TA7753-REG: Strengthening coastal and marine resources management in the Coral Triangle of the Pacific (Phase II)

Lessons learned and best practice guidelines for integrated coastal zone management and monitoring

Manus province, Papua New Guinea

Strengthening local capacity of vulnerable island communities in Papua New Guinea: an ecosystem-based approach to resource management

ASIAN DEVELOPMENT BANK

WILDLIFE CONSERVATION SOCIETY

ADB

WCS

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October 2016 – April 2018

Strengthening local capacity of vulnerable island communities in Papua New Guinea: an ecosystem-based approach to resource management

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CORAL TRIANGLE INITIATIVE
ON CORAL REEFS, FISHERIES AND FOOD SECURITY

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EXECUTIVE SUMMARY

The Asian Development Bank (ADB) allocated funds to strengthen coastal and marine resource management in the Coral Triangle of the Pacific, through subprojects in Papua New Guinea (PNG), Timor-Leste, Solomon Islands, Vanuatu and Fiji, which collectively form part of the Coral Triangle Initiative (CTI). The PNG Subproject and associated Technical Assistance (TA) was executed by the Wildlife Conservation Society at ten predetermined ADB community sites around the coastline of Manus province, PNG.

Subproject overview and description

Ten coastal communities were selected around the shoreline of Manus Island, Papua New Guinea (PNG), which are reliant on marine resources and which are deemed vulnerable to climate change and food scarcity. The waters that surround each ADB site encompass coral reefs, sea grass meadows and other marine habitats that support an abundance and diversity of species. Anecdotal evidence reviewed thus far indicates that population and technology driven increases in fishing pressure have led to the harvesting of smaller and fewer fish and invertebrates. In view of these challenges, the ADB Subproject aims to develop site-specific fisheries management plans for each ADB community. We anticipate that sustainable marine resource management will assist in strengthening food security and fortify marine ecosystems in light of predicted climate change threats.

Consisting of ten key stages, the subproject involved obtaining socio-economic, key fisheries and ecological data from each ADB site during 2017. A voluntary gillnet exchange programme, enabling fishers to trade small-meshed gillnets for less destructive larger-meshed nets, was also established, together with the deployment of a subsurface fish aggregating device (FAD) in order to attract open-water fish species and relieve pressure on less-resilient reef fish. Villagers were also asked to select fisheries management methods, which were considered appropriate for each community, enabling the development of site-specific fisheries management plans. This was followed by the collection of fisheries catch-and-effort and length based spawning potential data at each site, and the distribution of resilient crops and associated training in appropriate gardening methods. An outline of all the findings from all sites can be found in this report.

Lessons learned

A number of constraints and challenges arouse during the lifespan of the subproject. Summarised below is a list of some of the major lessons learned from the challenges that occurred during subproject implementation:

- During initial site visits, some villagers were not fully aware of the subproject: Community engagement and prior contact with ward councillors, outlining the purpose of the visit, is necessary to reduce confusion
- Time limits constrained the number of site visits, and the quantity of data collected: The subproject would have benefited from an extended timeframe
- Gillnets were not used at all sites: Prior community engagement should assess customary traditions practiced at each site
- Short timescale to compile necessary information for the fisheries management plans: Planning ahead, community workshops and compiling relevant information from each site for the management plans is vital
- Selecting representatives for the Marine Management Committee (MMC): The MMC should be selected by the community; all major clans should be represented to ensure rules are followed by all community members
- Setting penalties for non-compliance: Residents should set appropriate penalties for breaking fisheries management rules; community work can be included
- Problems in obtaining the FAD materials: Ordering materials in advance benefited the subproject
- Issues in deciding FAD deployment sites, due to customary land and sea tenure traditions: Diplomacy and community engagement was necessary between three sites (Ponam, Tulu 1 and Tulu 2) to ensure each community agreed upon the best approach for FAD deployment
- Unable to complete the third wave of catch-and-effort data collection due to time restrictions: FAD materials did not arrive until early 2018; therefore, there was insufficient time to complete the third wave of catch-and-effort data collection following FAD deployment. The subproject would have benefited from additional time to enable catch-and-effort monitoring
- Selecting sites for giant clam farming: At Ponam, there were some disagreements regarding clam pen locations. Community engagement and pragmatic advice from WCS helped the community leaders with decision making

A detailed account of all the challenged and associated lessons that were learned from the subproject is included within this report.

Guidance for coastal zone management and monitoring

An ecosystem-based approach to fisheries management and food security was employed at all ten ADB sites, which aim to increase local capacity and enable site-specific local governance through the implementation of fisheries management plans and establishment of locally-elected Marine Management Committees. From the lessons that were learned during the implementation of the subproject, several guidelines for integrated coastal zone management have been recognised, which include the following:

- Educational awareness programmes should be established to build local capacity
- Gaining an understanding of local key fisheries can lead to site-relevant management plans
- Fisheries management tools should be suggested to each communities, and villagers should be allowed to select tools they think are appropriate
- Communities must understand why the data is being collected; questionnaires used should be short and simple

- All data should be repatriated to the communities in a simple and visually interesting way
- Community facilitators should be equipped with project-relevant knowledge and take an approach that is culturally appropriate
- The subproject should be coordinated with the local government, other non-governmental organisation (NGOs), public awareness organisations, and regional stakeholders
- The Marine Management Committees (MMCs) should (i) be locally elected and include representatives of each major clan; (ii) convene on a quarterly basis; (iii) set penalties for rule breakers; (iv) adapt the management plans according observed changes; and (v) ensure information is disseminated to the rest of the community
- Materials for constructing FADS, large-meshed gillnets, clam pens and gardening activities, should be purchased in advance in case of logistical issues
- Regular monitoring is required to detect changes in fishing activity, catch rates, and fish sizes, as well alterations in community demographics and changes in coral reef community structure

Regular and consistent monitoring following the implementation of ecosystem-based management approaches is necessary to determine the impacts of the management measures used, and also to indicate areas for adaptive management. Key focus areas for monitoring plans following the ADB Subproject are to:

- Record observations and fish count numbers in dated logbooks
- Quantify population increase through a community census
- Check the usage of efficient fishing gears, including spear-guns and snorkelling sets, and also to monitor gillnet usage and mesh sizes
- Monitor the catch numbers, body sizes, and catch diversity of fish caught with larger-meshed gillnets and from around the community FADs, and following the implementation of the management tools
- Assess changes that may occur to coral reef habitats in designated no-take zones
- If possible, continue the catch-and-effort surveys at each site
- Monitor the germination success of seeds and tubers, and quality and quantity of climate-resilient crop yields

WCS will remain in contact with the ten communities, through the Marine Management Committees, and will continue to provide guidance and support. This includes advice with monitoring plans and, if sufficient funding should arise, WCS would be keen to carry out – and adapt, where necessary – the monitoring plans listed in this report.

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
CAE	Catch-and-effort
CPUE	Catch-per-unit-effort
CTI	Coral Triangle Initiative
FAD	Fish aggregating device
FMA	Fisheries Management Act
ICZM	Integrated coastal zone management
LB-SPR	Length-based spawning potential ratio
LLG	Local Level Government
MMC	Marine Management Committee
NARI	National Agriculture Research Institute
NFA	National Fisheries Authority
NGO	Non-governmental organisation
PNG	Papua New Guinea
SDA	Seventh-Day Adventist
SE	Standard error
TA	Technical assistance
WCS	Wildlife Conservation Society
WLG	Ward Level Government
WDO	Ward development officers

GLOSSARY OF TERMS

Acropora: A genus of hard coral species found in the Indo-Pacific region, which are important for the building of coral reefs. Can occur in a variety of forms, including branching and plate-like colonies.

Algae: Simple life forms that have no major organs and use sunlight to photosynthesise. Algae live in aquatic environments or moist areas and can be microscopic, free living in the water column (for instance, phytoplankton), or large in size and attached to the seabed (including seaweeds, such as kelp).

Anthropogenic: An event or process that occurs due to human activities, which is usually detrimental to the environment.

Biodegradable: A material that can be decomposed by bacteria, fungi or other life forms.

Biodiversity: The variety of plant and animal life in a particular habitat, a high level of which is considered important and desirable. Over 7% of global biodiversity is contained in Papua New Guinea.

Biomass: The total mass of all the organisms of a given type within a given area.

Benthos: Referring to the seafloor and organisms that live on or burrow into the seabed. Benthic organisms may be free-moving, such as worms, starfish and flatfish, or attached to the seabed, including seaweed, sponges and corals.

Carnivore: An animal that consumes other animals.

Cassava: A tropical American plant of the Genus *Manihot* that is cultivated for its starch-enriched roots.

Climate change: A long-term shift in climate over several decades or centuries, including changes in temperature, rainfall and air pressure, caused by natural events, such as volcanic eruptions, and anthropogenic sources, such as the release of carbon dioxide, methane and other gases from burning fossil fuels, vehicle exhausts, and agriculture.

Coral: A group of marine animals related to jellyfish that bear specialised stinging cells for defence and feeding. Adult hard corals, known as polyps, deposit limestone skeletons, which can form extensive reef systems. Around 500 coral species can be found in the waters surrounding Papua New Guinea.

Coral reef: A distinctive biologically-created seabed feature formed when hard corals grow and deposit limestone skeletons. Can be found in shallow and deep water areas, although the most familiar coral reefs are found in shallow tropical waters and support an abundance and diversity of other marine life.

Coral Triangle: A geographical term referring to the triangular-shaped area of tropical marine waters between the Philippines, Malaysia, Indonesia, Timor-Leste, Papua New Guinea and Solomon Islands. At least 500 reef-building coral species and a wealth of other marine life are found in this eco-region.

Crustacean: A large group of predominately aquatic invertebrate animals, which have jointed legs, a definite head with eyes, jaws and antennae, and a segmented body protected by a shell-like carapace. Worldwide, there are over 35,000 species of crustacean, which include many planktonic forms, such as water fleas and fairy shrimps, as well as larger barnacles, woodlice, prawns, crabs and lobsters.

Dugong: The largest herbivorous marine mammal; feed on sea grass and are related to manatees.

Ecosystem: A biological community (including microbes, plants, fungi and animals) and the associated physical environment.

Fertilisation: The union of male (sperm or pollen) and female (eggs or ovules) sex cells during sexual reproduction, resulting in the full complement of genetic material from both parents. For marine organisms, fertilisation can be external in the water column (such as for seaweeds, sponges, corals, worms and many reef fish) or internally, within the female body (including sharks, turtles and dugongs).

Fish aggregating device (FAD): An object placed on the seafloor, onto which a series of ropes and floats are attached. The upper-most part may be on or just below the seawater surface and arranged to enable the growth of algae, which in turn attracts open water fish, such as tuna and trevally. FADs provide coastal communities with a supply of open water fish, relieving fishing pressure on many reef fisheries.

Fishery: The industry of catching, processing and selling fish, and the location where this takes place.

Gamete: A reproductive cell that fuses with another reproductive cell during sexual fertilisation. Female and male animals produce different gametes, (eggs and sperm, respectfully). Plant gametes include female ovules and male pollen. Compared to other cells, gametes contain only half the genetic material, which becomes complete when two complementary gametes fuse during fertilisation, forming a zygote.

Genus: A category used to classify organisms, consisting of closely related species.

Gonad: The paired reproductive organs in many animals that produce gametes (sex cells), such as ovaries in females and testes in males. Gonads also produce sex hormones associated with development and reproduction, including oestrogen in females and testosterone in males.

Habitat: The place in which an animal or plant lives.

Haus boi: A traditional building in which only male residents (typically unmarried) reside; also a place for clan leaders and elders to make community decisions. In Manus, the *haus boi* system is an important aspect of community life in some areas, including Andra, Ponam, Tulu 1, Tulu 2 and Pelipowai.

Herbivore: An animal that consumes vegetation.

Hybrid: The offspring of two plants or animals of different species, such as drought-resilient crops.

Invertebrate: An animal that lacks a vertebral column (backbone). Includes sponges, corals, jellyfish, worms, snails, oysters, squids, spiders, crabs, centipedes, butterflies, ants, starfish and sea squirts.

Juvenile: An immature stage during the lifecycle of many marine animals, following the larval phase and prior to the adult phase. Many juvenile organisms resemble adults but are not yet sexually mature.

Larvae: The initial stage during the lifecycle of many marine animals, following the fertilisation of the sex cells and subsequent development of the embryo. Most larvae are vulnerable and found in open water, where they form part of the zooplankton. Larvae usually consume other plankton.

Limestone: A sedimentary rock composed primarily of calcium carbonate. Hard corals deposit a limestone skeleton, which is necessary for building the structure of a coral reef.

Lorengau: The provincial capital of Manus province.

Mangrove: Several species of tropical evergreen tree and shrub with aerial roots that form dense thickets along coastlines. One of the few plants to have adapted to living in the marine environment.

Melanesia: A region of western Oceania, characterised by the darker skin pigmentation of local inhabitants. Includes New Guinea, Solomon Islands, Vanuatu, New Caledonia and Fiji.

Mollusc: A large group of soft-bodied invertebrates that have a definite head, a non-segmented body, a muscular foot, and usually a protective shell. Includes snails, slugs, clams, oysters, squid and octopuses.

Organism: An individual living system, such as a microbe, plant, fungus or animal.

Overfishing: A form of resource over-exploitation whereby fish stocks are reduced to below acceptable or sustainable levels. Occurs when more fish are caught than the population can replace through natural reproduction.

Pelagic: Referring to the open waters of the marine environment and organisms that swim through or drift in the water column, including plankton, jellyfish and oceanic fish species.

