's Playground at around 8:00AM. Because it was dark and cloudy, the visibility was estimated to be only 7-10 meters, the lowest we've had during the trip so far. Some divers went down deep despite the low vis to explore what could be in the blue. It was a good call -- they witnessed a feeding frenzy, as if a marine ecology teacher wanted to show a class the food chain. There were jacks and snappers hunting and barracudas feeding on the silver slides. They even witnessed barrel sponges spawning! It was a sensory overload. During the dive, divers from another boat thought that someone left his camera in the water and took it. It was David’s and he did not drop it, just left it to use another camera.

Due to the low visibility, Gaia Love decided to cancel the second day dive and start traveling 50 miles to the next site: Blue Water Mangrove. During the travel, dolphins played by Gaia Love’s side. We reached the area past 2:30PM and started gearing up. The pre-dive briefing was a bit tense due to the site's history of a crocodile attack that injured a diver years ago. Divers were informed of different scenarios and responses.

The waters in Blue Water Mangrove were as flat as a lake. No crocodiles were in sight, so we got in the water. It was a postcard-worthy environment, with corals growing on the mangroves' roots. It was surreal to see hard corals and soft corals right beside and beneath mangroves! We also spotted a range of critters like a helicopter goby hopping about, a wasp fish, mantis shrimp, nudibranchs, archerfish by the surface. We also unfortunately found debris like sacks and a plastic cup.

The Fish and Coral Teams got a day off today. After the dive, the Microplastics Team went out for a trawl. A visual inspection showed plastic bags and other items - including one labeled "Made in the USA." A count using the microscope will be done tomorrow. It's also Jennifer's birthday, so the chefs baked a cake for her and we sang happy birthday at dinner. After dinner, the divers were able to squeeze in another blackwater dive!
By tonight, we'll start a journey of 105 miles to our next site.

Date: October 8, 2018
Boat location: Penemu and Yangeffo, Raja Ampat
Dive sites: Melissa's Garden (A26), Citrus Ridge (A24), Microplastics Trawl (MP08)
Weather conditions: Sunny

Penemu - Melissa's Garden	A26	S0° 35.390' E130° 18.909'	9:30	Corals
Yangeffo - Citrus Ridge	A27	S0° 30.646' E130° 27.348'	15:00	
Yangeffo	MP08	S0° 30.472' E130° 27.250'	16:45	

After traveling for several hours, we arrived in Penemu after breakfast. Divers on board Gaia Love explored Melissa's Playground, which was covered in diverse types of hard corals. The visibility was very good, enabling us to watch the schools of fish and other creatures with glee. The currents ranged from mild to moderate to strong to mild again. A blacktip shark swam by during the safety stop. We resurfaced at 11AM to give way to another group.

After lunch, we commenced our journey to Yangeffo, so there was no time for a mid-day dive. In Yangeffo, we went in Citrus Ridge. During the pre-dive briefing, we were told that we would see a lot of orange corals. We were in for a treat: in addition to orange corals, one group spotted a wobbegong - the first one for the entire trip! There was also a walking shark wedged under a coral, a leaf scorpionfish, a school of barracudas, hawksbill turtle, and sea krait. A Microplastics Trawl was done after dive 2.

The night dive was cancelled due to strong currents. We began traveling to our next site immediately after the cancellation. Tomorrow, we're aiming for four dives.

Date: October 9, 2018
Boat location: Batanta and Dampier Strait
Dive site: Pulau Dayang (A28), Cape Kri (A29), Sawandarek (A30), Channel (Blackwater - A31)
Weather conditions: Sunny and cloudy

Batanta - Pulau Dayang	A28	S0° 47.647' E130° 30.288'	7:30	
Dampier Strait - Cape Kri	A29	S0° 33.391' E130° 41.417'	12:30	
Dampier Strait - Sawandarek	A30	S0° 35.419' E130° 36.317'	16:00	Corals / Fish Biomass
Dampier Strait - Channel	A31	S0° 35.815' E130° 41.522'	19:30	Black water

Our first dive in Pulau Dayang was a shallow dive at 15-20m. The site is known to be a cleaning station for mantas, and the prediction did not disappoint: two reef mantas glided by, one mid-dive and another towards the end. Gaia Love then travelled to the second dive, Cape Kri, famous for its school of sweetlips at 40m and infamous for its ripping and whirlpool currents. The sweetlips were there where they were expected to be. The currents changed constantly, which was an enabling environment for a wobbegong, a school of jacks and barracuda, blacktip and whitetip reef sharks, and Napoleon wrasse to say hi. Divers resurfaced far from where they were dropped off.

During the third dive, our resident artist Arica Hilton had an underwater photo shoot with other divers from Gaia Love. The other groups proceeded to Sawandarek, a dive site underneath a jetty of a village. From the boat, it looked like a sleepy, nondescript area, but the first few minutes in the site already showed off a school of sweetlips at 5 meters. There were schools of unicornfish, snappers, silver sides, and jacks. There was also a lobster hiding under a reef and a hawksbill turtle that seemed to be confused whether it would take a breath or stay down.

In Sawandarek, Cass's strobe diffuser fell off without her noticing. She continued taking photos and saw David swimming towards her. She thought David was trying to model for her, until she saw what was on top of his head – her diffuser! After dinner, a smaller dive group proceeded to a blackwater dive, the fourth dive for the day and the last night dive for the trip! When the night divers returned to Gaia Love, the transit to Mioskon began.

Date: October 10, 2018
Boat location: Dampier Strait
Dive site: Blue Magic (A32), Cape Kri (A33)
Weather conditions: Sunny and cloudy

Dampier Strait - Blue Magic	A32	S0° 30.414' E130° 44.290'	7:30	
Dampier Strait	MP09	S0° 30.100' E130° 43.783'	9:35	
Dampier Strait - Cape Kri	A33	S0° 33.391' E130° 41.417'	11:00	

It's the last diving day before reuniting with the other expedition members. The first dive was in Blue Magic. The site lived up to its name: Blue Magic was enchanting, beginning with a wall of barracudas and a school of jacks welcoming the divers after entry. There were two wobbegongs – one lying on top of a reef, ready to model for photos, and the other hiding under a reef.

