Barefoot conservation

Barefoot Conservation
Science Progress Report
2023-2024

info@barefootconservation.org

www.barefootconservation.org

Arborek Island, Raja Ampat, West Papua

BAREFOOT CONSERVATION

Science Progress Report 2023-2024

For any questions regarding the data, findings or projects mentioned in this report, please contact our Head of Science, Josie Chandler, via j.f.chandler@outlook.com

Decorative imagery by Iris Uijttewaal

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All of the projects currently running at Barefoot Conservation collect observational data only, and the results of the research remain within Indonesia. Correct permissions were sought from both Chief of Arborek Village, Bapak Juan, and Head of BLUD, Pak Safry, before commencing any of the projects mentioned in this report.

Introduction

Barefoot Conservation is an Indonesian registered NGO (Yayasan Konservasi Jejak Kaki Indonesia: AHU-0004531.AH.01.04. Tahun 2018) working to conserve the unrivalled marine life of Raja Ampat, through monitoring, research and science training of the local community.

Barefoot has been running since 2012 and has been collecting data on reef health, manta populations, marine debris and crown of thorns starfish for several years, providing invaluable long-term datasets of the ecosystem over time. In 2022 we commenced several new projects, most notably a reef restoration project, but also a black corals project, cyanobacteria monitoring and anchor damage monitoring. This year, we have continued improving and expanding our scientific output with the addition of a Coral Ecology and Coral bleaching monitoring project. All of these projects will be outlined in more detail within this report, including background, progress and goals for 2024.

Our Science team at Barefoot currently consists of Lead Scientist Lena Pollett (Plymouth University), Project Scientist Reyhan Arifin (Jenderal Soedirman University), Science Interns Max Kimble (Plymouth University), Corey Cathcart (Bournemouth University) and the Head of Science Josie Chandler (James Cook University) who is working remotely from Australia. Our Head of Operations (Iris Uijttewaal), Dive Manager (Matt Perrodou), and Divemasters (Ferry and Markus) are also heavily involved in the science projects.

This year we focused on both old and new projects. We have continued to progress with the long-term data collection of Reef Check, hitting our monitoring targets each quarter and adding bonus sites to our data bank. With the new projects, we have refined methodology & began using new software to analyse these exciting datasets. Furthermore, with the threat of a bleaching event in Raja Ampat at the end of 2023 we commenced a monitoring project to track the reef status during the anticipated warming. One of the key projects we have been working towards this year has been monitoring the presence of cyanobacteria & macroalgae in the Dampier Strait, which we have recognised to be increasing dramatically in recent years. Rapid growth of cyanobacteria and macroalgae is an issue which has caused significant irreversible damage to coral ecosystems in the Caribbean and other parts of the Indo-Pacific. Therefore, we are currently working with the government to investigate this environmental change and exploring potential solutions.

This year has also seen new collaborations commence which we hope to build on further in 2024. This report provides an update on the progress of our major science projects in 2023.

1 Marine Debris Collections

1.1 Overview

Over the last 12 months Barefoot has continued to progress with it's Marine Debris and Beach Clean-up program. Starting in August 2022, Barefoot's dedicated staff and volunteers have continued to work hard to do their part in minimising the waste problem occurring in the Raja Ampat MPA and the island home of Barefoot, Arborek. The waste management system of the MPA and its inhabiting islands has been an ever-growing problem in previous years and with the increasing levels of tourism it will continue to be an issue. It is not uncommon to witness patches of floating trash as you travel by boat through the waters of Raja Ampat, these 'trash patches' are being carried through the surface waters by ocean currents through the Dampier Strait and are putting so many vital species including manta rays, which are often at the surface filter feeding on plankton, at risk.

Barefoot's marine debris project aims to collect trash from four designated sites around the island of Arborek, these sites surround the majority of the island and range from approximately 200m-300m. Volunteers embark on a clean-up once a week to one of the four sites, resulting in each site getting cleaned monthly.

Once all trash has been collected from the site it is brought to Barefoot camp to be weighed, separated and counted by our volunteers. The weighing of the trash is a new addition to the project and began in September 2023. Trash is separated into 14 categories which encompass major materials like metal, glass, cardboard etc. but also capture particular problem objects on Arborek including, plastic cups and plastic ice pop containers. Once separated and counted, certain trash will be disposed of alongside Barefoot waste (cardboard, glass and metal) whilst the rest of the waste is taken to a more secure landfill site in Waisai outside the MPA.

Figure 1 a): Arborek Island with the four sites of data collection for our Marine Debris Project marked out; b) & c): weekly beach cleans where trash is collected and sorted with the help of Arborek Ocean Warriors

1.2 Results

Figure 2 presents data from the weekly beach cleans conducted from August 2022-December 2023. The bar chart illustrates the annual variation in waste found at survey sites, which varied between 109 items to 2770 items per site per month. The data highlights that sites 1, 2 and 3 had the highest proportion of waste collected in November to April. However, site 4 experienced its highest abundance of trash during June. These spatiotemporal differences can likely be accounted for by seasonal changes in wind patterns across Raja Ampat. From June to September strong winds emanating from the south produce a higher frequency of storms and wave energy resulting in the transportation of larger quantities of trash to coastal areas (Yuanike et al., 2023). This may offer an explanation to the two months of higher trash collected at (South-west facing) Site 4. Figure 2b displays proportional waste types found at each of the four sites over 2023. At all sites, generally consisting of fuel containers and bottle tops. Soft the majority of waste was hard plastic (38-50%),plastic was the second most common waste type (34-38%), including plastic cups, ice pops containers, plastic bottles and food wrappers.

The aforementioned data- detailing the monthly abundance and makeup of beach trash found is vital for not only helping understand waste distribution and accumulation around Arborek, but also in its ability to inform local level management solutions. Armed with this new understanding, actions such as the implementation of low-waste fishing methods, installation of water fountains and establishment of more effective waste management facilities can be taken to help lower the waste output of this developing island. Furthermore, all data collected will be shared with the local MMO's and environmental agencies, informing all parties about our observations which may serve as a proxy for other small coastal communities.

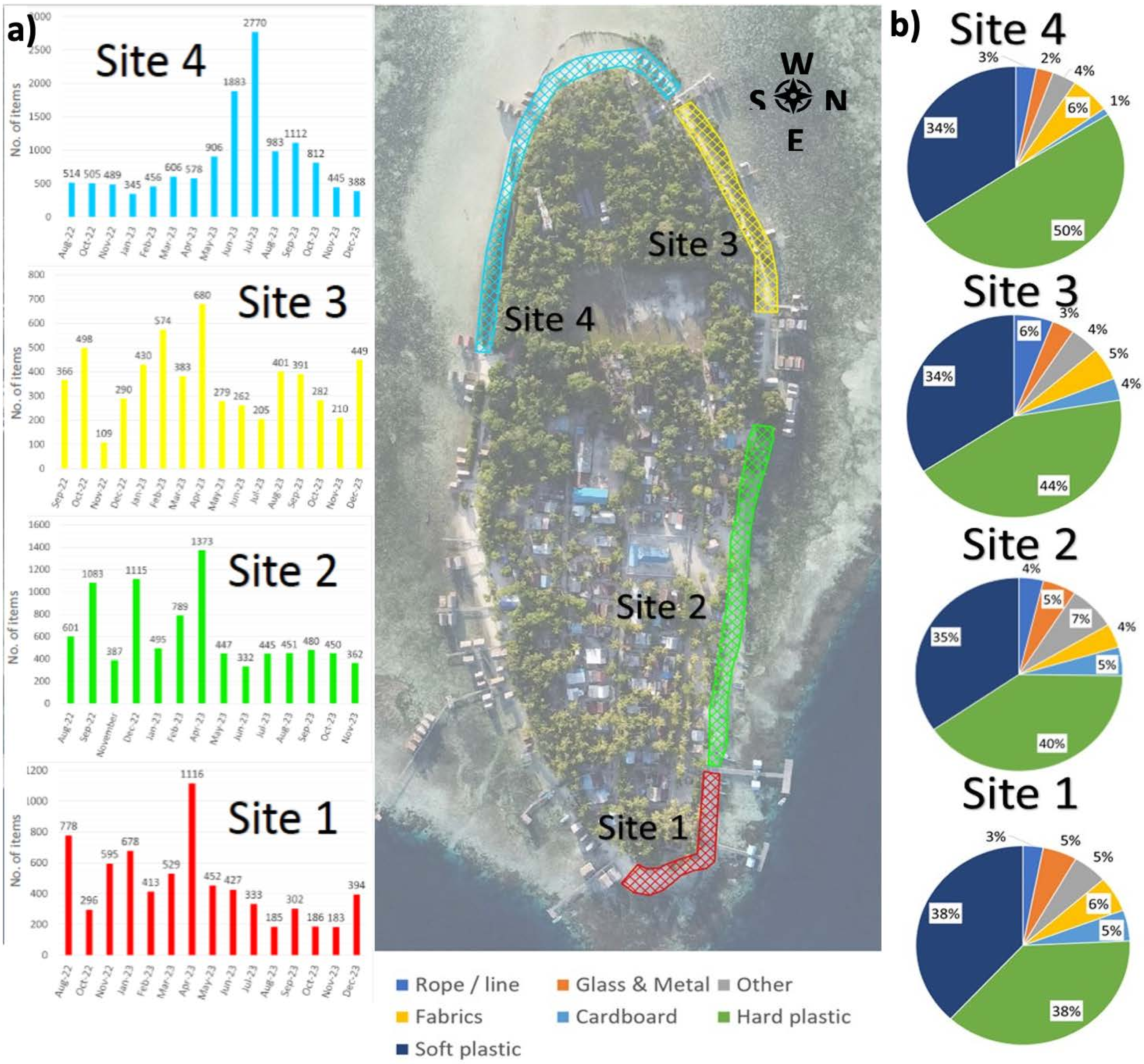
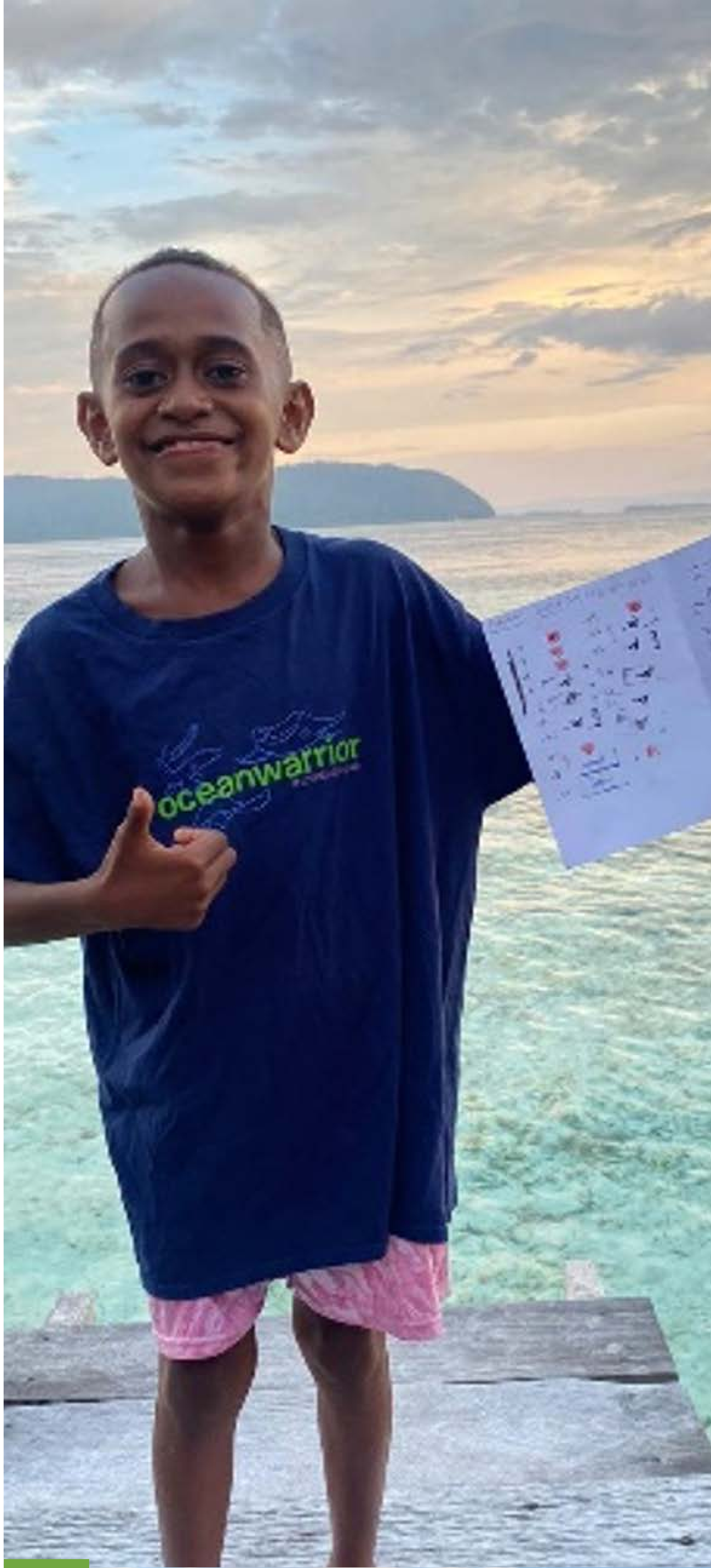


Figure 2: a) Total no. of waste items collected from each site each month, b) Proportional breakdown of waste types at each site

1.3 Ocean Warriors

One of the most important aspects of the marine debris project is the involvement of the Arborek children. In December 2022 the 'Ocean Warriors' project in collaboration with Child Aid Papua was reignited at Barefoot Conservation. This project aims to install a sense of environmental awareness within the community on Arborek, targeting specifically the future generation, the children. This ties in with the marine debris project at Barefoot as kids are encouraged to join and help out with environmental good deeds. All children on Arborek have Ocean Warrior books that they made themselves at a launch day in December 2022. After partaking in a beach clean/ trash sorting they will receive stamps in their books and receive prizes for gaining a certain number of stamps (5, 10, 15 etc), these stamps are ocean themed, a manta, shark and coral. At 25 stamps they receive an Ocean Warriors/ Barefoot conservation t-shirt. This year we have given out 100s of stamps for their involvement in the marine debris project and 4 t-shirts have been awarded to children.

Sorting and counting the waste types each week is a valuable exercise for both the children and staff/volunteers as it highlights the trash types which are contributing the most to marine debris. We hope that these marine debris activities not only clean up the beaches but also lead to generational changes in the future.



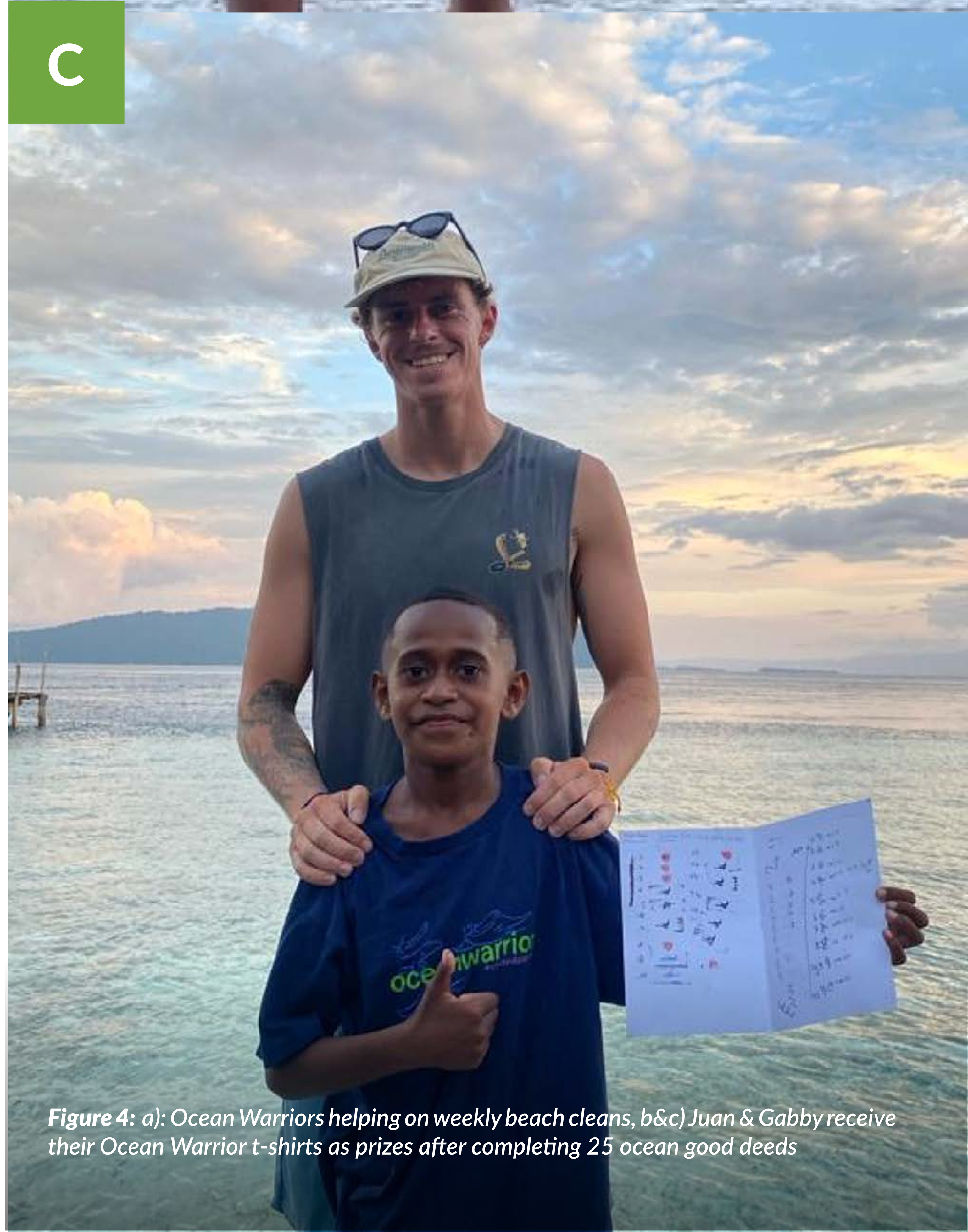


Figure 4: *a): Ocean Warriors helping on weekly beach cleans, b&c) Juan & Gabby receive their Ocean Warrior t-shirts as prizes after completing 25 ocean good deeds*