Plankton: Very small, open water organisms that drift passively with the current of an ocean, sea or lake. Plankton form an integral food source for other aquatic life forms and include phytoplankton (which photosynthesise and are the basis of most marine food webs) and zooplankton (small animals or larval animals that feed on phytoplankton or other zooplankton).

Porites: A genus of hard coral species found throughout the Indo-Pacific region, which are important for the development of coral reef systems.

Recruitment: The number of fish surviving to enter a fishery or to a particular life history stage, such as mature adults.

Sea grass: The only flowering plants that are fully adapted for life within the marine environment. Usually living in shallow, sunlit waters, sea grass beds provide a habitat for many other organisms.

Sedentary: Marine organisms that live on the seabed and cannot move very far, such as giant clams.

Sessile: Describes a marine animal that is attached to the sea floor, including sponges and corals.

Spawn: To release eggs. Many marine animals release their eggs and sperm into the water column in a process known as broadcast spawning, which enables fertilisation to take place. Usually, of the multitude of eggs released, only a small number will develop into adulthood.

Spawning aggregation: A mass assembly of fish gathered in order to spawn, usually at designated areas within the marine environment and at a time determined by the lunar cycle and the influence of the moon on the tides.

Spill over: The supply of marine ecological services to adjacent areas from a protected or managed zone.

Tenure: The ancestral rights to live in an area and to use the local land and coastal resources. Over 96% of Papua New Guinean land is held under customary ownership and through traditional tenure systems.

Trochus: Marine snail with a conical shell. Forms a key fishery for many areas in Papua New Guinea.

Tuber: A swollen underground stem or root of certain plants, which enable the plant to survive during periods of drought; tubers are also a means of asexual plant propagation.

Yam: A vine-like tropical or subtropical plant belonging to the Family Fabaceae, cultivated for its starch-enriched root tubers.

Yield: To produce or bear: An amount produced of an agricultural or fisheries product.

ACKNOWLEDGEMENTS

The Asian Development Bank (ADB) was the donor for the Subproject, entitled *Strengthening local capacity of vulnerable island communities in Papua New Guinea: an ecosystem- based approach to resource management*, which forms part of the Coral Triangle Initiative (CTI). The Wildlife Conservation Society (WCS), a global non-governmental organisation (NGO) based in Goroka, Kaviang and Manus, Papua New Guinea, were given approval to execute the Subproject; at the time of writing, Sven Frijlink, Sylvia Nobel and Ambroise Brenier were the WCS project managers. The current report is one of the key deliverables for the Subproject, which took place between October 2016 and April 2018. All the data and information used during the production of the current report were obtained courtesy of the local residents that live in the ten ADB communities (Andra, Baluan, Bipi, Lou, Mbuke, Pam, Pelipowai, Ponam, Tulu 1 and Tulu 2), and extreme gratitude must be given to all community members that took part in the Subproject.

The Senior Marine Biologist for the Subproject was Anthony Nagul who managed and co-ordinated all the Technical Assistance (TA) for the subproject, enabling the data collection and data analysis procedures to occur, as well as relevant stakeholder consultations. This report was written and compiled by Jonathan Booth. Field-based data collection and subsequent data entry was completed by Yvonne Wong, and the WCS community facilitators (CFs): Misu Nick, Rubbie Aron, Blaze Dimura, Lawrence Effi, Michael Londron, Bernard Manus, Thomas Molok, Alani Pohei and Simon Smith. The WCS skippers, Bernard Manus, Pondrax and Joe Ludwig, supervised all boat transport to and from the ten ADB communities from Lorengau on the mainland Manus.

FOREWORD

Only two degrees below the equator, the small Papua New Guinean island of Manus is surrounded by a wealth of marine habitats, including coral reef systems that support an abundance and variety of marine species. For millennia, human communities living on Manus have relied on their marine resources for sources of protein and income, a trend that continues to today. Despite this, many coastal environments are now threatened by rapid modernisation, population growth, and more efficient fishing methods, emphasising the need for local coastal zone management at the community level.

In recognition of the need to assist coastal communities with managing their marine resources, the Wildlife Conservation Society has been actively engaged with ten villages around Manus Island from October 2016 to April 2018. During this period, site-specific fisheries management plans were developed: the plans incorporated marine management tools – selected by each community – that were implemented and enforced by locally elected Marine Management Committees. The management plans focused on adaptive capacity building and also on key fisheries at each site: a process that combined customary needs with modern science, enabling the development of site-relevant initiatives.

Although the project was completed successfully, a number of challenges and constraints arose, which required appropriate mitigation and alleviation measures. Such incidents also provided an invaluable opportunity to adapt the subproject accordingly, and to assess the technical components, community engagement methods and project management strategies that were employed. Such critical assessments can benefit the development of subsequent project implementation and monitoring plans, as well as future ecosystem-based approaches to resource management, in Manus province and elsewhere in Papua New Guinea.

This publication aims to assist regional coastal zone managers, policy makers and other relevant stakeholders in making sensible management decisions at the community level, based on first-hand experiences at ten sites around Manus Island. The information provided in this report could be used for future adaptive capacity building, integrated coastal zone management, and climate change resilience plans around Manus province or elsewhere in Melanesia. It is hoped that future monitoring plans will be implemented during subsequent years to determine the success of the management approaches and to allow for adaptive management, to safeguard local marine resources and their habitats for future generations to utilise and enjoy.

1.0 BACKGROUND

In October 2016, the Wildlife Conservation Society (WCS) received approval from the Asian Development Bank (ADB) to undertake the subproject entitled *Strengthening local capacity of vulnerable island communities in Papua New Guinea: an ecosystem-based approach to resource management*. The subproject was to be carried out at ten coastal communities (Andra, Baluan, Bipi, Lou, Mbuke, Pam, Pelipowai, Ponam, Tulu 1 and Tulu 2) around Manus province, Papua New Guinea (Figure 1) from October 2016 until April 2018 (the original completion date, December 2017, was extended by four months).

Under this subproject, WCS provided support to each of the ten coastal communities in Manus province, to assist with the management of marine resources upon which the communities heavily depend. Climate change is predicted to have large-scale impacts on this area of high marine biodiversity, which is located in the eastern Coral Triangle, and the lack of government-led management undermines the social and ecological resilience of local communities. WCS's approach to addressing these threats includes improving the assessment, management, and monitoring of key fisheries and coral reef habitats, and increasing the capacity of communities to independently manage these resources.

Upon completion of the deliverables for the subproject, this report outlines the major findings from all ten ADB sites. The report continues by listing the challenges encountered during the implementation of the four key subproject objectives, as well as alleviation measures used to mitigate such problems. Following this, the report presents the lessons learned during the implementation of the subproject, and finishes by suggesting practical guidelines for integrated coastal zone management and future monitoring plans.

1.1 Objectives

The ADB subproject had four main objectives:

OBJECTIVE I: Build community and local partnerships

OBJECTIVE II: Strengthen local capacity to manage local resources

OBJECTIVE III: Strengthen appropriate management approaches

OBJECTIVE IV: Trial and replicate livelihood and climate change adaptation initiatives

For further details concerning the components of each objective, refer to Table 5, Table 6, Table 7 and Table 8, or consult the ADB Subproject Proposal.

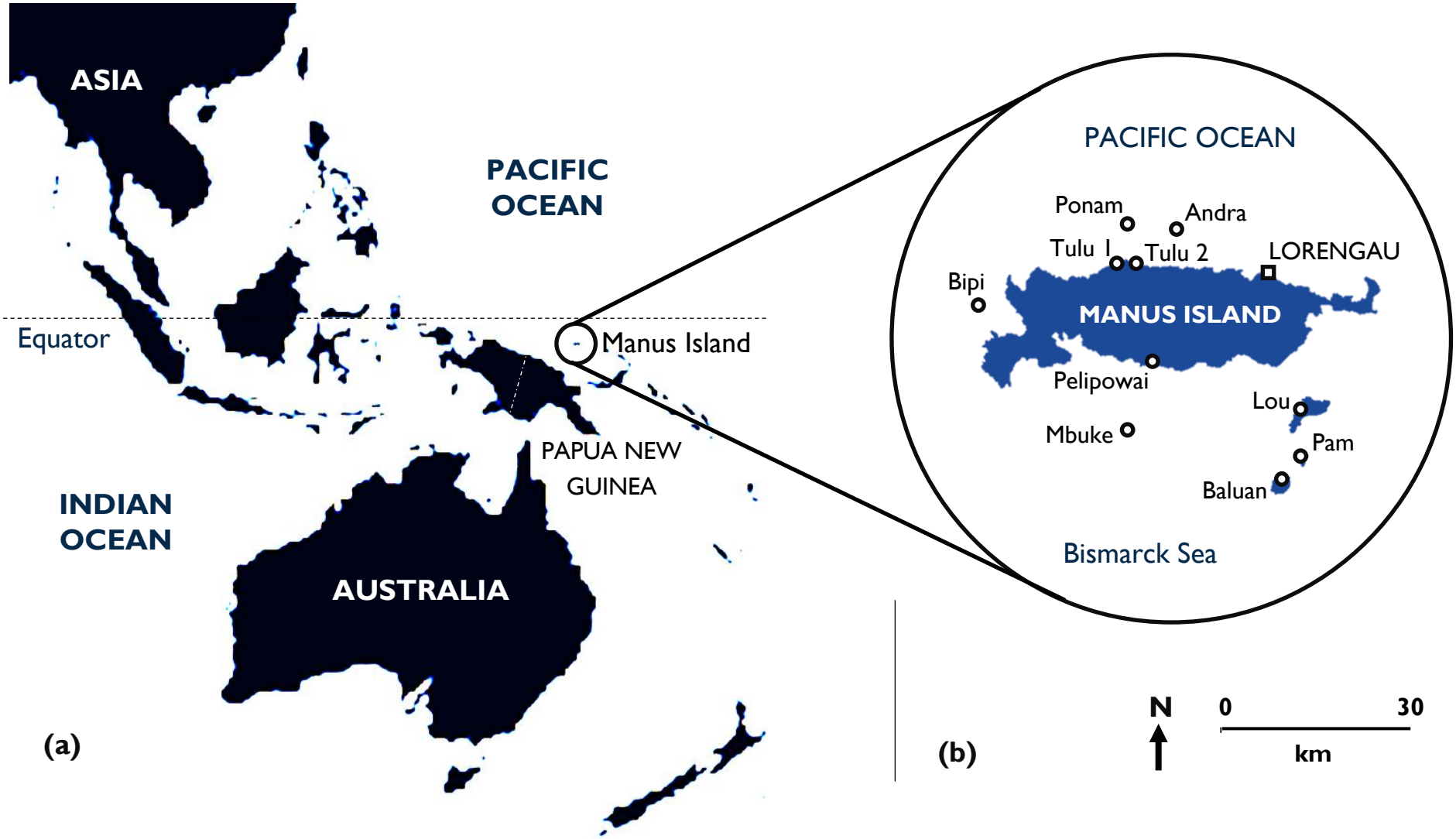


Figure 1: Papua New Guinea (a) is located in the Western Pacific Ocean, north of Australia and southeast of Asia. Just two degrees south of the equator, the island of Manus (b) forms the smallest province in Papua New Guinea and is where the ADB Subproject was conducted from October 2016 to April 2018. The ADB Subproject was carried out at ten coastal sites around Manus Island. The capital of Manus province is Lorengau.

2.0 PROJECT DESCRIPTION

The ADB Subproject has been developed through a participatory consultation process whereby the residents of the ten ADB communities were collectively and actively involved in providing necessary information during the various subproject components. The process included a number of steps, which were facilitated by WCS but reflected the community's views and requests, which enabled subproject implementation.

Some of the major deliverables of the subproject included:

- Producing site-specific fisheries management plans for each community based on socio-economic, fisheries and ecological data collected at each site; the plans incorporated fisheries management tools, rules and penalties that were selected by the communities and which were enforced by a locally elected Marine Management Committee (MMC);
- The deployment of a subsurface fish aggregating device (FAD) at each site to attract open-water fish in order to relive pressure on more vulnerable reef fisheries;
- A gillnet exchange programme within each community so that fishers can exchange fine-meshed nets for less destructive larger-meshed nets;
- Two waves of catch-and-effort assessments at each site to determine typical catch rates, catch compositions, levels of fishing effort, and the intensity of local fishing practices at each site, both before and after the gillnet exchange programme to monitor any fishing changes that may occur;
- Length-based spawning potential (LB-SPR) assessments of ten important reef finfish species around Manus (selected on the outcomes from the first wave of catch-and-effort data collection), to the deduce minimum size of maturity for each species, and set appropriate minimum size limits;
- Introducing novel gardening approaches to all ten communities and providing climate resilient seeds and tubers, which should assist community members with increasing crop yields despite the projected threats of climate change

Figure 2 provides an overview of the major components of the ADB Subproject, which occurred at all ten sites from October 2016 to April 2018. (In addition, trial clam gardening pens were established within the inshore waters at Andra and Ponam communities.)