The current picked up towards the end of the dive, which meant reef hooks needed to be pulled out during safety stops. We returned to Cape Kri for the second dive -- the last dive of the Expedition. We were better prepared for its ripping currents this time (mentally, at least). Many of divers paid a courtesy call to the resident sweetlips, then allowed the current to take them where it pleased. We cruised with the strong surge, watching the marine life as if it were on a screen – reef sharks, soft corals, hard corals, pufferfish, fusiliers, and a hawksbill turtle among Cape Kri's cast of characters. Upon returning, Kitty and their group's dive guide returned last because the current made them drift on the opposite side of the island.`

Summary from Team Echo - MSY Mola Mola

By: Jacqueline Lam

Team Echo
Alex Rose : Rebecca Ziegler : Marco Steiner : Andreas Jaschek :James Clarke
Gillian Clarke : Levente Rozsahegyi : Aaron Halstead : Jacqueline Lam : Yizhen Ong
Mary Sayre : Lindsey Dougherty : Matthew Smith : Lauren Thomas : Alexander Finden : Juan Romero

When I signed up to be a part of the Elysium team, I was full of excitement to be a part of Raja Ampat conservation efforts. This was the biggest scientific diving expedition that I had seen, with 3 boats and over 50 team members across the board. On the MV Mola Mola, we had a winning combination of passion and dedication to the cause, which helped the team soldier on when adverse weather conditions resulted in a change of route plans. Originally planning to look for whale sharks in Cenderawasih Bay, an incoming typhoon led us to stay within the confines of Raja Ampat. Nonetheless we were pleasantly surprised by the biodiversity in the area. The group kept an open mind of what to expect for marine life sightings, and were rewarded with critters including the bargibanti seahorse, electric clams, and plenty of wobbegong.

The scientific teams were able to complete all planned surveys, and had positive findings on coral as well as fish biodiversity. The plastics surveys also went well, with the team diligently trawling for microplastics samples. Working as a team, we helped to efficiently conduct the scientific surveys, share the boat's small stash of alcohol, and generally keep each others spirits up with antics like the equatorial crossing ocean jump and dining table climbing contests. I could not have asked for a better bunch to spend a week out at sea with, and would work with the group again in a heartbeat.

Day 1 (1 October 2018)
Matan - 00.57.276S 131.8.813 E
Cape Kri - 00.33.566S 130.41.240E
Mioskoon - 00.29.941S 130.43.474E
After a calm evening docked at the port in Sorong, the Mola Mola set out on her maiden voyage with the research crew of 16 and a boat crew of 18 on the Elysium Epic expedition. Before the departure there had been a key decision the team had to make regarding route changes. A typhoon was heading towards the path of our original route to Cenderawasih Bay for the whale sharks, and sadly the team had to opt for a route from South to North Raja Ampat instead. The opportunity to dive with whale sharks had been a big draw for the group, and understandably there was some disappointment at having to give it a miss. The cruise director rightly emphasized safety first in avoidance of the typhoon, and would later make sure that the Mola Mola team had some of the best dives they could have hoped for.

Our first dive starting 8am was at Matan reef, full of vibrant coral and marine life. There were shrimp hiding in sand dunes with gobies standing guard, and cuttlefish playing hide and seek with divers among coral reefs. We had 2 more dives in the afternoon in Cape Kri and at dusk in Mioskoon, before the boat continued on its journey to the next site in the Dampier Straits. Team captain Andreas Jaschek raised the expedition flag when we left port, together with the crew members. We are off to a great start with sunshine and blue skies over the horizon, with more updates to come.

Day 2 (2 October 2018)
Blue Magic - 00.30.414S 130.44.290E
Sardine Reef - 00.32.066S 130.42.977E
Yanbubak Jetty - 00.34.478S 130.39.393E
Team Mola Mola had an early start at 7am at the Blue Magic dive site, and was treated to a magical underwater scene of corals teeming with fish biodiversity. In between dives, we kept ourselves busy poring over fish and coral identification books to prepare ourselves for the scientific component of the expedition. There was also a spot of very rainy weather, after which we discovered that the roof of the Mola Mola was not completely water proof. Dinner was spent avoiding the streaming rainwater from the windows and roof, while some team members sought refuge on the deck after their bedrooms were also flooded with rain water.

The team completed our first surveys today: trawling for microplastics near Sardine Reef, surveying fish and coral life at Yanbubak jetty. The impact of climate change must be measured if it is to be managed. The first of our surveys in Raja Ampat will contribute towards longer term monitoring and assessment of marine life biodiversity in the region. Initial analysis of the microplastics show that majority of the type of plastics collected in Raja is line filament from fishing rope, second being plastic fragments. It is imperative that action is taken, not just amongst coastal communities. Plastics are being disposed of by urban residents further inland, and poor waste management in the region is resulting in much of the plastics we use ending up in the ocean, in fish, sea birds and ultimately in top predators of the food chain, including human beings.

Day 3 (3 October 2018)
Sauwenderek Jetty - 00.35.493S 130.35.911E
Manta Sandy - 00.34.798S 130.32.534E
Dayang Bay - 00.47.467S 130.30.349E
After a night of rainy weather and leaky roofs the weather cleared up spectacularly for Day 3 of our surveys. Team Mola Mola spent the day in Mioskoon and thoroughly enjoyed the sunny weather which created some pretty lighting conditions underwater. The Coral team went out to Sauwenderek jetty and found significant coral diversity, teeming with fish life. Lots of wobbegongs just lurking around amongst the corals, and we made some good progress with the fish surveys as well. Having dived mostly in Malaysia and the Philippines, seeing the wobbegongs in Raja Ampat was quite an experience. It was heartening to see them in healthy numbers and varying sizes, a proof of strong species health. Just before lunch, the team camped out at the Manta Sandy cleaning station for a silty dive and hung out with the manta rays. The gentle giants were much friendlier outside of the cleaning station, and granted us with graceful swim overs while the group watched in awe. The drone team were able to get some spectacular aerial shots of sunset, as well as the plastics team doing their regular trawl.

Day 4 (4 October 2018)
Balbulol Reef - 02.01.655S 130.41.316E
Wedding Cake - 02.12.081S 130.25.165E
It is another day in Mioskoon, starting with a morning dive in Balbulol Reef, and Team Mola Mola has made great progress with the surveys so far. At Sisters Reef on the second dive, most of the coral survey targets have been done, with positive findings of 100% coral cover on all surveys so far. We did our third dive at Wedding Cake, and were mesmerized by the tiered coral reef, which offered much to be discovered in the crevices of each tier. After completing 3 fish surveys, we have found 170 species in the regions covered to date. Similarly, the plastics surveys are going strong at the halfway mark and Mola Mola are starting on black water surveys today. The team found lots of baby squid, shrimp, jellyfish and other strange and wonderful marine micro organisms on our first black water dive. For many of us it was the first black water dive, and trying out the system for the first time made for an apprehensive experiment. Nonetheless the team very gamely went into the night and came back triumphant with some great footage. Go team!!