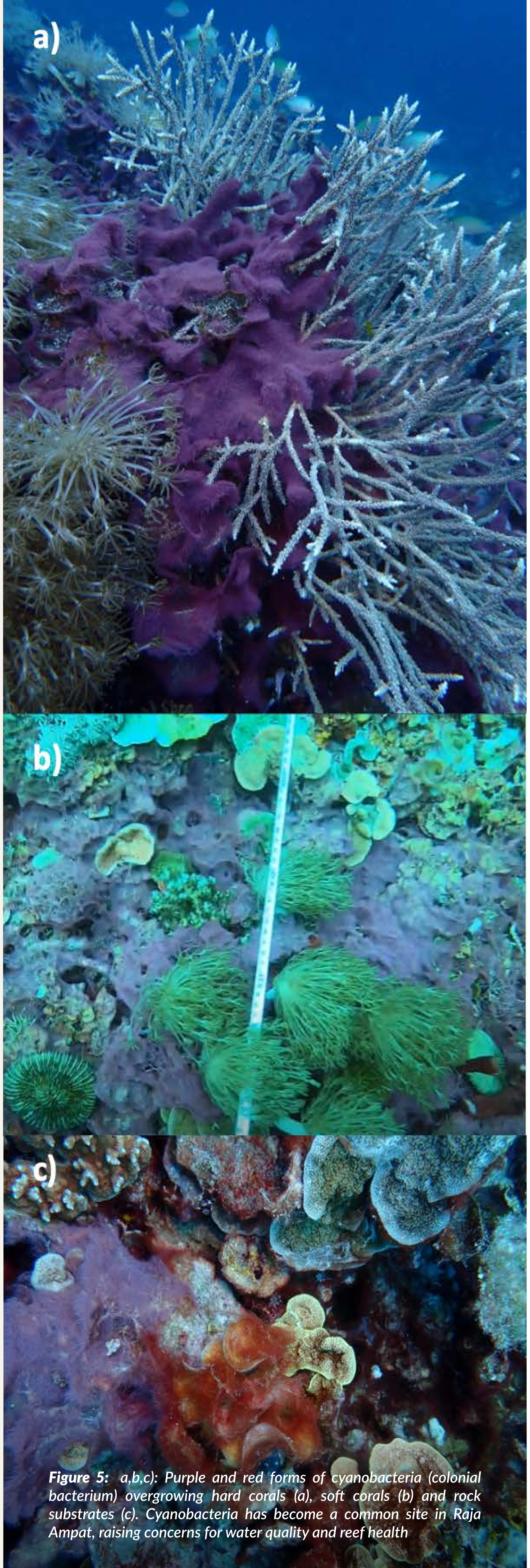


Figure 5: *a,b,c): Purple and red forms of cyanobacteria (colonial bacterium) overgrowing hard corals (a), soft corals (b) and rock substrates (c). Cyanobacteria has become a common site in Raja Ampat, raising concerns for water quality and reef health*

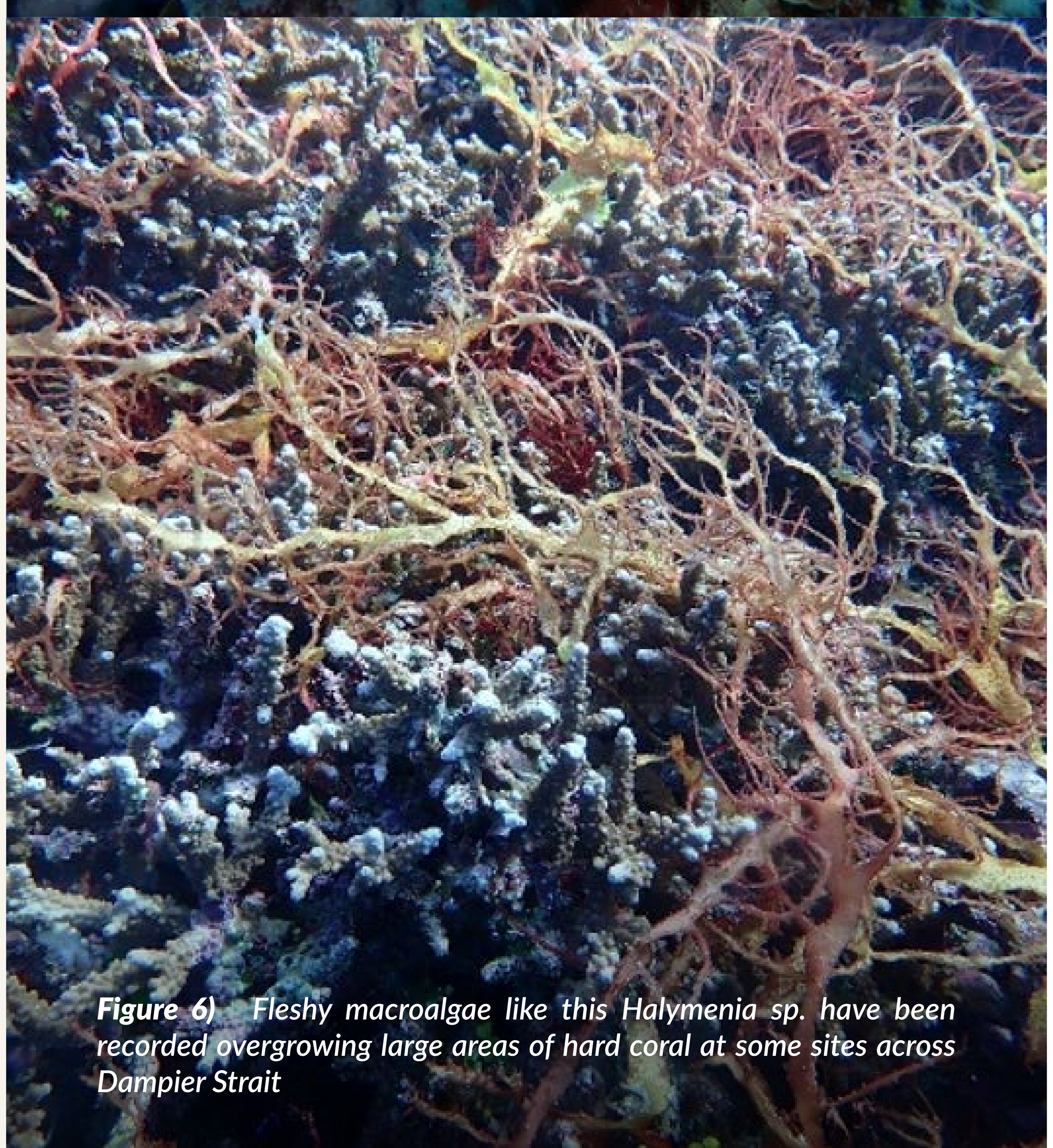


Figure 6) *Fleshy macroalgae like this Halymenia sp. have been recorded overgrowing large areas of hard coral at some sites across Dampier Strait*

2 Cyanobacteria & macro-algae monitoring

Following increasing observations of cyanobacteria negatively effecting coral reef health across the Dampier Strait region in 2022, monitoring surveys led by the science team and assisted by volunteers- assessing the presence and distribution of cyanobacteria across multiple dive sites, became an integral science project in 2023.

Cyanobacteria is a toxic colonial bacterium that blooms in the presence of nutrients that are not naturally recycled when excess amounts are found in marine habitats (Paerl et al., 2013). This specific bacterium thrives when Nitrogen, Phosphorus, and excess Oxygen enter the ecosystem through runoff of poorly treated waste water from human-developed coastal areas (Zuccarello et al., 2021). This may be from agricultural waste, sewage runoff, ongoing coastal development, poorly maintained beach toilets and other ill-managed human-derived waste spills that pollute the ocean environment (Zuccarello et al., 2021). If left unmanaged, cyanobacteria can continue to grow in abundance causing negative impacts to fragile marine habitats and will result in the death and decline of all affected corals (Charpy et al., 2012). Macroalgae is also known to proliferate in nutrient enriched waters and cause similar negative impacts to reefs through competition and smothering (Charpy et al.,2012).

We coupled data collection for the abundance of cyanobacteria and macroalgae alongside other ongoing science projects (Black Coral and Reef Check), where effective survey sites have already been established. Reef Check- a pivotal staple in our science programme consisting of nine core sites, and four bonus sites, both at 4-6 meters (shallow) and 7-9 meters (deep). Black Coral surveys have additional sites allocated at depths of 12 and 17 meters. Both of these surveys allowed cyanobacteria data to be collected along the same transect line used in each respective field.

The main aim of this project was to identify cyanobacteria coverage to determine the extent of bacterial blooms across our survey sites. To achieve this consistent surveying across a range of sites was conducted detailing the spatio-temporal distribution cyanobacteria within the study area. Data was collected by one of the members of the science team or a fully trained volunteer. Utilising an underwater camera in conjunction with a specially-made quadrat (44cm x 58cm)(Figure7a), the observer took images at 1m intervals, alternating sides along the transect tape.

The data collected was then uploaded and analysed within Coral Point Count (hereafter CPCe). This programme allowed for the percentage based computation of benthic cover as seen in Figure 7b.

All methods and survey designs were based on the methodology of local researchers as well as BLUD's research team. Following their outline this has enabled Barefoot's data to to directly assist the government's understanding of the distribution and potential drivers of cyanobacteria recruitment and growth.

In 2024 we hope data collected from Barefoot Conservation- coupled with sister surveys conducted across Raja Ampat and the Dampier Strait, will result in the establishment of effective solutions to reduce anthropogenic waste/sewage leading to the increased abundance in cyanobacteria. Furthermore, will continue to work together with BLUD, collecting data and aiming to drive positive, local led change.

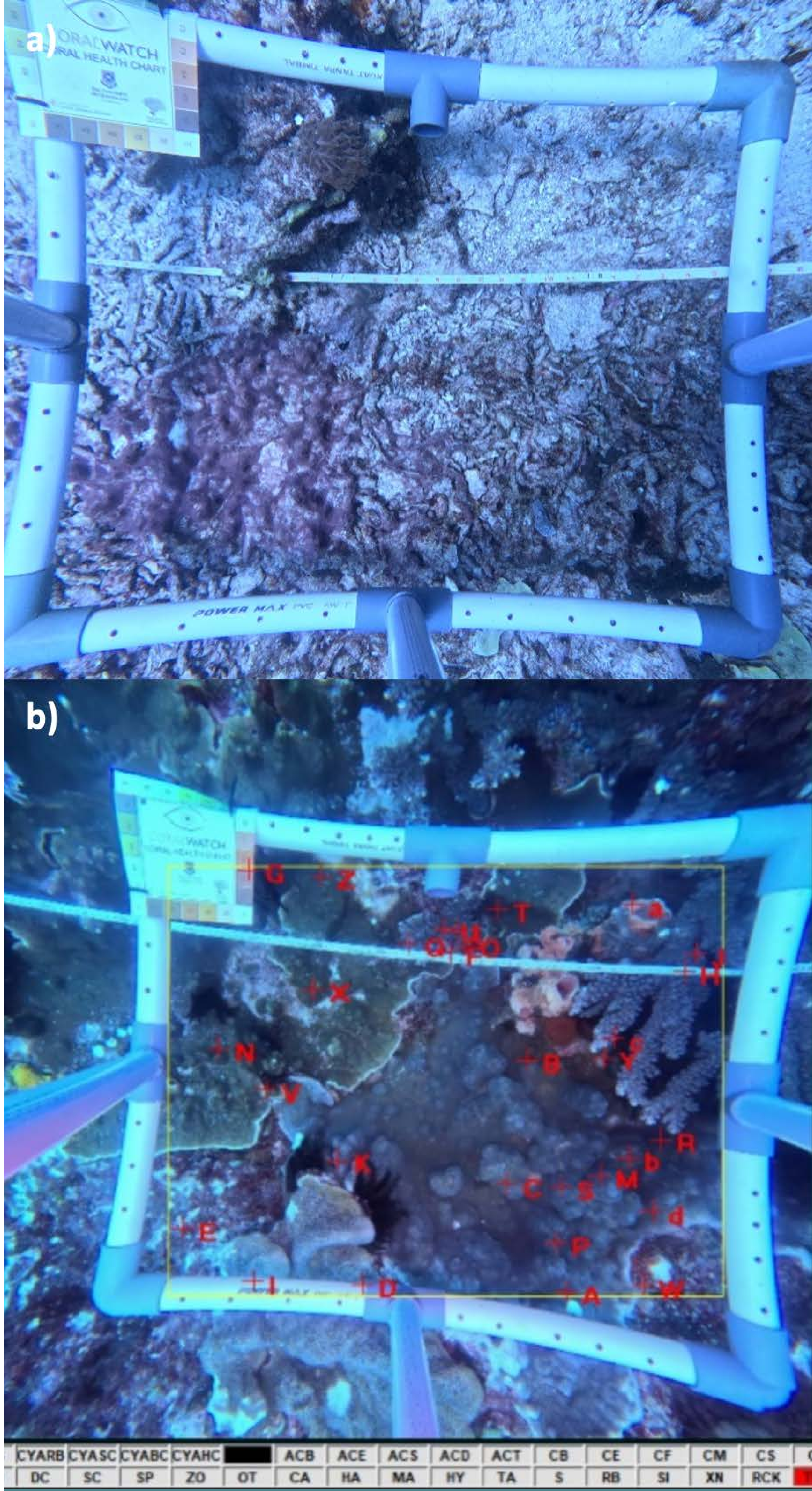


Figure 7a) Cyanobacteria surveys involve taking photoquadrats every 1m along a 50m transect, b) photoquadrats are analysed for % cover of cyanobacteria and other benthic groups using CPCe software, matching methodology used by other monitoring teams in Raja Ampat MPA

2.1 Survey results

Figure 8a presents data from our photoquadrats, analysed using CPCe, as described above. Looking specifically at cyanobacteria percentage cover (royal blue in Figure8a), it is apparent that there is considerable variation in cyanobacteria percentage coverage between survey sites. The sites with the highest cover of cyanobacteria were Barefoot Jetty Left (shallow) and Arborek South, with almost 20% of all substrate surveyed harbouring cyanobacteria. Both of these sites also presented relatively high proportions of soft coral coverage compared to other sites (>60% for Arborek South) which may also be an indication of poor water quality at these sites, as soft coral abundance is often correlated with water quality parameters such as dissolved inorganic nutrients (DIN) and sedimentation (Baum et al., 2016).

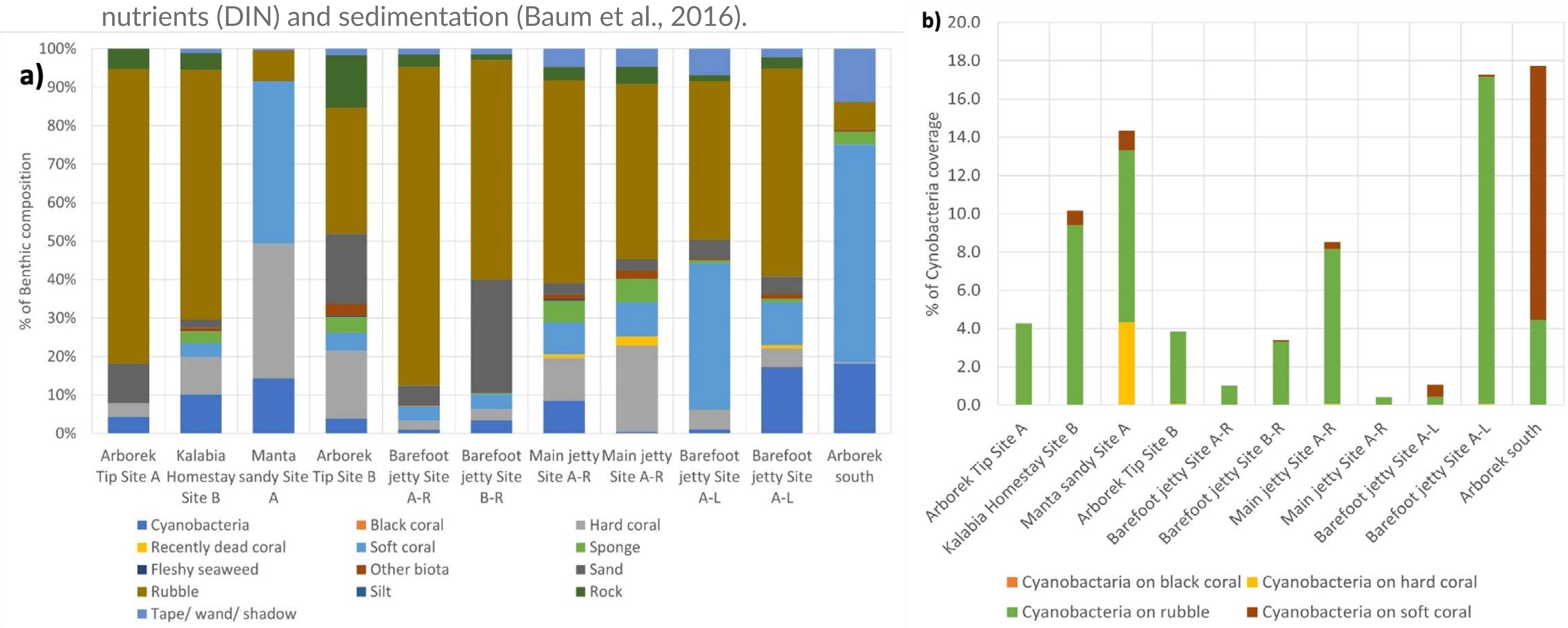


Figure 8a) Proportion of cyanobacteria and other benthic categories occupying the substrate, grouped by survey site, 8b) Dominant substrate-type that cyanobacteria is associated with

These sites are closely situated to densely populated parts of the island and are also sites of lower current movement, potentially causing an accumulation of nutrients due to low flushing rates, presenting favourable conditions for cyanobacteria recruitment.

