Barefoot Conservation Science Progress Report

2022-2023

BAREFOOT CONSERVATION

Science Progress Report 2022-2023

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

All photos by Josie Chandler and Iris Uijttewaal.

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1 Introduction

Barefoot Conservation is an Indonesian Yayasan (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 2016 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. Additionally, this year in 2022, several new projects have commenced, most notably a reef restoration project, but also a black corals project, cyanobacteria monitoring and anchor damage monitoring. All of these projects will be outlined in more detail below, including background, progress and goals for 2023.

Our Science team at Barefoot currently consists of three Indonesian marine science graduates: Afryan Maris Pappang Simon (Hasanuddin University of Makassar), Victor Hendrico (IPB University), Felicita Laura Annemarie (Victoria University of Wellington), a manta scientist from Plymouth University (UK) Lena Pollet, and the Head of Science Josie Chandler (James Cook University) who is working remotely from Australia. Our Project Manager, dive instructor, divemasters and doctor are also heavily involved in the science projects.

Despite the struggles of Covid that affected our monitoring in 2020/2021, we have achieved a lot this year both within science and also community outreach and training. We reached our survey goals for Reef Check and have seen some promising results in the first year of our coral restoration project. Importantly, we have built a strong foundation for an even stronger 2023, with lots of exciting collaborations and several new projects due to commence in January 2023. This report provides an update on the progress of our major science projects in 2022.

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

2 2022 Science Progress

2.1 Reef Check

2.1.1 OVERVIEW

Long-term monitoring of the reefs surrounding Arborek Island has occurred since 2016. The Reef Check survey methodology has been followed for assessing reef health, including benthic cover, fish abundance & invertebrate abundance. Other impacts to the reef such as bleaching, disease, trash and predation are also assessed during surveys.

The 'Core monitoring sites' which are recurrently monitored every six months are: Barefoot Jetty, Main Jetty, Juan's Bay, Juan's Reef, West Mansuar and Isai's Garden (see figure 1). Monitoring these sites long-term aims to record the natural and anthropogenic fluctuations in reef health experienced in this area of the Dampier Strait and alert managers to any unusual changes. All data will be reported to the local marine authority in Waisai, BLUD as well as sent to Reef Check Indonesia, every 6 months.

All sites are within the Raja Ampat Marine Park protected area. Arborek Jetty and Barefoot Jetty have been chosen as 'impacted reefs' to document the effect of divers and tourism on local reefs (medium anthropogenic impact). Juan's Bay and Juan's Reef has been chosen as impacted reefs to document the effect of a man-made fish farm (now shut down), on local reefs (medium anthropogenic impact). West Mansuar and Isai's Garden are reefs with low anthropogenic impact.

Additional monitoring sites are surveyed when the core sites have already been monitored twice within a 6 month period. These sites are: Arborek Tip/ East Arborek, JPP, North Arborek, South Arborek, Arborek West.

2.1.2 2022 RESULTS

In 2022 a total of 32 surveys were conducted around Arborek Island and the local area (see figure 1 and Table 1), this data has been sent to Reef Check Indonesia.

Overall, our team trained up more than 100 international volunteers and 2 local high school students from Sawinggrai Village to conduct scientific surveys following the Reef Check methodology. These skills will be used to conduct marine surveys all around the world, contributing to reef health data internationally. Enabling citizen scientists and students to collect this data will improve our understanding of current threats to reefs and inform management decisions for the protection of reefs.

Figure 1: Barefoot Conservation survey sites around Arborek Island. Sites marked in red are 'core monitoring sites' which get monitored at least once every 6 months, sites in green are 'additional monitoring sites' which are monitored opportunistically.

SITE NAME	CORE SITE?	# SURVEYS IN 2022
Barefoot Jetty	YES	4
Main Jetty	YES	3
Juan's Bay	YES	4
Juan's Reef	YES	4
West Mansuar	YES	4
Isai's Garden	YES	3
Arborek Tip/East Arborek	YES	2
JPP	NO	2
North Arborek	NO	2
South Arborek	NO	2
TOTAL		**32**

Table 1: Table of Reef Check survey sites conducted in 2022.

2.1.2.1 Benthic data

Figure 2 shows the distribution of benthic cover at each of the monitoring sites, split into benthic groups. Juan's Reef was found to have the highest hard coral cover (48%, SD=0.049), whilst South Arborek had the lowest hard coral cover (9%, SD=0.085.

Although the hard coral cover at Juan's Reef and Juan's Bay are relatively high, this data does not capture species diversity and it is important to note that the coral cover at these sites is largely monospecific with dominance by fast-growing staghorn Acropora and some foliose Montipora species. Low fish abundance data from these sites demonstrate that this high coral cover is not necessarily signifying a healthy reef. There is also the highest proportion of Nutrient Indicator Algae (NIA) species at these two sites which is likely a result of nutrient loading from the fish farm which was previously at this site.

East Arborek, West Arborek and JPP were found to have high hard coral cover, with some soft corals, sponges and low proportions of NIA. These are some of the healthiest sites around Arborek, with much higher species diversity of corals and you can see this reflected in the fish data for these sites too. Main Jetty and Barefoot Jetty were found to have lower hard coral cover than almost all other monitoring sites, which may be a result of the higher anthropogenic pressure on these sites from tourism, either breakage from divers/boats or chemicals/sewage from the island. It will be important to continue monitoring hard coral cover at these sites over time, in addition to monitoring the cause of mortality of corals. Water testing will resolve whether coral decline is resulting from poor water quality or other anthropogenic factors (see section 2.6 Cyanobacteria Project)

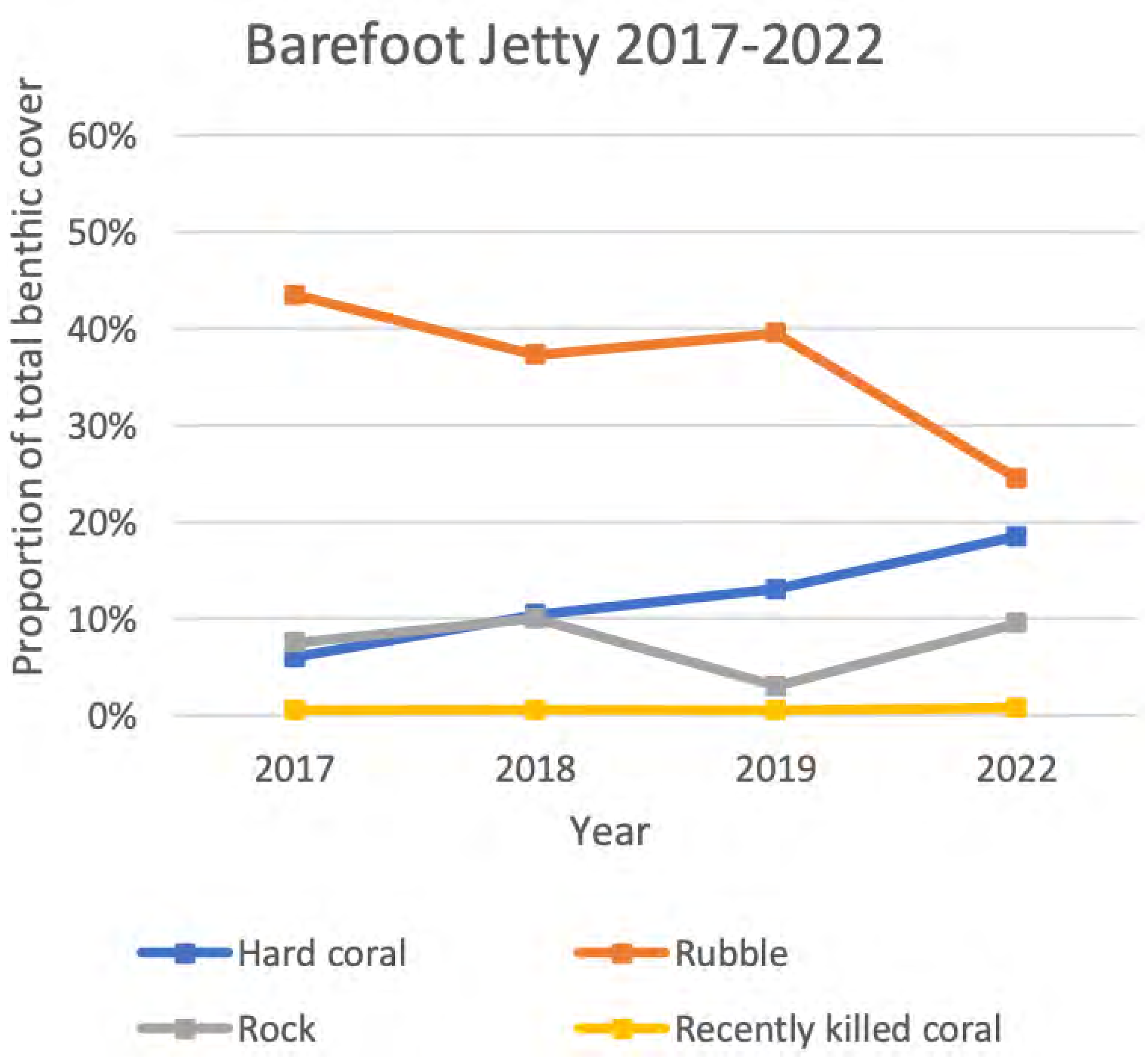

Figure 3a: Temporal changes in key benthic categories at two locations.

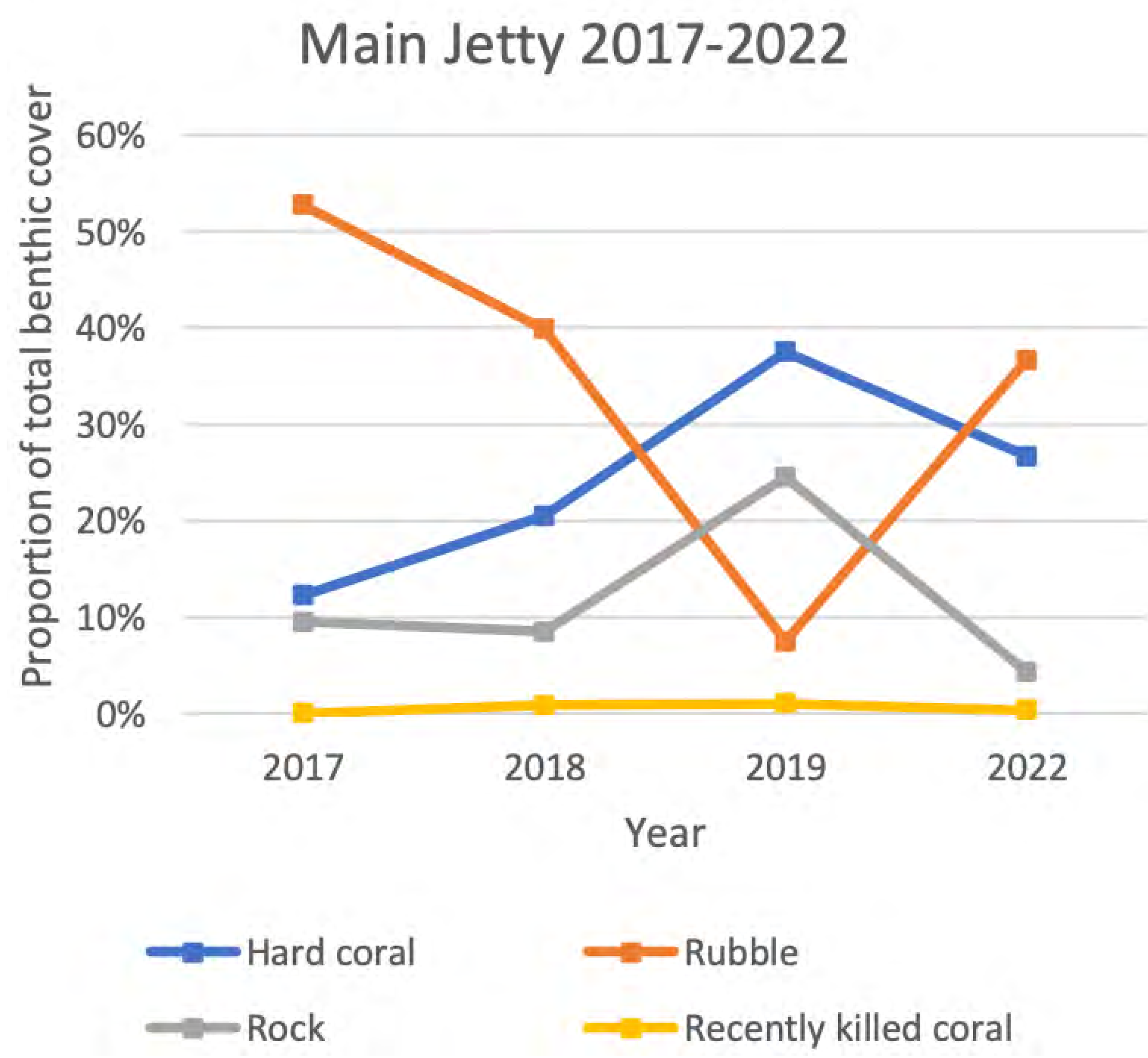

Figure 3b: Temporal changes in key benthic categories at two locations.