Day 5 (5 October 2018)
Having continued to Misool overnight, the team was raring to go and check out new dive sites in the area, starting with Wayil Pinnacle. We had some respite from rainy weather today, and everyone has enjoyed the sunshine on deck, and stunning views of the island clusters in Wayil, Misool. Underwater at Neptune's Fan, there was a myriad of critters greeting us, including more pygmies and nudibranch. We also dived at Raja Ampat, the site named after the famous islands. The group did a second black water dive tonight, and was able to get some footage of marine microorganisms: tiny shrimp, squid, jellyfish and zooplankton.

There were some minor hiccups with the black water dive logistics, all part of the learning process. There were ropes that had snapped on one of the dinghies, thanks to strong current and winds. The other dinghy's divers completed a full hour's dive, but did not get lucky with interesting critter sightings. Nevertheless we had some trippy footage of the black water dive from videographers Juan Romero and Alex Finden. After some discussions, it was agreed that the team would try out bonfire dives next, closer to the reefs.

Day 6 (6 October 2018)
Yilliet Reef - 02.11.757S 130.36.620E
Sagof Two Trees - 02.01.743S 130.44.062E
No Contest - 02.01.584S 130.41.431E

Some great wall dives today in Misool, with bountiful sightings of the endemic pontohi pygmy seahorse! We started the day at Yiliet Reef, and followed by Two Trees rock and No Contest. Current and swell were much stronger today but we soldiered on for the day, getting quite a workout from the strong current underwater. Team Mola Mola capped the day off with a beautiful boat ride into the lagoon for a lovely sunset, before sailing for the night to the north of Raja Ampat.

Day 7 (7 October 2018)
Melissa Garden - 00.35.390S 130.18.909E
Galaxy - 00.33.799S 130.16.501E
Having arrived in North Raja Ampat overnight, the team was raring to explore the northern islands and dive sites for the next 2 days. We kicked off with the first dive at Amphibox and were blessed with sunshine and blue skies today, the best conditions for taking in the view of Raja Ampat in all its glory. We've been surrounded by clear turquoise waters studded with lush green islands all day, and had an amazing time getting great drone footage. Equator crossing tonight, which was a special milestone for some of our team members! King Triton, gamely personified by Juan Romero, made sure that first time equator crossers (Rebecca, Alex and Aaron) marked the occasion with a late night swim on the equator crossing. The trio bravely hopped overboard with the team and crew cheering them on. It was a very memorable evening for everyone on board the Mola Mola!

Day 8 (8 October 2018)
Three Rich Rock - 00.09.844N 130.00.663E
Pelagic Rock - 00.10.741N 129.59.695E
Figure Eight - 00.10.379N 130.00.373E
Two Hump Rock - 00.10.238N 130.00.409E

Our second day in North Raja Ampat was marked with intense currents and big swells. What a ride! We started the day at Rich Rock, which was a little mild compared to the next dive site. The group decided to ascend after 35 minutes on the second dive at Pelagic Rock, as it was a challenge trying to fight the strong currents underwater. The boat proceeded to Figure 8 for the afternoon, and docked briefly in between dives. At this point, Mola Mola had some very special visitors right by the boat today while docked, as four reef sharks came by to check us out. They circled a couple of times and the team tried to get some footage of the curious visitors. As always, it was a joy to see several reef sharks which demonstrates overall reef health and strength of the marine biodiversity.

Later in the afternoon, the Coral and fish teams went for their surveys, which yielded positive but mild results in the shallow depth, although there was bountiful marine life at depth. For sunset, the team went on a little jaunt to the beach and did a little rock climbing before setting off for our night dive at the Two Hump Rock. Time sure passes quickly when you're having a blast!

Day 9 (9 October 2018)
Citrus Ridge - 00.30.646S 130.27.348E
Mayhem Reef - 00.30.777S 130.26.716ES
Arborek Jetty

We started back in the southern direction on Day 9, and ended up in Waigeo. The first dive was at Citrus Ridge, followed by Mayhem Reef just before lunch time. There was a palpable feeling of wanting to make the most of the last 2 days of diving, and the group especially relished our time in the water with the mild weather conditions we were lucky to find in Waigeo. We did two spectacular dives at the Arborek Jetty, which was teeming with marine life here. Our afternoon and night dives provided opportunities to see vastly different marine life during the day and at dusk. There were electric clams, heaps of crabs and schooling bat fish. We also paid a little visit to the Arborek village before sundown and met with the local dive shop owner and some of the locals in the village. Our drone team managed some specular sunset over-under shots by the jetty, together with the friendly village community and their equally friendly pet dogs. It certainly was another unforgettable day of diving and exploring for Team Mola Mola.

Day 10 (10 October 2018)
Sauwenderek Jetty - 00.35.493S 130.35.911E
Cape Kri - 00.33.566S 130.41.240E

Overnight, Mola Mola made its way back south to Sauwenderek Jetty and Cape Kri. We started the diving at 8am at the jetty, and what a treat it was. Sweetlips galore, and turtles all around. We did tearful farewells to a couple of the pontohi pygmies at Cape Kri, before heading back to dock in Sorong tonight. After the dives, the group worked together on the expedition presentation for sharing with the rest of the expedition team back on land. This is our last day on the boat, and we're all determined to make this a memorable evening! All Elysium boats were called to a meeting and photo shoot in the afternoon, and we were looking forward to exchanging stories and underwater photos with everyone. By the 9th day of the expedition, the team had cleaned out the alcohol supply on the boat, numerous bottles of Bintang beer, washed down with gin and whisky. We had to buy an additional supply from a friendly neighbour too (thanks Gaia)! All in all, this was an extremely rewarding expedition with like-minded marine conservationists, and we all formed great friendships from our time on the boat. The team’s great rapport and spirit of cooperation undoubtedly helped us get through the bouts of bad weather and leaky roofs. If you ask us, we unanimously had a great time together on board the Mola Mola and thoroughly our expedition as a team.

Summary from Team Whiskey - MSY Damai II

By Sam Shu Qin

Team Whiskey
Jayne Jenkins : Tracey Jennings : Renee Capozzola : Sabrina Inderbitzi : Sam Shu Qin
Virginia Bria : Ernie Brooks : Sally Vogel : Deon Viljoen : Linda Thomas : Brett Lobwein
Sarah-Jo Lobwein : Renato Morais : Emry Oxford : Josh Phua

The journey to Raja Ampat, the heart of the coral triangle, was truly magical. The lush coral reefs and kaleidoscopic array of marine life leave us in awe every single dive. The committed efforts by the Indonesian authorities and communities to protect their reefs were evident in vibrant reef communities and healthy coral especially in marine protected areas (MPAs). As we move further away from the MPAs, we undoubtedly encountered damaged and degraded reefs due to the adverse impacts of human activities, such as pollution and unsustainable fishing practices. Through this expedition, I believe that enforcement, research and education form the three main pillars of marine conservation and more efforts have to be done in community engagement to encourage a greater sense of public ownership in their natural heritage.