Figure 8b presents data on the substrate that the cyanobacteria was associated with. It can be seen that the majority of the cyanobacteria present was associated with rubble (green in Figure8b), however differences can be observed. Arborek South, with its high proportion of soft coral coverage (>50%), exhibited a high proportion of cyanobacteria which was on the soft coral itself, additionally, at Manta Sandy almost 1/3rd of cyanobacteria present was growing over the top of hard coral. This is of highest concern as cyanobacteria has been shown to smother and kill hard coral (Kuffner et al., 2006). Therefore, it is likely that the hard coral coverage at Manta Sandy will decline as a direct result of this cyanobacteria proliferation. Whilst cyanobacteria growing on rubble is not causing any conspicuous damage to corals, it is known to inhibit coral recruitment to these sites (Ford et al., 2018) which prevents natural recovery of degraded areas. It is also known to spread rapidly when conditions are favourable for growth (mats can cover up to 30km2 within 2-3 months; Albert et al., 2005) with the potential to spread to healthy hard coral patches within months and cause widespread damage.

2.2 Plans for 2024

For 2024 we plan to continue monitoring this important issue and commence water quality testing with the assistance of a team from the University of Sorong. In the first quarter of 2024 we will present our findings to the government after six months of intensive monitoring of this issue, as requested in previous meetings with BLUD officials.We will also be installing waste treatment septic tanks at Barefoot Conservation and facilitating the installation of a system at a homestay on the West side of Arborek. These systems will act as a trial run, to understand the feasibility of installing systems for all homestays and homes on Arborek. We will closely monitor changes in water quality and reef health following the installation of these systems and will present these findings in follow-up meetings with BLUD regarding this issue.

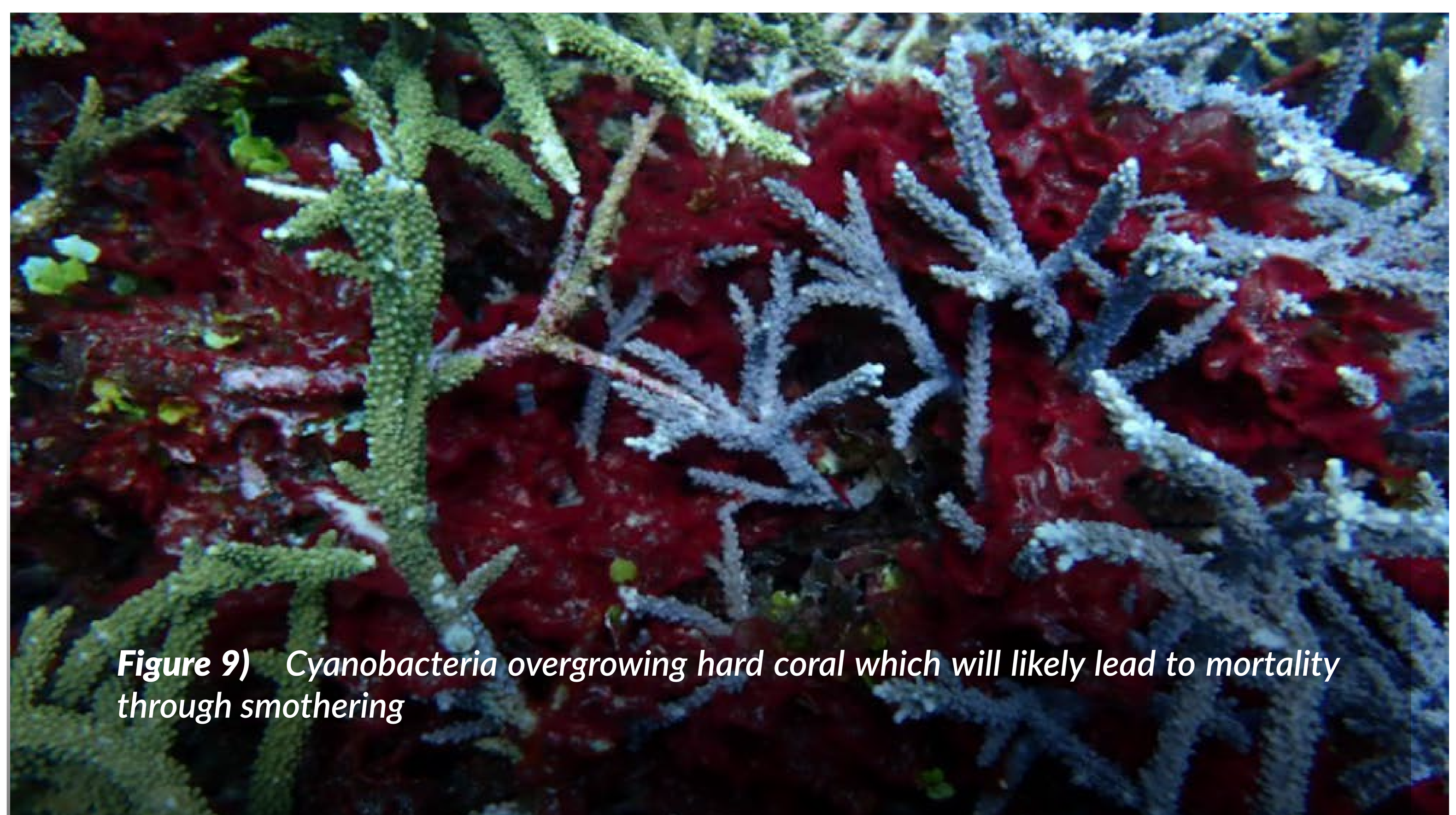


Figure 9) *Cyanobacteria overgrowing hard coral which will likely lead to mortality through smothering*

3 Reef Restoration Project

3.1 Overview

The restoration project was set up in late 2021 with three major aims: 1) to restore an acutely degraded section of Arborek reef which was not naturally recovering, 2) to educate and engage the local children about corals and how to preserve them, 3) to improve restoration science 'best practice' by undertaking research projects on different restoration techniques and filling research knowledge gaps. Given our 3 research goals, the project was best suited to a two-step nursery technique, the details of this technique are outlined in last year's annual report.

After one year of growing in the nursery, 2023 was the year where we transplanted large numbers of these corals to the reef and monitored various aspects of our restoration 'success'. We monitored growth and survival of corals within the nursery to identify which corals were suitable/ unsuitable for this method, we tested and compared different methods of outplanting to ensure the highest survival rates of our corals before rolling it out to the rest of the project, and we monitored overall changes at an ecosystem level which is part of a long-term assessment of restoration success.

Outplanting corals was a major feature of the project this year, as last year's coral fragments had grown to a healthy size within the nursery and were adequately sized to survive back on the reef. The 'outplanting' phase of two-step restoration is notoriously difficult with many projects reporting extremely high mortality at this stage, which is why we approached outplanting in a cautious and methodical way. Choosing the right method for transplantation was extremely important due to the unique hydrodynamic conditions of our transplant site which would make effective transplantation difficult. Details of the outplant comparison experiment are below.

Figure 10: Coral colonies growing in the nursery. Once large enough, they are outplanted to the reef

Figure 11: *A colony outplanted with a Coral Clip, now overgrowing the substrate*

Once the appropriate method for outplanting at our site was determined, we proceeded to empty the majority of corals from our nurseries, whilst making new ropes to continue growing corals for next year. Over 500 corals were outplanted from the nursery this year, with high rates of survival and many lessons learnt. We also improved the design of our nursery frames after experiencing some problems last year. This year has allowed us to trial and test various anecdotal methods of transplantation which have resulted in a streamlined and effective approach for growing and outplanting corals in the future, both for our own project and for other restoration scientists. We will be sharing our research findings with the government and at Indonesian coral restoration webinar in 2024.

3.2 Ecosystem-level monitoring

To date our restoration efforts have been confined to a 'restoration area' which was a degraded site near to Barefoot camp, spanning 900 m2 (fig 13a). Restoration focused within this zone will allow us to assess the success of our restoration efforts over time, not only at an individual colony level but also at an ecosystem level. Monitoring this site over 5+ years will be an important contribution to restoration research, as studies rarely span longer than one year and long-term monitoring has been called for in the literature. Preliminary results from this monitoring project will be reported next year, two years after corals were first transplanted to the site, to document any changes in fish biomass, natural coral recruitment and coral diversity. This restoration site will be compared directly to a control site where there has been no intervention, to ensure any changes are linked to our active restoration efforts as opposed to natural recovery. The restoration area which is the focal area for our restoration efforts exists of a large unstable rubble area (figure 13b, green box) and a hard rock area (figure 13b, yellow box). Our approach for restoring these two areas has differed accordingly.

3.3 Outplanting onto hard substrate

A total of 115 corals have been planted to the hard substrate area, using both the coral clip and cement method. These coral colonies have been tagged, mapped out (figure 14) and are being monitored over time for survival and growth.

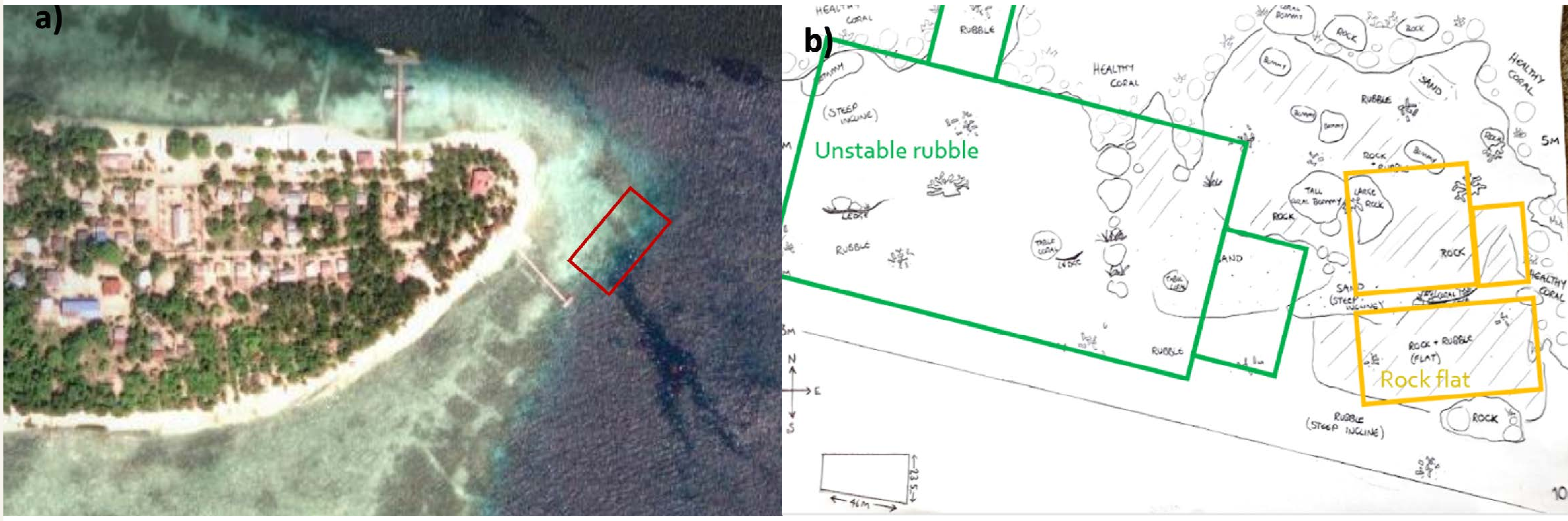


Figure 13a) *Site of the 'restoration area' marked as the red box, b) The restoration area is split into two substrate types: unstable rubble (green box) and rock flat (yellow box), outplanting to these two areas has been approached differently*

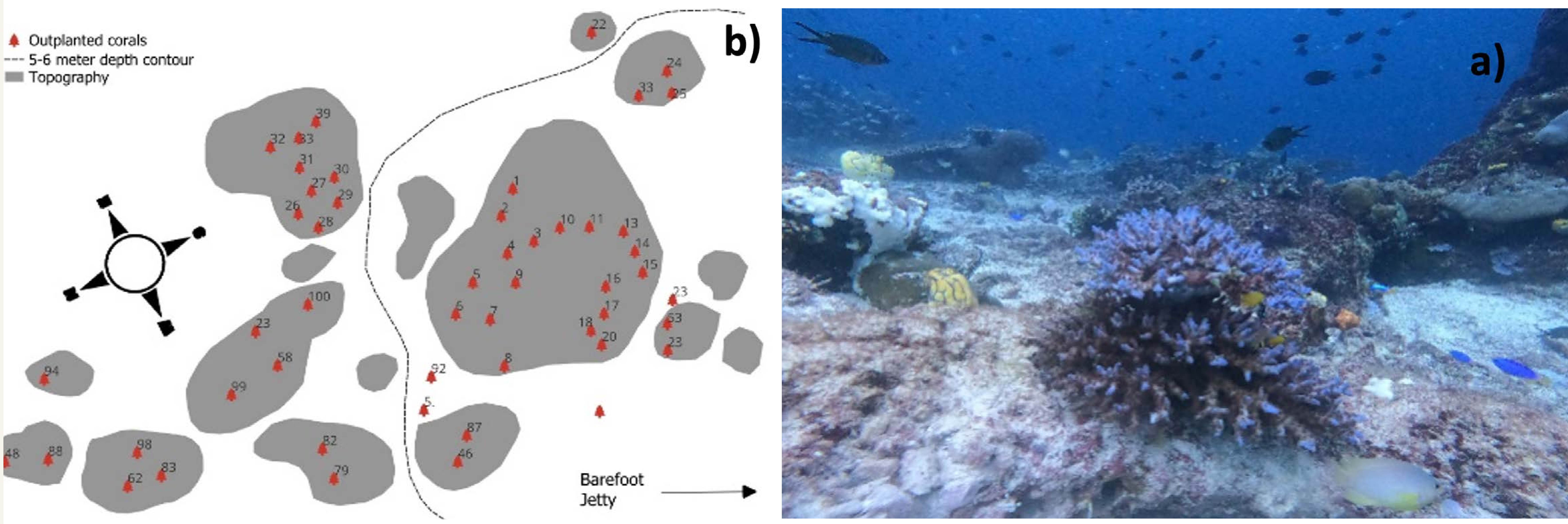


Figure 14) *An outplanted colony within the hard rock substrate area, b) Map marking 50 of the 115 outplanted corals within the restoration site hard substrate area*

Around 70% of these transplanted corals have permanently attached and are growing well, with <5% mortality of these transplanted corals and very low levels of disease or predation. Unfortunately, ~25% of transplanted corals have become dislodged since transplantation, with the vast majority of these corals (n=10) becoming dislodged from one particular exposed rock which is now thought to experience extremely high current flow, making it unsuitable for transplantation of corals that are not massive or submassive. However, this further provides us with knowledge on unsuitable areas for outplanting and provides us with a better understanding of the limitations of our transplant methods for certain locations.

We continue to monitor 50 of our transplanted corals by photographing them monthly from an aerial perspective alongside a scale bar (see figure 15a). Image J software is being used to estimate the 2D area of the outplanted corals (figure 15b) which will be used to determine monthly growth rates of each transplanted coral. Results of this study will be presented in next year's report.

These 50 transplanted colonies are also being monitored for stress, predation, disease and in particular bleaching, compared to natural colonies. It has been predicted in 2024 that we may experience high levels of bleaching worldwide, including Raja Ampat (Coral Reef Watch, NOAA) and so monitoring these colonies for bleaching, alongside natural colonies on the reef (see section 15) will provide important information about our nursery colonies' resilience to stressors. Bleaching resilience may also be a trait that we actively select for in the future when growing corals in the nursery, if bleaching does begin to detrimentally effect corals in Raja Ampat, so monitoring this is important. These 50 transplanted colonies will also be closely monitored during the spawning season via gravid checks to determine whether our transplanted colonies are reproducing and contributing to the reproductive potential of the region.

A key success of this project has been the rearing and successful transplantation of corals from a wide variety of coral genera and growth forms. This is noteworthy because the vast majority of restoration projects around the world focus restoration efforts predominantly using Acropora species due to their fast-growing nature and ease of fragmentation. However healthy and resilient reefs are made up of a range of coral genera, each playing vital roles within the system, and so 'successful' restoration must also strive to restore reefs to this diverse state. Within this project, more than 15 different genera of corals have been transplanted, with multiple species present within each genera (figure 16). Although this approach may present slower results than an Acropora dominated restoration project, the benefits are ultimately greater..