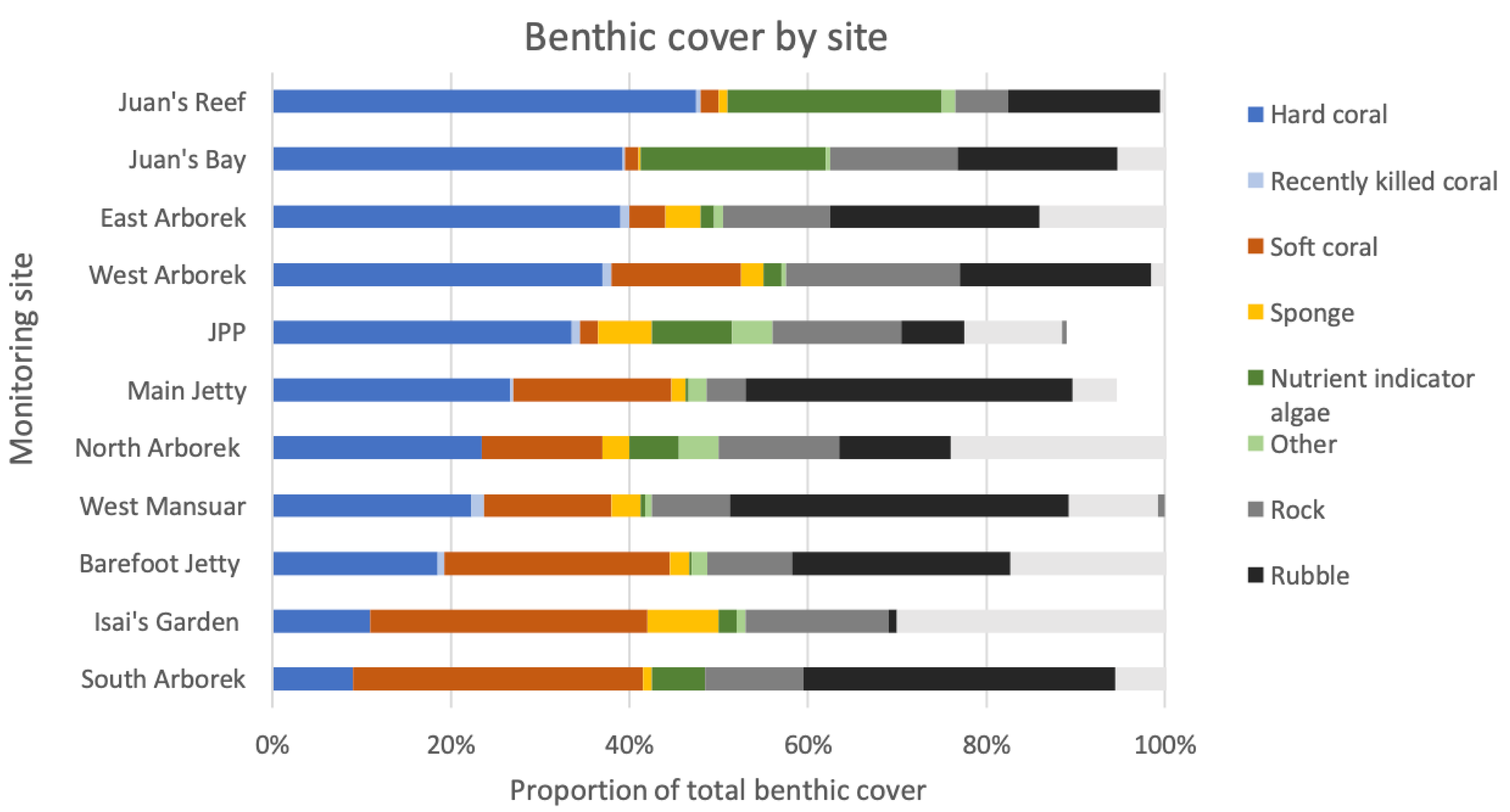

Figure 2: Variation in the benthic composition at 11 survey sites in the Dampier Strait.

Figure 3 looks at changes in hard coral cover (and other benthic groups) at Barefoot Jetty and Main Jetty over time (2017-2022). The trends are not conclusive and could be representing the fact that surveys were conducted in slightly different locations each year.

At Barefoot jetty the trend shows an increase in hard coral cover over time, whilst rubble coverage decreases. This is encouraging data which will hopefully be further improved by our Restoration Project at this site.

At Main Jetty, hard coral cover had been slowly increasing between 2017 and 2019, however between 2019 and 2022, there was a sharp decline, whilst rubble cover concomitantly increased. This change may be as a result of increased breakage of corals by divers, or result from other unknown forces.

Importantly, Recently Killed Coral remains low in all years, which shows that coral is not obviously dying at any of our sites.

2.1.2.2 Fish Data

Figure 4 shows data from Barefoot jetty and Main Jetty, where fish counts have been compared over time (2017-2022). Both sites show highest densities of butterflyfish and parrotfish, with higher average counts of snapper, grouper and Haemulidae (sweetlips) found at Main Jetty compared to Barefoot Jetty.

As butterflyfish are primarily obligate corallivores (strictly eating coral), changes in butterflyfish populations can often indicate changes in hard coral cover, which is why they are surveyed as an indicator species. At Main Jetty however, declining trends in butterflyfish (2017-2019) do not match up with benthic data from this site, as hard coral cover was actually found to be increasing in these years. It may be that butterflyfish populations were reacting to other stressors, or that the data collected is not truly representative of the population state. The increase in fish densities shown between 2019 and 2022 at Main Jetty may be as a result of the restoration efforts that have brought an increase in coral cover to this site. It will be interesting to monitor this trend over the next few years.

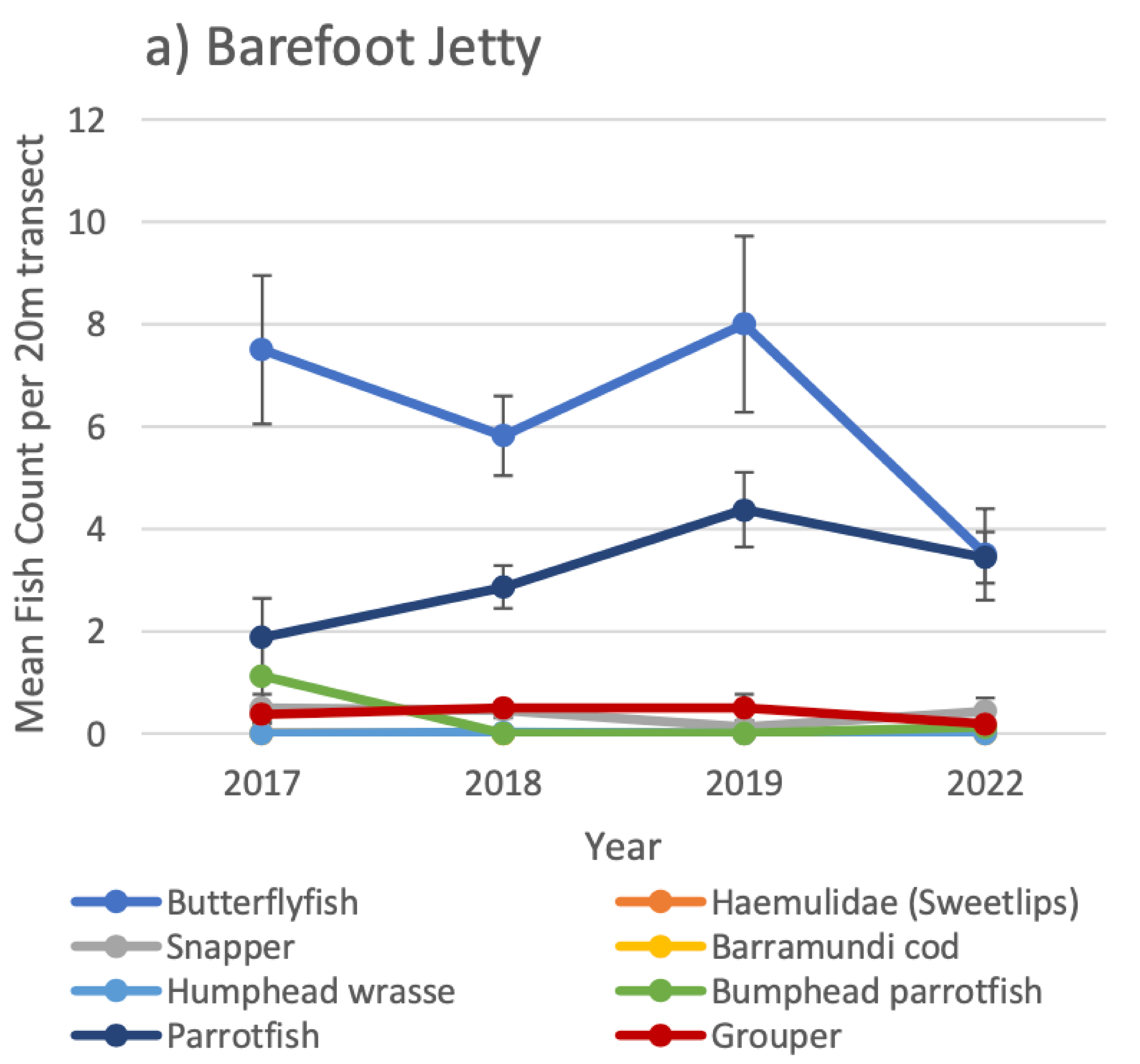

Figure 4a: Variation in fish counts over time at two sites a) Barefoot Jetty and b) Main Jetty between 2017-2022

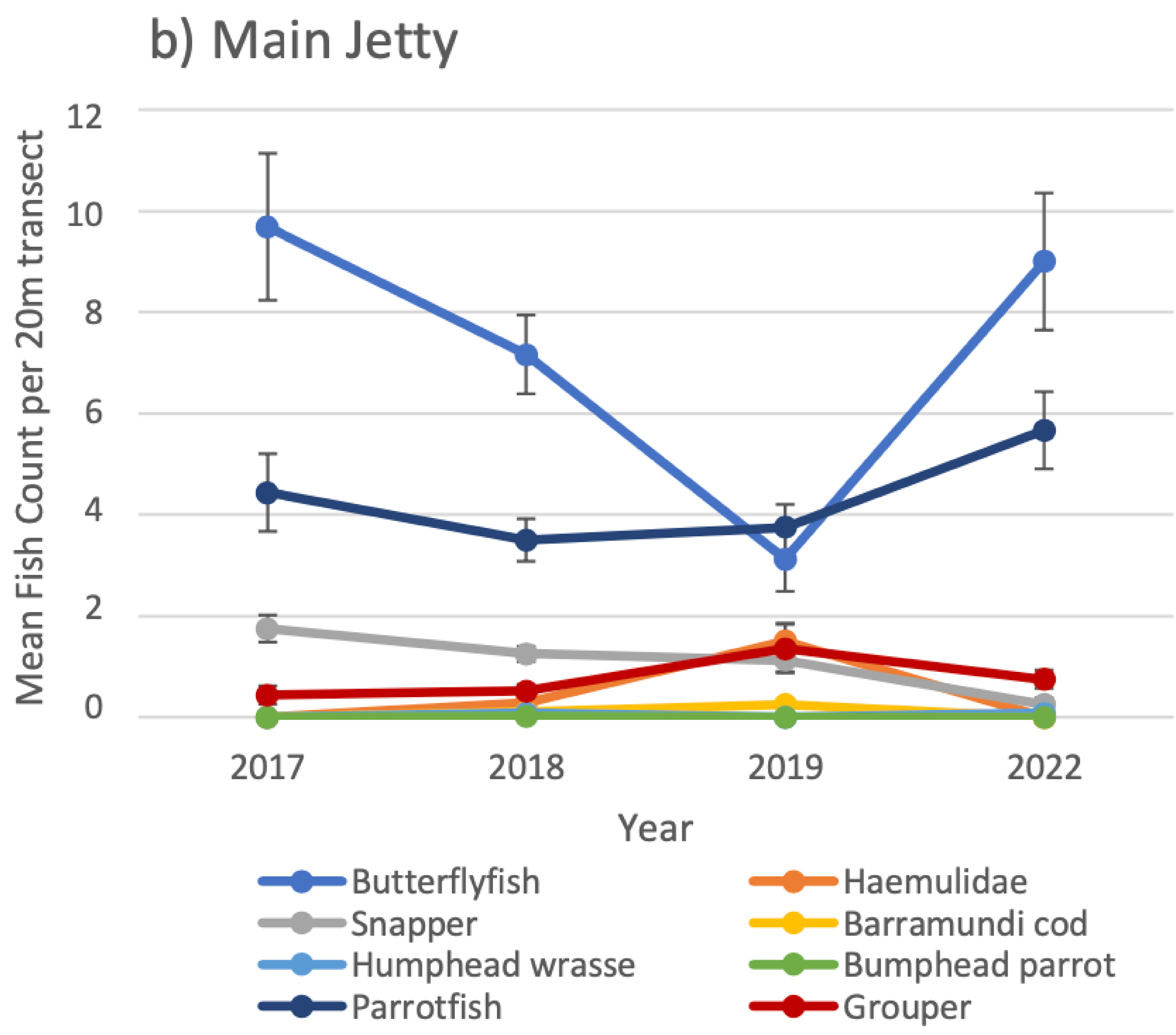

Figure 4b: Variation in fish counts over time at two sites a) Barefoot Jetty and b) Main Jetty between 2017-2022

At Barefoot Jetty, densities of both butterflyfish, parrotfish and other species have all declined between 2019-2022. This is an interesting finding, as human presence at Barefoot camp was actually lower during this time (Covid-19) and so the effect of tourism is unlikely to be explaining declines in fish populations here. Butterflyfish are also not a target fishing species, so it is not the result of increased fishing pressure. It is more likely linked to the status of the reef, which although increasing, remains degraded (<20% hard coral cover). It will be important to look at 2023 fish data at Barefoot Jetty to see whether populations continue to fall or not. Hopefully the effect of our restoration project at this degraded site will bring an increase in fish populations over the next 5 years.

Although their densities are relatively low, grouper densities seem relatively stable at both sites, which is good as these fish are often targeted by fishermen. Snapper populations however, which are also a targeted fisheries species appear to be slowly declining at Main Jetty and almost absent at Barefoot Jetty, so this should be monitored in the coming years. Low levels of Barramundi cod, humphead wrasse and bumphead parrotfish is not surprising as they are relatively rare fish.

2.1.2.3 Invertebrate Data

Invertebrate data from Main Jetty (figure 5) shows two main findings; firstly, that since 2017 the mean number of Crown of Thorns starfish has significantly reduced and now remains well below 'outbreak' limits. This reduction in numbers is likely related to the interventive action taken by the local government in 2017/2018 after the government were notified of the high densities of crown of thorns, through our monitoring programme. Secondly, almost all target invertebrate species have increased in numbers between 2019 and 2022, aside from lobsters, and collector urchins. It will be important to monitor the abundance of lobsters, as this is a target fishery species which is currently at low levels.