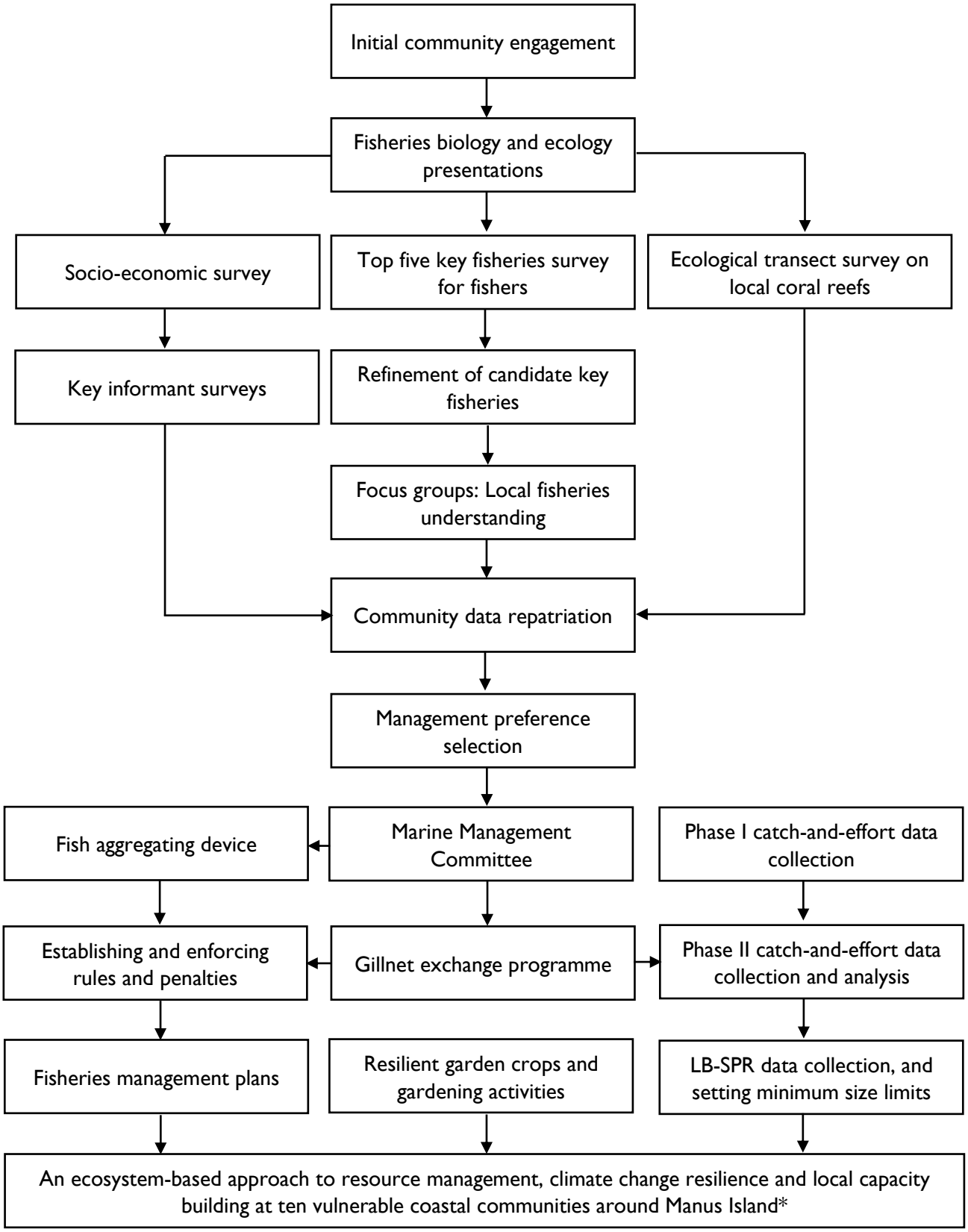


Figure 2: Schematic representation of activities undertaken between the ADB sites and WCS in order to develop an ecosystem-based approach to resource management, climate change resilience and local capacity building at ten vulnerable communities around Manus Island, Papua New Guinea. The subproject lasted from October 2016 to April 2018. (*Giant clam pens were also established at Andra and Ponam).

3.0 FINDINGS

During the subproject, specific sets of data were collected at each of the ten ADB sites around Manus province, from October 2016 to April 2018. This section outlines the key findings from the socio-economic, key fisheries and ecological surveys, as well as an overview of the (i) fisheries management plans, (ii) fish aggregating device deployments, (iii) gillnet exchange programmes, (iv) garden training activities, and (v) clam pen trials. A summary of the catch-and-effort and stock spawning assessments are also included. For a more detailed account of the data collection procedures and findings, refer to the relevant reports that accompany this lessons learned report.

3.1 Socio-economic findings

In total, 219 households across all ten sites completed socio-economic questionnaires during 2017, providing data for 1,441 individuals. Of the pooled participants across all sites, 743 (52%) were male, and the average age was 27.3 years old. Apart from at Lou, Pam and Baluan, the proportion of youth (aged 18 and under) at each site was higher than the global average, which according to World Bank figures is 38% (Figure 3), indicating population increase at such sites. A larger population will require more fish for protein-consumption and market sales, placing additional pressure on local coral reefs.

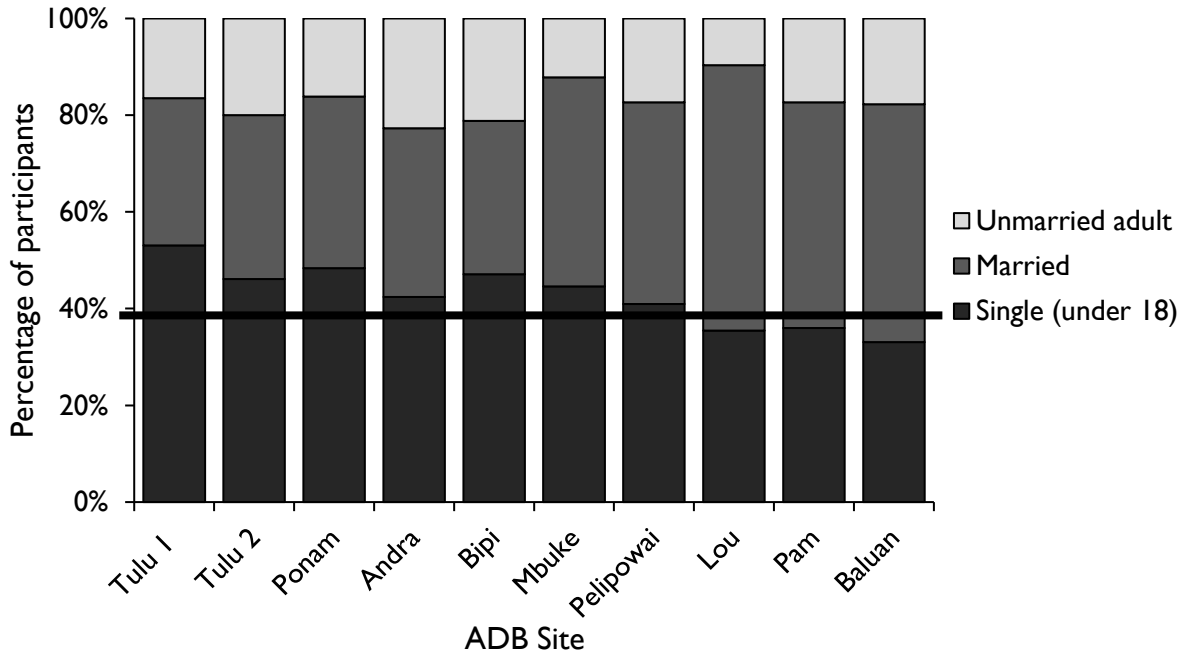


Figure 3: The proportion of youth (aged 18 or less) at each of the ten communities surveyed around Manus Island during 2017. The black bar denotes the global average of under-18-year-olds, which according to World Bank data is 38%. The high proportion of young residents indicates population increase.

Across all ten sites, the majority of surveyed residents relied on the consumption of reef fish for dietary protein intake (eaten 1,423 times during the week prior to surveying), indicating the importance of local reef fisheries to each community (Figure 4). Canned fish (eaten 676 times), shellfish (consumed 224 times) and canned meat (eaten 125 times) were the next most important protein sources, respectfully. Apart from at Pelipowai, no mangrove habitats are found adjacent to the communities, which could explain the low consumption of mangrove products (mud crabs, kina shells, ark shells, mangrove snails and mangrove beans).

The socio-economic surveys also included questions on marine science, designed to assess the knowledge and understanding of marine biology and fisheries science of each participant. When the data was pooled from all ten sites, it was apparent that the majority of participants had a good understanding of fisheries science; however, fewer residents were knowledgeable about more general marine biology concepts. For example, across all sites, only 16% of the participants knew that sharks typically produce a small number of young during a single reproductive cycle, and only 14% were aware that groupers are, in general, slow growing fish (Table 1). Such outcomes indicate the importance of developing local knowledge and capacity regarding marine science and sustainable fisheries understanding, which in turn will help with local resource management.

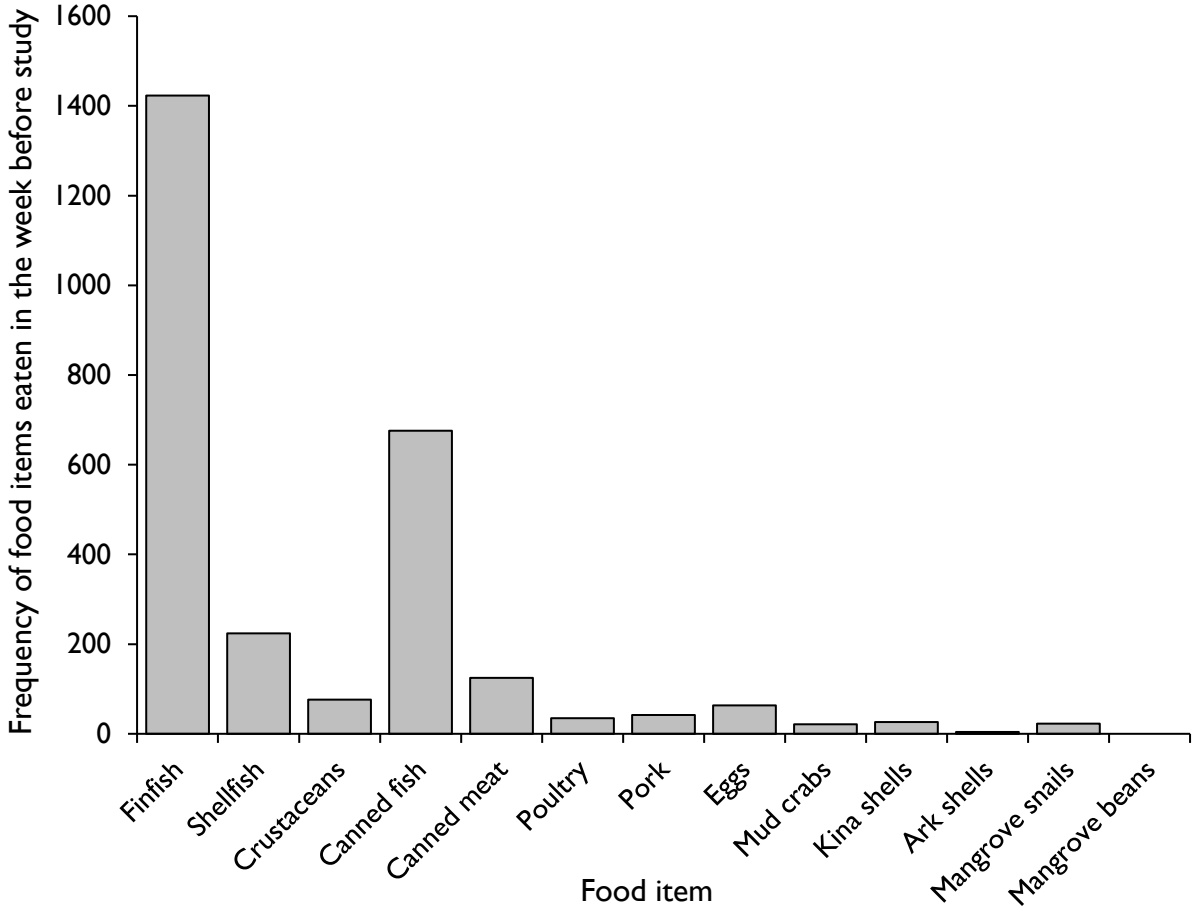


Figure 4: The consumption of selected food types (which are rich in protein and typically eaten in many coastal areas around Papua New Guinea) at the 219 surveyed households from all ten ADB communities, during the week prior to data collection. The data were collected during Phase One site visits throughout 2017. Most people consumed finfish caught on local coral reefs, as well as canned fish purchased from trade stores, while no one consumed mangrove beans.

Table 1: Responses from each surveyed household from all ten sites to the fisheries science and marine biology-based questions listed in the socio-economic questionnaire. The correct answers are shaded in grey and the percentage of respondents answering correctly is also given. Data were collected during 2017.