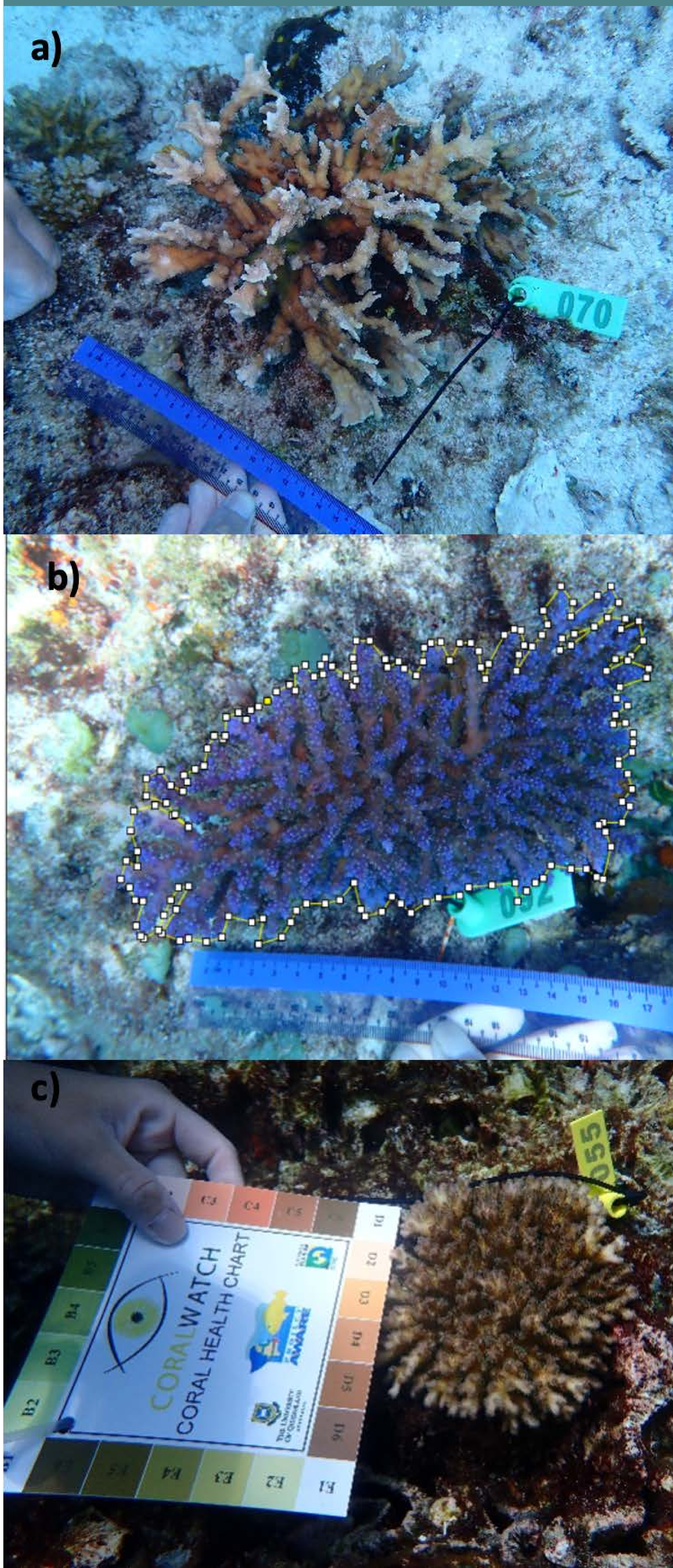


Figure 15 *a) An outplanted colony photographed with a scale bar during monthly monitoring dives, b) calculating planar area (cm2) of each colony using ImageJ software to compare growth over time, c) monitoring outplanted colonies for signs of disease or bleaching, in comparison to colonies on the natural reef*

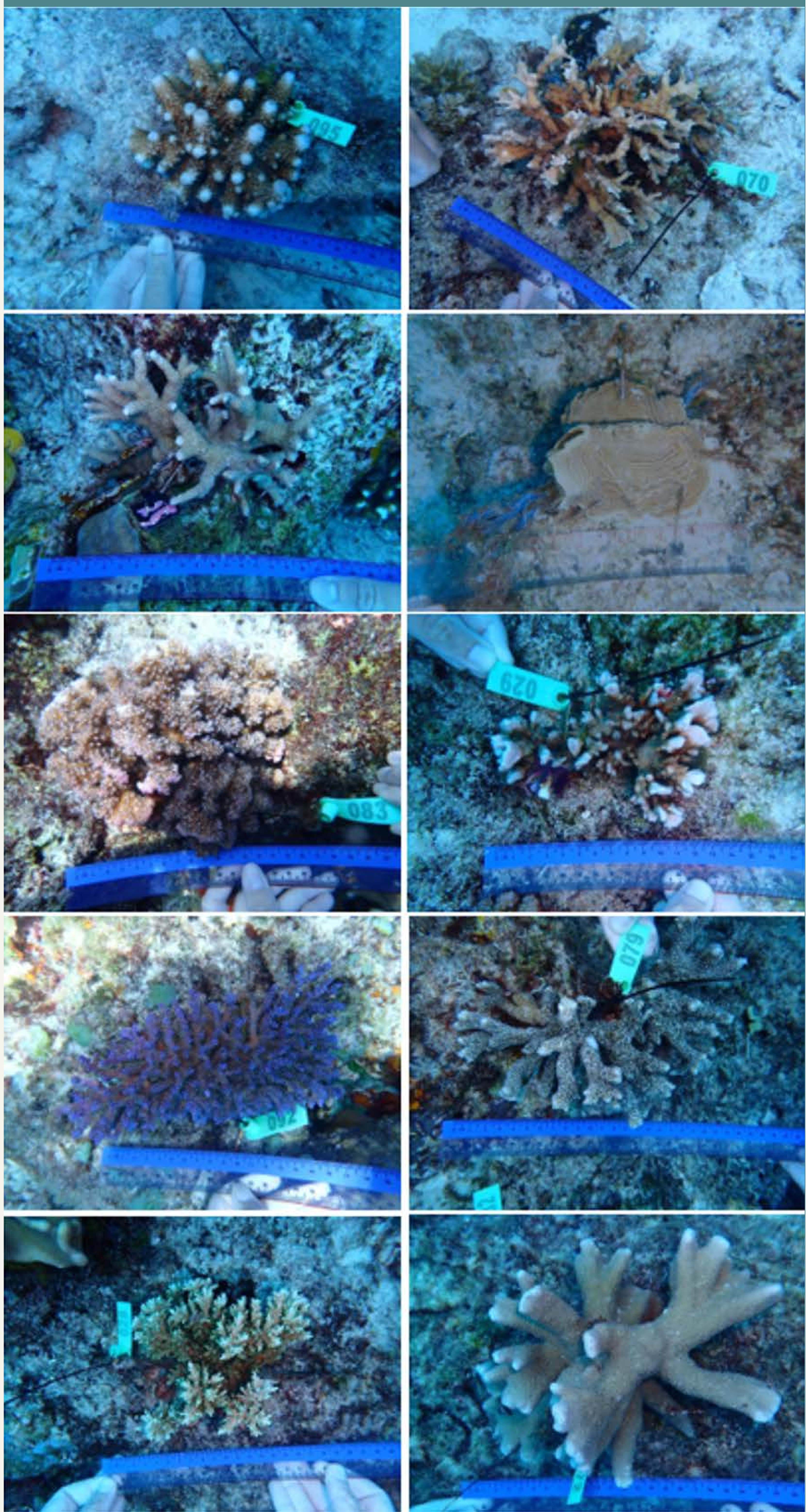


Figure 16) *An outplanted colony photographed with a scale bar during monthly monitoring dives, b) calculating planar area (cm2) of each colony using ImageJ software to compare growth over time, c) monitoring outplanted colonies for signs of disease or bleaching, in comparison to colonies on the natural reef*

3.4 Stabilising ruble substrate (green box)

An effective method to stabilise and restore a loose substrate/rubble area has been long sought after by restoration scientists, and whilst many attempts have been made, very little long-term success has been reported (Ceccarelli et al., 2020). For stabilisation of our rubble area we designed a hybrid method that would attempt to stabilise the substrate with a mixture of artificial structures and natural stabilisation capacity of corals. This consisted of a matrix of metal frames hammered deep into the rubble, combined with rows of fast growing staghorn corals which have the capacity to grow and stabilise substrate naturally (see fig 17).

Over the past year, five stabilisation frames have been deployed and 8 coral ropes have been secured to the loose substrate. A diverse range of rare corals from our stock nursery were attached to the stabilisation frames to kick-start the recovery of diverse corals to this area. The corals on the frames are growing well (figure 18) and include table Acropora, columnar Isopora. Importantly, the rubble underneath the frames appear to be consolidating which was a key aim of this approach. The frames themselves will also allow natural settlement of coral spawn which would not have previously been possible with a mobile substrate. The ropes of staghorn corals which were hammered into the ground are thriving (figure 17) and have formed natural barriers as planned, preventing rubble from falling down the slope and subsequently allowing areas of rubble to stabilise around it. Overall, we are extremely pleased with how this stabilisation attempt is going and have more than 300 coral colonies from a variety of genera growing in an area which was previously barren and inhospitable to coral settlement. Fish numbers have evidently increased, with fish resident to certain transplanted corals, particularly those from our Acropora ropes. We will continue to stabilise this area in 2024 by expanding the matrix of stabilisation frames and staghorn ropes.

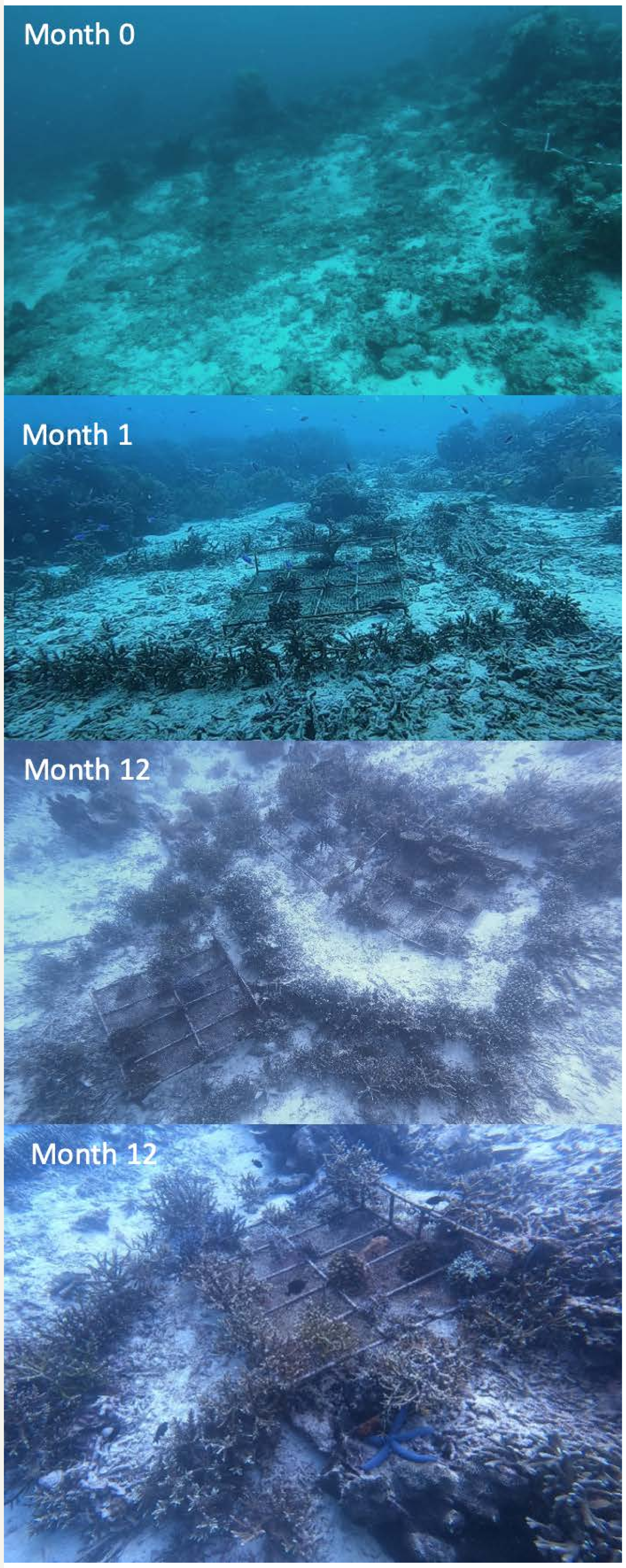


Figure 17) *The unstable rubble area within the restoration area, photographed over 12 months. Our stabilisation frames and coral ropes have improved stability and coral cover at this site in 12 months. Stabilising this area will allow natural coral recruitment to occur which was previously inhibited by the*

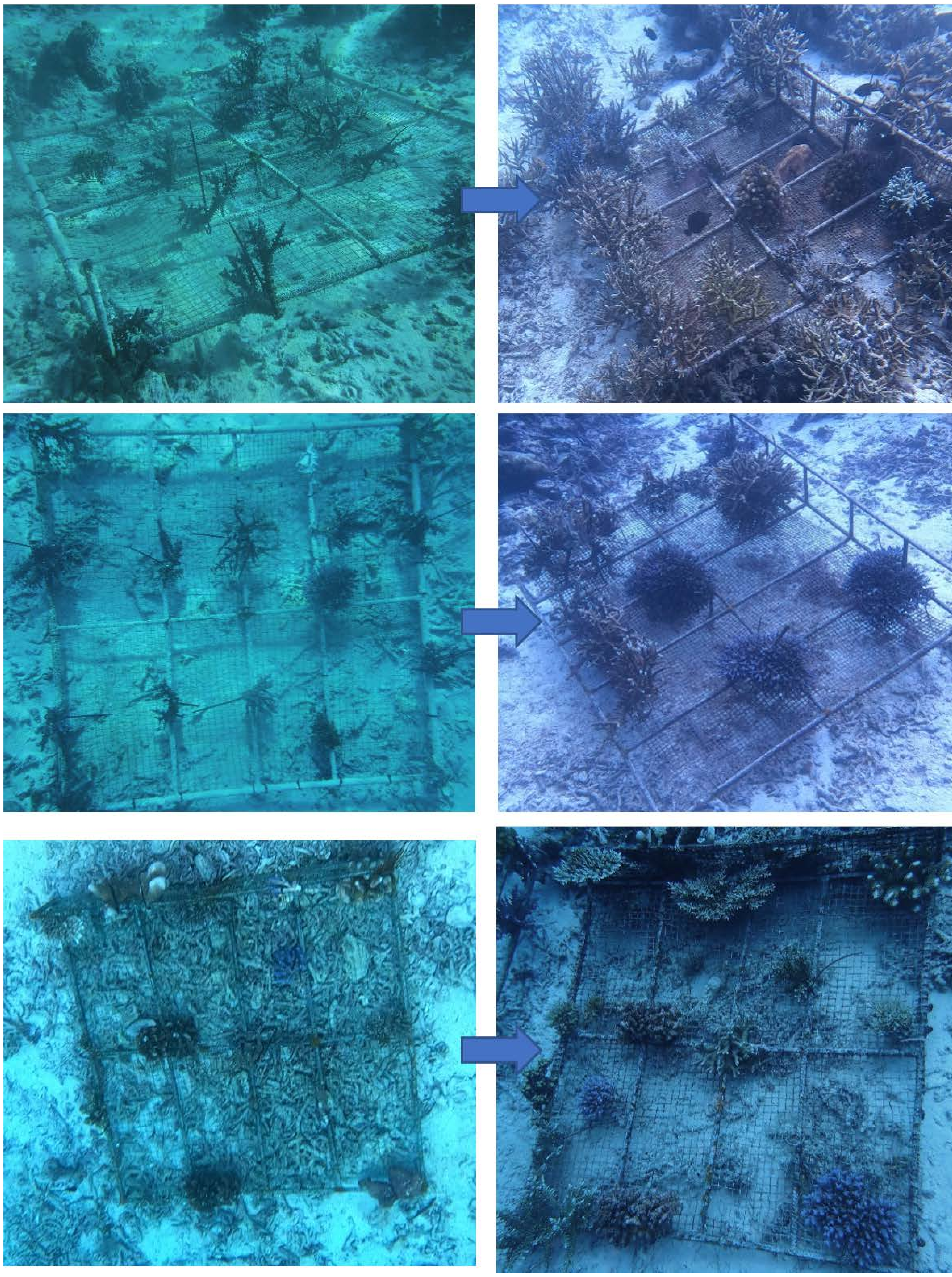


Figure 18) *Our stabilisation frames, designed with 5 legs hammered deep into the substrate to stabilise surrounding rubble and with a shelf behind to enable rubble build-up and natural accretion. A diverse range of coral species were selected for attachment that would supplement the staghorn corals laid all around the frames.*

3.5 3D Modelling of outplant area and colonies

Another new development this year was our capacity to use 3D photogrammetry to produce highly accurate 3D models of our coral outplants and outplant areas, this project was led by our science intern Max Kimble who has training in this method. This new technology is able to turn photographs of a colony (captured from all angles) into 3D models which can produce highly accurate assessments of size and surface area. We have been exploring this technology as a method to capture fine-scale changes in the size of our outplanted colonies over time. Furthermore, we are using it to image the wider outplant area, to visualise how it is changing as the multiple outplanted corals grow.

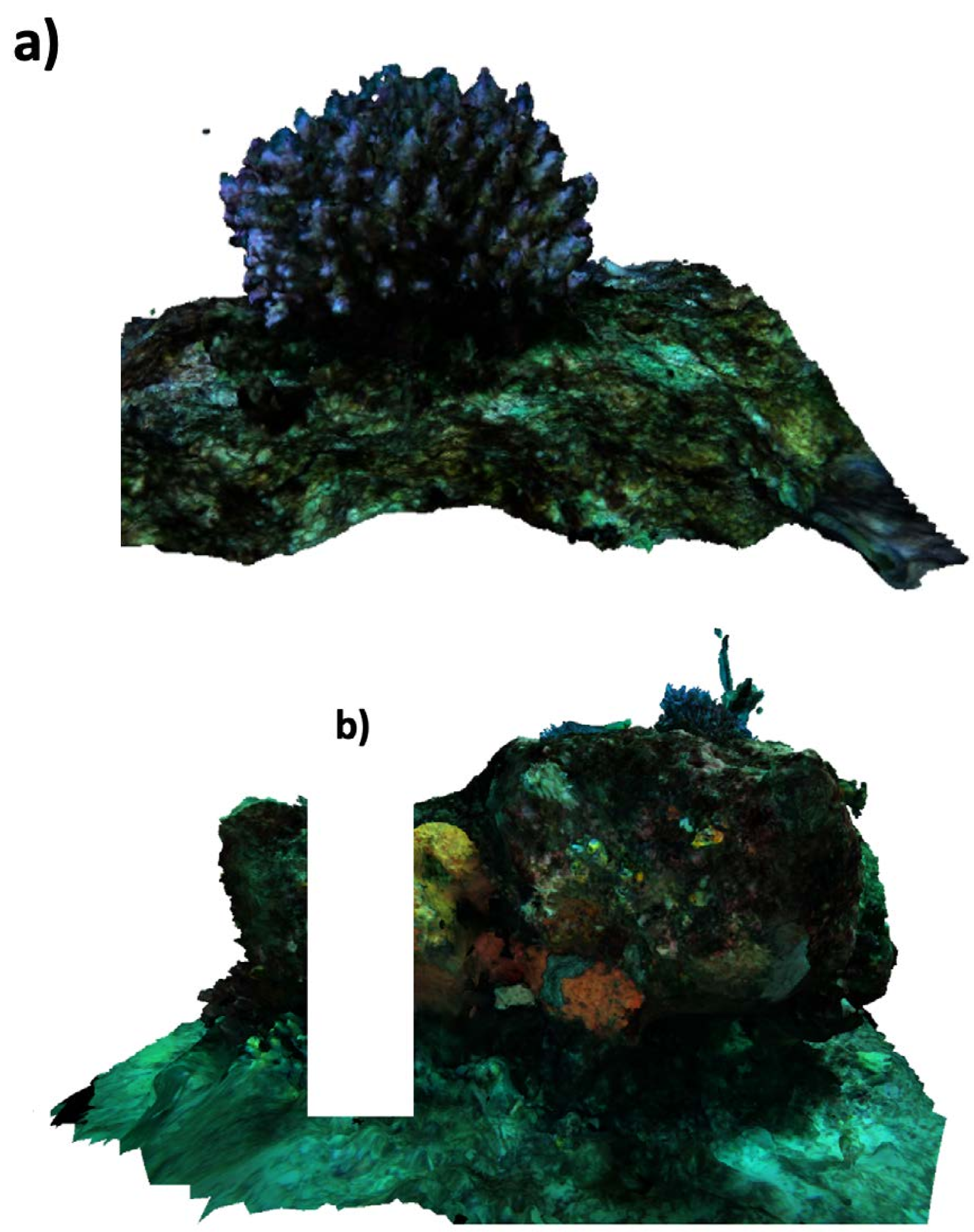


Figure 19: 3D models of a) outplanted coral colonies and b) outplant areas with multiple colonies. These models allow us to calculate fine scale changes in surface area over time.