2.1.2.4 Impacts Data

Data on Impacts from Main Jetty (figure 6) shows a general reduction in all coral damage between 2017-2022, with only fishing net trash showing an increase this year. This is good to see, and the significant reductions in 'Trash: general' may in part be as a result of the continuous beach cleans which Barefoot have been conducting, including the beach nearest to main jetty. It may also be as a result of the raised awareness to the problems of plastic pollution.

It is good to see that levels of disease remain low, however this is something which is often difficult for newly trained citizen scientists to detect. As we closely monitor the impact of increasing tourism and eutrophication on these sites it will be important to closely monitor disease prevalence in the coming years.

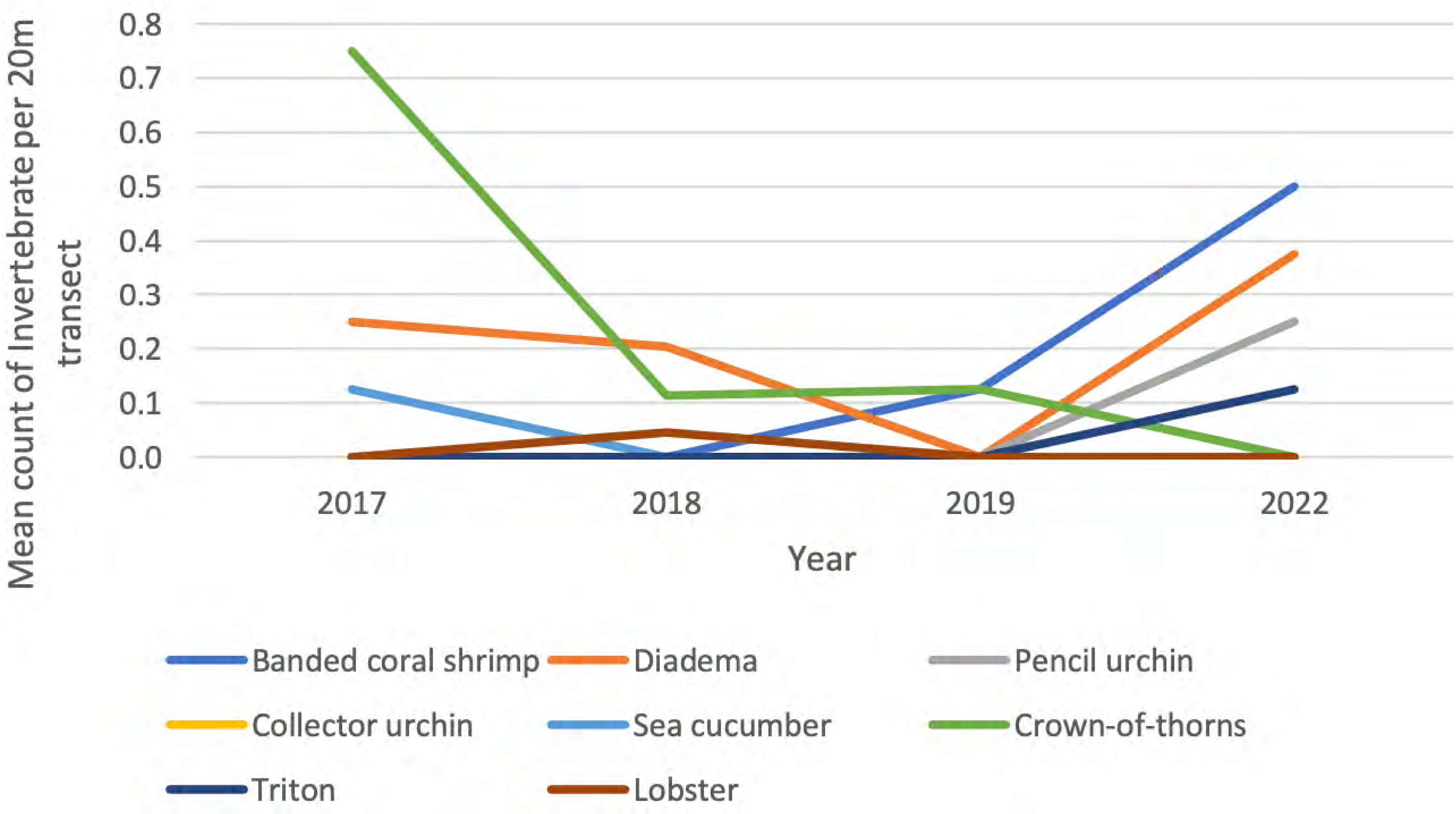

Figure 5: Variation in invertebrate counts over time at Main Jetty between 2017-2022

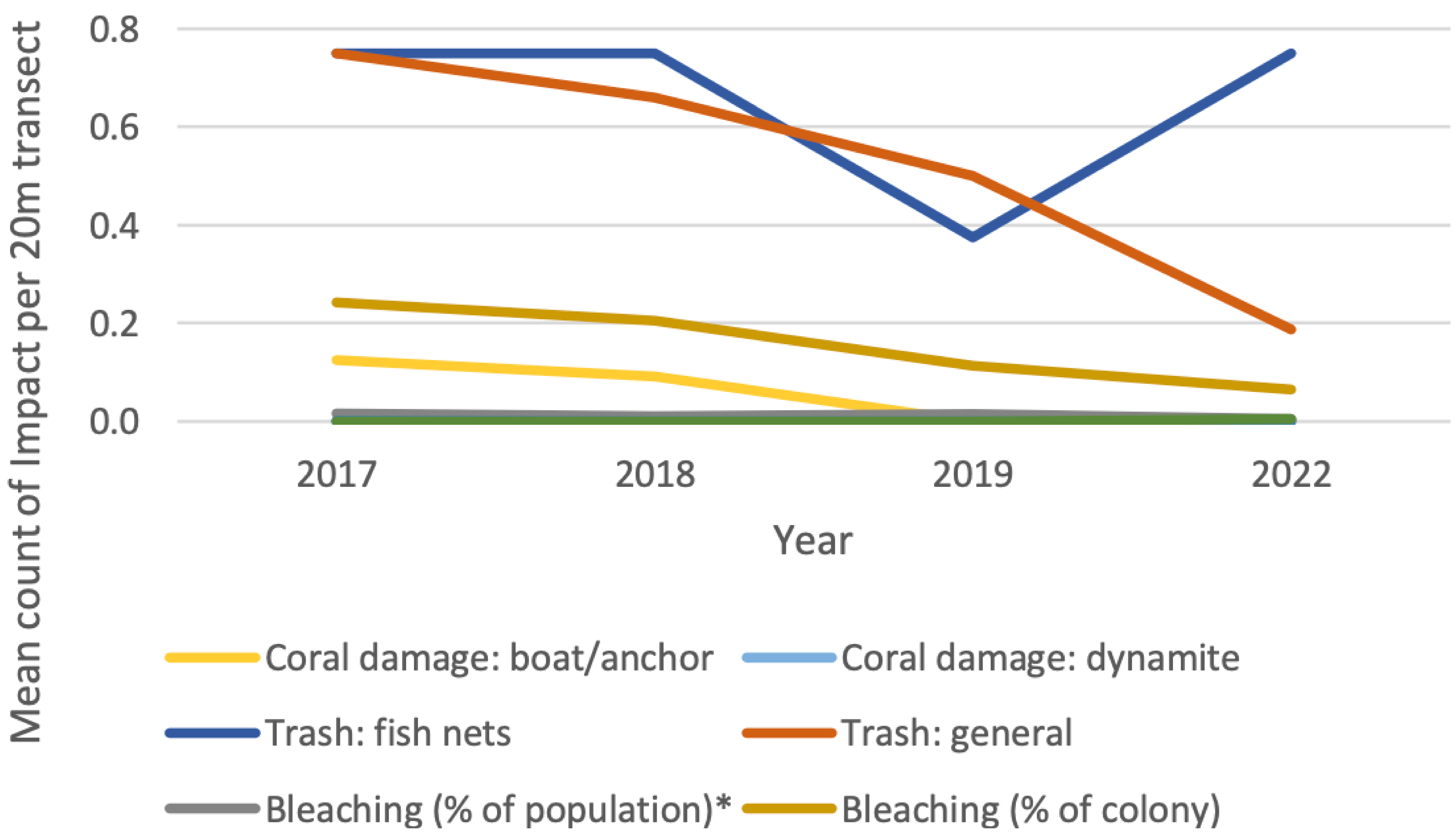

Figure 6: Variation in 'Impact' counts over time at Main Jetty between 2017-2022

2.1.3 REEF CHECK PLANS FOR 2023

For future surveys, our long-term monitoring data would benefit from higher resolution identification of benthic cover. With this noted, from 2023 onwards we will commence annual surveys of each of the core monitoring sites, identifying corals to genus level. This will require specialist expertise and only science staff trained in advanced identification techniques will be able to collect this data.

In 2023 we will add four additional monitoring sites to our 'core monitoring locations' these will be South-west Arborek, Lalosi, Manta Sandy and JPP. The first three sites have been included as they have been identified as key sites which are experiencing increased cyanobacteria and macroalgae occurrence and we would like to closely monitor this as part of 'cyanobacteria monitoring programme' (Section 2.6: Cyanobacteria Project). Additionally, JPP has been added due to the high incidence of anchor damage which has been observed at this site in 2022, which we would like to monitor closely (Section 2.4 Anchor Damage Monitoring).

We will also take action to ensure surveys are consistently being conducted at the same points, which will be enabled with the use of GPS start points and possibly marker buoys. This will ensure the data that is being collected is directly comparable each year.

2.1 Reef Restoration Project

2.2.1 OVERVIEW

Barefoot's Reef Restoration project was started in November 2022, after receiving permission from Bapa Juan (Head of Village), Bapa Buce (land owner) and Pak Safry (Head of BLUD).

Whilst we try to protect reefs at a larger scale by encouraging volunteers to reduce their carbon footprint, limit pollution and eat sustainably sourced fish, at a local scale we have commenced active restoration of an ecosystem which will bring both environmental and socio-economic benefits to
Raja Ampat. The project has been started as a small pilot project, to test the feasibility of effectively restoring a degraded reef at Arborek Island. If the methods are successful, we hope to use our techniques to restore reefs in the area which have been badly damaged by ship groundings (i.e. Crossover Reef).

The restoration technique we use at Barefoot is a 'coral gardening' method, where coral fragments are grown in a coral nursery for around 1 year before being outplanted to their final destination. We chose this method because it requires extremely small quantities of corals initially to start the restoration process, and can continue 'farming' corals for many years based on the original fragments. This method has been used in restoration projects internationally, and was discussed widely at the Bali Reef Rehabilitation Network Webinar and Australian Marine Sciences Conference, both of which Barefoot scientists attended.

For the restoration project, no coral fragments are harvested from healthy corals, only damaged 'corals of opportunity' are selected. These corals would otherwise die and so using them in the restoration project is providing them with a second chance, and at the same time, no damage is being sustained to the healthy reef. This is a very important part of the project, we never cause damage to the reef in the process.

Three coral nurseries were set up, with different purposes outlined on the next pages:

- Educational Nursery
- Stock Nursery
- Research Nursery

2.2.1.1 Educational Nursery

Nursery 1: The Educational Nursery was set up with the aim of community engagement. All coral ropes put into this nursery are made with the help of the local community, in particular the local children. This nursery is primarily used to engage the local children in the project to provide a deeper understanding of coral reefs and foster marine stewardship from a young age. Each coral rope made with children has a tag signed with their names (see figure 7), so they can check on their corals in the nursery as they grow and feel a part of the project, they are also shown photographs of their corals as they grow. This is the first step in a process of providing internships and eventually employment within the reef restoration project, for the teenagers. It is important that they have been involved in every step of the project.

Before setting up the coral restoration project, several classes on corals were taught to the local children, including topics such as threats to coral reefs and different restoration approaches. After discussing these topics, the children helped to decide the best method to use for our reef restoration project at Barefoot, together with our science team's guidance.

Figure 7: Teaching Arborek children about corals and restoration techniques and children making coral ropes for the Educational Nursery.

2.2.1.2 Stock Nursery

Nursery 2 is the Stock Nursery. This nursery was carefully planned to specifically grow corals which are more rare and slower growing than common Acropora species, but provide important ecological roles in an ecosystem. The corals we have chosen to grow in this nursery will continue to provide stock for outplanting to degraded reefs over several years and enable the reefs we restore to be provided with a diversity of species and growth forms, which is important for a healthy and resilient ecosystem. Corals in this nursery include tabular Acroporids, foliose corals such as Pachyseris and Monitopora, a variety of Pocilloporid species, Turbinaria, Galaxea, Porites, Hydnophora and so on.