After working alongside so many talented expedition team members from diverse backgrounds, I was intrigued by the possibilities of integrating science and visual arts to convey conservation messages in creative ways to inspire positive change among individuals. It was a joy to lead the coral team for surveys, documenting coral species, live coral cover and extent of reef damage for some dive sites. Even though it was initially a challenge to turn marine science and research diving into fun tasks for the volunteer photographers, the scientists were deeply encouraged with the team's enthusiasm and willingness to share marine science in their own ways of storytelling. Understanding fish behaviours and attempting to identify marine animals through photographs and videos gradually became part of our after-dinner team activities.

The experience has undoubtedly provided me valuable insights to develop more programmes to inspire marine stewardship. The exchange of knowledge and best practices among the team made me a better scientist, diver and photographer.

Expedition log
Day 0: 29 September 2018
The entire Elysium Heart of the Coral Triangle expedition team has gathered at Swiss-Bel Hotel Jakarta by 29 September 2018. We had the expedition briefing by Project Director Michael Aw, Alexandra Rose and lead scientists Dr Paul Muir, Renato Morais and Charlotte Rose at 14:00. The team subsequently met with their respective team leaders to discuss research techniques and expedition objectives.

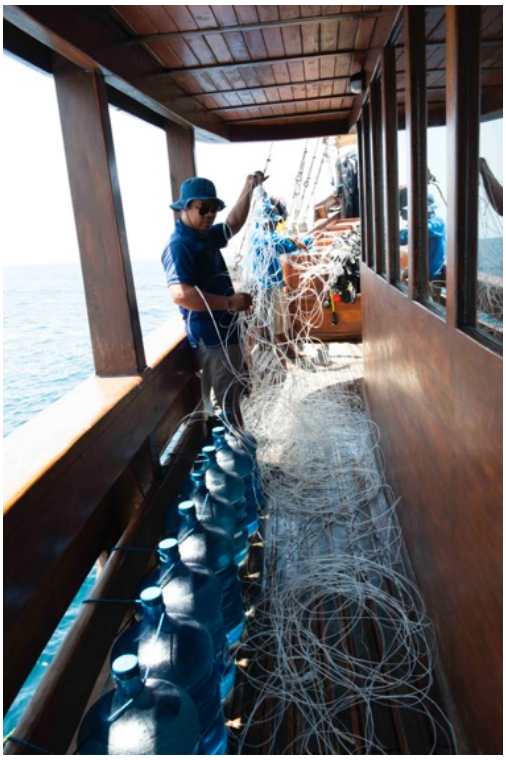
Day 1: 30 September 2018
Team DAMAI arrived in Saumlaki Mathilda Batlateri Airport after an overnight flight. The team and almost 700kg worth of luggage were promptly transferred to M/V DAMAI II. The crew welcomed the team and introduced us to our home for the next ten days. DAMAI II commenced the Elysium Heart of the Coral Triangle expedition at 13:30.

We spent the rest of the afternoon preparing cameras and scientific equipment for the next day. During dinner, we had a special birthday celebration for plastic team leader Sarah-Jo Lobwein!

Emry Oxford preparing his Seacam set up for the next day.

Day 2: 1 October 2018
The team finally arrived at Nils at 10:00 and started their expedition dives after a long and rough twenty hours overnight sail. Renato Morais, our principal fish scientist of the expedition, and Sam Shu Qin, coral team leader briefed their respective team to take a general visual of all fish or corals encountered during the dives for a baseline survey of animals within Indonesian waters. Our first expedition checkout dive at South West Ridge, Nils Desperandum 6° 37.079’S, 129° 46.698’E was rewarding, the sight of the school of hammerhead sharks made everyone’s morning.

Feeling pretty impressed with the site, the team decided to explore the Northwest Corner, Nils Desperandum 6° 36.480'S, 129° 46.749'E. While waiting for the next dive, the boat crew pulled up a huge pile of long line! We were all so glad that no animals were found entangled or harmed by the retrieved debris.



The crew removed a massive bunch of longline from the waters, look at how far it stretches!

For the second dive at 13:00, Renato, Sam and Joshua teamed up to conduct a combined fish and coral trial survey. Renato and Sam located a sweet spot at 6m and laid their respective transect tapes in opposite directions. Joshua assisted Renato with the fish survey using a specially designed set-up. With this set-up, Renato is hoping to overlay videos of both cameras with photogrammetry technique. Sam tried out Dr Paul Muir’s line-intercept transect method of coral survey and complementing the results with a video along the transect. After the dive, documentary lead Sabrina Inderbitzi conducted an interview with Renato against the picturesque backdrop of the ocean.

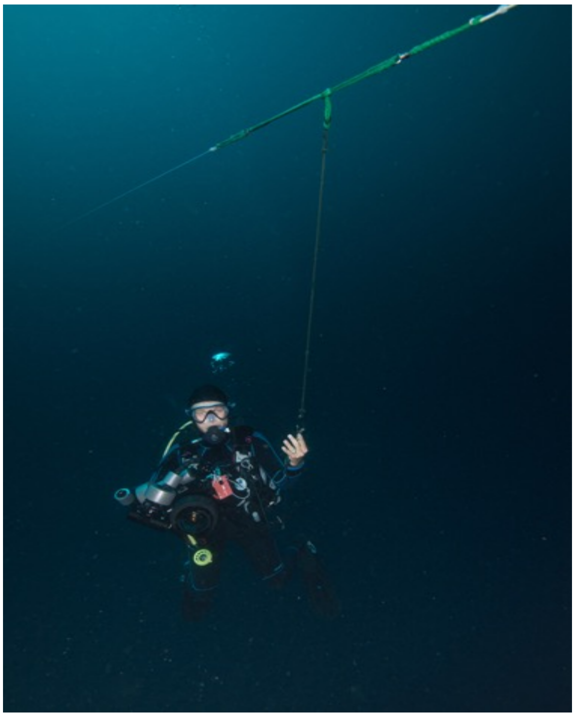
Renato Morais, our principal fish scientist, demonstrating his set up for fish survey.