3.6 Outplant technique experiment

An experimental trial was designed for the rock flat substrate, with the aim of comparing three different transplantation methods described within the literature. The three methods trialled were: a) Coral Clips (Suggett 2020), b) Cement with admixture (Unsworth et al 2021) and c) nail & cable tie (Unsworth et al 2021). The results of this experiment would inform the next steps of the outplanting process, where large numbers of colonies would need to be effectively transplanted to the site.

The experiment was conducted in December 2022 at Arborek Tip, and involved transplanting 6 corals within a 1m2 quadrat, with eight replicate quadrats (total=48 corals). Within the 1m2 quadrat, three different techniques were used to transplant 6 corals, with 2 replicates of each method. Four of the eight quadrats were located at 7-10m (deep) and the other four were located at 4-7m (shallow). At each depth, two of the quadrats contained small coral fragments, whilst the other two contained whole coral colonies and two of the quadrats contained species A (Pocillopora verrucosa) whilst the other two contained species B (Porites rus). The experimental design is explained in a diagram below (figure 20), as well as with photographs (figure 20). We wanted to trial the three different transplanting techniques and their efficacy for both small fragments and whole colonies. The results are outlined below.

3.6.1 Results

The results of this study demonstrated that 1 of the methods (nail and cable tie) was inferior to the others, with 87.5% of all coral fragments and 75% of all coral colonies becoming loose over the 2 month monitoring period. The coral clip method and the cement with admixture method had higher success rates, however the attachment rates for these methods were influenced by the size of the coral – the coral clip method had the highest attachment rates for the fragments (50% attachment) however only demonstrated 25% attachment for the colonies, whereas the cement method was successful for the colonies, securing 66.7% but only secured 37.5% of smaller fragments. There was no significant difference in attachment rates between Porites sp. and Pocillopora sp.

	Proportion of all corals fully stable at Week 8	
Method	**Fragments**	**Colonies**
Cement with admix	37.5%	66.7%
Nail & cable tie	12.5%	25.0%
Coral clip	50.0%	25.0%

Table 1 : *Proportional success of coral attachment after 8 weeks, comparing three different transplantation methods*

important contribution to restoration research, as studies rarely span longer than one year and long-term monitoring has been called for in the literature. Preliminary results from this monitoring project will be reported next year, two years after corals were first transplanted to the site, to document any changes in fish biomass, natural coral recruitment and coral diversity. This restoration site will be compared directly to a control site where there has been no intervention, to ensure any changes are linked to our active restoration efforts as opposed to natural recovery. The restoration area which is the focal area for our restoration efforts exists of a large unstable rubble area (figure 13b, green box) and a hard rock area (figure 13b, yellow box). Our approach for restoring these two areas has differed accordingly.

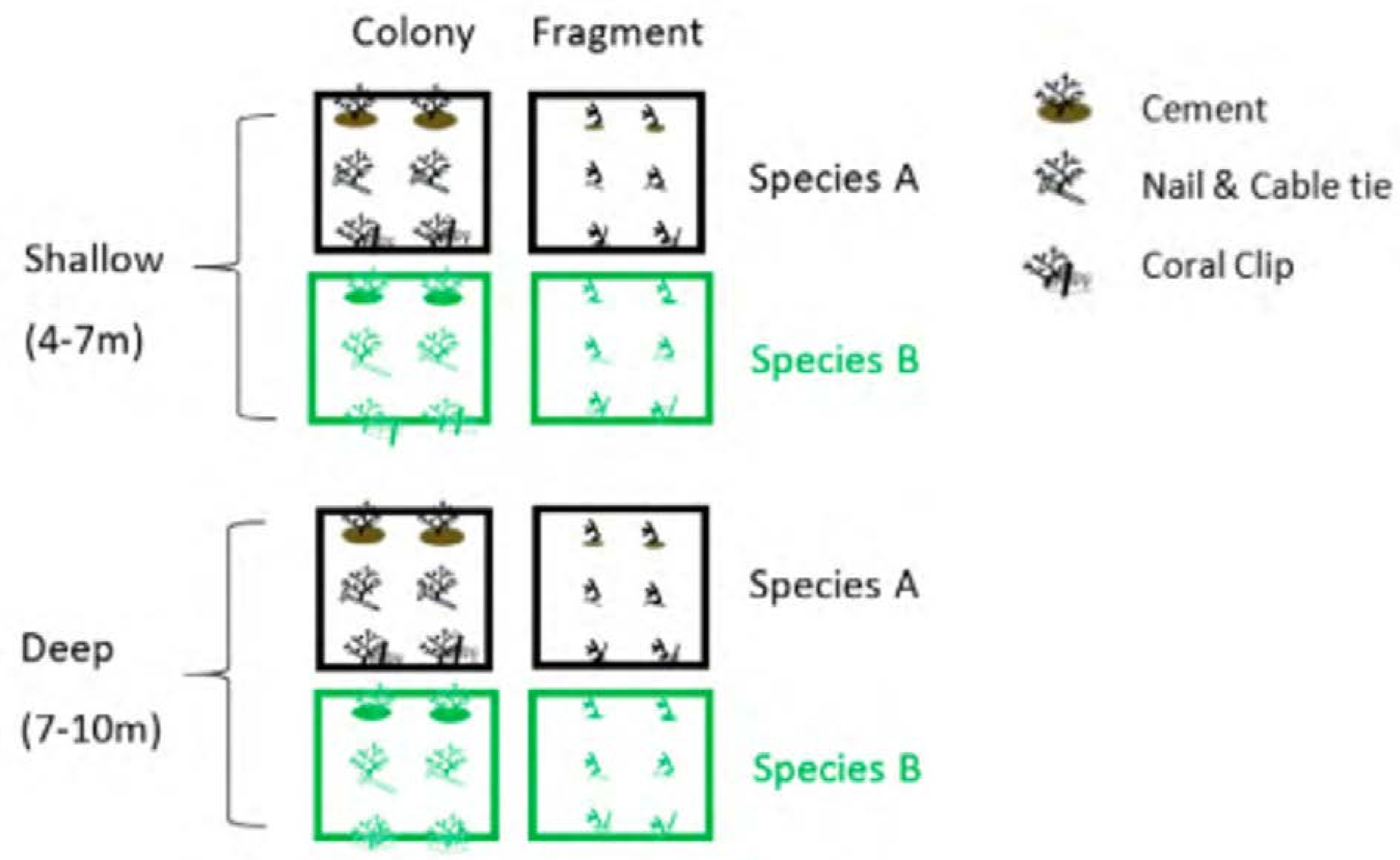


Figure 19: *Experimental design of transplant experiment at Eastern Arborek, trialling the use of three different transplant methods on two species, two coral sizes and at two depths*

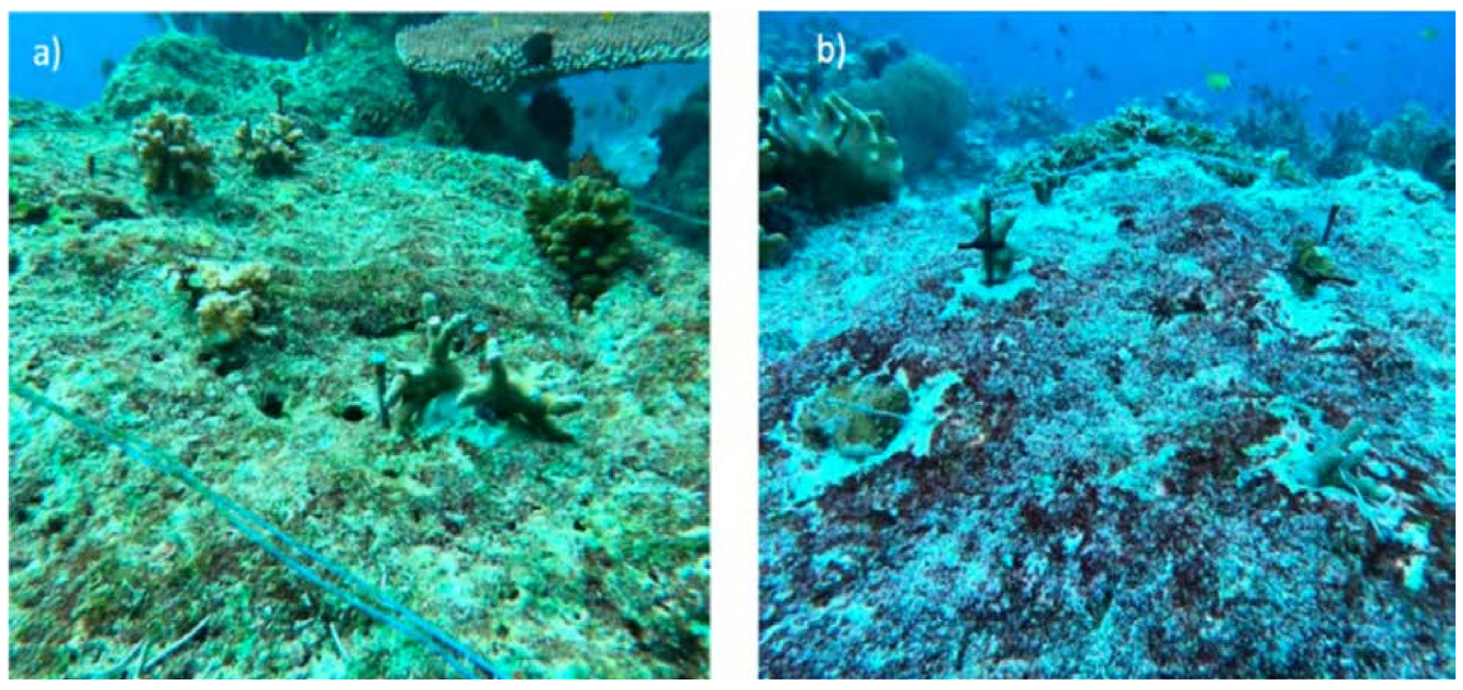


Figure 20: *Photographs of the transplantation experiment in situ, a) shows the 1m2 quadrat with 6 whole colonies transplanted using the three different methods, b) shows 6 coral fragments transplanted with the three methods*

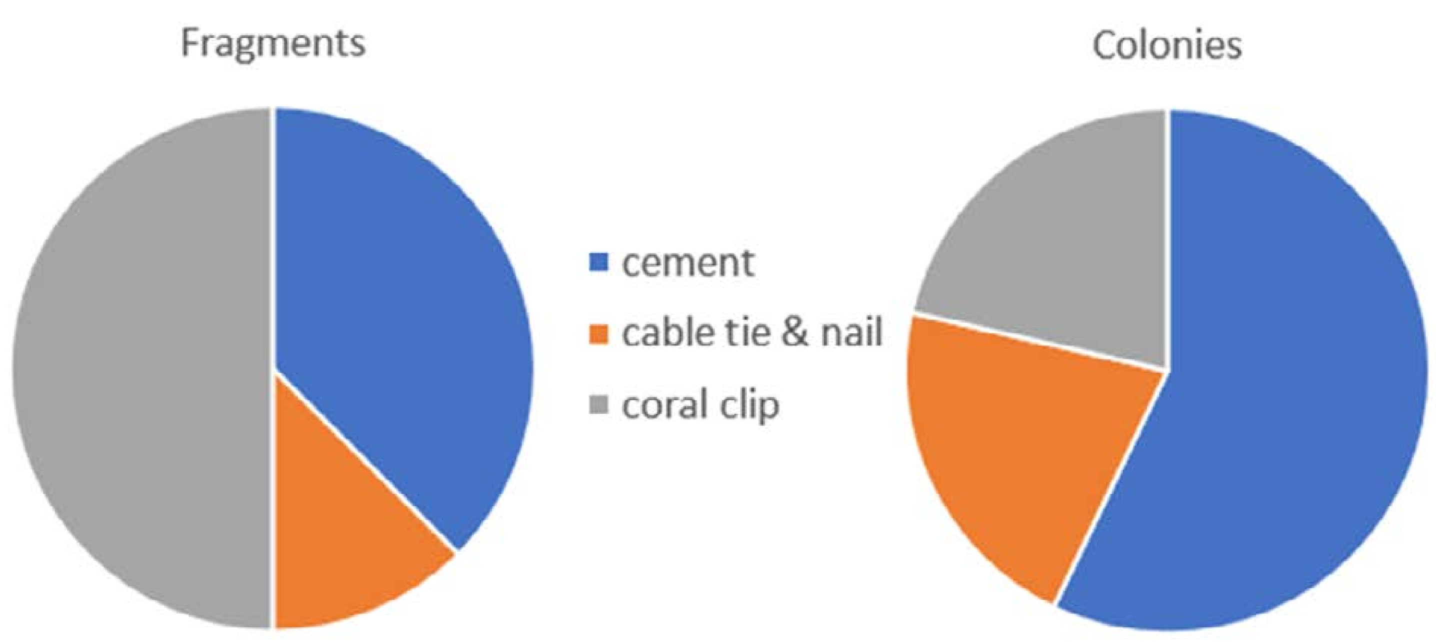


Figure 21: *Proportion of all corals that self-attached after 8 weeks post transplantation. Success rates of coral fragments and coral colonies were compared separately.*

These results have guided us to avoid transplantation using the nail and cable tie method which was an interesting finding because our initial review of the literature suggested that this method would be the cheapest and most time efficient, making it a front-runner for us to choose, prior to this experiment. As this project will primarily be transplanting larger colonies which have grown to size in the nursery, the data from this experiment suggests that the cement method will provide us with the best results.

4 Manta Ray Project

4.1 Overview

Raja Ampat is home to both species of manta ray – reef manta ray *(Mobula alfredi)* and oceanic manta ray *(Mobula birostris)* (Setyawan et al., 2020). Currently, both species are threatened, with M. alfredi listed as vulnerable and M. birostris listed as endangered on the IUCN Redlist (Marshall et al., 2016, Marshall et al., 2019). This is due to persistent anthropogenic threats including target-fisheries, driven by the demand of gill plates in Asian markets, by-catch, ocean pollution, habitat degradation, and unmanaged tourism (Setyawan et al., 2020). Furthermore, continually rising sea surface temperatures in response to climate change are reducing potential food availability for both species (Richardson et al., 2008). These pressures, combined with the conservative life-history traits of manta rays, exhibited as late maturity, slow growth, and low reproductive output, make populations vulnerable to rapid declines (Harris et al., 2021).

However, within Indonesia, manta rays have received full protection since 2014 (MMAF No.4/KEPMEN-KP/2014) with Raja Ampat holding the highest level of protection as an established shark and ray sanctuary since 2012. This has enabled populations to thrive within the area resulting in Raja Ampat hosting the second largest reef manta ray population in the world with 1800+ individuals identified (Setyawan., 2023, unpublished data). Although the population in this region is protected, the main threat these elasmobranchs face is unmanaged and unregulated tourism (Setyawan et al., 2022). With Raja Ampat's eco-tourism industry increasing annually and the area becoming more popular and accessible to tourists this may become a persistent issue. Furthermore, with little literature published on manta rays in this region, there is a lack of understanding of their distribution patterns and how an increase in exposure to people may negatively affect populations. Therefore, the manta project at Barefoot Conservation, with its growing database of individuals movement patterns, offers vital data which can be used to further our understanding of these species and thus identify if further management is required.

Barefoot Conservation's manta project has continued to advance exceptionally well this year. Organisation and development within the project has excelled due to the help of our full-time Manta Scientist, Lena Pollett.

Mobula alfredi have been seen within the Dampier Strait region for the majority of 2023. The northwest monsoon season (November-April) showed to have a higher frequency of sightings, especially during the months of January and

February. This is a result of favourable environmental drivers such as higher sea surface temperatures (SST) bringing in high plankton density (food source) which drives M. alfredi movement patterns (Ahsin et al., 2022). Conversely, the southeast monsoon (May- October) brings strong winds from the south driving upwelling resulting in nutrient-rich and cooler waters from a greater depth. Therefore, we observed fewer ID's, aside from the resident subpopulation within the area.

Mobula birostris sightings were infrequent this year with only two recorded in 2023. The season for this species ranges between January to May, however, sightings are rare due to the species' pelagic habitat selection, resulting in a majority of their time spent in open water. Due to the lack of data on *M. birostris* the majority of the results presented herein will be analysing the M. alfredi data.

Barefoot conducts training for volunteers and staff on manta ecology/behaviour, threats, how to responsibly interact with mantas (following Manta Trust's Code of Conduct), and how to ID manta rays. Once trained, volunteers are able to scuba dive at our known manta cleaning stations and collect manta ID photographs as well as collect data on individual demographics such as sex, size, maturity, colour morph and species. Furthermore, data regarding environmental variables, injury types/locations, behaviour and pregnancies are collected. Generally, we have two known cleaning stations (Manta Ridge, Manta Sandy) and one known feeding area (Mambarayup) which we visit regularly to observe reef manta rays. However, this year it has been found that West Arborek is also a popular feeding ground for these elasmobranchs and have frequent sightings of *M. alfredi* around Arborek.