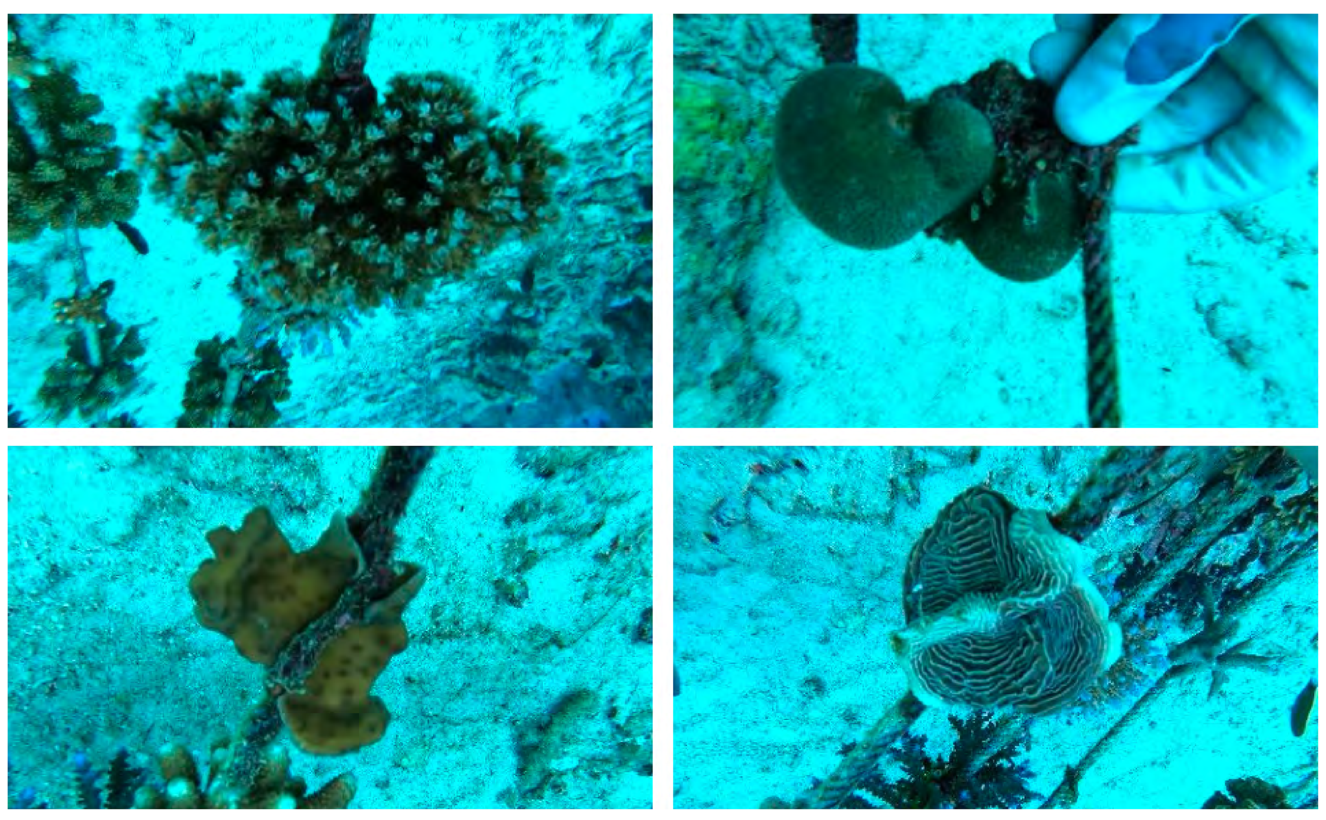

Figure 8: Uncommon coral genera in Nursery 2 (stock nursery) growing well on the lines after 12 months; Galaxea, Cyphastrea, Turbinaria and Pachyseris

2.2.1.3 Research Nursery

Nursery 3 is the Research Nursery. This nursery is used to test out which methods/species will provide optimal growth and should be utilized when the project is scaled up. For example, the growth and survival of 5 different coral growth forms and 10 different coral species was compared over 12 months in 2022. The results from this study (outlined below) have demonstrated which species will be important reef builders that can be grown quickly in the nursery, and others which were not well suited to the rope nursery technique. All data is useful within this study, so we never replaced corals which died or became damaged, as it was important to collate this information. In 2023 the research project will be related to testing the optimal starting size for growing corals from fragments.

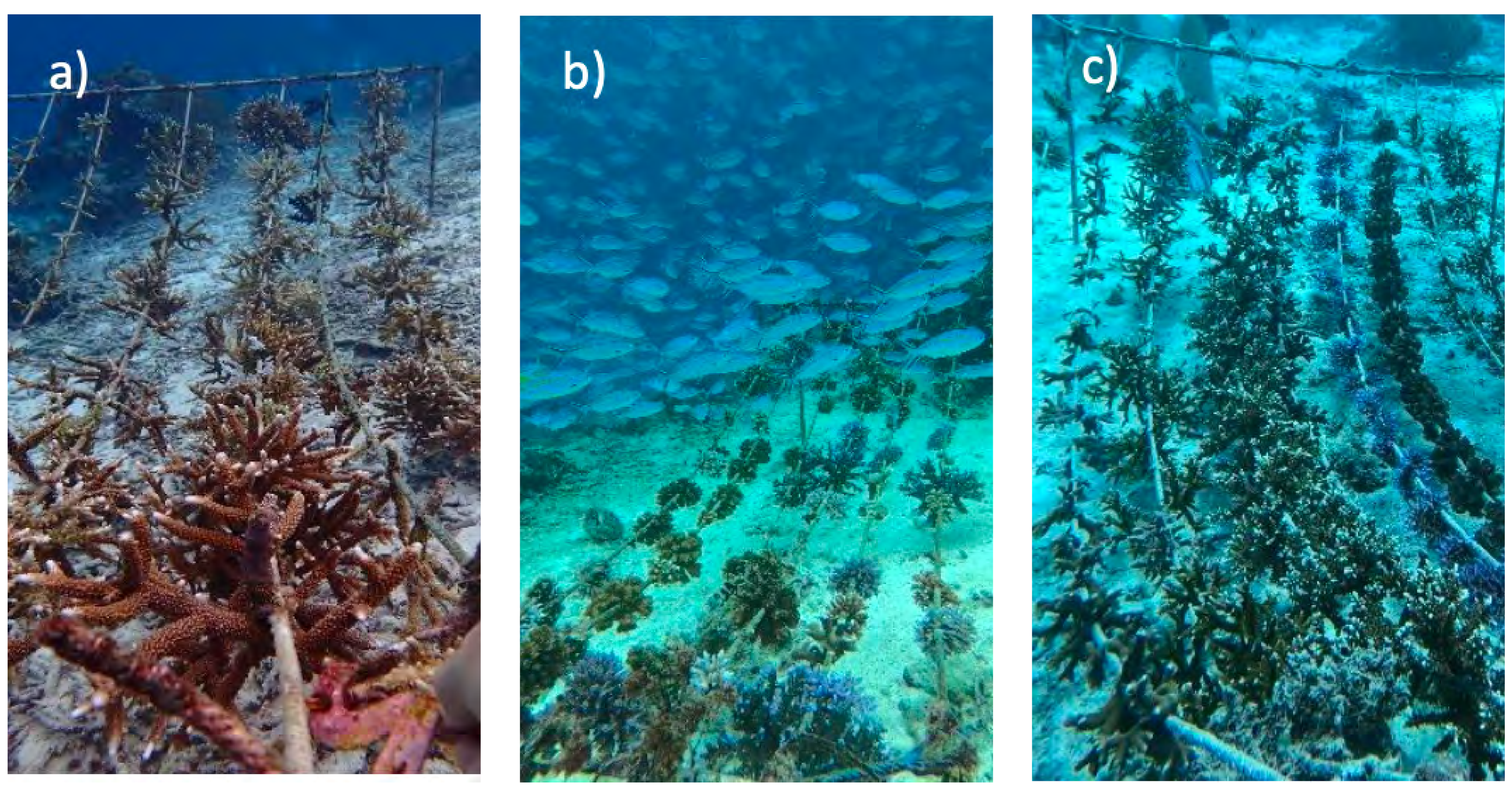

Figure 9: a) Educational nursery, b) Stock Nursery and c) Research Nursery, all showing considerable growth during 10 months

2.2.2 2022 RESULTS

Overall, growth in all three nurseries has been very good which demonstrated that the location chosen provided good conditions, including strong water flux and light. However, due to the distance from the natural reef, it was observed that ropes were becoming overgrown by algae, sponge and tunicates, likely because natural grazing by herbivores at this sandy site was low. Early on, some mortality was experienced as a result of this, however the team found that frequent visits to the nursery to shake and clean the lines (1-2 times a week) prevented the majority of overgrowth from occurring.

We photographed each rope in the nursery every 2 months (see figure 10), to monitor growth and survival of all corals and create a database of qualitative growth rates for different species. It is also useful to be able to clearly display the growth of the corals when updating the local community and children on the progress of the project. For quantitative monitoring, measurements of growth and survival were conducted for each fragment, but only for the ropes in the Research Nursery.

In the 12 months since the nursery was set up, we have successfully completed the 'growing phase' for corals in nurseries 1 and 3 and have already started outplanting these corals to their final destination (see Outplanting section). Some fragments from corals in the Stock Nursery have also been taken to provide diversity to the outplant sites, these corals continue to grow on the lines.

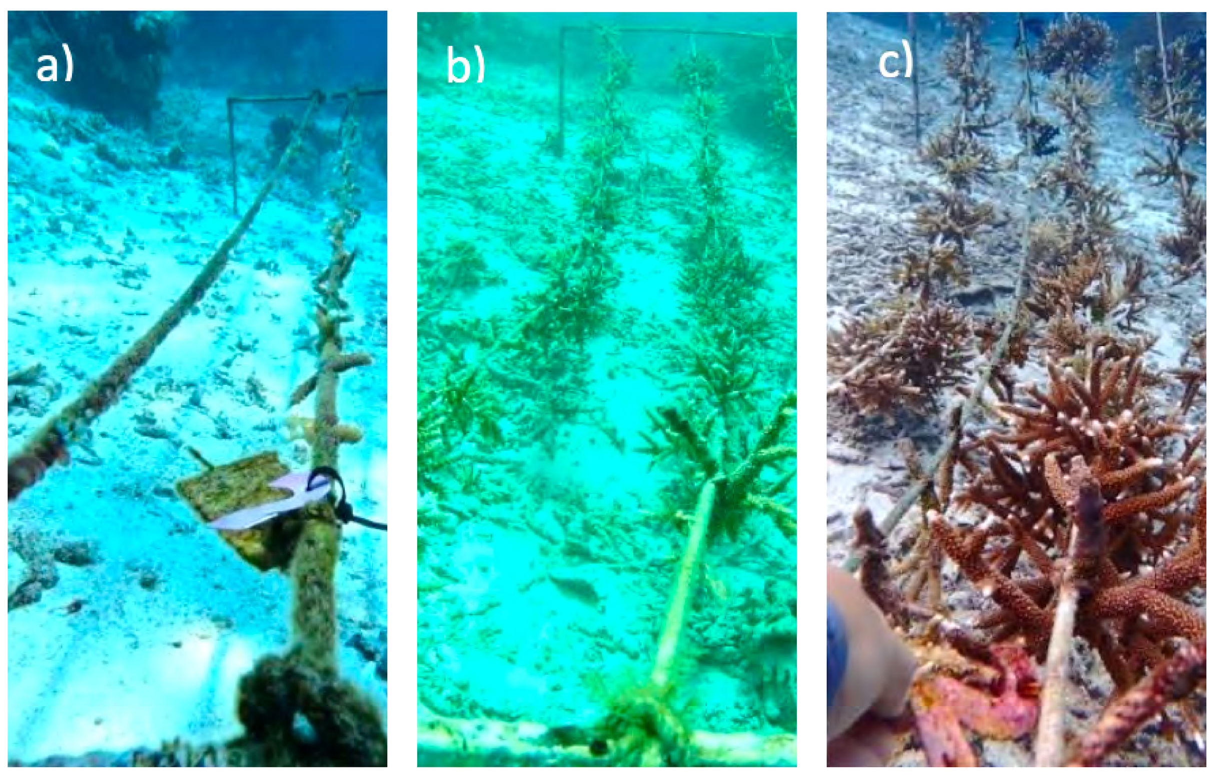

Figure 10: Coral growth from one rope photographed over a ten month period; a) rope 002 on day 1, b) rope 002 after 6 months, c) rope 002 after 10 months.

2.2.2 Research Nursery Results

For the research project on growth and survival conducted last year, 10 different coral species were compared, each species had 20 replicates on the same rope (see figure 11). At the beginning of the project in Nov 2021, 20 x ~6cm fragments were placed within each rope. Each fragment within one rope was taken from the same mother colony so that all corals within one rope were genetically identical to each other, with the same starting size. This provided optimal design for comparing growth and survival between species. The ten species that were compared were: *Stylophora pistillata, Pocillopora verrucosa, Porites rus, Echinopora spp*, and 6 different Acropora spp. The 10 species were chosen to also fall within five separate growth forms: 2 x corymbose, 2 x staghorn, 2 x tabular, 2 x digitate and 2 x hisdispose. This provided not only comparisons between species and genera, but also between common growth forms.

Rope label	Genus	Growth form	No. of replicates
A	Stylophora	Corymbose	20
B	Acropora	Staghorn	20
C	Acropora	Tabular	20
D	Pocillopora	Digitate	20
E	Acropora	Tabular	20
F	Echinopora	Corymbose	20
G	Acropora	Hispidose	20
H	Acropora	Staghorn	20
I	Porites	Digitate	20
J	Acropora	Hispidose	20

Figure 11: Table detailing each of the 10 ropes (A-J) within the Research Nursery, which were measured monthly for growth and monitored for mortality. Photo shows ropes A-J from left to right.

Overall, survival within the experiment was high, with only 17 fragments out of 200 dying within the 10 month period, giving overall survival rate of 85%. Five of the ten ropes showed 0% mortality over the course of the experiment, with the other five ropes showing mortality rates between 5-40% (see figure 12).