Joshua Phua trying out the cameras for fish survey

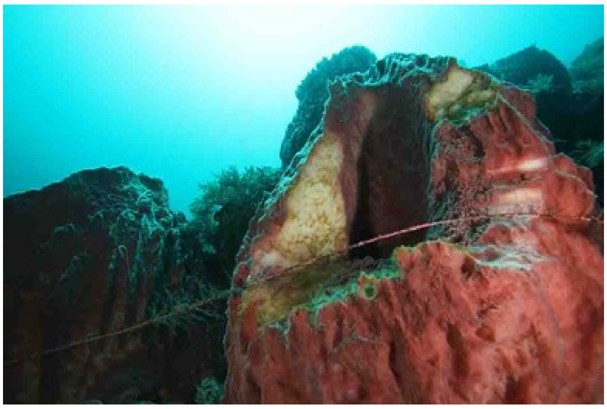
Sam Shu Qin is documenting the corals in Indonesian water

Sam Shu Qin, DAMAI’s coral team leader, laying the transect tape for a trial coral survey.

During the third dive at 16:00 at the South West Ridge, Nils Desperandum 6° 37.079'S, 129° 46.698'E, the team continued to take general photographs of fish and corals. While some of the team were greeted by hammerhead sharks, some divers also encountered abandoned long lines in mid water and on the reefs. We spent the night uploading photographs and analysing trial survey results.



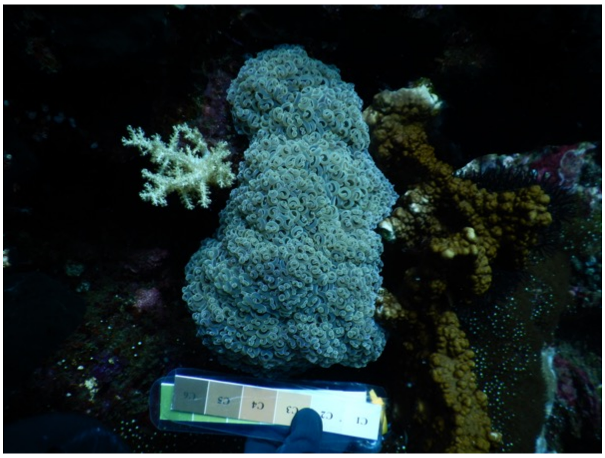
The team encountered long lines in mid waters



And sometimes, even sponges.

Day 3: 2 October 2018

The team started our day bright and early at Manuk. As explained by our cruise director Irene, Manuk is a volcanic island where sea snakes roam around the coral reefs. As we approach the dive site on a tender, we were enthralled by the sight of frigates and boobies soaring high around the island. Tracey Jennings even saw the birds fighting over a sea snake in the air! We had many close encounters with the sea snakes during our first dive at North West, Manuk 5° 32.569'S, 130° 17.875'E at 10:30. Renato even had a surprise visitor along his transect during his fish survey! Sam conducted her trial coral survey with Josh and was pleasantly overwhelmed by the huge diversity of corals.



Sam encountered a strange-looking coral.

At 13:30, the scientists teamed up with Joshua and Virginia for a second trial survey at North East, Manuk 5° 32.403'S, 130° 18.183'E while the rest of team continued their hunt with sea snakes and general photographs of coral reefs. After with our last dive at South West, Manuk 5° 32.774'S 130° 18.658'E at 17:00, Sarah-Jo and Brett did a trial run with the plastic trawl and sieving of retrieved trawl contents. The sea was rough today and some of the team decided to rest early for the night.

Team DAMAI’s first plastic trawl deployment.

The team figuring out the best way to sieve the trawl contents

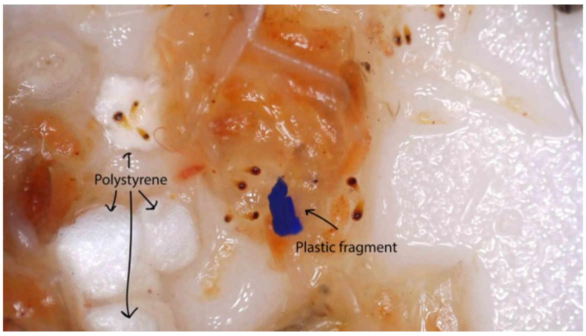
Day 4: 3 October 2018

During the sail from Manuk to Koon, rough seas have delayed our schedule. Decision was made to miss out on Koon as we will not have arrived there until early evening. In the serious business of ocean conservation, the DAMAI team showed that it is possible to also have a whale of a time. In the early morning at 8:00, we got up close and personal on our tenders to some majestic whales! Drone photography, shots from the boats and search images from the web have confirmed sightings of both fin whales and blue whales.

Warm greetings from the whales!

Utilising the calm sailing weather, Sarah-Jo was able to start the trial microplastic analysis - sorting, identifying and classifying the type and abundance of microplastic pieces collected in our first 30-minute sea surface trawl. Over a distance of 1.09 nautical miles, most of the 500-micrometre sieved sample was gelatinous and crustacean larvae with only a few microplastic pieces – including a 2mm blue fragment, five 1mm granules (needs chemical analysis); pieces of filaments including a long thread, ten polystyrene foam that is most probably contamination from the neuston net packaging, and six unknown black fragment that may be plastic or organic.

Sarah-Jo Lobwein sorting microplastic pieces from the organics in our first plastic trawl.



Microscope image of blue microplastic fragment (2mm length) and polystyrene pieces of various lengths and thickness.