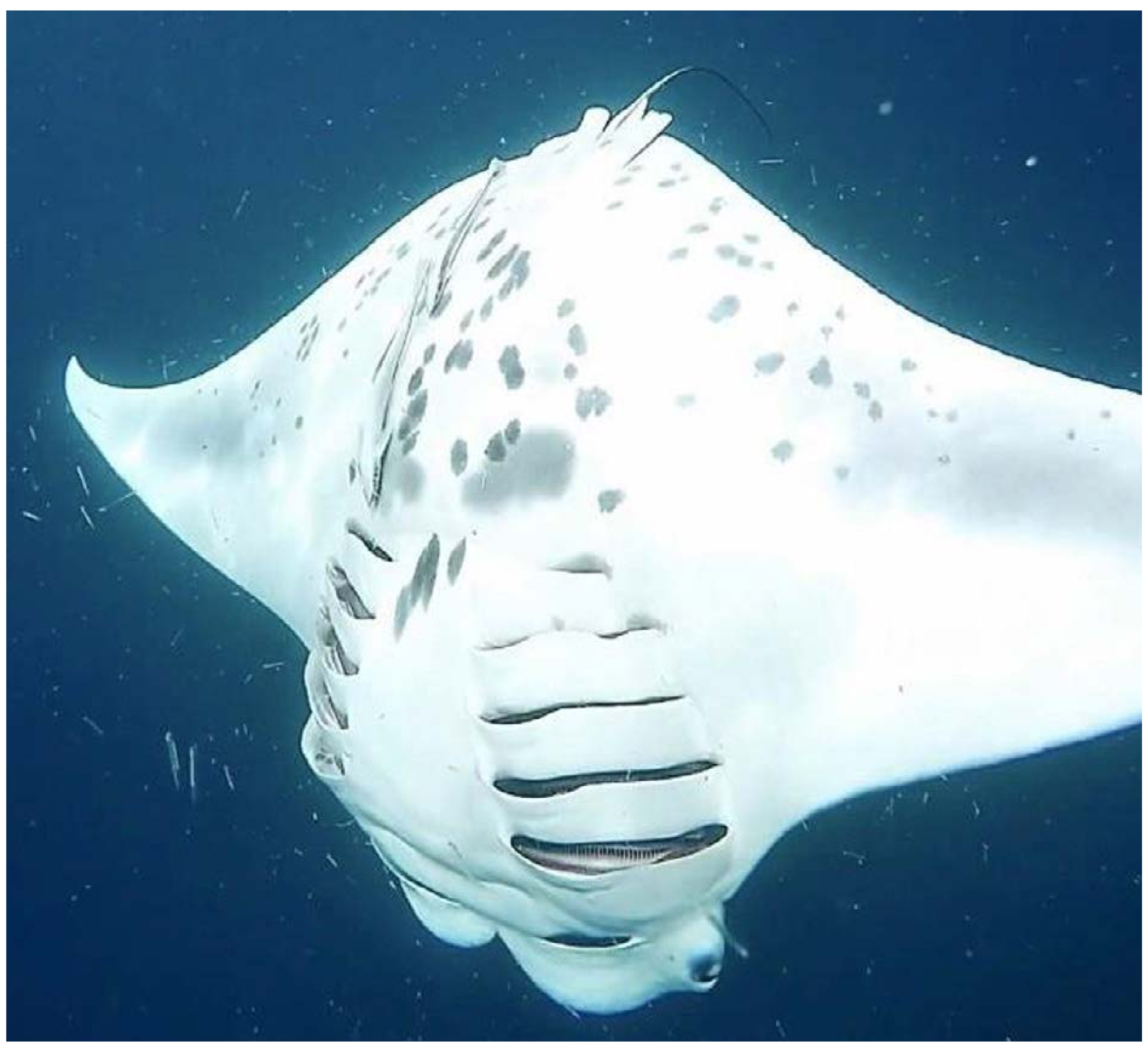


Figure 22: *Mobula alfredi barrel rolling off of Arborek jetty during January 2023 (Credits: Jeremy Ogden)*

Lena has also been providing manta ray talks to numerous liveaboard guests that visit Arborek, commencing at the start of the liveaboard season in October. These talks consist of detailed information on how to ID a manta ray, behaviour displayed and Code of Conduct, promoting conservation for these species. Additionally, she has asked for these liveaboards to put up posters of Manta Trust's Code of Conduct and further provides her contact details so they may send any manta ID shots taken during their trip. Through receiving liveaboard data Barefoot's database has increased significantly, and we are now able to include cleaning stations such as Dayang into our results, as well as sightings from Misool. The liveaboards provided with presentations are as follows: Ratu Laut, Calico Jack, Anne Bonny, Solitude Adventures, Gaia Love, Scubaspa zen, SeaTrek and Aqua Blu.

Figure 23: *Lena Pollett providing a manta ray presentation on Gaia Love liveaboard*

This year Barefoot Conservation has continued to collaborate with Raja Ampat Manta Ray Conservation Research by sending them our ID photos and data once ID'd. This collaboration further assisted Edy Setyawan with his PhD on the metapopulation within the Bird's Head Seascape.

Moreover, we have also had an intern from The Netherlands join us this year writing her final year report on 'Environmental drivers influencing distribution patterns of reef manta rays situated in the Dampier Strait region'. Lena (Lead Manta Scientist) and Max (Assistant Manta Scientist) have aligned their skill sets and assisted her on this project as co-supervisors. Lastly, we were also fortunate enough to encounter two rare elasmobranch sightings this year. One of an Ornate Eagle Ray *(Aetomylaeus vespertilio)* in January at RSB, near to Manta Ridge and another of a Giant Guitarfish *(Rhynchobatus djiddensis)* in November at Sawanderek. Knowledge on the importance of these sightings led us to report the information and photos to Elasmobranch Project Indonesia, where the data can be used for future re-assessments on the species distribution and vulnerability status.

4.2 Mobula alfredi 2023 results

A total of 217 sightings of *M. alfredi* were recorded in 2023 (January – November) from which 154 (71%) were female and 63 (29%) were male. The sightings consisted of 145 different individuals with 106 new ID'd individuals added to the database this year. The most resighted individual was MR-0291 (adult/female/chevron) being seen on seven different occasions at the beginning of the year primarily at Manta Sandy. Furthermore, two pregnancies were also identified this year (Figure 24) and on three different occasions courtship behaviour was observed.

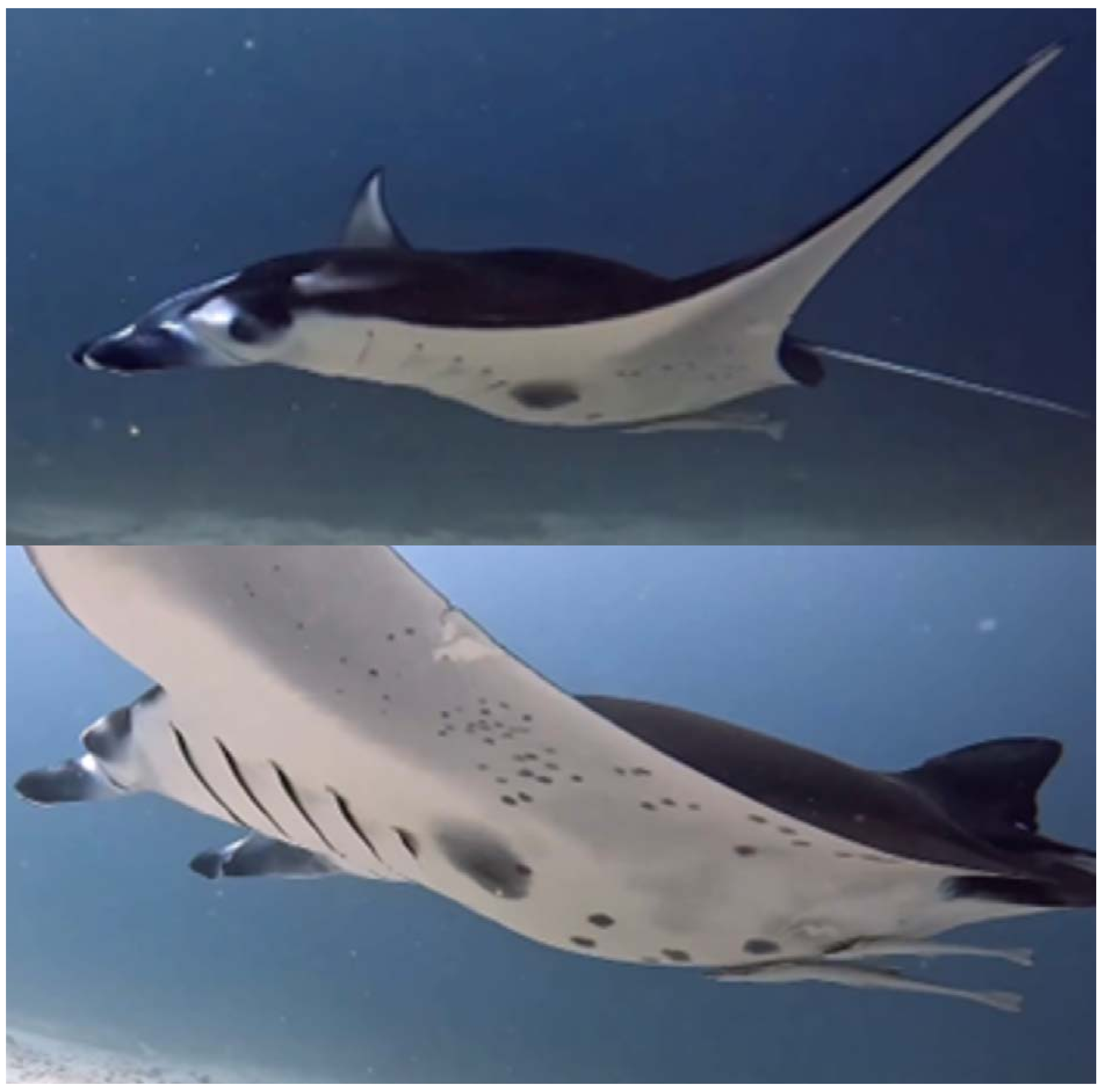


Figure 24: *Pregnancy of individual MR-0291 at Manta Sandy in May*

4.3 Mobula birostris 2023 results

Two *M. birostris* individuals were sighted in 2023 both of which showed to be new individuals to Barefoot's database. Sightings were located at West Mansuar and Blue Magic during the months of March and June. The M. birostris database now consists of 12 individuals with a majority of sightings found at Blue Magic, a known oceanic cleaning station.

4.4 Mobula alfredi demographics in database

Across the total database (n=336) the ratio of female to male manta rays observed was 1.7:1 respectively, with 210 females and 126 males. A greater difference can be seen between colour morphs with 222 individuals found to have chevron (normal) colouration and 114 individuals with a melanistic (black) colouration (figure 25). These findings are similar to results found on the whole metapopulation within Raja Ampat (Setyawan et al., 2020).

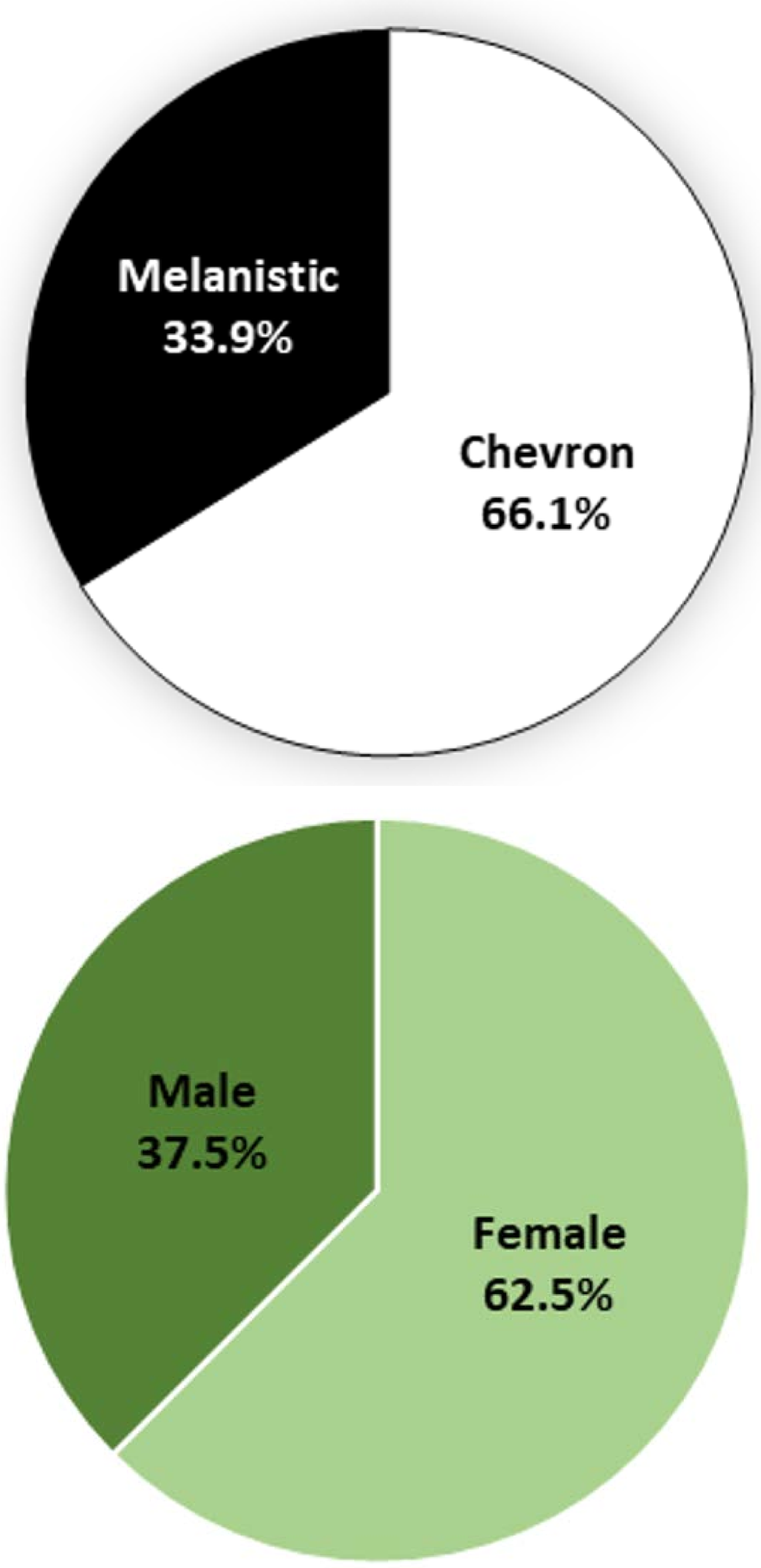


Figure 25: *Pie charts summerizing the percentage demographics (colour morph and sex) within the Barefoot database*

4.5 Mobula alfredi sightings comparable over months and sites

February showed to have the highest number of sightings with a total of 69 individuals observed followed by January with 43. In September there were no *M. alfredi* identified and only one individual was seen in the month of July (Figure 26, next page).

4.6 Mobula alfredi sightings across sites

In total, data was recorded across five different sites within the Dampier Strait area, including Manta Ridge, Manta Sandy, Mambarayup, Dayang and around Arborek Island. The most visited sight by *M. alfredi* was

Manta Ridge with a total of 78 sightings followed by Manta Sandy (table 2 & figure 27).However, it should be noted that we do visit these two sights most frequently, therefore, referring to the average sighting per sight in relation to number of visitations by divers provides a better understanding of sites most visited by *M. alfredi*. Table X further demonstrates the three cleaning stations (Manta Ridge, Manta Sandy and Mambarayup) to be visited most frequently by *M. alfredi* and Mambarayup having the fewest mean sightings.

SITE	LATITUDE	LONGITUDE	NUMBER OF SIGHTINGS	MEAN SIGHTINGS
Manta Ridge	-0.5546567	130.572203	87	3.5
Manta Sandy	-0.579878	130.541014	71	2.7
Mambarayup	-0.5796581	130.5373423	3	1.5
Dayang	-0.7942672	130.5038556	28	2.5
Arborek	-0.5671546	130.5073391	28	2.3

Table 2: *Shows the five site names, coordinates and mean number of sightings across sights (frequency of sightings/number of visitations)*

Figure 26: *Graph illustrates the number of sightings of M. alfredi across the months in 2023 excluding December*

Figure 27: *Illustrates the number of sightings across five known manta sites with circle size indicating frequency of sightings*

4.7 Plans for manta ray project 2024

In 2024, we aim to continue to collaborate with local scientists, governmental organisations and liveaboard operators to further manta ray scientific output, conservation & management for these species. To achieve this, we hope to increase our communication and outreach with organisations such as BLUD with the aim for more efficient and effective management, especially at manta cleaning stations. We hope to achieve this through video evidence and data collection on number of divers and diver behaviour at particular manta dive sites, such as Manta Ridge which may have detrimental impacts to manta rays natural behaviour e.g. cleaning. We also hope to continue collaborating with local scientists in the area by sharing our resources and data.

Another goal for 2024 is to increase awareness & education of manta rays and sharks within the local community. Through our regular school visits we will introduce more marine -based material focusing on why these organisms are important to the ecosystem and how to conserve them.

Lastly, after establishing the lack in literature on environmental drivers influencing distribution patterns of Mobula alfredi, Lena and Max have decided to collaborate in researching this topic further with the hope of presenting findings to governmental organisations in the middle of 2024. This may further illustrate seasonal movement patterns of *M. alfredi* and identify temporal locations where greater management, particularly on boat speed, may be required.

5 Coral Ecology & Bleaching Project

As global ocean temperatures continue to rise, coral bleaching events have increased in severity and frequency in the last few decades (Hughes and Anderson, 2018). Luckily, due to its unique topography and strong currents, Raja Ampat has been subject to thermal refugia, receiving cool deep water, alleviating potential heat induced stress (De Clippele et al., 2023).

Unfortunately, despite this cool water flushing, high biodiversity and species richness, Raja Ampat experienced its first bleaching event in 2023. Furthermore, NOAA Coral Reef Watch predicted a 80-90% chance of large scale bleaching events to take place during the months of December, January, February and March 2024. This is the first time in Raja Ampat's history that a bleaching event of this magnitude has been predicted.

In response to this, Barefoot Conservation rapidly established a Coral Ecology and Bleaching Project, aimed at recording and monitoring the health of selected coral colonies on one of our local reefs in an effort to capture high resolution bleaching data if such a phenomenon were to happen.

To ensure high quality data is collected if a bleaching event is witnessed across the Raja Ampat region, three sites along our house reef were established. Each site is comprised of a 20 meter transect running across healthy, previously unbleached corals. Surrounding this transect are 20 tagged corals. Each of the tagged corals have been specifically chosen to ensure a range of morphologies and species are being monitored, allowing a potential difference in bleaching response to be observed.