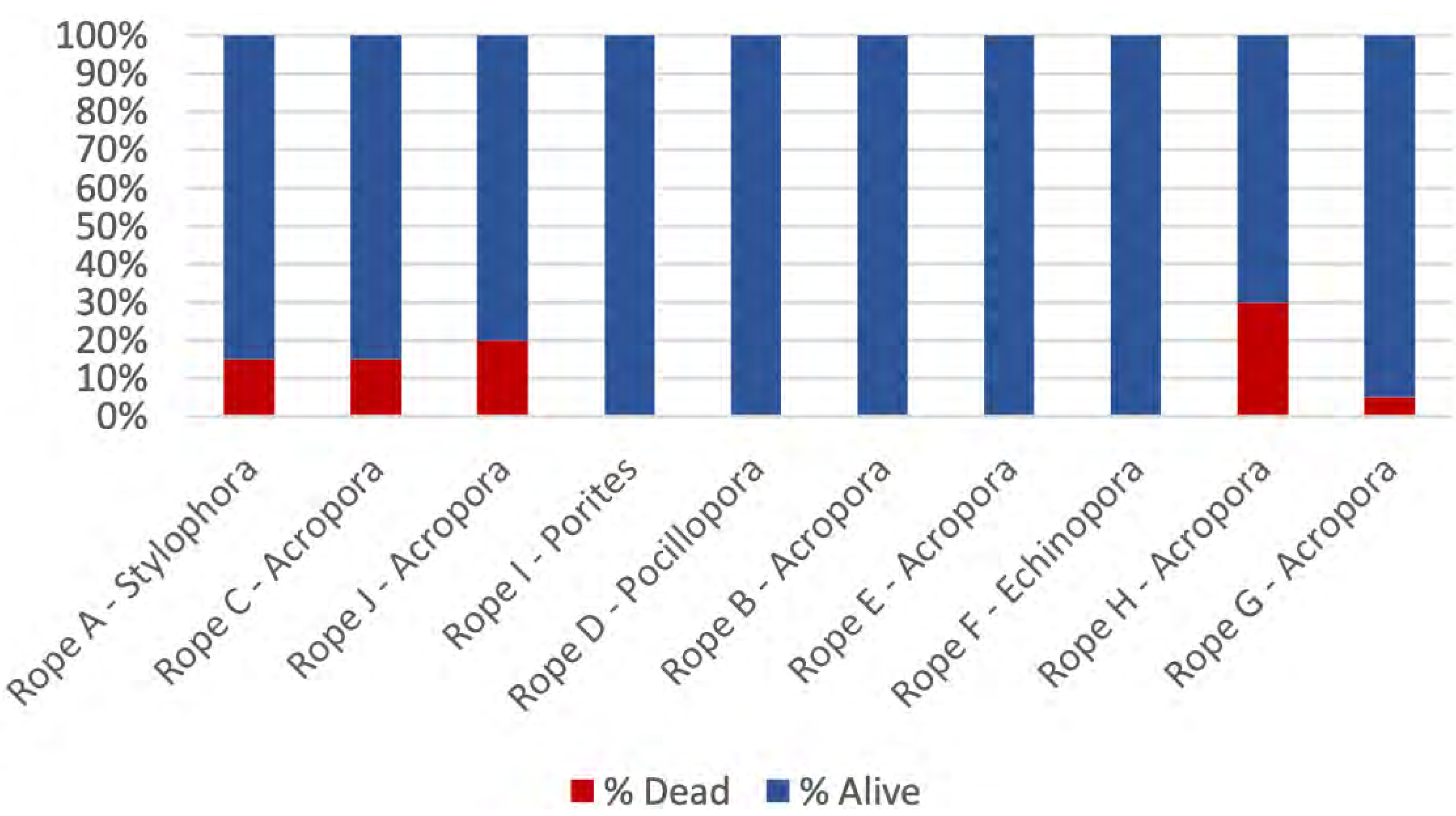

Figure 12: Mortality rates of coral ropes A-J in the Research Nursery. Ropes are ordered according to growth rates (see figure 13)

Growth between species varied considerably, which was expected. The slowest growth rate was demonstrated by the *Stylophora pistillata* species (rope A) with only 2.26mm (SD=1.38) per month average growth, compared to the fastest growing species, the hispidose *Acropora spp* (rope G) which grew 16.04 mm per month (SD=6.93). Figure 13 displays the variable growth rates of each coral species. There were some surprising results, for example the faster growth rate of corymbose *Echinopora* (rope F) compared to staghorn *Acropora* (rope B) and also the very slow growth rate of the hisdipose *Acropora* in rope J. This rope showed quite high levels of mortality (20%), due to overgrowth by sponge, and it could be that this was also slowing down its growth. Interestingly rope A, *Stylophora pistillata*, was notably stressed during the duration of the study, showing bleached dorsal side for over 10 months (see figure 14). It may be that the depth or location of the nursery were not providing suitable conditions for its growth.

These findings provide a useful insight into the capability of different coral species and growth forms to survive and grow in a nursery environment. For example, the species used in rope A, C and J had higher mortality rates and slower growth than the majority of other corals, demonstrating that they would not be suitable for using in future nurseries. However ropes I, D, B, E and F, whilst not the fastest growers, showed 100% survival and consistent, sustained growth. They would be worth including in future nurseries and demonstrate that species aside from Acropora can be successfully grown using this nursery method.

One drawback of this study was the limited ability to accurately measure growth over time. The growth rate which has been presented here is only linear (where the two widest points of the colony are measured), which does not account for the 3D nature of coral growth. This is underestimating the 'true' growth rate, however without the ability to capture increasing volume over time, this is the best method that we could use. It is still a valuable measure for comparing growth between species, photographing the lines every month also provides additional qualitative information on 3D growth of corals.

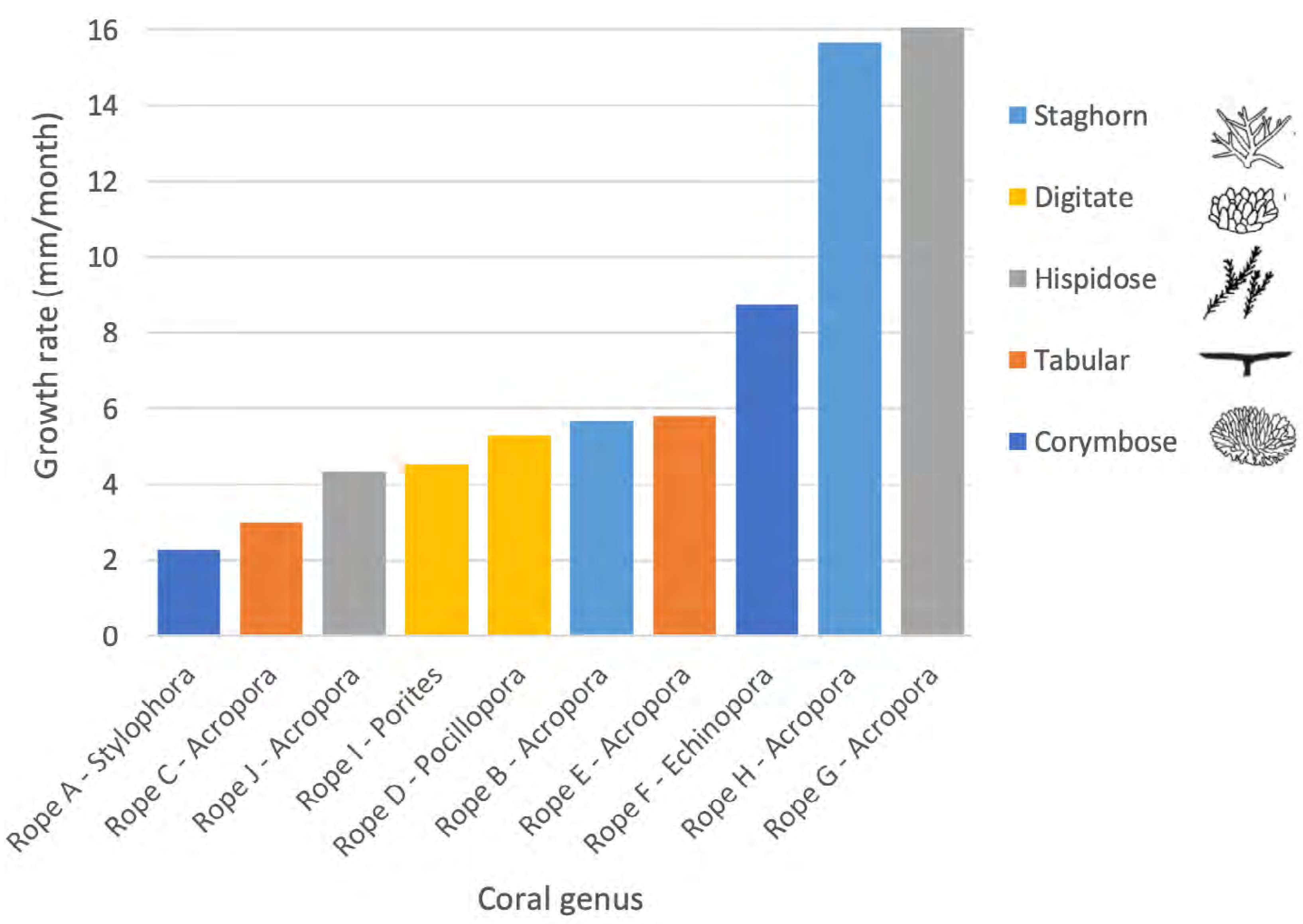

Figure 13: A comparison of growth rates from different coral genera and growth forms, within the nursery. Growth rates are taken over 10 months.

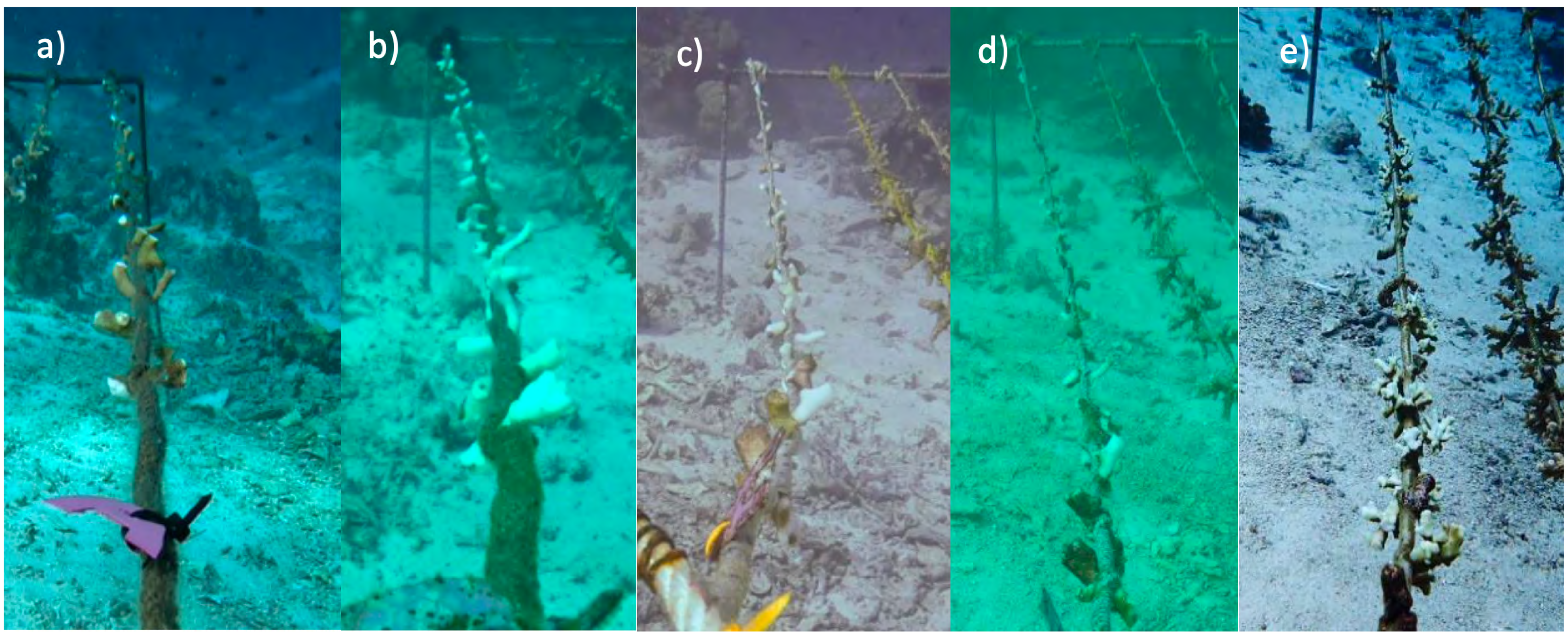

Figure 14: Interesting observation: Rope A with Stylophora pistillata showing pale colouration (bleaching) for the duration of the study, however 17 out 20 fragments still remain alive and growing (albeit slowly) after 10 months. The bleaching is only visible on the dorsal surface of colonies, with normal colouration on the ventral surface suggesting bleaching is perhaps due to light stress. Rope A was the only rope in the research nursery to sustain bleaching. a) day 1; b) 1 month; c) 3 months; d) 5 months; e) 10 months

2.2.2.2 Outplanting Results

At the end of 2022, phase two of the restoration project – the outplanting process commenced. This took place after growing the corals in the nursery for 12 months.

The outplanting was approached in two different ways as there were two distinctly different areas to the restoration site: 1) unconsolidated rubble, and 2) an area of rock flat and bare bommies (see figure 15). Literature was reviewed extensively to understand methods that have been used in the past, and which methods would be most appropriate for our particular sites. A scientific conference was also attended (Australia Marine Sciences Conference), where modern restoration techniques were discussed.

2.2.2.2.1 Outplanting 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. Choosing the right method at this early stage was extremely important due to the unique hydrodynamic conditions of our transplant site which would make effective transplantation difficult.

The experiment was conducted in December 2022 at Arborek Tip, and involved transplanting 6 corals within a 1m² quadrat, with eight replicate quadrats. 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 16), as well as with photographs (figure 17). This experiment would trial the three different transplanting techniques and their efficacy for both small fragments and whole colonies.