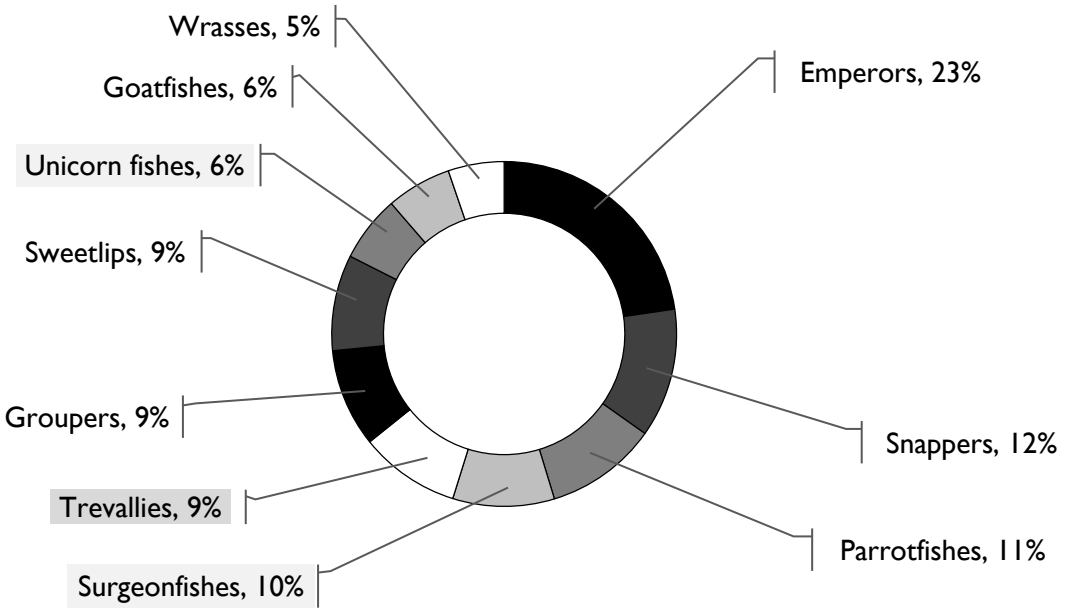
	Participants who responded with:			Total correct (%)
	True	False	Unsure	
Harvesting fish before they are sexually mature will make their numbers decrease*	262	29	27	82%
Fishing in neighbouring communities can have an impact on fish in your community*	270	25	23	85%
Protected areas can help increase the numbers and sizes of some marine animals*	308	6	4	97%
Breaking corals to catch octopuses is not destructive to the reef*	84	215	19	68%
Using small-meshed gillnets is not destructive to local fisheries*	88	206	24	65%
Harvesting crabs and lobsters that are carrying eggs will not harm their populations*	60	237	21	75%
Most types of fishing do not have an impact on the health of our fisheries*	72	213	33	67%
Groupers grow very fast†	102	45	171	14%
Rabbit fish can be found in both seagrass beds and coral reef areas†	271	11	36	85%
A female shark can give birth to lots of babies each year†	108	50	160	16%
Seagrass provides habitat for baby fish†	271	11	36	85%
Most baby fish are so small that you can hardly see them†	264	10	44	83%
All of the fish that are caught on the reef in your community spend their whole life there†	102	155	61	49%
Parrotfish like to eat seaweed†	88	149	81	28%

*fisheries-based question; †marine biology focused question

3.2 Five key fisheries findings

Across all ten sites, 266 residents completed the key fisheries surveys during 2017; in total 1,294 fish and invertebrate groups were selected by all the participants. The ten most important fish groups from all the sites have been presented in Figure 5(a). During the key fisheries analysis, pelagic species were removed from the outcomes because the emphasis of the study was on reef-associated species; thus, due to their pelagic lifestyles, the trevally species were removed. In addition, surgeonfish and unicorn fish belong to the Family Acanthuridae; accordingly, the results for both surgeonfish and unicorn fish were combined, refining the key fisheries outcome for all ten sites (Figure 5(b)). The top five fisheries for each site, including the percentage of fishers that selected each fishery, is presented in Table 2.

(a)



(b)

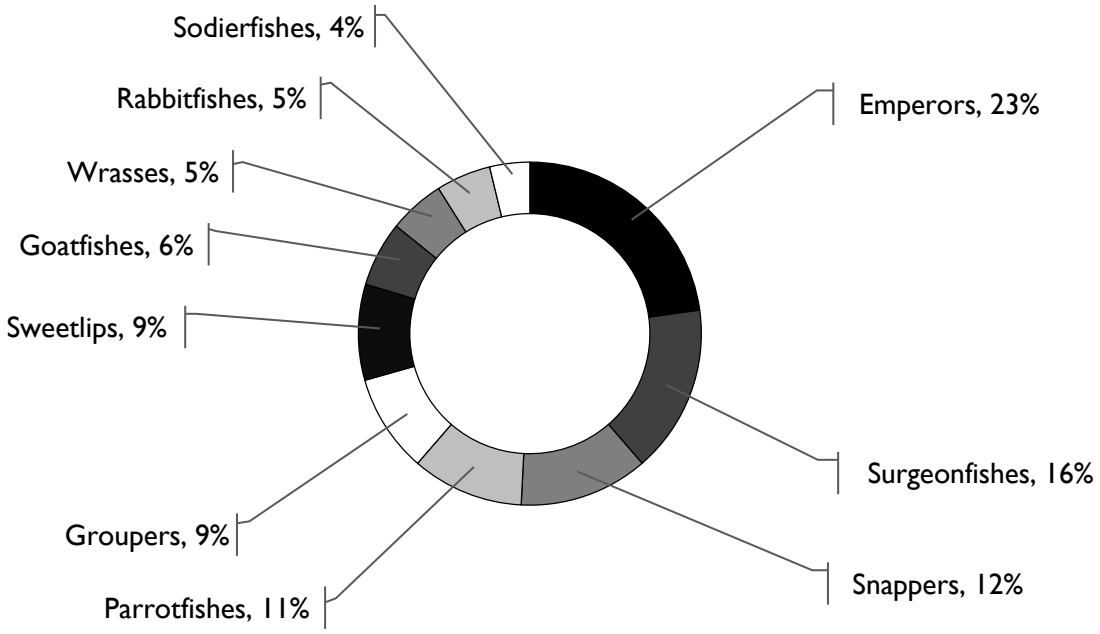


Figure 5: The proportion (a) of key fisheries pooled from all ten ADB sites. Because surgeonfish and unicorn fish are both classified within the Family Acanthuridae, such outcomes can therefore be combined. In addition, trevallies are pelagic fish; considering the focus of the subproject is on reef fisheries, trevallies can be removed from the assessment. The updated outcomes (b) from the key fisheries surveys across all ten sites. The data were collected throughout 2017.

Table 2: The top five fisheries selected by surveyed participants at each of the ten sites around Manus, Papua New Guinea, during 2017. The percentage of fishers that selected each key fishery is also included.

Community	No.	Family name	Common name	Percentage of fishers selecting each fishery
Tulu 1	1	Siganidae	Rabbitfishes	21%
	2	Scaridae	Parrotfishes	17%
	3	Lethrinidae	Emperors	10%
	4	Lutjanidae	Snappers	10%
	5	Serranidae	Groupers	10%
Tulu 2	1	Acanthuridae	Surgeonfishes	25%
	2	Lethrinidae	Emperors	18%
	3	Acanthuridae	Unicorn fishes	15%
	4	Serranidae	Groupers	11%
	5	Lutjanidae	Snappers	7%
Ponam	1	Lethrinidae	Emperors	34%
	2	Lutjanidae	Snappers	17%
	3	Scaridae	Parrotfishes	12%
	4	Mullidae	Goatfishes	10%
	5	Siganidae	Rabbitfishes	8%
Andra	1	Scaridae	Parrotfishes	17%
	2	Lethrinidae	Emperors	16%
	3	Acanthuridae	Surgeonfishes	11%
	4	Serranidae	Groupers	10%
	5	Haemulidae	Sweetlips	10%
Bipi	1	Acanthuridae	Surgeonfishes	26%
	2	Scaridae	Parrotfishes	14%
	3	Haemulidae	Sweetlips	14%
	4	Lethrinidae	Emperors	10%
	5	Trochidae	Trochus snails	8%
Pelipowai	1	Lethrinidae	Emperors	28%
	2	Lutjanidae	Snappers	18%
	3	Serranidae	Groupers	13%
	4	Mullidae	Goatfishes	8%
	5	Scaridae	Parrotfishes	8%
Mbuke	1	Lethrinidae	Emperors	28%
	2	Lutjanidae	Snappers	24%
	3	Serranidae	Groupers	11%
	4	Scaridae	Parrotfishes	10%
	5	Mullidae	Goatfishes	7%
Lou	1	Lethrinidae	Emperors	17%
	2	Haemulidae	Sweetlips	17%
	3	Acanthuridae	Surgeonfishes	14%
	4	Serranidae	Groupers	10%
	5	Mullidae	Goatfishes	8%
Pam	1	Lethrinidae	Emperors	31%
	2	Lutjanidae	Snappers	18%
	3	Acanthuridae	Surgeonfishes	7%
	4	Serranidae	Groupers	7%
	5	Mullidae	Goatfishes	7%
Baluan	1	Serranidae	Groupers	17%
	2	Haemulidae	Sweetlips	17%
	3	Acanthuridae	Surgeonfishes	15%
	4	Lethrinidae	Emperors	12%
	5	Lutjanidae	Snappers	8%

3.3 Ecological study findings

In total, 49 transects (each 50m in length; along each transect coral cover and other benthic features, such as sand, rock, or macro-algal growth, were recorded at 0.5m intervals) were conducted along coral reef systems within the inshore waters of all ten sites, providing at total of 4,900 observation points (Table 3). Where possible, transects were conducted in both areas of shallow water (<5m deep) and deeper water (>5m deep); however, due to time constraints, the majority of transects were conducted in shallow regions. Along all the transect lines, 27 hard coral genera were noted, although only species belonging to the Genus *Acropora*, Genus *Porites*, Genus *Pocillopora* and Genus *Favia* provided more than 200 hard coral observations. The hard coral fauna was dominated by the reef-building *Acropora* and *Porites* species. Other important benthic features included soft corals, macro-algae, exposed rock, sand and rubble (Figure 6).

When averages were made of the major benthic features (based on observations taken from all transect lines at all sites), it was apparent that there was variation in seabed composition. For example, Andra, Pelipowai, Mbuke and Lou had the highest proportion of *Acropora* cover when compared to the other sites. Ponam and Mbuke had among the highest proportion of *Porites* cover, while Andra, Ponam and Bipi had the lowest proportion of soft coral recordings in comparison to the other sites. Macro-algal coverage was highest at Tulu 1, Tulu 2, Bipi and Pam, and lowest at Andra, Ponam, Pelipowai and Mbuke. The transects conducted at Ponam, Andra, Bipi, Pelipowai and Baluan had among the highest proportions of exposed rock, while high proportions of sand and rubble cover were observed at Mbuke, Pam and Baluan (Figure 7). Despite the observations that were made, the low number of transects that were conducted at each site limited the reliability of the outcomes. More robust and reliable data would be obtained if a larger number of transect replicates were made at each site.

Table 3: Details concerning the ecological studies that were conducted at each of the ten ADB communities. Due to time constraints, poor weather conditions, and SCUBA diving insurance delays, only shallow water transects could be carried out at Bipi, Lou, Pam and Baluan. Sea conditions and the local geology of some reef systems also resulted in more shallow water transects (for example, in some areas there was no accessible reef slope, or deeper water regions were further offshore and in more dangerous areas). The data were collected from June to October 2017.

Community	Number of transects	Shallow water transects (<5m)	Deep water transects (>5m)	Hard coral genera observed
Tulu 1	3	2	1	9
Tulu 2	4	0	4	8
Ponam	5	4	1	6
Andra	5	3	2	6
Bipi	5	5	0	13
Pelipowai	6	5	1	7
Mbuke	6	3	3	7
Lou	3	3	0	16
Pam	6	6	0	17
Baluan	6	6	0	14

Figure 6: The frequency of major benthic feature observations across forty-nine transects from all ten ADB sites, which were conducted throughout 2017. The reef-building *Acropora* and *Porites* species comprised the main hard coral genera that were observed at all sites. Soft coral species do not deposit a limestone skeleton; however, they are important constituents of a healthy reef community. Areas of high macro-algal cover (including turf algae, calcareous algae and other large algal growths) can indicate high levels of spear-gun and dive fishing, which typically target the herbivorous fish that manage the growth of algae on a coral reef. Exposed rock indicates levels of disturbance (which can be natural or anthropogenic in origin), but also provides surfaces for coral larvae to settle and grow into new coral colonies. Sand usually occurs in areas exposed to physical factors, such as regions of regular tidal movement, strong water currents, or intense wave action, and rubble may comprise the remains of damaged coral skeletons. The *Other* group includes all other hard coral genera, including *Pocillopora* and *Favia* species, which were found in abundance at some sites, as well as sponges, sea anemones, hydroids, giant clams and other sessile invertebrates.

3.4 Fisheries management plans: summary

Information exchanged through a series of workshops, presentations, focus groups and questionnaire surveys enabled the development of site-specific fisheries management plans, which were developed in collaboration between each of the ten communities and WCS. A main focus of each plan was the implementation of certain fisheries management tools that were tailored to the requirements of each community. For example, some communities, such as Mbuke, had already established locally enforced restricted fishing zones, and Pam was keen to establish a no-take zone prior to the implementation of the plans. While other communities, such as Tulu 1, Tulu 2, Andra and Ponam, indicated that they were not keen on the gillnet exchange programme because gillnets were not regularly used at those communities and could be considered taboo. The cultural diversity and traditions that varied – sometimes extensively – between the communities provided both challenges and rewards, and underlined the importance of both community engagement and tailoring the management plans to the requirements of each community.