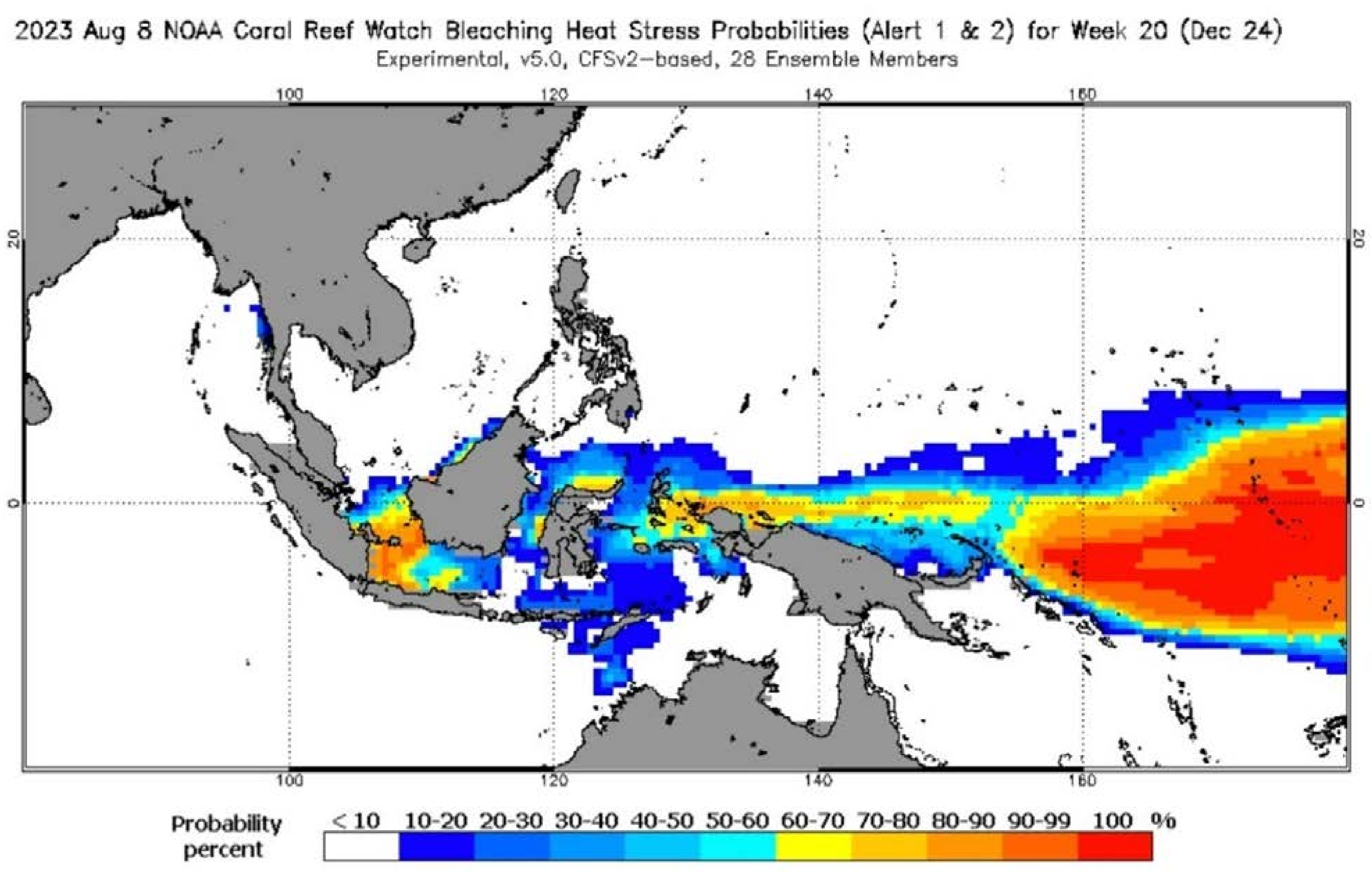


__Figure 28:__ NOAA Coral Reef Watch Bleaching Heat Stress Probabilities (Alert 1 & 2) for Week 20 (Dec 24th 2023) (accessed on Aug 8 2023)

During the survey we employ the use of CoralWatch colour cards, a mobile quadrat with a mounted camera, and two torches. Half of the dive team make their way along the 20m transect taking photos every 1m using the camera attached to the quadrat (see figure 29), this ensures the same spatial resolution is achieved when analysing the images in a software. The second half of the dive team will search the site around the transect for 20 tagged corals, at each tagged coral they will place the CoralWatch colour chart next to the tagged colony and a high resolution photo will be taken, whilst simultaneously the closest colour match for the lightest and darkest shade of the coral will be recorded on a slate. After this survey has been repeated multiple times, any trends or shift in colour/ shade due to potential bleaching will be able to be recognised, creating a detailed long-term data base of multiple corals at differing depths.

All data collected is being shared with local authorities, marine management organisations, University of Queensland (CoralWatch) and NOAA Coral Reef Watch team who have requested real-time data from the field to ground truth their satellite models. With the high quality, fine scale data we will collect, Barefoot conservation has the potential to collect and distribute invaluable data for predicting future bleaching events whilst also assessing the resilience and recovery window required for the coral species in Raja Ampat. This data aims to fill knowledge gaps and aid policy making processes regarding the outlook of Raja Ampat's coral reef ecosystems.

Figure 30: *Bleaching surveys conducted with the CoralWatch colour chart. Data is shared with University of Queensland*

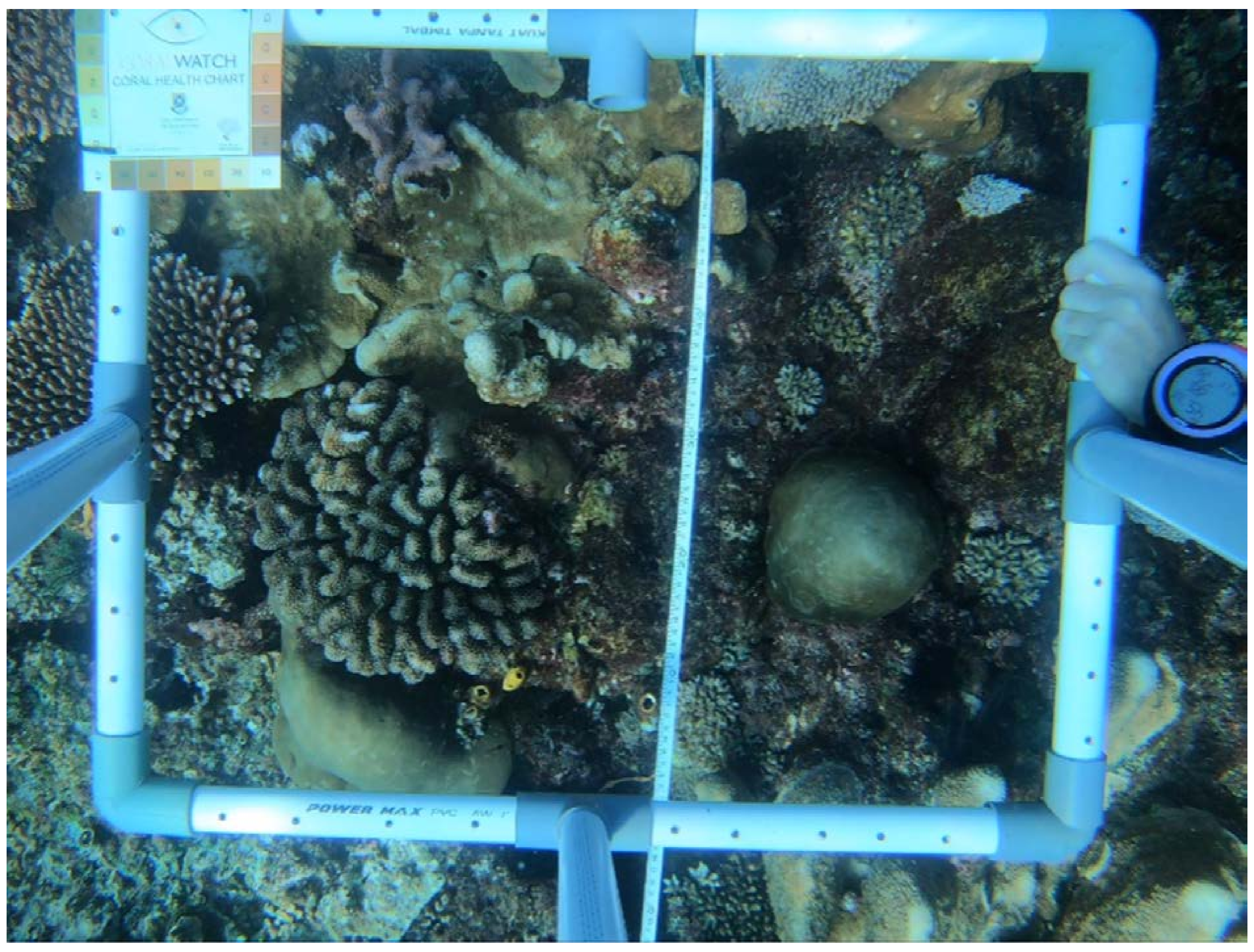


Figure 29: *Photoquadrats are also conducted during bleaching surveys.*

We plan to continue this project until at least April 2024 and recommence as the waters warm up at the end of the year again. Not only will this ensure bleaching events are captured, but also allow us to monitor the recovery of our reefs if a bleaching event happens.

This project is still in its infancy with only 12 full surveys conducted so far. In mid- December some evidence of paling was detected, particularly for Goniastrea colonies which are known to be some of the first corals to react to warming waters, however widespread bleaching was not observed and pale colonies returned to normal in the following weeks. There is still a chance of bleaching to occur in the first months of 2024 and so we will continue to monitor changes carefully until the warming has pass. Additionally, changes across the tagged corals have been witnessed with respect to other threats; namely the predation of a branching Acropora by sponge *(Chalinula nematifera)*, we will continue to monitor the progression of this sponge in our surveys.

6 Reef Check

6.1 Overview

Monitoring of the coral reef ecosystem conditions around Arborek Island began in 2016. The Reef Check method has been used to observe the health of the reef ecosystem, which includes data on benthic cover, fish abundance, and invertebrate abundance. Other things that impact coral reef health such as bleaching, disease, trash, and predation are also monitored at each survey location.

Our 'Core survey sites' are monitored a minimum of once every 6 months, including Barefoot Jetty, Main Jetty, Juans bay, Juans reef, West Mansuar, and Isais garden (figure 31). Long-term observations at these key sites aim to record any fluctuations that occur both naturally and influenced by anthropogenic factors and to provide information related to unnatural changes around the survey area. All data obtained is reported to local policy makers in Waisai, BLUD annually, and to Reef Check Indonesia every 6 months.

Survey sites Arborek Jetty, and Barefoot Jetty were selected as "Impact sites" to document the effects of diving and tourism on coral reef areas. Juans Bay and Juans Reef were chosen to be monitored as they are known to be impacted by historic fish farming. JPP was selected as a site known to be affected by illegal anchoring. This year in 2023, sites Manta Sandy and Southwest Arborek were included as core sites because an increase in cyanobacteria and macroalgae was documented at these sites last year which we wanted to monitor more regularly. In 2023, a total of 18 surveys have been conducted around Arborek Island with the help of international volunteers. All target sites were monitored between 2-4 times (at two depths) and additional bonus sites were also surveyed, meaning that our 2023 targets for Reef Check monitoring were surpassed.

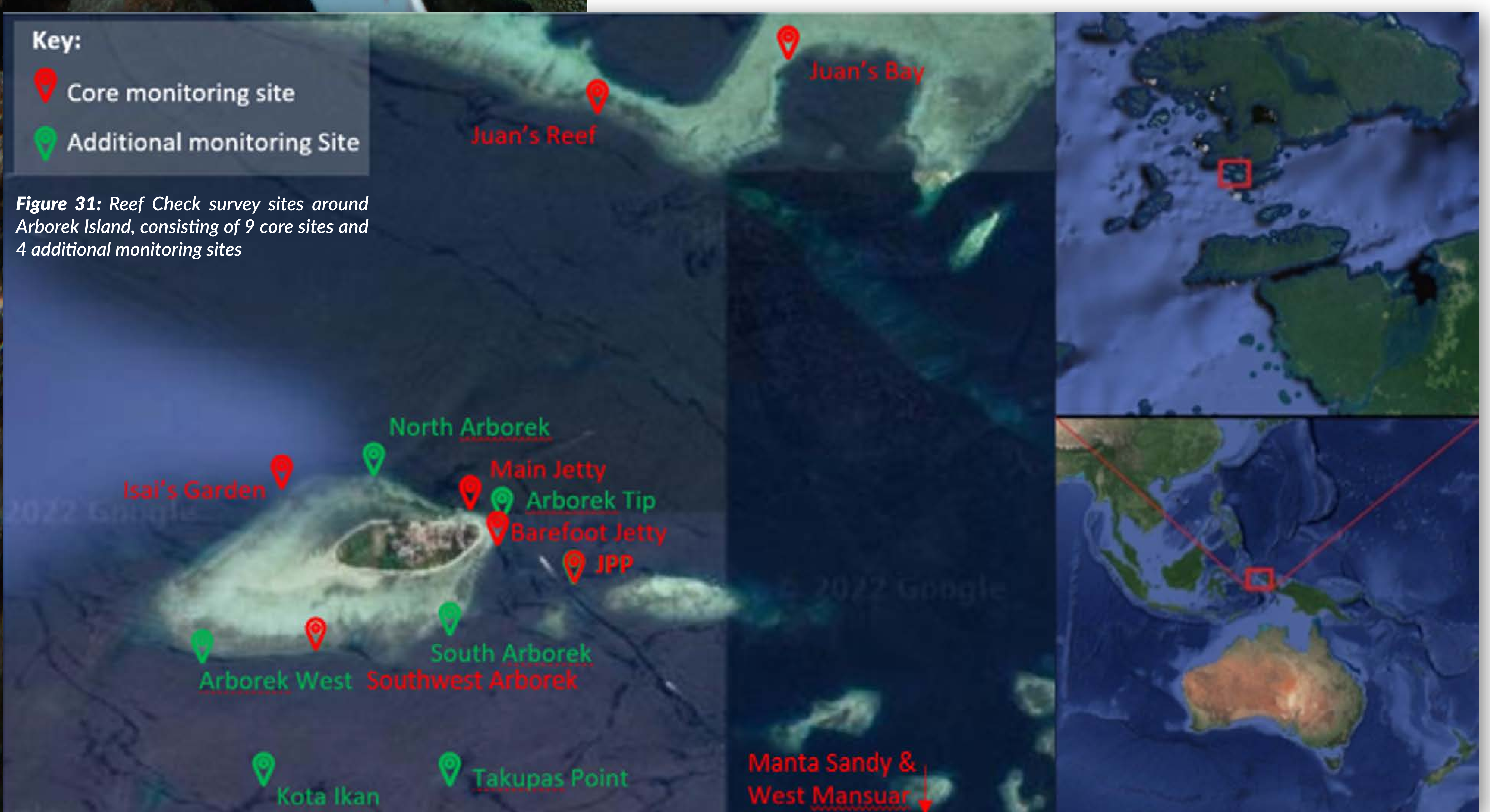


Figure 31: *Reef Check survey sites around Arborek Island, consisting of 9 core sites and 4 additional monitoring sites*

6.2 Benthic data results

The results of benthic surveys using the Reef Check method conducted at all survey locations are divided by each benthic category and presented in figure 32. This data was collected using the Point Intercept Transect technique along 100m transects at 3-5m and 7-9m depths. Data below is pooled by site.

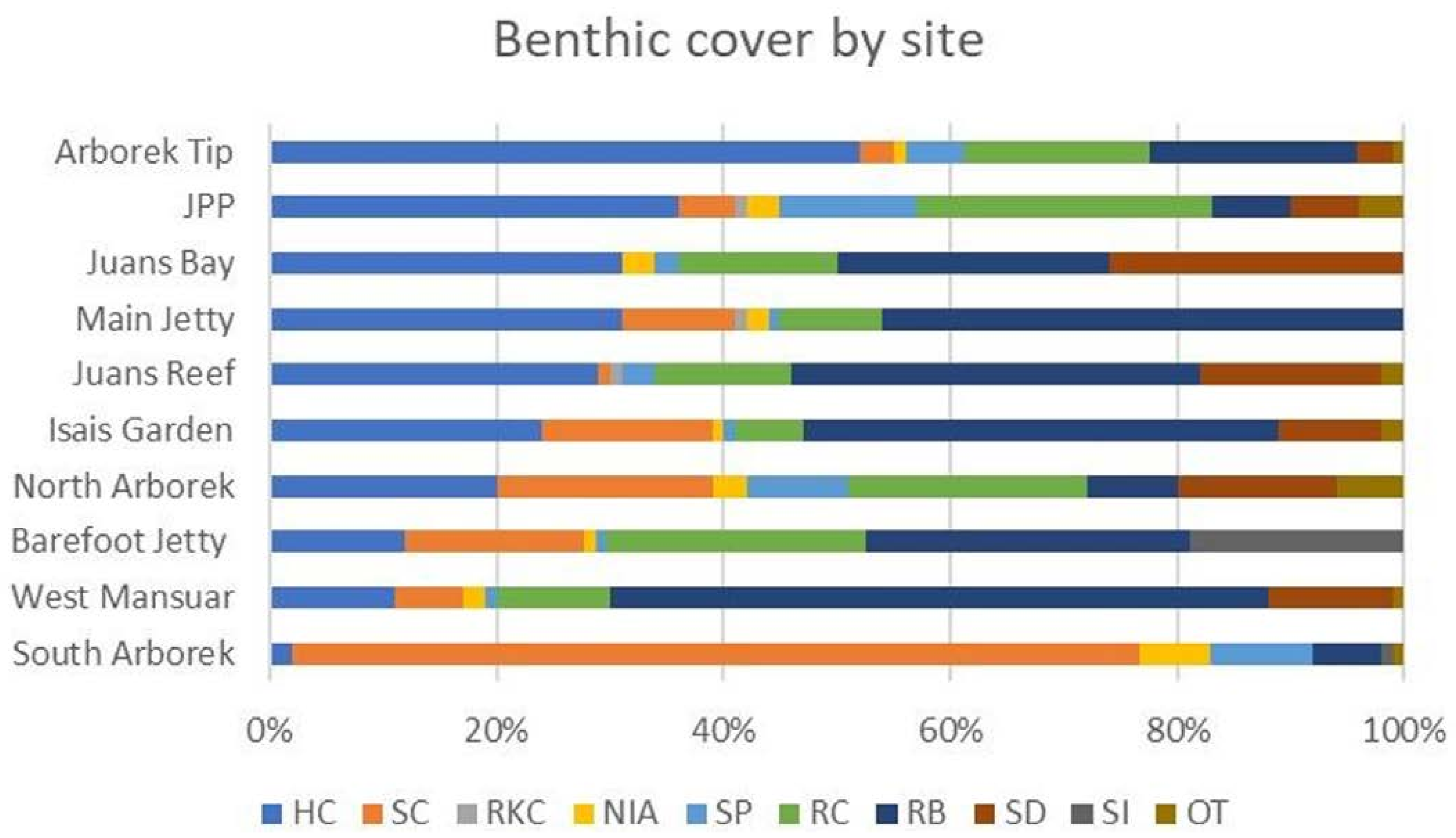


Figure X: *Proportional benthic composition at key survey sites around Arborek Island*

Figure 32 shows that Arborek Tip has the highest hard coral proportion of all the sites (51% HC), whilst South Arborek has the lowest proportion of hard coral (2% HC). The proportion of hard coral cover at South Arborek has declined from last year by 7% and the proportion of soft coral at this site has increased by two-fold (38% in 2022 to 72% in 2023). South Arborek is becoming increasingly dominated by soft coral, cyanobacteria and nutrient indicator algae (NIA), which are signs of a phase-shift to a degraded site, likely as a result of poor water quality (see section 2).