So far after 1 month, the results of the experiment are promising, with 98% retention of corals after 2 weeks (n= 48). The results will be presented in next year's report, but already we have noticed that some methods (i.e. cement) are providing an excellent hold on the corals with no movement at all, and signs of coral overgrowth already. The coral clip

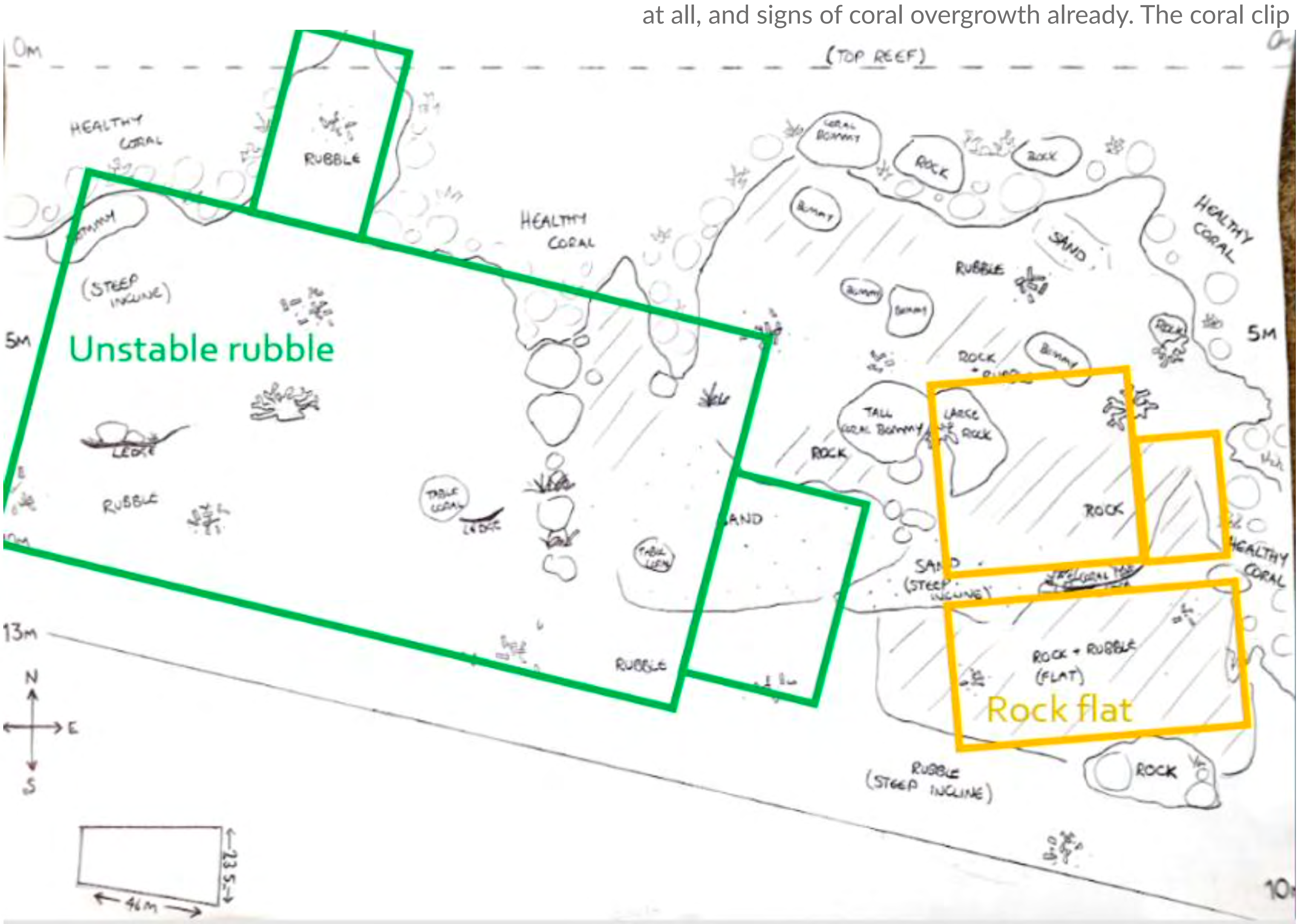

Figure 15: Map of the restoration site at South East Arborek, separated into two main reef types: Unstable rubble and rock flat. These two areas would be restored using different techniques

method is also promising due to the efficiency of deploying corals with this low-cost and simple method, it has also held corals well.

In March, once the experiment has run for three months, we will analyse the results and use this to inform our decision about the best method for transplanting multiple colonies from the nursery to this hard substrate area.

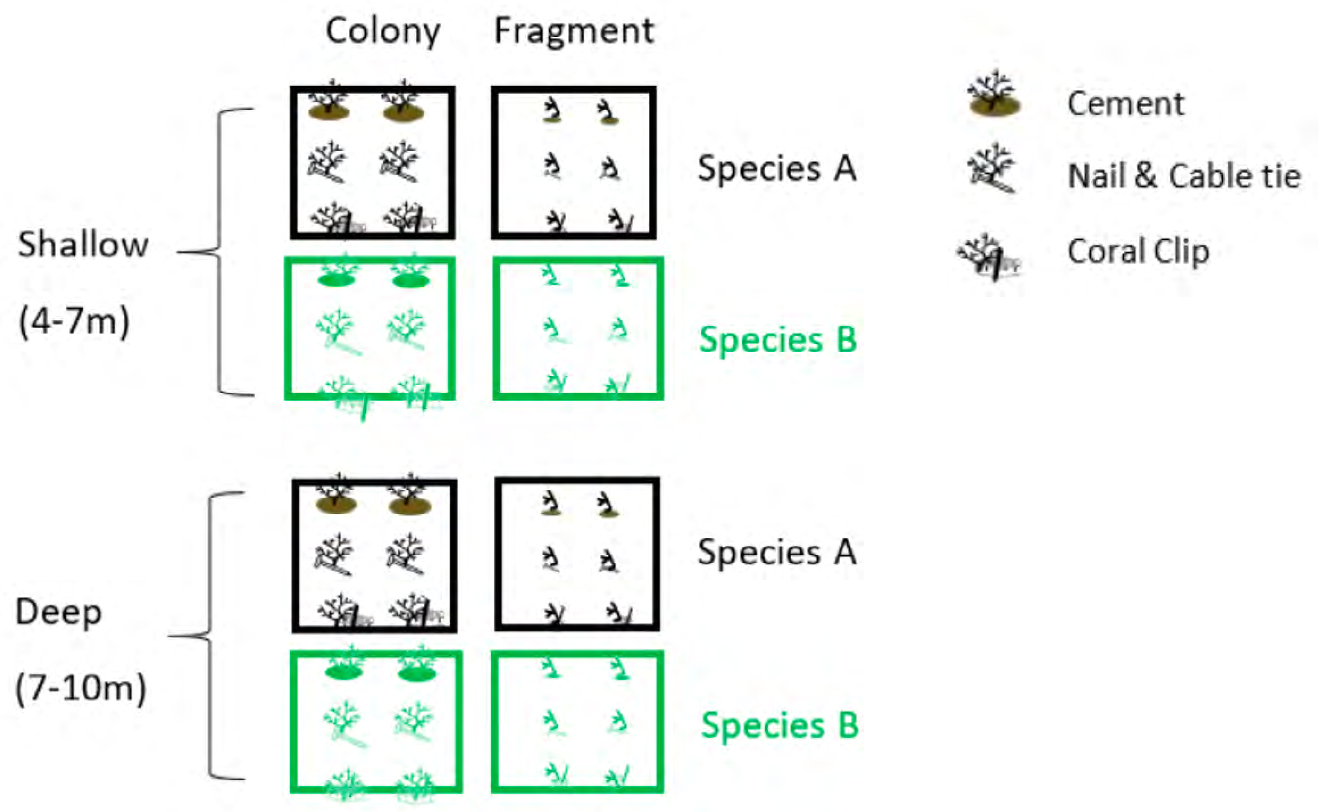

Figure 16: Experimental design of transplant experiment at Eastern Arborek, trialling the use of three different transplant methods on two species, two coral sizes and at two depths.

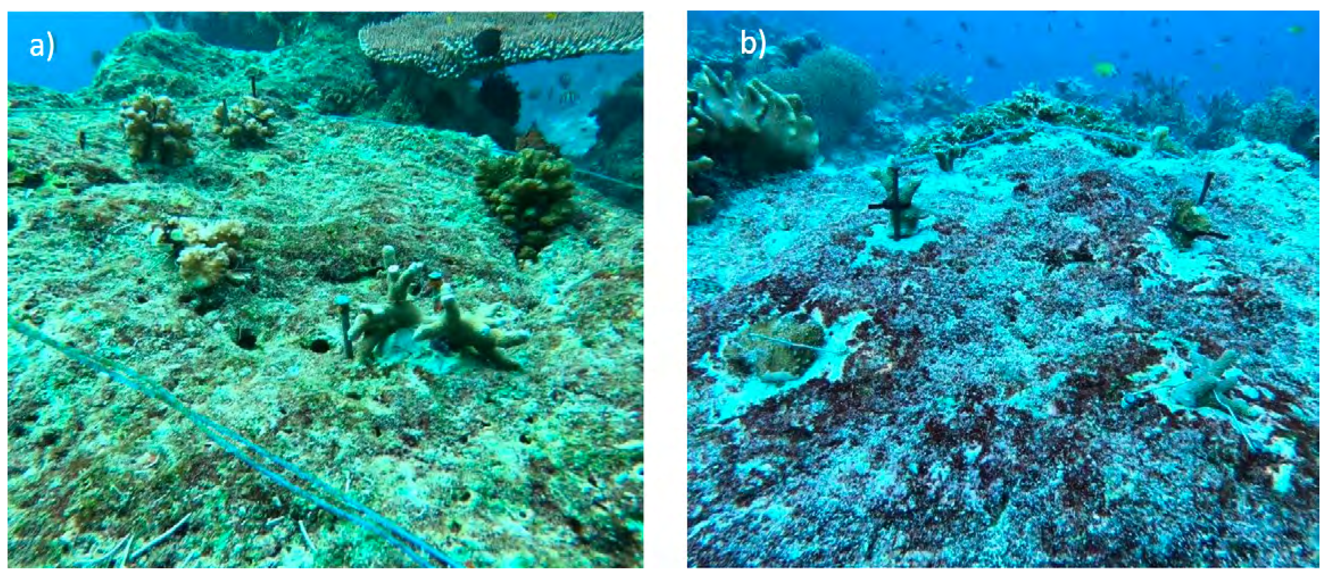

Figure 17: Photographs of the transplantation experiment in situ, a) shows the 1m2 quadrat with 6 whole colonies transplanted using the three different methods, b) shows 6 coral fragments transplanted with the three methods

2.2.2.2.2 Unconsolidated rubble transplantation site

The second area in our restoration site was an area of unconsolidated rubble. This area is very unlikely to recover naturally, due to the highly mobile nature of the rubble which does not allow coral recruitment or binding of fragments together in stablisation. The conditions of this site were analysed and no explanations were found as to why coral could not be supported here, once the substrate become stabilised. The main task for restoring this site was to stabilise this substrate, which would allow for natural recruitment to take over in the future. However, restoration of rubble areas is notoriously difficult.

A plan was developed to stabilise the reef substrate using a matrix of entire coral ropes, and metal stabilising structures. This method has never been trialled before. Ropes were chosen from Nursery 1 (educational nursery) where every colony on these ropes are large, multidimensional staghorn Acropora corals. These corals were chosen due to the fact that staghorn corals naturally grow in the sand/rubble on these slopes and act to stabilise it, so this natural process was mimicked by planting our coral ropes in this way. The coral ropes were laid down in a criss-cross matrix (see figure 18), and secured with metal pins hammered deep into the ground. Within the centre of each square, a metal stabilising structure was secured. The metal structures were designed with 5 metal 'legs' which were hammered deep into the substrate, and the metal frame was hammered down until the mesh was flush with the substrate and tightly secured all of the rubble underneath it. Corals were carefully selected from Nursery 2 and 3 to be attached to these metal frames, with careful consideration over spacing, species diversity and natural reef composition. The aim of this design was to kickstart stabilisation with fast growing corals, whilst hoping natural recruitment would follow.

The plan was implemented, starting from the shallowest part of reef degradation and would move down slowly over time as new coral ropes and frames get added. This approach would allow for natural herbivory by reef fish and prevent mass die-offs by invasive sponges or drupella, as has been reported in previous Outplanting attempts.

Three staghorn Acropora ropes were initially laid down and monitored for 1 month, before the rest of the plan was implemented. This was to test whether corals would become smothered by sand, or too stressed when planted directly onto the rubble. Coral colonies on the three ropes were monitored after 3 days, 1 week, 2 weeks and 4 weeks and the results found very good survival (100%) (see figure 19). After two months of being in place, fish and commensal crabs had already moved in the coral colonies were actively stopping the movement of rubble down the hill. The test

in future months will be whether the colonies can grow at a quick enough rate to retain the rubble from smothering them. We will be monitoring this closely in the next six months.

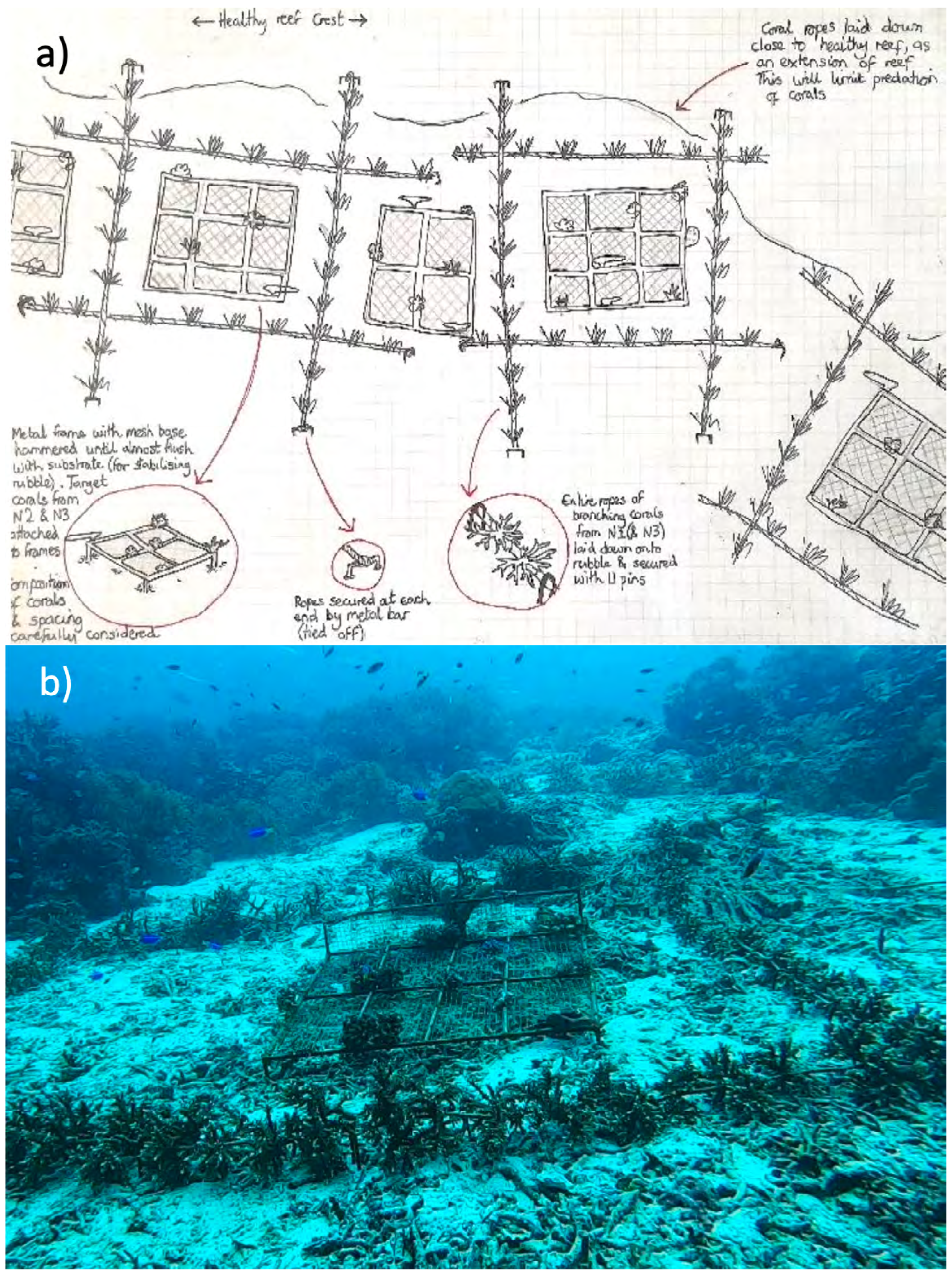

Figure 18: a) Original design of rubble stabilization and b) coral ropes and stabilization frame after being implemented at the restoration site.