Day 5: 4 October 2018

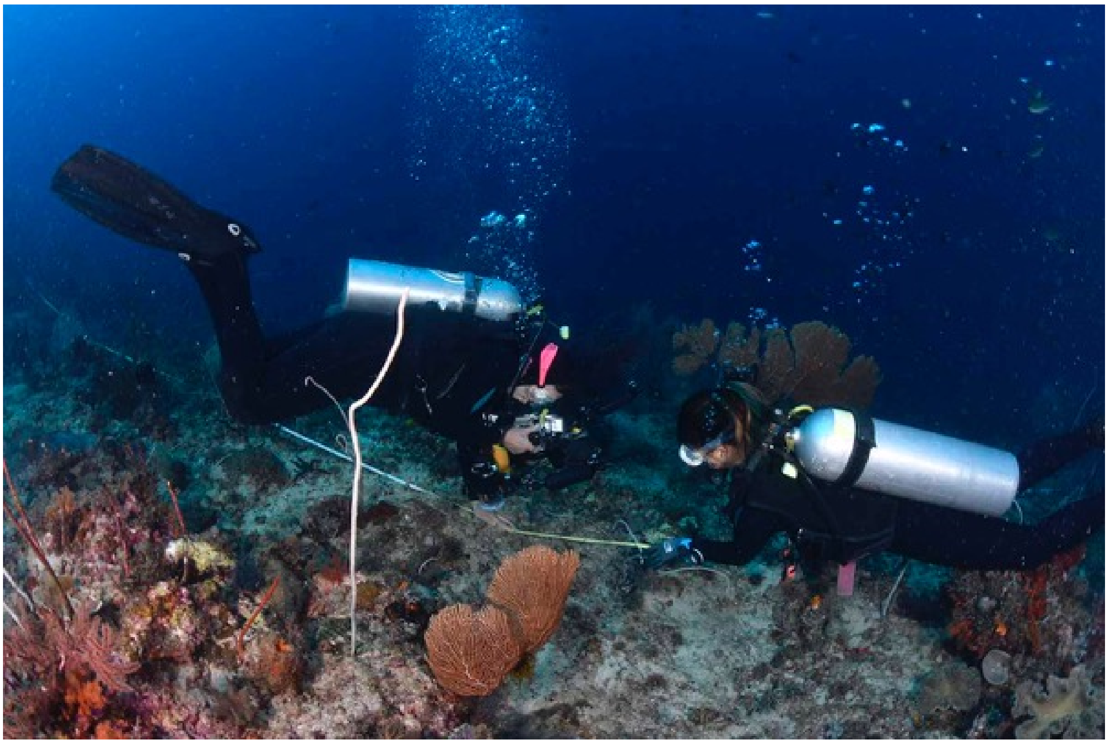
"We've got 42 hours of surface interval!" exclaimed Brett at the breakfast table. As we spent the previous day travelling from Manuk, everyone cannot wait to hit the waters and start diving. As DAMAI II slowly come to a halt, we find ourselves surrounded by several majestic islands. We have finally arrived in Raja Ampat. It was the first time that everybody was punctual for our 8:00 hrs dive briefing at the deck. Magic Mountain, Misool 2° 15.557'S 130° 38.878'E lived up to its name! The team was greeted with manta rays, wobbegongs, napoleon wrasses and a spectacular school of baitfish!

Our second and third dives in the afternoon at Tank Rock, Misool 2° 13.136'S 130° 34.063'E and Boo Windows, Misool 2° 13.295'S 130° 36.700'E did not disappoint as well. With lush soft corals and schooling fish, the dive sites served as stunning backdrops for our photographers. Scientists Renato and Sam (with the help of Joshua, Virginia and Renee) did their respective fish and coral surveys for both sites. The surveys were challenging due to surge and currents but the team managed to complete the tasks. Sarah-Jo and Brett conducted their second plastic trawl between Tank Rock and Boo Windows. Good news! No microplastic was recovered in the sieved sample. The team planned to do more trawls as we get closer to civilisation.

At 19:00, we ended off the day with a bonfire dive at Yilliet, Misool 2° 11.757'S 130° 36.620'E. This was a first experience for many of us and we were so intrigued by those drifters!

Day 6: 5 October 2018

"Are we 'sciencing' today?" Joshua asked before he started to gear up for the team's first dive of the day at Whale Rock, Misool 2° 13.163'S 130° 33.552'E. 'Sciencing', coined by fish scientist Renato, is doing science while diving! Virginia and Joshua helped Sam and Renato with their respective coral and fish survey. Some of us even joined the legendary photographer Ernest Books II and Sally Vogel on their snorkel trip after the dive!



Virginia helping Sam with coral survey

Back on the boat, Brett took our CC Remotely Operated underwater Vehicle (ROV) out for a spin. As soon as the CCROV hits the water, it met with two remoras! He piloted the CCROV on its first test run to 50m and found small bommie filled with gorgonians and whip corals on the sandy bottom. We even had an inquisitive triggerfish! Sarah-Jo and Brett also did another sea surface plastic trawl between Nudi Rock, Misool 2° 13.103'S 130° 33.936'E and Magic Mountain, Misool 2° 15.557'S 130° 38.878'E. In the sieved sample, they found a mixture of colourful fragments and filaments ranging from 0.5mm to 5mm!

Brett trying out the CC Remotely Operated underwater Vehicle during surface interval.

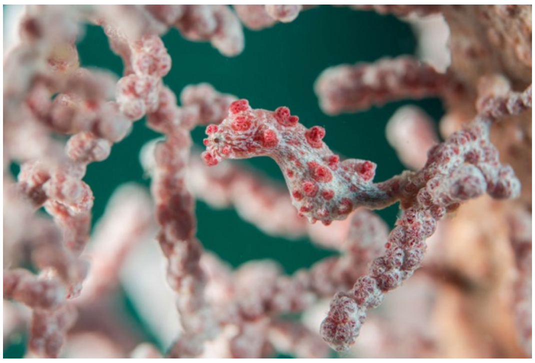
The deployment of CCROV attracted those remoras almost instantly!

At 11:30, the researchers teamed up with Emry and Joshua for another survey at Nudi Rock (with some distractions from manta rays!). Subsequently, the dive at Magic Mountain was breath-taking. Upon descent, the team found a huge manta ray circling around them! After some kicks, we found ourselves in the middle of the jacks' hunting game. Some of us we were so caught up with the jacks and fusiliers' showdown that we spent 40 minutes against strong currents at the same spot!

The day ended with a beautiful sunset and a bonfire dive at Yillet, Misool 2° 11.757'S 130° 36.620'E for some of the team members. Oh, we heard that Brett even found himself a pet squid during the dive!

Day 7: 6 October 2018
Dive sites: Four Kings, Neptune's Fan Sea, Barracuda Rock, Barracuda Rock (Bonfire and Blackwater)

At 08:00, the team descended into the deep and was amazed at the majesty of the four pinnacles at Four Kings, Walibatan 2° 12.500'S 130° 22.678'E. We were instantly surrounded by a huge ball of baitfish and walls of massive sea fans. During surface interval, we took the tender out and cruised around a nearby traditional bagan (floating fish platform) which the fishermen used light to lure baitfish into the nets. We were all wondering if it was illegal for these bagans to be bringing in those catch, the captain reassured that these boats were issued permits to do so! The second dive at Neptune's Fan Sea, Walibatan 2° 12.745'S 130° 27.446'E was stunning. The myriad of marine creatures left the divers in absolute awe. Some team members found pygmy seahorses in the deeper waters while Sam even found corals that she has not seen at other sites. Renato was so intrigued with the cleaning stations where yellow-tail fusiliers lined up to get groomed.