Figure 33 shows variation in key benthic groups at Barefoot Jetty over time (2017-2023). This data shows the that hard coral cover under Barefoot Jetty has

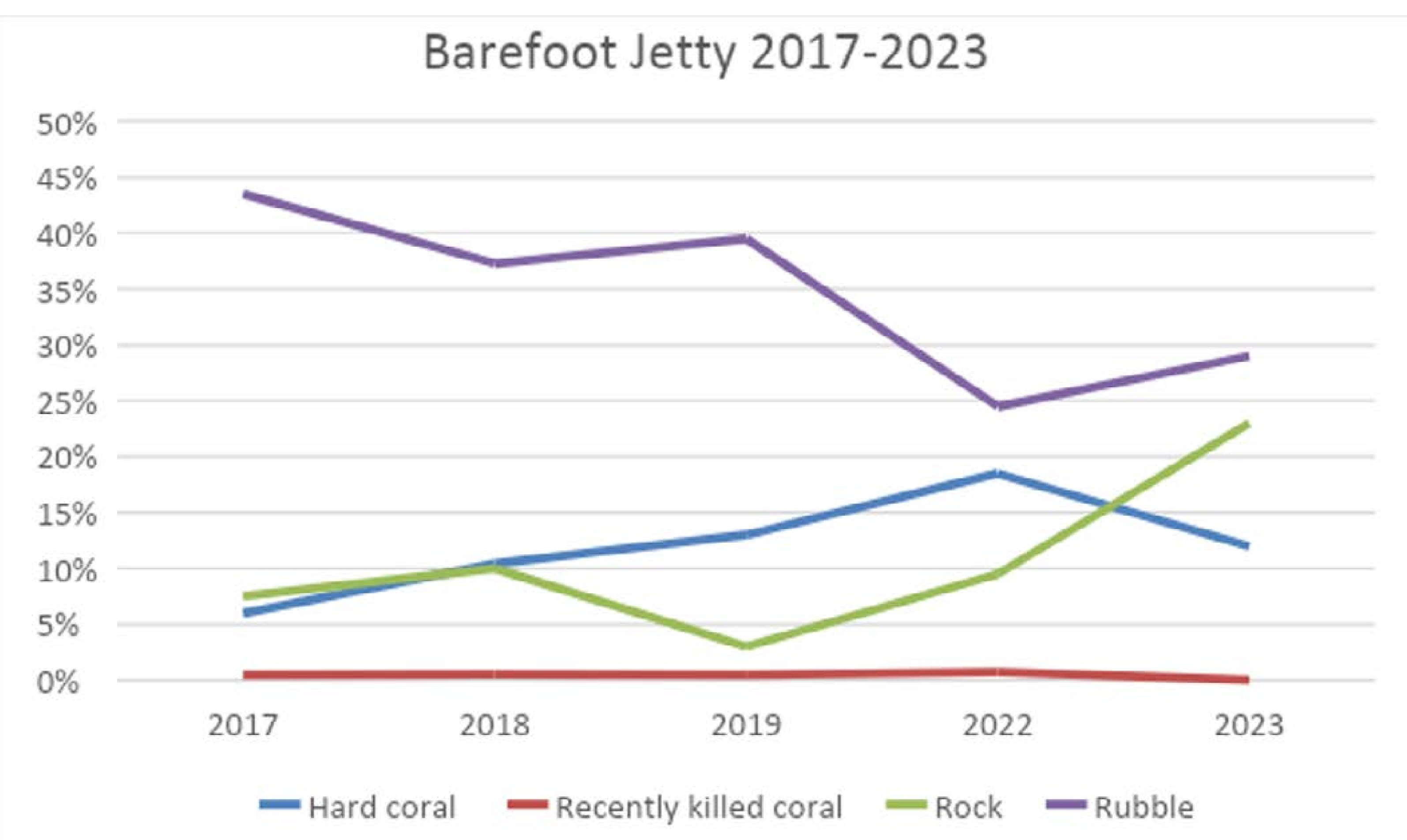


Figure 33: *Temporal variation in benthic cover at Barefoot jetty from 2017-2023*

slowly been increasing between 2017-2022 but has declined slightly (~6%) between 2022 and 2023. The survey is conducted over our 'unrestored area' control reference site, near to the jetty where coral cover is low. The reduction in hard coral cover by 6% may be a sampling discrepancy or may be as a result of coral loss related to the increase in cyanobacteria at this site. At Main Jetty (figure 34), percentage of hard coral cover has increased from 27% in 2022 to 31% in 2023, which is good as it declined between 2021-2022.

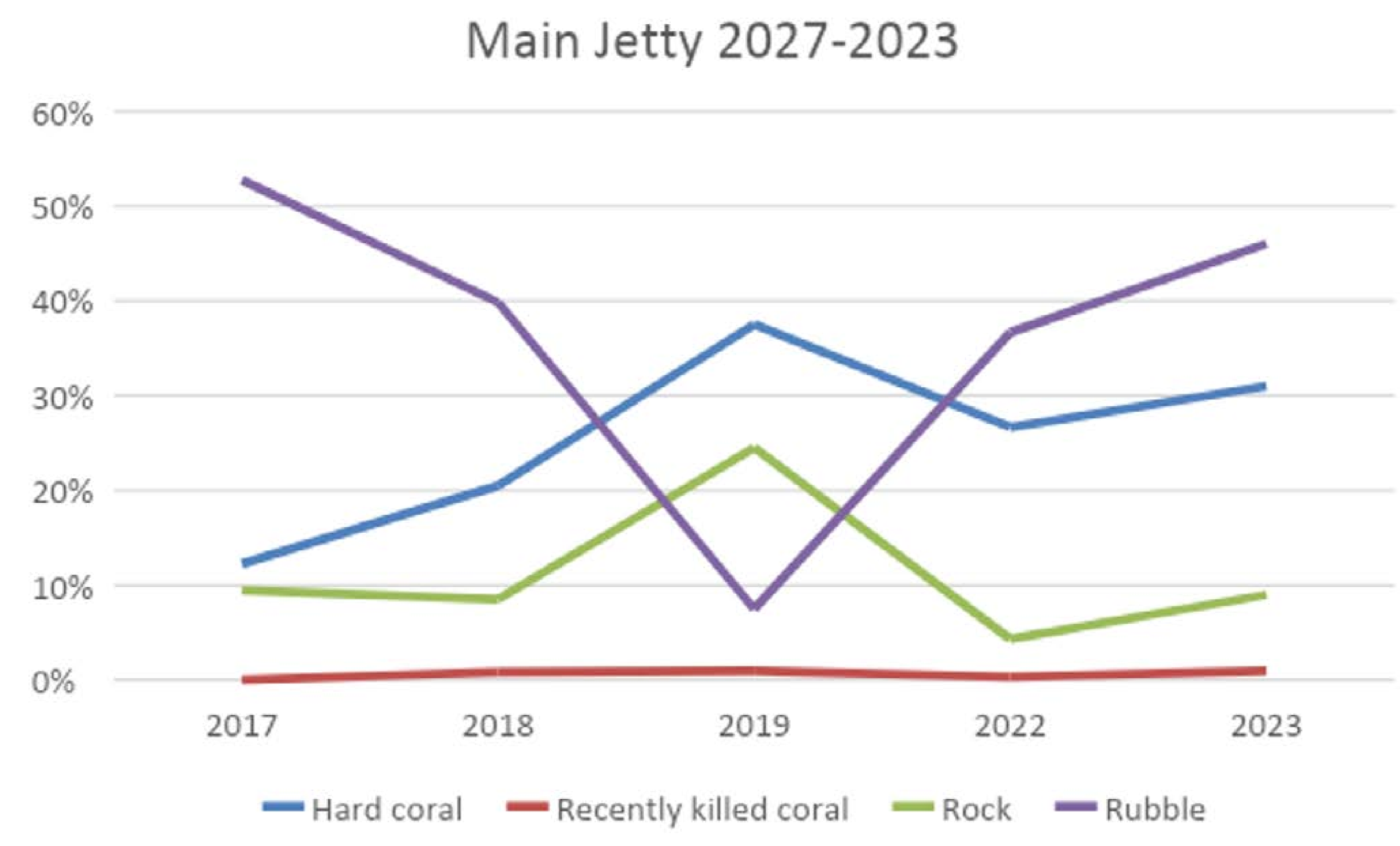


Figure 34: *Temporal variation in benthic cover at Main Jetty from 2017-2023*

6.3 Fish data results

Figure X shows fish data from Barefoot Jetty and Main Jetty for 2023. The results for both sites are relatively consistent with each other, with high average numbers of butterflyfish (7-8 per 20m transect) and lower levels of Haemulidae (sweetlips) and snapper of ~1 per 20m transect. At Barefoot jetty, butterflyfish numbers have increased since last year (4 per 20m transect in 2022) whilst at Main Jetty they have stayed relatively similar to 2022 levels. As the majority of butterflyfish are obligate corallivores (they only eat coral), high average numbers is an indication of good reef health, which is one of the reasons we count butterflyfish on these surveys. Sweetlips and snapper are often targeted by fisheries so these families indicate the levels of fishing pressure at our survey sites. Snapper and sweetlips numbers are higher than they have been in previous years which is a good sign.

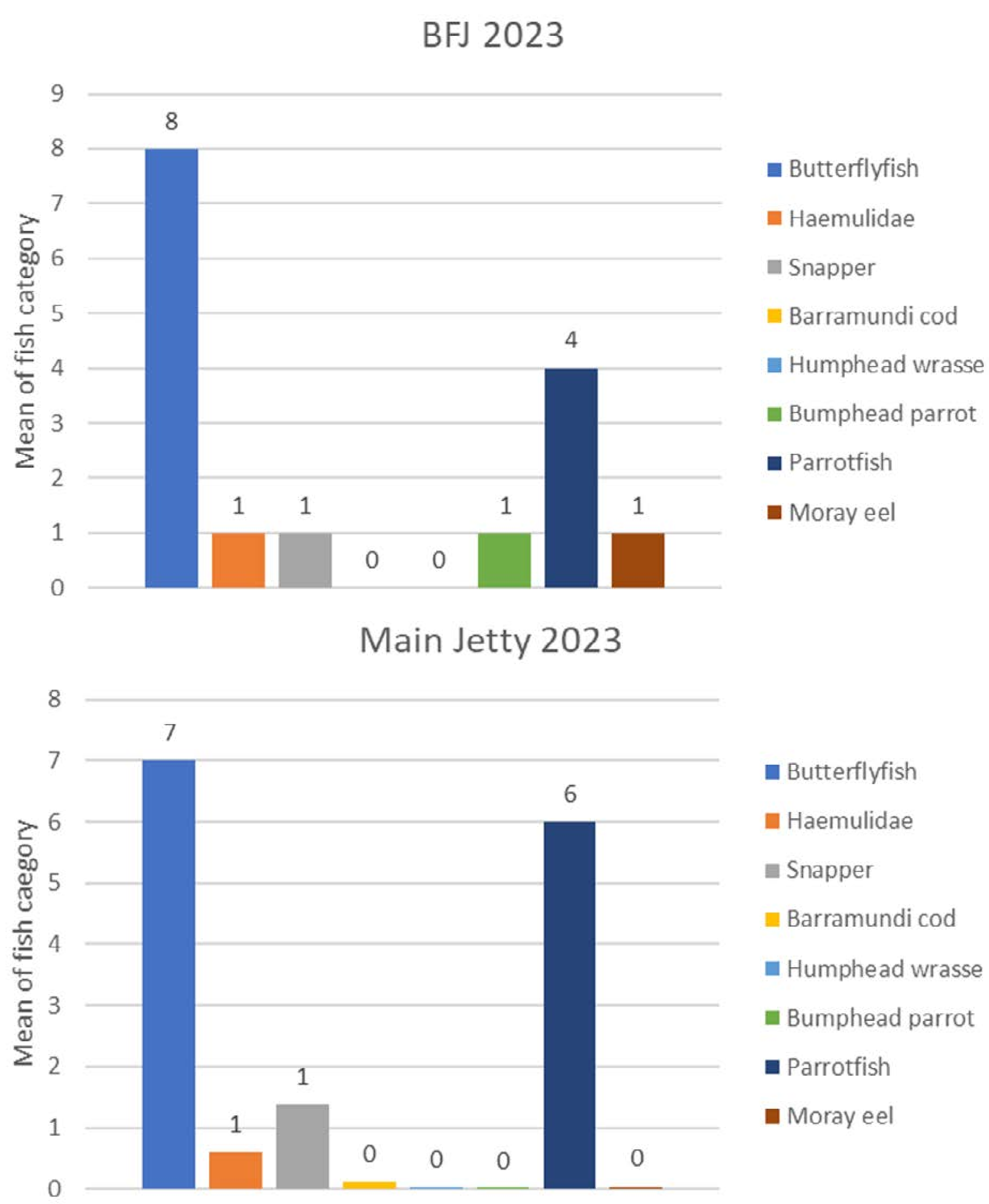


Figure 35: *Temporal variation in fish data at Barefoot jetty from 2017-2023*

7 Community outreach & education

Community outreach at Barefoot Conservation has grown in 2023 with weekly visits to Arborek school commencing in June. Currently, we visit Arborek school every Thursday morning for an hour where we split volunteers and staff members into three classrooms. The main curriculum taught is English with the goal to better improve the children's basic English language skills. However, we have also incorporated marine based material especially on specific days of the year that celebrate our ocean. These included World Ocean Day and World Manta Day. On World Manta Day we did an interactive lesson explaining the role manta rays have in the ecosystem, threats they face and how we can help protect them as individuals and as a community.

In September, we partnered up with Child Aid Papua in Sawinggrai to also begin providing English lessons on a weekly basis. Child Aid Papua has strong marine based lessons already incorporated into their curriculum. Therefore, we combined our English lessons with science, teaching the children about corals, bleaching, manta rays and sharks. We also did some practical lessons with the kids using CoralWatch cards and showing them how they may also use them to monitor coral reef health and identify possible bleaching.

In 2024 we will be hosting two local university students from University of Papua (UNIPA) who are studying Marine Sciences. They will conduct a three month internship at Barefoot where they will undergo their own research project as part of their university studies. During their internship they will be mentored by our Science team and gain scuba diving certifications and reef health survey qualifications. We hope to provide this internship opportunity every year to UNIPA students to enable training opportunities in diving and conservation for local marine scientists.

Figure 36: *English classes are held every Thursday at Arborek school*

In 2024 we will be hosting two local university students from University of Papua (UNIPA) who are studying Marine Sciences. They will conduct a three month internship at Barefoot where they will undergo their own research project as part of their university studies. During their internship they will be mentored by our Science team and gain scuba diving certifications and reef health survey qualifications. We hope to provide this internship opportunity every year to UNIPA students to enable training opportunities in diving and conservation for local marine scientists.

Figure 37: *Barefoot staff and volunteers visit Child Aid Papua to teach about marine science and English language. This group photo was taken after a World Manta Day event.*

Figure 38: *Volunteer and scientist Max teaching Child Aid Papua students a coral bleaching monitoring methodology during a special, practical science training event at Barefoot.*

Figure 39: *Science officer Reyhan teaching Child Aid Papua students about cyanobacteria monitoring methodology during a special, practical science training event at Barefoot.*

Aknowledgements & partners

Our special thanks goes out to, first & foremost, Simon Barden, for founding Barefoot Conservation back in 2012 and managing the organisation on a daily basis, jumping hurdles and seeking out exciting opportunities to increase our impact every step of the way.

Secondly, we would like to thank our Head of Science, Josie Chandler, for her inexhaustible drive to establish new and level up exciting science projects at Barefoot Conservation while involving the local community wherever possible, fueled by a passion for marine conservation which inspires the team every day.

None of the projects would have been possible without the Barefoot Conservation management team on site, led by our determined and relentlessly hardworking Head of Operations, Iris Uijttewaal. The team works long days every day to make sure data is being collected, science is moving forward and volunteers are being trained to a high-quality standard. Thank you both current and previous team members (either voluntarily or on payroll) for your relentless dedication to marine conservation and community development the past year.

The local staff are the absolute backbone of Barefoot Conservations, without skippers, compressor operators, cooks and maintenance work Barefoot Conservation camp would simply not be operational. Thank you Pak Manto, Papa Ribka, Papa Klara, Sakarius, Maikel, Teni and Kelvin.

We look forward to continue to conduct marine science research, collect data, expand community projects and education in 2023.

Partners involved are:

- The Regional Public Service Agency Regional Technical Implementing Unit (BLUD UPTD) in the Management of the Conservation Area (KKP) of the Raja Ampat Islands
- POKJA Manta - BLUD UPTD Raja Ampat, Konservasi Indonesia, Waisai
- Child Aid Papua, Sawinggrai Village
- The Community of Arborek Island
- Erika Gress, James Cook University
- NOAA, Reef Check Indonesia, CoralWatch and Raja Ampat Manta Conservation Research,
- Ratu Laut Liveaboard, GaiaLove Liveaboard, ScubaSpa Liveaboard, Solitude Adventure Liveaboard, Anne Bonny Liveaboard and Calicojack Liveaboard

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For any questions regarding the data, findings or projects mentioned in this report, please contact our Head of Science, Josie Chandler, via j.f.chandler@outlook.com

Decorative imagery by Iris Uijttewaal