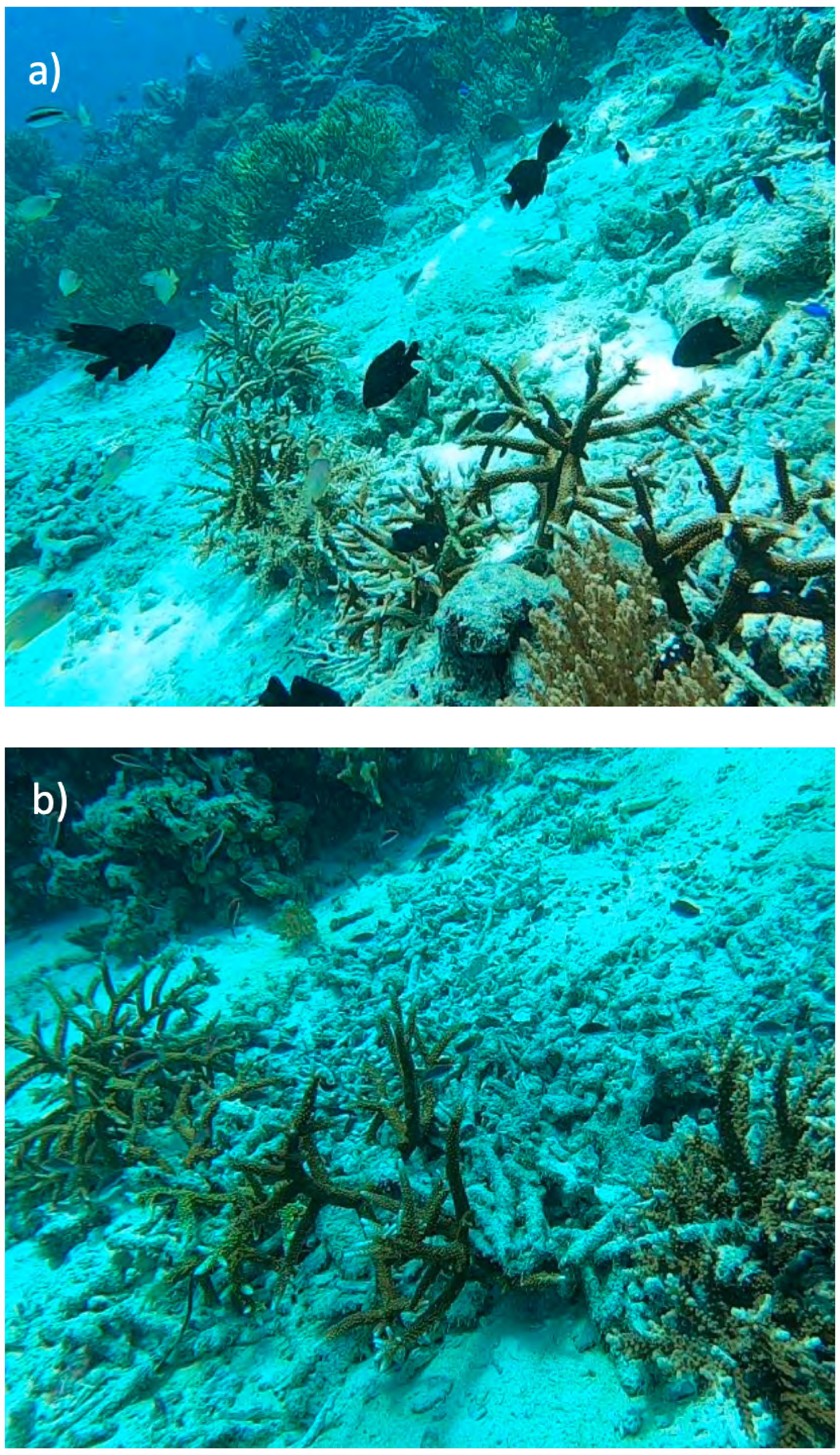

Figure 19: Coral rope after being transplanted to rubble site for two months. Image a) shows the coral associated fish which have now inhabit the coral colonies, b) shows the corals acting to prevent the fall of rubble further down the slope, as they would in natural systems.

2.2.3 Black Corals in the Restoration Project

As a new area of restoration research, we trialled the feasibility of restoring Black Corals, this has never been trialled before. We opportunistically collected Antipatharian fragments which had been found floating free, after a boat anchor had dislodged a large colony. Fragments of the black coral were attached with the use of sponge and coral clips, to see whether this rare coral could permanently reattach and grow, with some assistance. The black coral fragments were secured alongside the hard coral colonies in the outplant experiment, and they will also be monitored over the next 6-12 months. Results on the black coral transplantation will be presented in next year's report.

Figure 20: Black coral (white arrow) attached with coral clips within the transplant experiment quadrat.

2.2.4 Ecosystem Level Monitoring

In addition to monitoring coral growth and survival within the nursery, and the survival/attachment of corals outplanted, a long-term ecosystem-level monitoring project has also been set-up. This monitoring project will assess the ecosystem changes of the entire restoration area over 5 years (fish, benthic cover to genus, invertebrates, coral recruits, structural complexity). The long-term monitoring project involves monitoring three sites: 1) the restoration site, 2) a control unrestored site and 3) a healthy reference site. Monitoring takes place every 4 months, using similar methodology to Reef Check however with additional parameters such as coral recruitment, genus- level benthic ID and structural complexity assessments. Monitoring commenced 6 months prior to restoration efforts and will be ongoing until at least 2027. This dataset will be one of very few long- term restoration research projects (>1 year) and aims to inform restoration science with our findings on long-term ecosystem restoration.

2.2.5 Restoration Project Plans for 2023

In 2023 more corals from our nursery will be outplanted (ropes and colonies), utilizing the techniques which we have trialled. In February 2023, a new research project will be set up in the Research Nursery, starting from small fragments again. This year corals will be measured more regularly (every month) to capture the subtle changes in growth rates that occur during the year, according to fragment size and conditions. The optimum size for first planting a coral will also be explored.

Some well-needed maintenance will be carried out on coral frames and the addition of a fourth nursery is also planned – for slow growing corals which are not well suited to the rope nursery. This will allow us to expand the number of different species which we can outplant to our restoration sites, to ensure high diversity is being met.

As the restoration project has so far proven successful during it's pilot phase, we will commence talks with government about restoring some sites which have been recently affected by boat groundings (i.e. Crossover Reef). We will discuss the possibility of upscaling our methods and setting up large scale rope nurseries at these sites.

2.3 Manta Ray Project

2.3.1 OVERVIEW

The manta programme has improved a lot in 2022. Since October we have employed a full-time Manta Project Scientist who has overseen the running of manta research projects and other manta activities.

In 2022 (and 2021) we were lucky enough to see mantas *(m.alfredi)* all year round, without the defined manta seasons which are normally apparent in Raja Ampat. This is likely as a result of the unusual El Niño Southern Oscillation/La Niña weather events in these years which have impacted various environmental parameters, most likely including prey (plankton) availability within Raja Ampat. Mantas were sighted in every month, however peak sightings were in February/ March, August and October to December.

Barefoot conducts training for volunteers and staff on manta ecology and threats, how to responsibly interact with mantas following the Code of Conduct, and how to ID mantas. Once trained up, volunteers are able to collect Manta ID photographs as well as collect data on individual demographics such as sex, size, maturity, colour morph and species. Our manta scientist also collects data on abiotic and biotic conditions, manta behaviour and injuries. We have also started to collect data on number of boats and diver misconduct at key manta sites such as Blue Magic and Manta Sandy.

To assist with the efficiency of matching ID photographs to our database of over 300 individuals, we invited ex- volunteer (Stef) back to Barefoot who had been working on developing a software to speed up the ID process. Stef has been working on this programme as part of his university thesis in software engineering. The programme he developed has provided a faster and more efficient process when IDing individuals.

This year our manta scientist has orchestrated connections with local scientists within the area to help with their ongoing research through citizen science. We continue to provide ID photographs to local manta scientists operating in Indonesia, to expand the reach of their research.

Another new relationship has been with visiting liveaboards. Our manta scientist regularly visits two liveaboard boats to provide evening presentations to their guests about manta rays and spread awareness about the Code of Conduct and the importance of interacting with mantas properly. The presentations have been very well received and the talks also provide an opportunity to gather ID photographs from guests, guests also continue to provide photographs of manta rays even after leaving Arborek..

Figure 21: Manta Scientist, Lena Pollet, presenting onboard a visiting dive liveaboard boat. Guests are briefed on the Code of Conduct for diving with mantas.

2.3.2 2022 RESULTS

In 2022 we were able to recognize 68 resightings of reef mantas *(m.alfredi)* from our ID database and discover 9 new individuals, which had never been sighted before. Overall, the ratio of chevron to melanistic mantas was 1:1. Our database now has 309 individual reef manta rays.

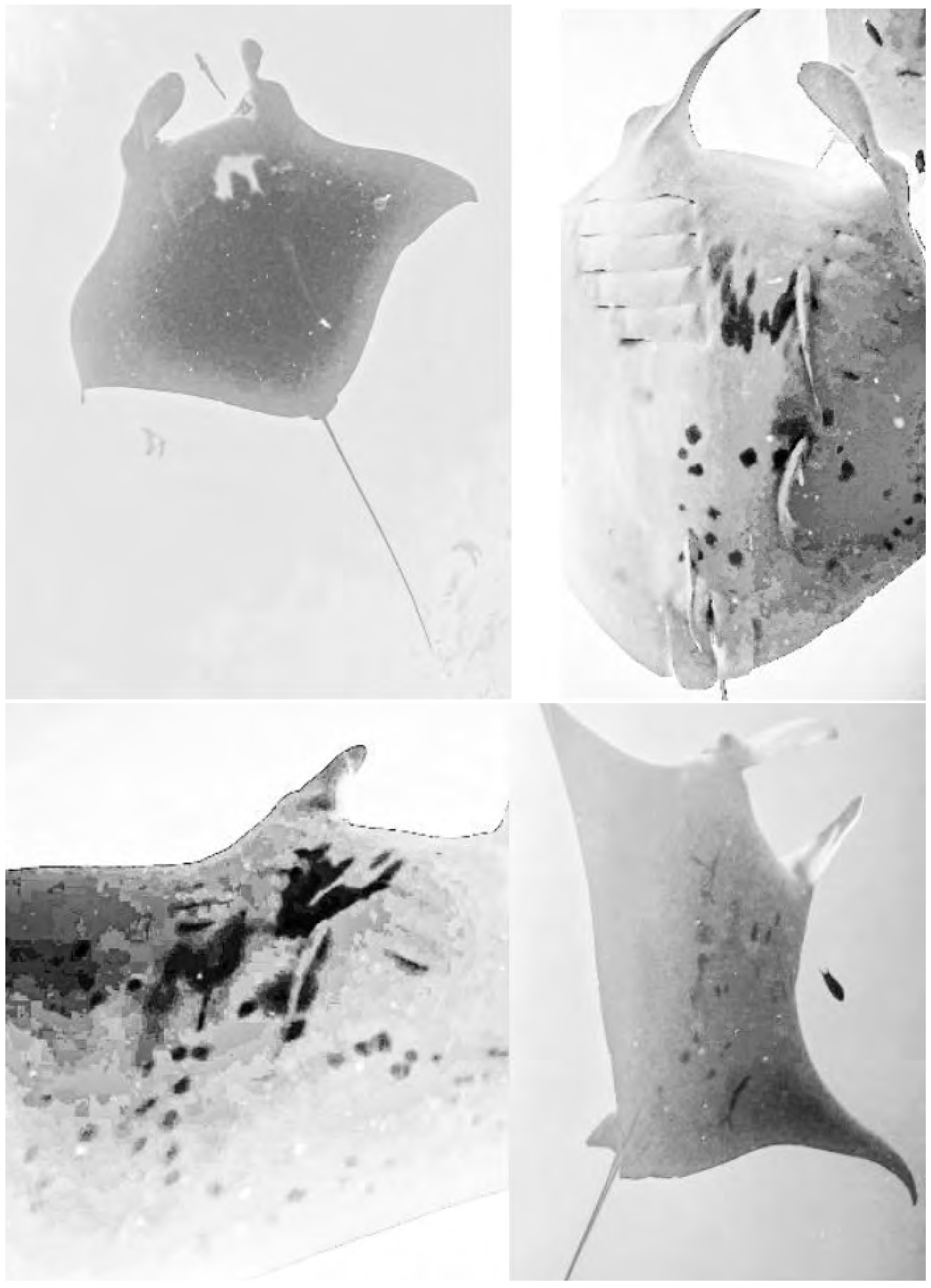

Figure 22: Four of the new individuals photographed during 2022. Each of these mantas have been assigned a name and number and added to our database, so that we can monitor when we are resighting the same individuals.