Pygmy at the passage.


It's grooming time for the batfish!

The scientists decided to do their respective surveys the next dive at Barracuda Rock, Walibatan 2° 11.721'S 130° 25.647'E. Challenged by strong currents, Renato was forced to abort his survey. Sam, along with Virginia, found a pretty sweet spot and finished their tasks.

At 19:00, we ended our day with a mix of bonfire, blackwater and reef dive at Barracuda Rock under the starry night.

Day 8: 7 October 2018
The team started the day early at 06:00 as we were hoping to catch the best light at Jellyfish Lake. After a pretty rushed breakfast, we hopped into DAMAI II's tenders and made our way to Goa Keramat Cave, Tamulai 1° 57.131'S 130° 21.580'E. We passed by rows and rows of cultivated oysters from the pearl farms before entering the passage. With crystal clear waters and beautiful reef against the majestic limestone karst, this place is a paradise for water babies! It started to drizzle as we approach the cave. "Torches! Snorkels! Mask! Fins! Life vest!" The boat crew reminded us again as we disembarked from the tender. Yes, all of us took a life vest as a float for our cameras! The cave was a spectacular nature's work of art – filled with interesting rock formations and bats.

We hiked a short distance and found ourselves at the Jellyfish Lake 1° 58.077'S 130° 28.227'E. A closer look at the jellies revealed three different kinds – Spotted jellies, moon jellies and upside down jellies. The rest of the time was spent exploring the underwater scene of the hidden gem.

Reflections of the spotted jellies

A spotted jelly cruising along the lake.
At 15:00, we headed to Three Sisters, Farondi 2° 0.170'S 130° 38.376'E, one of the top dive sites in Raja Ampat. The team experienced waves of cold and strong currents but yet had a fulfilling dive with sightings of whip corals, pygmy seahorses and an epaulette shark! Renato did his fish survey with Sam's help. Sam was thrilled to find corals that she has not encountered in past dive sites.

During surface interval, Sarah-Jo conducted another plastic trawling between Three Sisters and Wagmay Bay, Farondi 2° 0.259'S 130° 38.654'E. Some of our team then took a ride out to Wag Mag Beach to help Sarah-Jo with her microplastic assessment. Upon arrival, we saw a lot of plastic water bottles labels and food packaging in the water. We subsequently spent the next hour picking up and sorting macro plastic debris which include plastic PET bottles, flip flops, marine ropes, polystyrene and plastic bags. With only four pairs of hands, we retrieved 12 bags of trash, 113 flip flops and shoes in just 60 minutes!

Guess how many flip flops we found?

Meanwhile, Sarah-Jo did a quick microplastic survey halfway between low and high tide. Sieving the top two centimetres of the one-tenth of a metre quadrant, Sarah-Jo will then compare the data with the sea surface trawl. The team ended the day with a night dive (both bonfire and blackwater) at Way Mag Bay.

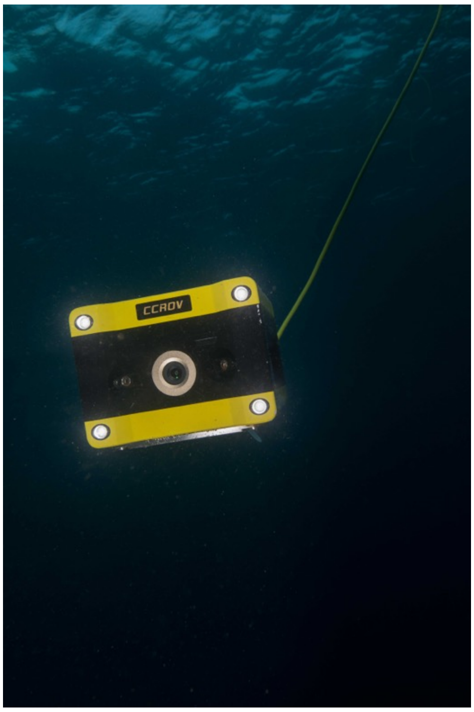
Day 9: 8 October 2018
At Blue Hole, Farondi 2° 0.260'S 130° 38.638'E, the team slowly faded away as silhouettes against the waters as we swim through the cave. As we exited the hole, we were pleasantly surprised by the vibrant reefscape at the other side. Sam, Emry, Joshua and Renato spent some time on the transects as the others went around hunting for their best footages.

Heart of the (*Acropora)* coral

We descended into a huge pinnacle at our second dive at Two Trees, Farondi 2° 1.684'S 130° 44.055'E. The team was rewarded with a feeding frenzy of the jacks hunting the baitfish. We even managed to spot a huge wobbegong shark resting in its cave! Sarah-Jo and Brett conducted another plastic trawl between Two Trees and Three Sisters.

The wobbegong shark was so well camouflaged!

The team chose to head into strong currents at Three Sisters, Farondi 2° 0.170'S 130° 38.376'E, and crossing our fingers that we will meet the giants upon descend. We saw a couple of bumphead parrot fish, giant groupers and even a giant clam! We even found so many different nudibranchs too! Renato and Joshua hid behind the currents and teamed up for another fish survey. The team launched the CCROV at a back reef of Three Sisters. Albeit challenging conditions with strong currents and poor visibility, we successfully sent the CCROV down to 90m in a bluewater dive.



CCROV in action!


Stonefish with such pretty colours!

The rest of the day was spent with Sabrina hunting the team down for interviews footages. Lastly, the team called it a day after a bonfire dive. The team even saw crown-of-thorns sea stars at the bay (we have not seen any on the reefs so far)! We are headed to Batanta with another crossing through the night.


Crown-of-thorns sea stars spotted at the bay.

Day 10: 10 October 2018
Dive sites: Algae Patch 1, Algae Patch 2 / Ernie's Corner, Algae Patch 2 (Night dive)
Weather conditions: Sunny and smooth waves (0.1 – 0.5 m high)
"Happy hunting!" That was it from Irene, our cruise director, for our first dive briefing of the day. It was muck diving day! The 15m visibility was great at Algae Patch 1, Batanta 0° 54.610'S 130° 34.404'E and it probably made finding critters slightly easier. The team, with the help of dive guides and their satay sticks to mark out cryptic animals, managed to find many nudibranchs, sea slugs and even anemone fish eggs among the black sand!

Peacock mantis shrimp.

Ferocious defender.