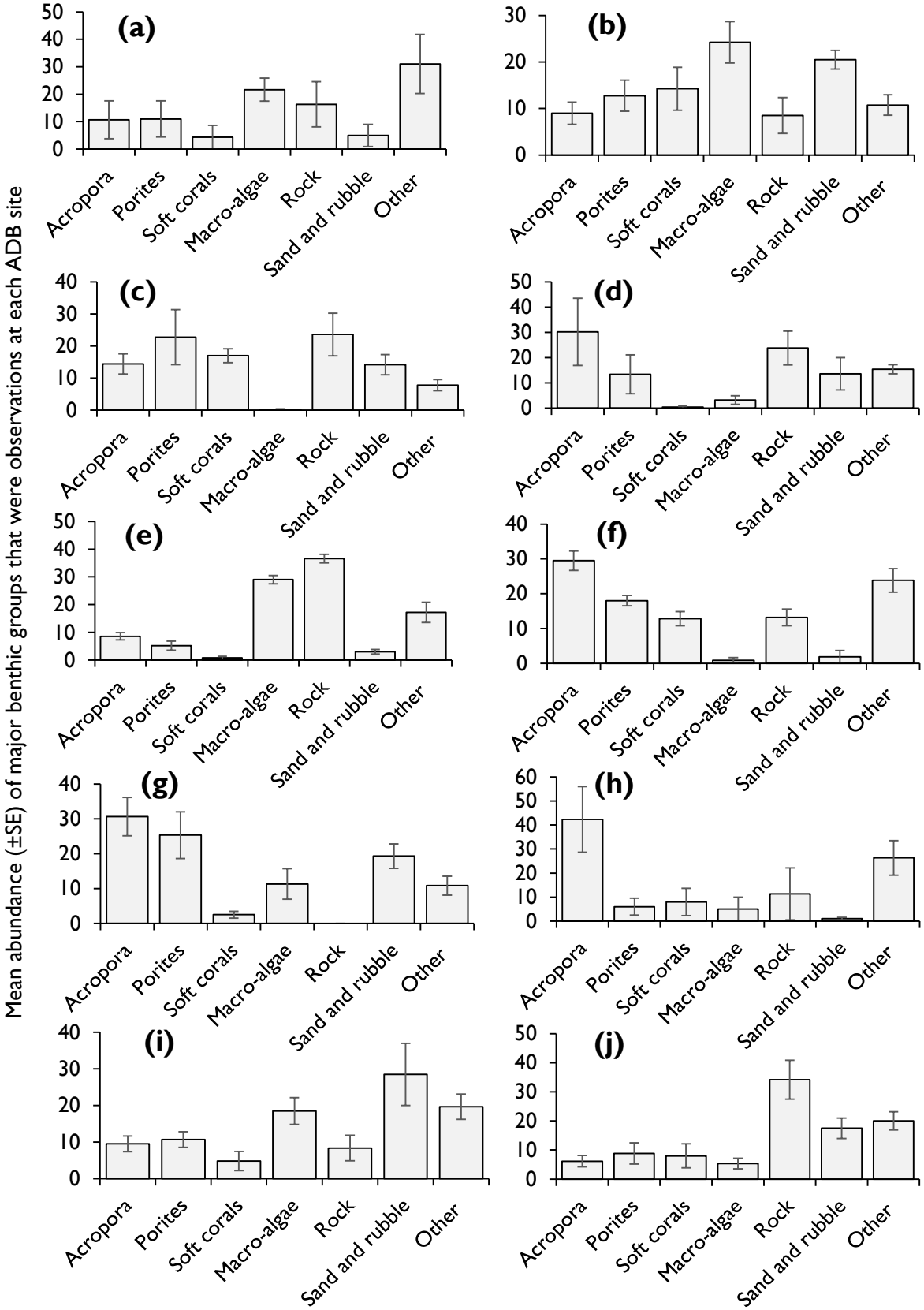


Figure 7: Mean abundance (±SE) of *Acropora*, *Porites*, soft coral, macro-algae, rock, sand and rubble, and other biota, which were observed at each ADB site. The data from each community were pooled to provide averages. Macro-algae included calcareous and coralline algae. Other biota comprised other hard coral genera, sponges, sea anemones, hydroids and other sessile benthic fauna. (a) Tulu 1, (b) Tulu 2, (c) Ponam, (d) Andra, (e) Bipi, (f) Pelipowai, (g) Mbuke, (h) Lou, (i) Pam, and (j) Baluan.

Once the fisheries management plans had been developed, a Marine Management Committee (MMC) was established within each village to enforce the management rules that were decided by the community, and also to set penalties for non-compliance. The villagers were responsible for selecting MMC members and for devising appropriate penalties. Usually, the village court system, councillors, clan leaders and other influential community members would be involved in founding the MMC, and penalties often involved community work due to local cash flow issues in many areas. In addition, the MMC was responsible for selecting the location for the fish aggregating device (FAD), and for assisting with the gillnet exchange programme (if gillnets were customary within the respective community). At Andra and Ponam, giant clam gardens were established; the responsibility for the clam pens also lay with the respective MMC. For further details concerning the management plans, refer to each of the site-relevant Fisheries Management Plans that were written in collaboration with each of the ten communities. In addition, the form used to obtain the names for the MMC, and also to develop site-specific rules and associated penalties for the fisheries management plans, is presented in Appendix II (the fisheries management plan feedback and evaluation form is also included in Appendix II).

3.4.1 Fish aggregating devices

A key component of each fisheries management plan was the deployment of a fish aggregating device (FAD) at each site. A FAD is a weighted object positioned on the seabed, onto which a series of ropes and buoyancy devices are attached, arranged so that the upper-most floats are on or near the seawater surface. FADs, which have been used by offshore fishers (and particularly tuna fishers) for decades, are now starting to be used at inshore locations to attract pelagic fish, such as tunas, mackerels, trevallies and dolphin-fish. All ten communities rely on adjacent coral reefs for obtaining finfish for protein intake, and reef fish also provide an important source of income at Andra, Ponam, Bipi, Mbuke, Pam and Baluan. Therefore, within the context of the fisheries management plans, a FAD should assist in transferring fishing effort from the more vulnerable reef fisheries to less vulnerable offshore fisheries.

Every community was keen to receive a FAD, and particularly the island communities. However, there were some disputes among some of the communities that are within the same geographical region, and especially between Ponam, Tulu 1 and Tulu 2. The customary land and sea area of Ponam encompasses the inshore waters of Tulu 1 and Tulu 2 (both of which have land tenure that extends into mainland Manus) (Figure 8). For these reasons, Ponam expressed that any FAD positioned within the waters that lie adjacent to Tulu 1 or Tulu 2 would become the possession of Ponam. Due to the community disputes between the three sites, along with the short time span of the subproject, FADs were not deployed at Tulu 1 or Tulu 2.

3.4.2 Gillnet exchange programme

Using fine meshed gillnets can result in the capture of a large proportion of immature fish. Juvenile fish are necessary for increasing the future spawning biomass of a fishery and also for increasing subsequent fish yields. To ensure a fishery is sustainable by maintaining a large population of juvenile fish, using gillnets that have a mesh size of less than 2.5 inches (>2.5 inches) can enable juvenile fish to escape. (Incidentally, small-meshed gillnets were permitted for the capture of bait fish, such as sardines, at some

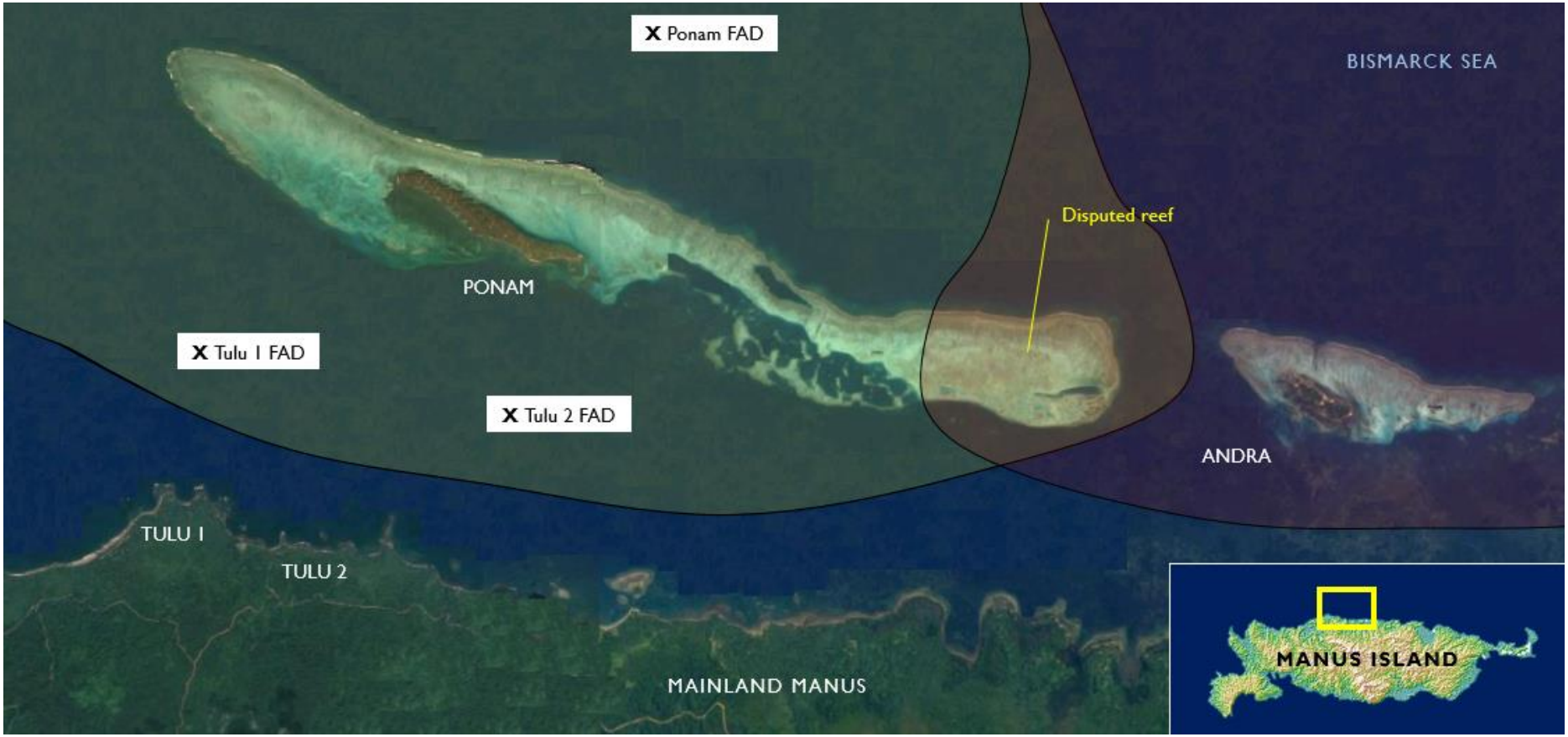


Figure 8: Disputes concerning the customary ownership of reef areas that lie adjacent to the ADB sites of Ponam and Andra (two coral atolls located off the northern coast of Manus Island), caused some disruptions to the data collection procedures at each site. The customary marine tenure area of Ponam also lies close to the shoreline of the two ADB sites of Tulu 1 and Tulu 2, both located on the northern coastline of the Manus mainland, which caused contention regarding the locations of the fish aggregating devices (FADs). The base map was adapted from Google Earth, 2018.

sites). WCS arranged for a voluntary gillnet exchange programme to take place at each of the ten sites to assist with the sustainable management of local fisheries. Table 4 presents the number of individuals from each site who were keen to exchange their existing small-meshed gillnets for more sustainable larger-meshed nets. Compared with other management methods, the gillnet exchange programme was less popular, with many fishers expressing concern that they will catch less fish if small individuals can escape through larger meshed nets. In response to such concerns, presentations and workshops were arranged at each community to demonstrate the importance of allowing juvenile fish to develop into adults that can then reproduce, resulting in more fish in the future.

There were also some complications concerning the traditional usage of gillnets at certain sites. Gillnets are traditionally used at Bipi and the southern sites of Pelipowai, Mbuke, Lou, Pam and Baluan. At the northern sites of Tulu 1 and Tulu 2, however, only the leaders or chiefs of certain clans are traditionally allowed to use gillnets. Moreover, at Ponam and Andra, local fishers use corral-nets: such nets are suspended across large wooden frames, the sides of which are manoeuvred through shallow inshore waters by several villagers in order to capture fish, including surface-dwelling needlefish. Residents at Andra went further, expressing that within one of the six major local clans, gillnets could only be used by clan leaders. Accordingly, the gillnet exchange programme was carried out at Bipi and the five southern sites; while at the four northern sites, each respective Marine Management Committee was issued a set number of gillnets for subsequent distribution (Table 4). (It was considered appropriate to allow the locally elected MMC members to make sensitive management decisions, such as the distribution of gillnets at sites that do not conventionally use gillnets.)

Table 4: Details concerning the gillnet exchange programme at each site, including the number of individuals keen to exchange gillnets, and details concerning gillnet usage at sites within certain geographical areas. Gillnets are not traditionally used at the northern sites of Tulu 1, Tulu 2, Ponam and Andra. Accordingly, the Marine Management Committees at each of the northern sites were issued five gillnets for subsequent distribution. Names for the exchange programme were collected from April to October 2017, and were reconfirmed during March 2018 (when the larger meshed gillnets were distributed to each community).

Community	Gillnets exchanged	Gillnets for MMC	Details concerning the gillnet exchange programme
Tulu 1	-	7	Gillnets are not traditionally used in Tulu 1 or Tulu 2; each respective MMC was issued five gillnets
Tulu 2	-	7	
Ponam	-	7	Gillnets are not used in Ponam and Andra; each respective MMC was issued five gillnets
Andra	-	7	
Bipi	4	2	Gillnets are more commonly used in the west and south of Manus province
Pelipowai	6	2	
Mbuke	3	4	
Lou	1	5	
Pam	5	2	
Baluan	7	1	

3.4.3 Giant clam gardening (Andra and Ponam)

Apart from Lou, Pam and Baluan, where the majority of residents follow the Seventh-Day Adventist (SDA) denomination of Christianity*, which forbids the consumption of shellfish and certain other groups of marine organisms, the collection and consumption of the six native giant clam species that inhabit the inshore waters of Manus Island was a common activity. However, due to their slow growing and sedentary nature, adult giant clams can be overharvested, leading to population declines. Moreover, if adult clams are not within close proximity to each other, there is a reduced chance of reproductive success during spawning periods, resulting in lower clam recruitment. At Andra and Ponam, local villagers were trained in giant clam gardening, and steel-framed giant clam pens were distributed to each site (six pens to Andra; four pens to Ponam).