For Oceanic manta rays *(m.birostris)* we sighted 3 different individuals, including one individual with very pale ventral markings (see figure 23). This is extremely rare as Oceanic mantas typically have distinctive dark triangles under their fifth gill, dark trailing edges on the ventral side of their wings and dark markings around their eyes and mouth. The light ventral markings seen in our videos and the reduced pigmentation on the dorsal side, classifies this individual as a 'leucistic' colour morph of manta ray (Venables et al., 2019), which is extremely rare, especially for Oceanic mantas. This exciting encounter has been logged with elasmobranch.id. Our database now has 11 Oceanic manta rays.

Figure 23: A rare 'leucistic' M.birostris sighted at Blue Magic in March 2022.

2.3.3 2022 MANTA RAY PROJECT PLANS FOR 2023

In 2023 we hope to continue working with manta ray scientists in Indonesia and contribute to local research goals.

With a full-time manta ray scientist on the team, we will expand our research to include additional data on every manta dive including environmental conditions and social interactions.

We hope to increase the number of liveaboard boats which we are presenting to and additionally work together with liveaboard boats to collect data on boat numbers at popular manta sites which are not visible from Arborek.

We hope to expand our ID database further, with a more efficient process for IDing manta rays and the use of better cameras.

2.4 Anchor Damage Monitoring

In 2022 we noticed an increase in the number of private boats anchoring irresponsibly, in particular near the popular dive site JPP. On numerous occasions we have asked skippers to relocate, and some skippers have brought to our attention that this site is highlighted as a 'safe anchoring site' on a sailing App.

As soon as possible we hope to determine the name of the app which is causing tourists to anchor on JPP and contact the app, asking them to remove this site as a safe anchorage. In early 2023 we will also deploy a marked buoy which states that anchoring on this site is prohibited and carries a fine. This has already been agreed by Papa Juan.

Additionally, we have started monitoring anchor damage sustained by private boats at this site and will be reporting responsible boats to both the local chief, and also BLUD. The below images were taken on 28th of December where one catamaran was found to have 24m of chain lying over the reef. The coral damage was significant with numerous large table corals, massive and submassive corals broken and overturned. A huge 3m x 3m black coral was also completely uprooted by the anchor. We have multiple videos and images of the extent of the damage.

Figure 24: Monitoring photos of anchor damage sustained at JPP dive site in December 2022.

2.5 Black Corals Project

In June 2022, we invited an international expert on Black Corals (Antipatharia), Erika Gress from James Cook University, to Barefoot Conservation to give a presentation on the ecological significance of Black corals, and why Raja Ampat was an important site for them. Erika has since worked with our team during two visits to set up a monitoring programme which will document the occurrence of Black Corals around the Dampier Strait, as an additional aspect of our long term monitoring programme. This data will provide unprecedented information on the species diversity and habitat preferences of Black Corals in Raja Ampat, something which has never been documented before. We are very excited to commence this exciting research project and work with Erika in the future to understand more about this understudied Order of coral.

As discussed above, Black corals have also been incorporated into our reef restoration project. This research is also the first of its kind, testing out the feasibility of restoring black corals after they sustain damage i.e. from anchors. This is another exciting project to monitor in 2023.

Figure 25: Top: Erika Gress providing a lecture on black corals for Barefoot Conservation volunteers. Below: Black corals at Arborek Tip dive site.

2.6 Cyanobacteria Project

In 2022 Erika Gress, and other visiting scientists, highlighted that the occurrence of cyanobacteria and coral disease was notably higher in Raja Ampat than in previous years. In particular, it was noted that sites with the highest visitation rates by tourists, were showing elevated levels of the cyanobacteria (e.g Manta Sandy and Arborek Main Jetty).

The occurrence of cyanobacteria is strongly tied to eutrophication from excess nutrients which can result from high densities of humans i.e. at tourism locations. In extreme situations, such as what has been experienced in the Caribbean, eutrophication and in particular cyanobacteria can result in mass mortality of entire reef systems by smothering corals and depleting oxygen levels.

For these reasons, Erika and Barefoot Conservation have set up a monitoring protocol to start tracking the occurrence of cyanobacteria at various sites around Arborek and the wider region. In addition to monitoring its occurrence, the Raja Ampat Marine Park Authority (BLUD) have also been contacted and advised on the situation and provided with a written account of the problem.

In order to ascertain whether poor water quality around Arborek and popular tourist dive sites in the area is indeed contributing to eutrophication (and also coral degradation through diseases etc), Barefoot Conservation will be contracting a company to conduct a series of water tests, to compare water quality at several sites and gain evidence on the situation.

In 2023 meetings with BLUD will continue to discuss the plan of action for this issue, whilst Barefoot will provide critical monitoring data of cyanobacteria occurrence and empirical data on water quality.

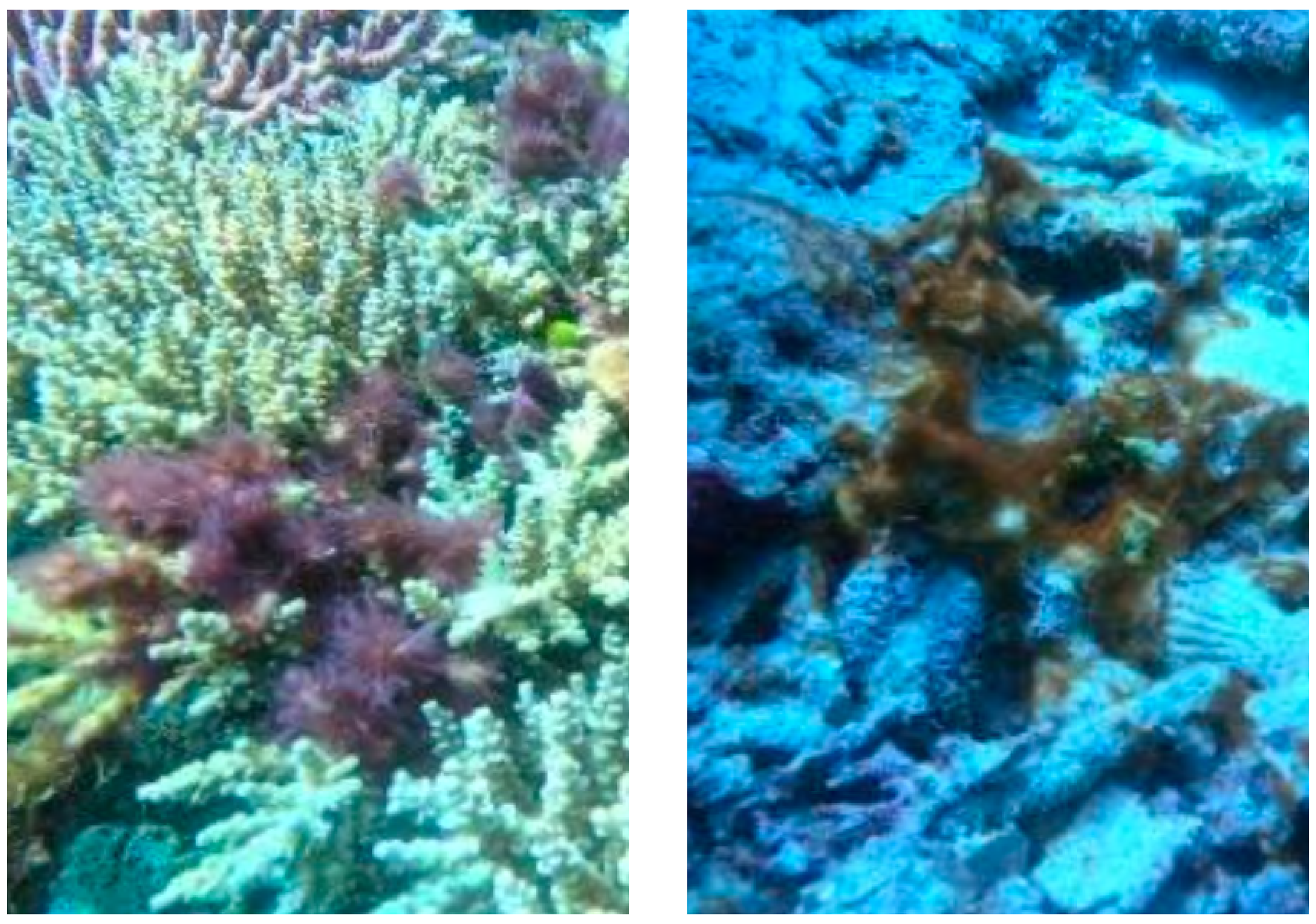

Figure 26: Cyanobacteria photographed at popular dive sites around Dampier Strait

2.7 Marine Debris Monitoring

Every Wednesday beach cleans are conducted around the island, with the help of volunteers and local children and data is collected on the waste that is collected. The site of the beach clean alternates each week between the North, South, East and West beaches of Arborek. After all the waste has been collected into bags, the waste is separated into categories, and the quantity of each category is counted. In addition to collecting useful data for local management, this activity is also a useful education tool, for the children (and volunteers) to start noticing which waste types are most common.

The project is a collaboration with Child Aid Papua, a NGO providing quality education for local children, located in Sawinggrai, Gam Island.

Figure 27: Top: Weekly beach cleans conducted by Barefoot team and Arborek children. Below: sorting the plastic waste into categories and recording count data for each type

3 Arborek Community Involvement

3.1 Engagement with Village Elders

We always seek permission from our Head of Village, Papa Juan, before proceeding with a new project, and also the villagers whose land is nearby our sites. We approached Papa Juan to discuss starting the reef restoration project in 2021, and in 2022 we spoke with him about incorporating black coral into the project too. Other environmental issues which we encounter through our monitoring, such as anchor damage were also presented to Papa Juan this year.

We planned a community event 'Coral Restoration Day' for December 2022 and handed out invites to the whole village. The day would have been opened by the Chief of the village, followed by a church blessing, guest speakers, and then a presentation by Barefoot Scientist about the coral restoration project, providing an update and showing photographs. The afternoon would be finished with the opportunity to make a coral rope along with the children, or to dive and see the coral nursery and a feast would have been served. Unfortunately, this event had to be cancelled on the day before the event due to circumstances outside of our control, it has been postponed until February.

3.2 Kids Science Clubs

In 2022 we worked a lot with the local children of Arborek. We held many science classes and activities at Barefoot, hoping to improve their knowledge of marine life and provide them with relevant education to be responsible eco-minded citizens and even progress in the marine conservation field if they would like to. We provided Discover Scuba Diving sessions with some of the local teenagers, to get them more acquainted with diving, we hope to follow this up with OW qualifications next year.

In December we relaunched our Ocean Warriors programme, where Arborek children are rewarded with stamps for ocean good deeds, for example attending a science class, joining a beach clean or do something else good for the ocean. The launch party saw more than

50 children attend and make Ocean Warriors cards, where their stamps would be collected and they can work towards prizes such as 'Ocean Warriors' t-shirts, snorkelling excursions and picnics.

3.3 Local High School and University Internships

This year we hosted two local teenagers from Sawinggrai Village for an internship at Barefoot. Edy and Melando joined us from Child Aid Papua School and stayed at Barefoot Camp for 2 weeks. During this busy internship they underwent training in Reef Check survey methods, as well as a variety of other topics such as overfishing, plankton, tides and currents and even underwater photography. The boys learnt very quickly during their internship with us and were able to pass their Reef Check tests in record time, both qualifying as Reef Check Ecodivers, which will be a valuable qualification to add to their CVs. In 2023 we hope to provide further internship opportunities and even part-time employment related to the reef restoration project to some Arborek teenagers.

In 2023 we have plans to host university students from Universitas Papua (UNIPA) at Barefoot Conservation for 4 months. This internship will enable the students to collect data for their theses as well as improving their diving and fieldwork skills, under the guidance of our science team. We hope this can be the start of an ongoing relationship with UNIPA, whereby Barefoot can play a part in assisting young local students to develop into the marine scientists of the future.

Figure 28: 'Science for Kids' class underway at Barefoot Conservation.

Figure 29: Ocean Warriors launch party, an ongoing club where Arborek children earn prizes for attending science classes and activities or doing 'good deeds' for the ocean.

Figure 30: Interns Edy & Melando stayed at Barefoot for 2 weeks where they took classes in marine science topics and underwent their Reef Check training.

3 Summary

2022 has been a productive year. We have set-up and made significant advances within our restoration project, exceeded our Reef Check survey goals, contributed to Manta ID databases in the region, trained up local students in survey techniques, taught local teenagers how to dive, and commenced novel research on black corals with leading experts, to name just a few achievements. Our science team has also expanded to a team of five, which means our capacity for new and exciting research projects has also grown. The addition of a Head of Science has allowed us to improve our science projects, provide consistency, and given us capacity to reach out to collaborators, to work together with researchers and institutions in the region.

Next year we hope to continue working on the projects mentioned above but with the addition of several new projects such as water quality testing, new restoration projects, 'Advanced Coral ID' modules for volunteers, and the expansion of our manta research scope. Additionally, we will be adding new sites to our Reef Check core monitoring sites, adding genus-level surveys to our data collection for benthic surveys and starting cyanobacteria and black coral monitoring on our surveys.

One of our main goals of 2023 will be to enable science excellence by local Papuan researchers, and to this end we will be hosting local marine science university students at Barefoot for fieldtrips and internships, setting up a Reef Restoration Internship for Arborek teenagers, teaching more children to dive and forging relationships with local scientists operating in the region. We hope to involve the Arborek community in the work being carried out at Barefoot more, through continued community events, employment and diving opportunities.

Aknowledgements

Our special thanks goes out to, first and 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. 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) Hans Budiarto, Victor Hendrico, Felicita Laura Annemarie, Lena Pollett, Matthew Perrodou, Gemma van Huyssteen, Dodi Roman, Evan Pubescen, Afryan Maris and Iris Uijttewaal for your relentless dedication to marine conservation and community development the past year.

The local staff are the absolute backbone of Barefoot Conservation as without skippers, compressor operators, cooks and maintenance work Barefoot Conservation camp would simply not be operational. Thank you Adhi, Manto, Andi, Carlos, Maikel, Rudi and Papa Ribka.

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

Partners

Partners involved in this research 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
- Ratu Laut Liveaboard, Solitude Adventure Liveaboard and Calicojack Liveaboard