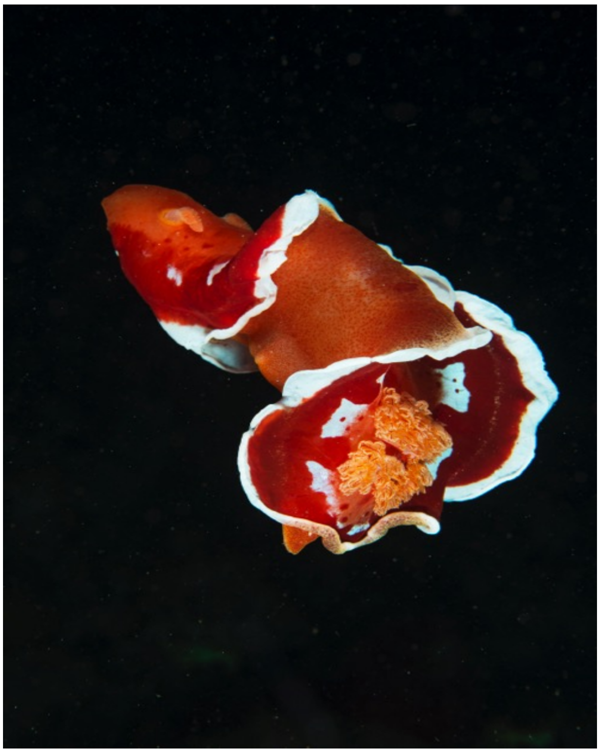
At 14:30, the team went for their second dive at Algae Patch 2, Batana 0° 54.654'S 130° 36.495'E while the researchers checked out the reef Ernie's Corner, Batana 0° 54.378'S 130° 34.168'E next to it. We definitely did not expect such vibrant fish and coral communities at a muck diving site. However, there were signs that we were nearing civilisation. Fishing lines, abandoned burlap bags, food wrappers were in the waters – around corals and in between reef crevices. Despite the presence of marine debris, Sam and Renato chose a nice spot and did their respective fish and coral surveys along with Emry and Sabrina. After sightings of crown-of-thorn sea stars on the previous day, Sam spotted a group of coral-eating violet coral shell (*Coralliophia violacea)* on a *Porites* coral! While snorkelling, Sally and Ernie found some sick corals and parasites getting a free ride (or lunch!) from the fishes. Sarah-Jo and Brett did another plastic trawl during surface interval around Algae Patch and we are all expecting to see more debris in the analysis!

Violet coral shell, *Coralliophia violacea*, munching on *Porites* coral.

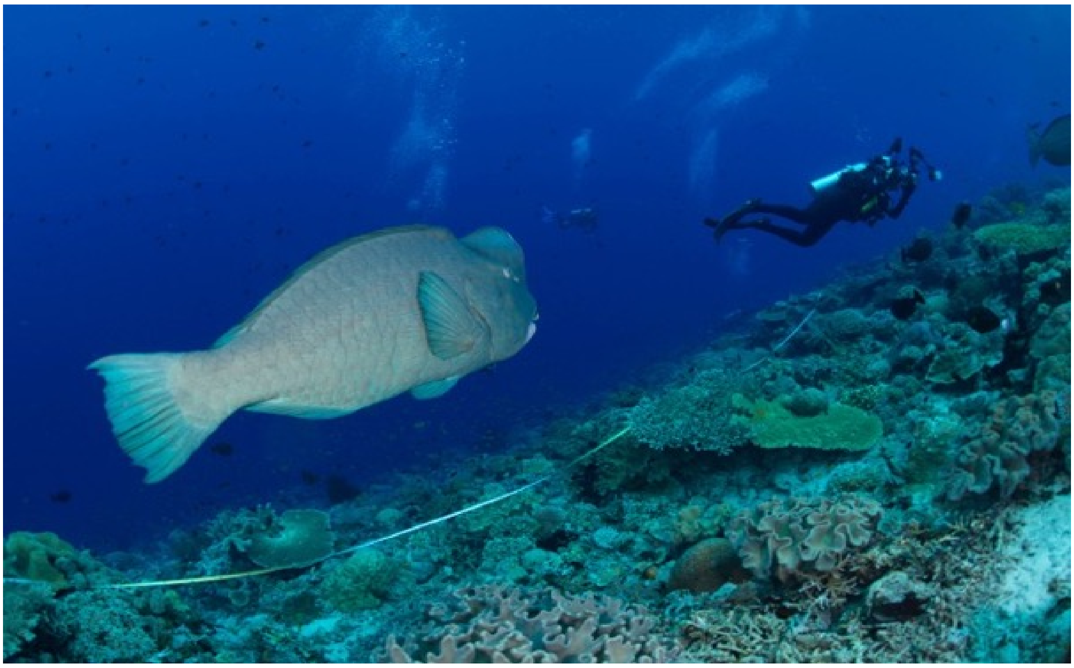
An *Acropora* coral with white band disease

Isopods hitch-hiking on humphead bannerfish.

We then ended the day with a night dive at Algae Patch 2 in search for wonderpus and blue ring octopus. No octopuses to be found but there were strong currents, Spanish dancers, and a frogfish!


Spanish Dancer in the dark.

Day 11: 11 October 2018
Dive sites: Cape Kri, Blue Magic, Sawandarek Jetty
At 07:00, the team head for their first dive at Cape Kri, Dampier Strait 0° 33.391'S 130° 41.417'E which apparently hold the world record for the largest number and variety of fish at one site! Divers took their turns to shoot while not disrupting the famous school of sweetlips at 40m. We were also pleasantly surprised with the school of bumphead parrotfish, along with massive napoleon wrasses and groupers. Renato did his final fish transect and Sam also encountered some bleached branching corals.


Massive bumphead parrotfish.

The team was fighting against current during their second dive at Blue Magic, Dampier Strait 0° 30.414'S 130° 44.290'E. The reef hook was definitely one’s most prized asset at that time. The pinnacle was so full of life and packed with schools of fish such as barracudas, jacks and tunas. With heavy hearts, we jumped right into Sawandarek Jetty, Dampier Strait 0° 35.403'S 130° 36.328'E at 16:00 for our last dive of the expedition. The dive site was one of a kind. The marine life under the jetty was picturesque against the jetty stilts. The shallow reef was interestingly covered with a type of weedy Echinopora coral and *Sacrophyton* soft corals. We also explored the coral nurseries and admired those giant clams in awe. After a long dive, we surfaced just in time to see the warm glow of Raja Ampat’s sunset.

Day 12: 12 October 2018
At 09:00, the team departed DAMAI II and headed to Swiss-Bel Hotel Sorong for expedition debrief and presentations by various expedition members.

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Acknowledgements

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