At Andra, the six pens were deployed so that they were in close proximity to each major clans (which, in general, inhabit different geographical areas of Andra Island), and each clam pen was linked to the respective *haus boi* system†. At Ponam, there were some disputes regarding the locations of each of the four pens around the island, especially because there are the thirteen major clans that form the Ponam community. To assist the community in making pragmatic decisions regarding the locations of the pens, it was decided to position two pens along the northern coast (one to the north-west of the island and another to the north-east) and two pens along the southern shoreline (again, one to the south-west of Ponam and another to the south-east). After further consultation with the residents, it was apparent that the seabed along large swathes of the southern shoreline of Ponam consisted of fine sediments that are unsuitable for clam gardens. Thus, the decision was made to have three pens at accessible points along the reefs that run parallel to the northern shore, and one pen in a suitable area on the southern coast.

3.5 Catch-and-effort study findings

Two waves of catch-and-effort data were conducted at all ten sites. Phase I of the data collection occurred between August and November 2017; Phase II of the catch-and-effort data collection took place from February to April 2018. Table 5 overviews that diversity of organisms that were captured during both catch-and-effort data collection phases. From the data, it is clear that Manus supports diverse fisheries, which includes a variety of reef fish species. Data collection from the ten sites also indicated differences in how each community relied on their marine resources. Across all ten sites, the mean CPUE was 1.11 $kg^{-1}/person^{-1}/hr^{-1}$, which is lower than the outcomes from similar studies conducted in the region. Due to the lower CPUE values, it is apparent that many reef fisheries around Manus could be under pressure due to increasing rates of fishing activity. In addition, most of the total number of fish species caught came primarily from the small island communities, yet these sites also had comparatively lower total catch biomasses, indicating that such communities are now catching smaller sized animals.

* The Seventh-Day Adventist Church is a Protestant denomination of Christianity that was established in the USA during the 1860s. Followers of the faith consider the Sabbath to be on Saturday, the seventh day of the week (according to the Jewish calendar), and also believe in the imminent second coming, or advent, of Jesus Christ. Internationally, there are around 20 million Seventh-Day Adventist followers. The faith has a number dietary restrictions, including many items of seafood that are consumed elsewhere in the Manus region.

† The *haus boi* is traditional building in which only male residents (typically unmarried) reside; it is also a place for clan leaders to make community-based decisions. In Manus province, the *haus boi* system is an important aspect of community life in many areas and continues to be practiced in Andra, Ponam, Tulu 1, Tulu 2 and Pelipowai.

Table 5: An overview of the organisms sampled during both the Phase I and Phase II catch-and-effort data collection sessions at ten sites around Manus Island. Phase I data collection occurred from August to November 2017; Phase II data collection took place from February to April 2018. Sharks and rays are included with the finish. Despite possessing backbones and belonging with the reptiles, the turtles have been grouped with the invertebrates because turtles are measured across the length of the upper shell; in contrast, fish (which like turtles, are also vertebrates) are measured along the total length of the body.

Data collection phase	Number of fishing trips intercepted	Number of organisms caught	Number of families sampled	Number of species sampled
Phase I	334	7,720	Fish: 42 Invertebrates: 10	Fish: 302 Invertebrates: 22
Phase II	260	5,960	Fish: 31 Invertebrates: 8	Fish: 310 Invertebrates: 14

Concerning gear types, some of the highest CPUE values were for fishers that used spear-guns. Spear-guns are efficient at targeting surgeonfish and parrotfish, which graze on algae growing on a reef. The removal of algae grazers, through increased spear-gun usage, could lead to an ecological shift from a coral-based habitat to an algal-dominated system; a phenomenon that could occur around Manus if the current trends of fishing effort and population increase continue. Spear-gun management, such as bans on nigh-time spear-gun usage, could be a simple and pragmatic measure to introduce. However, due to local differences across all ten sites, implementing a management method requires the support of the community. Indeed, the importance community awareness and engagement cannot be overstated.

Another key finding concerned the proportion of ten selected reef fish species that were below recommended minimum size limits. Over half of six of the species chosen for size assessment were below the minimum size levels deemed necessary for maintaining a sustainable fishery. Four of the six fish were emperors and snappers, which are slow-growing species prized by fishers. Due to their slow growth rate, it is apparent that mostly juvenile animals were captured, resulting in a diminished adult population. In addition, for most fish families assessed in this report, it was evident that the larger animals were destined for market sales, demonstrating the high market value for larger individuals and the incentive for targeting larger animals.

3.6 Length-based spawning potential findings

Length-based spawning potential (LB-SPR) assessment is a technique used to understand fishery stocks. The method requires two data components: (i) the spawning potential ability of a fish stock (in other words, the proportion of breeding adults within a population), and (ii) fish size dimensions. Usingsuch data, an estimate of the size in which a fish species matures can be made, along with the proportion of spawning potential for the local fishery. It is generally accepted that when a fish population maintains a spawning potential of 20%, the stock is at its replacement level (the number of offspring produced replaces the rate of fish mortality); above 40% spawning potential would suggest the fish stock is less heavily fished; below 20% spawning potential would indicate a fishery that is in decline (Prince, 2017).

Although ten fish were selected for LB-SPR study, sufficient data were only obtained for five species: (i) the surgeonfish *Ctenochaetus striatus*, (ii) the rabbitfish *Siganus canaliculatus*, and three emperors, (iii) *Lethrinus harak*, (iv) *L. lentjan* and (v) *L. obsoletus*. Estimates of spawning potential were generated for the five species, which were sampled at ten sites around Manus, from February to April 2018. The spawning potential values indicate that *L. harak* and *L. lentjan* are experiencing unsustainable fishing pressure and therefore recruitment overfishing. The spawning potential outcomes for *L. obsoletus* indicate that the species is experiencing less recruitment overfishing fishing than the other two emperors. The outcomes for *C. striatus* and *S. canaliculatus* suggest that each respective stock is not facing unsustainable levels of recruitment overfishing fishing pressure (Figure 9).

3.7 Gardening and needs analysis overview

A key part of Objective IV involved conducting a needs assessment at each site, and distributing high-yielding climate-resilient seeds and tubers, including yellow corn, cassava, mung beans and African yams, to each community. Accompanying the crop distribution were a series of training workshops, which focused on how to cultivate the crop varieties and how to make the soil more fertile for future crop cultivation. The high-yielding crop varieties will assist the communities with future food security, especially in light of projected climate change threats. The management of soil fertility and pest control will help communities to reuse garden plots, while also reducing the need for clearing areas of forest that would be required to create new gardening land. The gardening work was successful, and of keen interest to the residents of Lou, Pam and Baluan. Due to the limestone and coral-based soils at Andra and Ponam, there were some complications in cultivating crops in these areas.

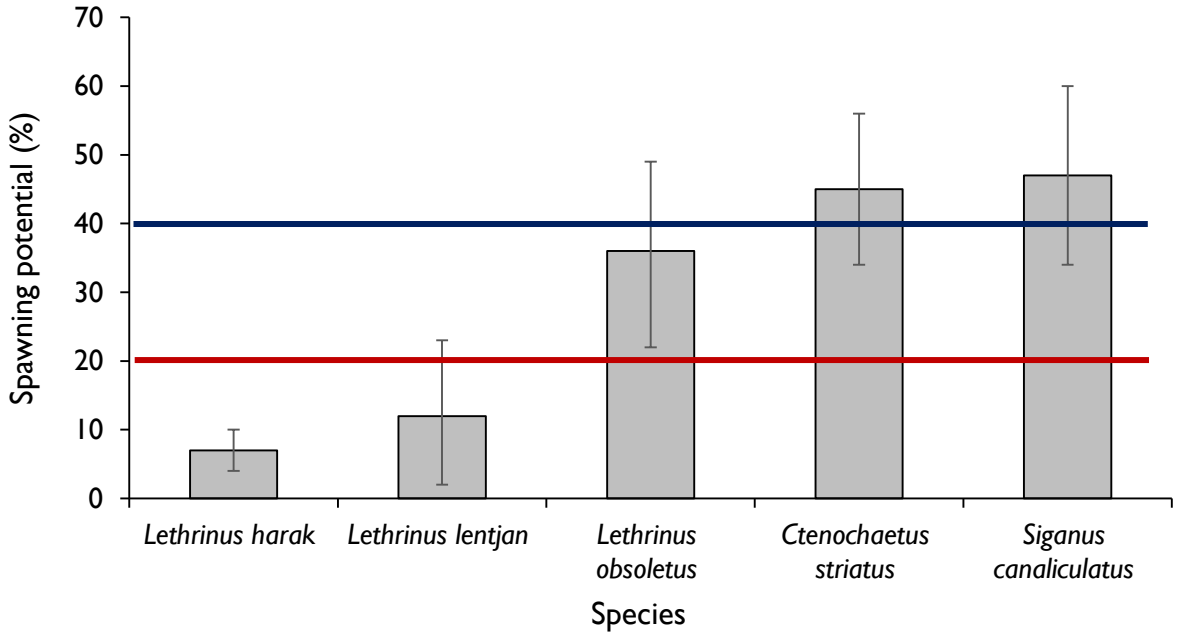


Figure 9: The estimated levels of spawning potential (%) for the five reef fish species that were assessed (±95% confidence intervals), according to the outcomes of the length-based spawning potential (LB-SPR) model. It is generally accepted that below 20% spawning potential, a fish species is at risk from population decline due to intensive fishing activity and a reduction in spawning stock biomass. Above 40% spawning potential indicates a fish population that is less heavily fished. The red bar denotes 20% spawning potential; the blue bar represents 40% spawning potential. *Lethrinus harak* and *Lethrinus lentjan* are both at risk from intensive recruitment overfishing; *Ctenochaetus striatus* and *Siganus canaliculatus* appear less vulnerable. Data were collected from ten sites around Manus Island, Papua New Guinea, between February and April 2018.

It took four months for the seeds and tubers to arrive from the National Agricultural Research Institute (NARI) in Morobe province on the mainland of Papua New Guinea. In addition, there was insufficient time to conduct long-term performance assessments of the different crops. Following project completion, voluntary model farmers will continue with the performance assessments on experimental plots to determine which crop types are most suited to the environmental conditions of each site.

3.8 Final feedback and evaluation outcomes

Following the establishment and implementation of the fisheries management plans and other management initiatives at each site, Marine Management Committees (MMC) were invited to complete short feedback and evaluation forms. The questions that were listed in the feedback forms have been presented in Table 6, and the combined responses from each site have been colour-coded: green for when all respondents provided a positive response; yellow for when there was any uncertainty among one of more of the participants; orange for when there were one or more negative responses, combined with uncertainty or positive responses; and red for all negative responses.

From the feedback forms, it is apparent that all of the sites apart from Tulu 2 and Ponam understood that managing local fisheries was the responsibility of the community. However, there was more uncertainty regarding whether the management rules will be successfully implemented, along with how the community members will respond to the rules, and whether such rules will be followed by the local villagers. The role of further education and awareness will, therefore, continue to be paramount in order to assist community members in adjusting their views and attitudes to fishing, and to enable residents to perceive the benefits of sustainable fisheries management for future generations. The final page of Appendix II includes the original feedback and evaluation form that was used.

Table 6: Summary of the pooled outcomes from the feedback and evaluation forms that were issued to the Marine Management Committee members once the management rules and regulations had been completed. The combined outcomes have been given colour codes: green indicates a unanimous an affirmative or positive response; yellow denotes uncertainty; orange signifies one or more negative response together with expressions of uncertainty or positive feedback; red represents a negative response from all the Marine Management Committee members at each site. The outcomes from all ten sites are included, which have been arranged geographically: Tulu 1, Tulu 2, Ponam and Andra are in the north of Manus; Bipi is in the west; Pelipowai and Mbuke are in the south; and Lou, Pam and Baluan in the south-eastern region of Manus province. The surveys were conducted at each site around Manus Island, Papua New Guinea, from February to March 2018.

	FEEDBACK AND EVALUATION QUESTIONS	TU 1	TU 2	PON	AND	BIP	PEL	MBU	LOU	PAM	BAL
1	Are you concerned about the future of your fish stocks and marine resources in your community?										
2	Do you think your community is responsible for managing your future fish stocks?										
3	Do you think the fisheries management plans will be successfully implemented in your community?										
4	Will your community be willing to follow the fisheries management rules?										
5	Do you think the Marine Management Committee will be able to enforce the management rules?										
6	How do you think your community and all the major clans will respond to the management rules?										
7	Are you happy with the WCS work within your community?										

TU 1, Tulu 1; TU 2, Tulu 2; PON, Ponam; AND, Andra; BIP, Bipi; PEL, Pelipowai; MBU, Mbuke; LOU, Lou; PAM, Pam; BAL, Baluan.

4.0 LESSONS LEARNED

The ADB Subproject was executed during a relatively short timeframe, spanning from October 2016 to April 2018, and was based at ten sites located around the shoreline of Manus province. As with all community-based projects, a number of challenges and problems were encountered, which required careful alleviation measures to mitigate such constraints. Although many problems were due to time limitations, others arose due to the geography of Manus Island, which is located far from the Papua New Guinean mainland, or due to the disparate customary traditions of some of the communities situated around the island province. The following section outlines the lessons learned during the implementation of the subproject, which have been grouped according to each of the four main objectives of the subproject.

4.1 Objective I: Build community and local partnerships

Listed below are some of the major lessons learned from problems or challenges that occurred after implementing the components of Objective I. For a detailed account of the problems that were encountered during the implementation of each objective component, as well as mitigation measures, further evaluation and lessons learned, refer to Table 7.

- During the initial visit to each site, some community members were not fully aware of the subproject or why WCS were present within the community: Community engagement and prior contact with the ward councillors, outlining the purpose of the visit, is necessary to reduce confusion among community members.
- Time limits constrained the number of site visits that could be made, and the quantity of socio-economic, fisheries and ecological data that could be collected from each site: The subproject would have benefited from an extended timeframe, to enable additional site visits and longer data collection procedures.
- Uncertainties among some villagers arose regarding the reasons for conducting the questionnaires, and how the data will be used: The ward councillors and clan leaders at each community need to be well-informed about the purpose of questionnaire-based data collection prior to site visits, in order to assure village residents and also to provide information regarding the reasons for the surveys. This information should be reinforced during the initial community engagement presentations, so that community members are aware of the project, as well as the purpose of the data collection, and why such activities are important for the each villager and the community.
- Gillnets were not traditionally used at all sites: Prior community engagement must be arranged to appreciate what customary traditions and fishing methods are practiced at each site, and whether any management approaches are considered culturally taboo.

Table 7: Overview of the problems and mitigation measures encountered during the implementation of Objective I of the ADB Subproject at ten community sites around Manus Island, from October 2016 to April 2017. The table has been arranged according to the components of the first subproject objective. An evaluation of the mitigation and alleviation measures has also been provided, accompanied by a colour-coded impact effect that is based on the success of the mitigation and alleviation measures. Lessons learned from each problem have been provided in the final column. For further details of the colour-coded impact effects column, refer to Appendix I.

OBJECTIVE I: BUILD COMMUNITY AND LOCAL PARTNERSHIPS

OBJECTIVE COMPONENT	PROBLEMS ENCOUNTERED	MITIGATION & ALLEVIATION	EVALUATION	IMPACT EFFECT	LESSONS LEARNED
Workshop to evaluate fisheries management options	Some community members were not fully aware of why WCS were present	During all subsequent presentations and community engagement activities, residents were informed about the subproject, why WCS were present, and why data was collected and how it would benefit the community	Increased community awareness leads to further cooperation among residents, local stakeholders and WCS; ambiguity can lead to confusion	**QUITE STRONG EFFECT**	Ward councillors need to be instructed in advance about purpose of the subproject and the reasons for WCS coming to the community
	At Andra, some residents reacted negatively to the presence of WCS				Information from WCS needs to be disseminated to the wider community
					Introductory presentations must be given prior to data collection
Train villagers in fisheries management techniques	Language barriers – especially with local vernaculars	Interested villagers were enlisted as voluntary translators so that all community members could understand	Efforts should be made to know species names and geographical terms in the local language	**STRONG EFFECT**	Encourage community engagement at project onset and gain terms in local languages, to increase site-specific knowledge acquisition and community sense of belonging to the project
Participatory rural appraisal and mapping of land and seascapes	General information was obtained, which was not necessarily associated with the five key fisheries outcomes	The activity was repeated during subsequent site visits, with a focus on five key fisheries, and other information for the management plans	Repeated activities enabled more fishers to take part, increasing community participation and interest in the project; also allowed more information to be acquired	**STRONG EFFECT**	Ensure information gathering activities are scheduled according to when the information is required

Collect ecological data	Limited timeframe and number of trained personnel to collect data; restrictions in conducting a robust survey design	Efforts were made to collect data when weather permitted, which sometimes required spending extra days at each site	The purpose of the survey must be determined before data collection; survey design should be planned in line with knowledge obtained by experienced community members, and with sufficient replicate sampling to enable robust data analysis; this requires further time and trained personnel	**LOW EFFECT**	To conduct rigorous ecological studies at each site, and to enable comparisons to be made between site treatments (for example, between areas that have different known levels of fishing activity, and the effects of fishing activity on coral cover or coral diversity), time is required to plan site-specific survey designs based on local knowledge, and to enlist and train interested community members. The purpose of the study should also be defined prior to data collection, which includes knowing the data analysis methods that will be used so that appropriate data is collected.
	Poor weather conditions and low tidal ranges prevented boat transport to reefs	Data was collected during high tide or during subsequent days when the weather cleared			
	Uncertainties in accurate coral identification	Researchers studied coral taxonomy; identification cards were made			
Undertake survey to identify key fisheries	Fish identification books were used during the surveys; participants therefore focused on listing key finfish species rather than invertebrates	*PowerPoint* slides were created and projected during each survey, which included images and names of commonly caught invertebrates to assist residents with their choices	Once the CFs were informed to include invertebrate options, provided on the screen, both finfish and invertebrate species were selected during later surveys	**STRONG EFFECT**	All fishery choices should be presented to the communities during the key fishery surveys, including invertebrates (such as trochus snails, green snails, giant clams, cuttlefish, squid, octopuses, shrimps, crabs, lobsters, and sea cucumbers)
	Some survey participants included residents that did not go fishing or invertebrate harvesting and therefore gave inaccurate information	The CFs were instructed to survey residents that regularly went fishing and therefore had relevant local knowledge and experience	Only fishers were surveyed during subsequent key fishery surveys at all the other sites		Appropriate training of the CFs and other data collectors allowed for quality data to be acquired from experienced fishers and invertebrate collectors

Conduct socio-economic surveys	Some participants questioned the purpose of the surveys	CFs were instructed on how to approach the surveys in a diplomatic manner, while explaining the purpose of the questionnaires	Communities were more responsive and interested in the project once the purpose of the surveys was explained	**STRONG EFFECT**	Ward councillors and community leaders should be knowledgeable in advance about the project, and why it is important that the community members are informed and present at the introductory presentations
	Complaints regarding how the data will be used, and issues of privacy	Presentations, made prior to the surveys, were made to explain the project, how the data will be used, and how all data will remain anonymous	Residents who attended the presentations saw the need of the project and were often keen to take part in the project		During the introductory presentations, the importance of the project and community involvement should be stressed; similarly, the importance of privacy should also be highlighted
	Concerns about data repatriation	All data was repatriated to the communities	Data repatriation was welcomed by all, enabling residents to understand the project		All data must be repatriated via presentations and reports; and where possible booklets (such requests were made by Andra and Mbuke)
	Some marine science questions were considered too difficult	CFs were instructed to explain difficult questions in the *Tok Pisin* language	Some of the marine biology questions could be simplified		Future questionnaires should be set at an appropriate level, using simplified language
Collect data on traditional land use and practices	Questions concerning salaries were considered too personal	CFs were instructed to ask questions in a polite manner; all participants could decline to answer whenever they wished	When engaged appropriately, the participants were more receptive	**MEDIUM EFFECT**	Privacy is paramount; the participants should not feel uncomfortable completing the questionnaires
	Complaints about the number of surveys	Apologies and gratitude was given to the participants for their time and patience	Ensuring residents attended the opening presentations would reduce complaining		Less is more: Shorten the questionnaires so that they extract only relevant information during a short timespan
Survey on marine resource management preferences	Issues concerning the use of gillnets (sometimes considered taboo) at some sites	The focus was directed to other management options; gillnet options were rejected	Not all sites use the same fishing approaches; ensuring there were alternative options saved local frustrations.	**STRONG EFFECT**	Information regarding standard fishing practices and customary traditions should be obtained from each site prior to project initiation

4.2 Objective II: Strengthen local capacity to manage local resources

The major lessons that were learned from problems that transpired while implementing the components of Objective II are listed below. A detailed account of the problems encountered following the completion of each Objective II component, as well as alleviation measures, and additional evaluation, can be found in Table 8.

- Due to the limited timespan of the subproject, capacity building presentations and educational awareness workshops were restricted to single site visits, which could lead to information overload for community residents: The project would have benefitted from additional time to enable the presentations and workshops to be shortened and spread out over several weeks.
- Not all the community members were aware that the presentations or workshops were taking place: Prior communication with the ward councillors and tribal leaders is necessary to assist with the dissemination of information concerning WCS presentations and workshops to the wider community. This includes the times and locations of each presentation and workshop, which could be difficult to arrange at larger community sites. WCS also played BBC natural history documentaries prior to each presentation or workshop to attract community members.
- Limited timeframe for the thorough training of WCS staff: Although FAD, catch-and-effort and LB-SPR training workshops were arranged for WCS staff, additional training sessions on topics including data entry, biological classification and taxonomy, marine ecology, fisheries science, and climate change would have benefited the staff.
- Volunteers from each community were enlisted to assist with the questionnaire surveys, sometimes in abundance, and yet at other times it was difficult to recruit such assistants: Enlisting the assistance of the ward councillors allowed suitable volunteers from each community to help with the data collection. The community facilitators (CFs) also assisted and trained the volunteers, which helped to maintain their interest in the data collection procedures.

4.3 Objective III: Strengthen appropriate management approaches

Key lessons that were learned from problems that occurred during the implementation of Objective III are listed below. A more detailed account of the problems that were encountered from each of the Objective III components, together with mitigation measures, and additional evaluation notes, has been presented in Table 9.

- Short timescale to compile the necessary information required for completing the separate fisheries management plans: Planning ahead and compiling the necessary information from each community for developing the plans is vital to ensure the plans are completed on time.
- Selecting representatives and members for the Marine Management Committee (MMC): It is essential that the members of the MMC are selected by the community, although for the subproject to be successful, it is important to ensure all major clans are represented in the MMC by influential clan members to ensure the rules are enforced across the community and to enable information to be disseminated among members of each clan. If a clan is not included, they might not follow the rules.

Table 8: Overview of the problems and mitigation measures encountered during the implementation of Objective II of the ADB Subproject at ten community sites around Manus Island, from October 2016 to April 2017. The table has been arranged according to the components of the second subproject objective. An evaluation of the mitigation and alleviation measures has also been provided, accompanied by a colour-coded impact effect that is based on the success of the mitigation and alleviation measures. Lessons learned from the various problems have been provided in the final column. For further details of the colour-coded impact effects column, refer to Appendix I.

OBJECTIVE II: STRENGTHEN LOCAL CAPACITY TO MANAGE LOCAL RESOURCES

OBJECTIVE COMPONENT	PROBLEMS ENCOUNTERED	MITIGATION & ALLEVIATION	EVALUATION	IMPACT EFFECT	LESSONS LEARNED
Community engagement meetings.	Not all the community members were aware of the purpose of the project and why WCS was present.	Prior to subsequent visits, efforts were made to ensure community leaders and members were aware of the visits.	Confusion often arises when people are not informed. Communities should be told in advance when each visit will occur.	**QUITE STRONG EFFECT**	Ward councillors, community members and other leaders should be informed in advance about planned visits; such information should be disseminated to reduce confusion.
Basic and advanced level marine awareness presentations.	A lot of information was provided during a short time period.	Presentations were updated and simplified, with pictures and animations to convey concepts to the audience.	Residents were responsive, engaged and requested copies of the slides.	**STRONG EFFECT**	Education is paramount: providing simple, engaging and interesting site-specific information involves the community, increases local capacity, and promotes project importance.
	Problems in obtaining a generator for the projector	A generator was purchased	Teachers asked for marine science lessons to be given to students.		School lessons were provided, focusing on marine biology, at several sites and often to several year groups.
Fisheries management workshops.	Not all the communities were aware of the workshops.	Letters were issued to ward councillors, to give information about the workshops, which was to be disseminated to the other residents.	Although efforts were made to inform communities in advance, turn out varied among sites, and depended on other activities taking place, the weather, and size of community area.	**QUITE STRONG EFFECT**	Excluding external factors, community leaders should be informed in advance to ensure relevant community members (such as fishers) are aware of the project workshops. Educational BBC natural history documentaries were also played before the workshop activities to attract residents.

Train villages in ecological monitoring.	At some sites, there was an abundance of volunteers who wanted to join the coral reef trips.	A selected number were chosen, according to the views of community leaders.	Responsibility could be given to the community leaders, who could select the most appropriate villagers.	**STRONG EFFECT**	Enthusiasm should be strongly encouraged, yet for health and safety reasons, only a limited number of volunteers can join each trip. Such matters are best left to community leaders.
Train villagers in socio-economic monitoring.	Some volunteers demonstrated a lack of interest in the questionnaire surveys.	CFs were instructed to assist volunteers during the data collection process; volunteers were selected according to school qualifications and enthusiasm for the project.	Efforts were made to ensure volunteers were engaged and understood the data collection process.	**STRONG EFFECT**	Ensuring all the volunteers were aware of why the data was being collected, how it will be used, and the importance of collecting quality data should help maintain interest in during data collection process.
Train WCS staff in project management and evaluation.	Limited time to thoroughly train WCS staff.	Additional training was provided, concerning catch and effort and LB-SPR data collection, FAD construction, and data entry.	Due to the intensive time and activity requirements of the subproject, sometimes there were only limited timeslots to train WCS staff.	**QUITE STRONG EFFECT**	Staff capacity building is essential: Future projects should have sufficient time that is allotted to staff training and evaluation. When staff are knowledgeable about the project and trained appropriately, it will assist the project and enable information to be disseminated to the wider communities.

- Setting penalties for non-compliance: It is necessary for community members to select appropriate penalties for residents that break the rules set in the fisheries management plans, once they have been enforced. Appropriate penalties may include community work, such as beach cleaning, mangrove planting, or transplanting coral fingerlings to restore coral reefs.
- Problems in obtaining the FAD materials: Manus is a relatively isolated province in Papua New Guinea, and the materials needed for FAD construction had to be shipped in from abroad (from Australia, Japan or Taiwan). Accordingly, there were complications in sourcing the materials and logistical problems in arranging for the materials to be delivered to Manus. Ordering the materials in advance benefited the subproject.
- Not all sites regularly went fishing, hindering the collection of catch-and-effort data: It was apparent that at Tulu 1, Tulu 2, Pelipowai and Lou (communities that traditionally construct gardens for growing cash crops), not all fishers regularly went fishing, limiting the collection of catch-and-effort data. Research prior to project implementation, to determine the time needed for data collection and also to know when local fishers usually go fishing, could help alleviate such issues.
- Issues on deciding where to deploy FADs, especially considering customary land and sea tenure disputes: Diplomacy and community engagement was necessary to help settle issues between Ponam, Tulu 1 and Tulu 2, and to ensure each community could agree on the best approach for FAD deployment. Pragmatic suggestions can also help to alleviate such disputes.
- Unable to complete the third wave of catch-and-effort data collection due to time restrictions: The FAD materials did not arrive until early 2018; therefore, there was insufficient time to complete the third wave of catch-and-effort data collection following FAD deployment. The subproject would have benefited from additional time to enable continued catch-and-effort monitoring following the deployment of the FADs at each community.
- Limited number of laptops for entering data collected in the field: Due to the limited number of laptops and computer facilities, not all data could be entered at once. Additional laptops would help hasten the data entry and analysis procedure.
- Difficulties in explaining scientific concepts to local residents, such as the procedures for LB-SPR assessment: Some of the scientific theories and processes were complex; thus, simplified and engaging presentations and workshops were required, with illustrations, diagrams and animations, to help increase the knowledge base and understanding of the villagers.
- Difficulties in fish and invertebrate identification: Identifying species is a skill; additional training in taxonomy would have benefited staff, data collectors and community members.

4.4 Objective IV: Trial and replicate livelihood and climate change adaptation initiatives

The lessons learned from problems that arose while implementing the components of Objective IV are listed below. A detailed account of the problems encountered following the completion of each Objective IV component, together with alleviation measures and further evaluation have been listed in Table 10.

- Selecting the most appropriate sites for giant clam farming: At Ponam, there was some disagreement among community members regarding suitable locations for the giant clam pens. Community engagement and pragmatic advice from WCS helped the community leaders in deciding on the most appropriate locations for each clam pen

Table 9: Overview of the problems and mitigation measures encountered during the implementation of Objective III of the ADB Subproject at ten community sites around Manus Island, from October 2016 to April 2017. The table has been arranged according to the components of the third subproject objective. An evaluation of the mitigation and alleviation measures has also been provided, accompanied by a colour-coded impact effect that is based on the success of the mitigation and alleviation measures. Lessons learned from the process are provided in the final column. For further details of the colour-coded impact effect, refer to Appendix I.

OBJECTIVE III: STRENGTHEN APPROPRIATE MANAGEMENT PRACTICES

OBJECTIVE COMPONENT	PROBLEMS ENCOUNTERED	MITIGATION & ALLEVIATION	EVALUATION	IMPACT EFFECT	LESSONS LEARNED
Draft community level fisheries management plans	Limited time to compile all relevant information necessary for completing the plans	Efforts were made to ensure all relevant sections of each plan was completed in advance and on time	Time was a limiting factor; forward planning was essential	**STRONG EFFECT**	Additional time would have significantly benefitted the development of the fisheries management plans
	Issues concerning the setting of penalties	Community work penalties were suggested as an alternative to financial penalties	Offering community work penalties was welcomed by the community members and leaders		All penalties need to be agreed upon by MMC members prior to plan development. Community work penalties can include beach cleaning, mangrove planting, and transplanting coral fingerlings to restore reefs.
	Concerns raised over Marine Management Committee (MMC) membership	All major clans at each site were included in the development of the MMCs	Residents agreed that unless all clans were included in plan development of the plans, project success was less likely		It is vital that all major clans (and where possible, minor clans) are included in the MMC and the development of the plans in order for the rules to be made and enforced
	Issues with gillnet usage at some sites	If gillnet usage was a source of contention, other management options were suggested	Research and community engagement can identify potential problems in advance		The importance of site-specific plans cannot be over stressed. Site relevant management approaches are necessary to ensure the project is successful.

Link community based fisheries management plans to ward development plans	The ward plans are expected to be reviewed each year, yet this did not happen due to limited local level government (LLG) funding. Thus, it is difficult to review the ward plans and incorporate them into the fisheries management plans.	WCS will facilitate meetings with ward councillors and ward development officers (WDOs) from all ten sites, including their LLG managers, in order to review the sections relevant to the fisheries management plans.	The councillors were keen to cooperate with WCS and appeared impressed with the work that was happening at their respective communities.	**QUITE STRONG EFFECT**	The ward plans were developed two to three years ago; reviewing them on an annual basis is a costly exercise for the LLGs. Thus, we have to come up with an alternative approach.
	Bipi Island does not have a ward development plan	WCS cannot do much on this; the management plans for Bipi will be made available to the community as a separate document without any link to the ward development plans.			
Workshop to finalise management plans	Apart from time delays due to community deaths, no problems were encountered.	All interested parties were invited to the WCS office, to discuss finalising the management plans.	Working with all stakeholders is necessary for ensuring project success.	**STRONG EFFECT**	Everyone involved appeared impressed with the WCS work and the subproject.
Community feedback and evaluation surveys.	Complaints concerning the number of survey forms.	One page evaluation forms were issued to each community, which enabled participants to provide feedback and evaluate the subproject in a succinct manner.	Community members were pleased to complete short and focused survey forms.	**STRONG EFFECT**	Ensuring all questionnaires and survey forms are focused and relevant allows information to be obtained while not overwhelming the participants.

Convene a FAD training workshop	FAD workshop happened nine months before FAD deployment	Due to timing issues, the FAD workshop happened in advance of the FAD deployment. Refresher sessions and supplementary FAD handbooks were used to assist WCS staff and community facilitators with the relevant technical skills that are required for FAD deployment.	Only so much time could be given to FAD training, which happened in May 2017, before the FAD materials were delivered and used to construct the FADs	**MEDIUM EFFECT**	Ideally, the FAD training would happen just before FAD deployment, with sufficient time for training
	Limited information was provided on where to obtain materials for constructing the FADs				Assistance, where possible, with obtaining and importing FAD materials would be have benefited the subproject
Construct and deploy FADs	Disputes between Ponam, Tulu 1 and Tulu 2 over FAD locations. The Ponam customary sea area encompasses the waters of Tulu 1 and Tulu 2, where the respective FADs were to be deployed.	Community discussions and diplomacy was necessary. Ponam expressed that a FAD positioned within the waters adjacent to Tulu 1 or Tulu 2 would become the possession of Ponam. Due to the ongoing disputes and the short timeframe of the project, FADs were not deployed at Tulu 1 and Tulu 2.	Customary land and sea ownership is one of the defining characteristics of any Melanesian culture. Therefore, detailed knowledge about land and sea ownership prior to project implementation can help alleviate problems that may arise, especially between communities with historical ties and that are within close geographical proximity.	**MEDIUM EFFECT**	Sources of potential contention demonstrate the vital nature of community engagement, and diplomacy, and the importance of tailoring the management plans to the needs of each community – especially prior to project implementation.
Train villagers in water safety and fishing techniques	Delays in safety kit arrival.	The safety training took place during the FAD deployment.	Even though there were delays, the safety kits were issued during the final site visits.	**STRONG EFFECT**	There can be logistical challenges when ordering materials from outside of PNG. Ordering in advance can reduce the impact of delayed shipments.

Assess the number of gillnets that require replacing	Some community members did not want to replace their small-meshed gillnets	Educational awareness presentations (emphasising the importance of larger-meshed gillnets for enabling juvenile fish to escape and grow into adults) helped to inform the communities about the importance of gillnet management	Community members maybe uncomfortable with the idea of exchanging small-meshed nets for larger nets, claiming that they will catch less fish; therefore, increasing awareness can inform the communities about the importance of gillnet management.	**STRONG EFFECT**	Educational awareness regarding the importance of gillnet management is necessary to inform the village residents about the harmful impacts of small-meshed gillnets.
	Some community members provided inaccurate information in order to obtain extra gillnets	Fact-checking helped to avoid the distribution of additional gillnets	Enlisting the assistance of the community leaders and elders can assist in deterring opportunistic hopefuls		Assistance from the community elders and clan leaders can help deter residents from issuing false information. Such assistance can be developed through rapport building.
	Gillnet usage is considered taboo by some communities	The gillnet exchange was introduced as a voluntary practice, so people could choose whether they wished to take part	Not all sites use the same fishing approaches; offering alternative management options saved local frustrations.		Information regarding standard fishing practices should be obtained from each site prior to project initiation.
Import and distribute larger meshed nets.	Time delays when importing gillnets.	Ordering gillnets in advance ensured that they arrived in time.	Gillnets arrived during early March 2018 and were distributed to all sites by the end of the month.	**STRONG EFFECT**	Manus is an isolated island province in Papua New Guinea. Sufficient time is required when importing any materials to Manus, in order to ensure project completion.
Develop a data collection protocol and train CFs to collect catch-and-effort data	Issues with recording the scientific names of sampled species; likewise, spelling errors occurred when entering names into the database	The CFs were instructed to take time when identifying species and recording information; care was also needed when entering names into the database	Recording names requires patience, especially when under pressures in the field; entering names into the database is not a race – care is required	**QUITE STRONG EFFECT**	Patience and remaining calm can assist the data collectors when entering catch-and-effort data

	Inaccuracies with fish and invertebrate identification	Various full-colour identification guides were provided to all the CFs prior to data collection.	Species identification is a skill, and practice makes perfect. Time and patience is required to ensure all identification is correct		Taxonomy and classification workshops can benefit data collectors, and cameras can be used to take photographs of unknown specimens for later identification
Undertake catch-and-effort data collection programme.	Confusion arose at some sites regarding the purpose of collecting catch-and-effort data	CFs provided basic catch-and-effort training to residents while at each site so local communities understood the procedure	Education and awareness allowed the community members to appreciate the importance of the data collection process	**STRONG EFFECT**	Informing the residents in advance, coupled with training and conveying information to the communities, is necessary for lessening confusion
	Not all sites took part in regular fishing trips (especially Tulu 1, Tulu 2, Pelipowai and Lou).	Catch-and-effort data collection was difficult at some sites due to the local reliance on gardening rather than fishing	Working with the community ensured as much data as possible could be collected		Future projects would be of benefit to communities that rely on fishing for sustenance and income.
	Insufficient time to enable a third wave of catch-and-effort data collection following the deployment of the FADs.	An unrealistic monitoring plan could be achieved given the allotted time span of the subproject. To monitor temporal trends and the impacts of the FADs, waves of data collection need to occur several months (not days of weeks) after FAD deployment.	Initially, catch-and-effort monitoring would occur after FAD deployment, to monitor fishing changes; however, time constraints did not permit such monitoring schemes. In total, only two waves of catch-and-effort data collection took place.	**LOW EFFECT**	Time was a limiting factor, especially with regards to the logistical problems associated with purchasing and importing the FADs. Realistic time spans are necessary to ensure appropriate waves of catch-and-effort data collection take place before and after a management tool is implemented. And time is needed for the management tools to be effective, which can take months or years.
	Insufficient time to enable the second phase of catch-and-effort data collection to occur following the programme.	Due to time constraints, the second phase of catch-and-effort data collection took place during the gillnet exchange programme.	Even if gillnets were distributed, the limited timeframe of the project would not demonstrate the impacts on local fishing.		Time is required following the implementation of a management initiative to enable the associated fish stocks to respond to the change. The limited timeframe of the project prevented this from happening.

Convene a five day workshop on LB-SPR stock assessment methods	Some of the LB-SPR content was complex for some of the WCS staff members	The CFs worked in pairs to assist each other	The staff members who were comfortable with the data analysis process assisted other staff members	**STRONG EFFECT**	Assisting each other builds capacity for all involved and develops a sense of teamwork
	Jeremy Prince, who conducted the workshop, spoke at a fast pace, confusing some CFs	Jeremy Prince was asked to slow down during the workshop, enabling some of the CFs to catch up	Jeremy Prince was amenable to the CFs in the room		Ensure all workshops are conducted at the correct level and pace for the audience
	A limited number of laptops were available for carrying out the data analysis	The CFs worked in pairs and the laptops were shared	Additional laptops would have been beneficial		Make sure there are enough facilities for all the staff; even so, pair-work bolstered team-working skills
Training villages to collect data for LB-SPR stock assessments	Difficulties in explaining complex science to the communities	A four-part presentation was created, which explains the LB-SPR procedure and other marine science concepts in a simple, engaging and easy to understand manner	Educational materials, which are set to the appropriate level, can build local capacity and help residents understand the importance of the project.	**STRONG EFFECT**	Education and capacity building is a vital part of the subproject. The more community members and stakeholders know about the project, the more likely the project is to be successful.
	Problems in accurately indenting fish species	Species cards for each of the ten fish species that were selected for LB-SPR analysis were created for the CFs to use within the communities	Ten species were selected for LB-SPR assessment, so ensuring correct species identification was crucial		Correct species identification is necessary for accurate stock assessments; therefore, efforts should be made to ensure all data collectors are able to correctly identify candidate species for analysis. Names in the local vernacular are also useful.
	Difficulties in determining fish maturity of some individuals during dissection	If in doubt, and the fish gonads were not obviously male or female, the individual would be considered a juvenile	It can be difficult to determine fish gender when it is transitioning from juvenile to adult. Such fish could be considered immature		Differentiating adult male fish from adult female fish is quite straightforward. All ambiguous individuals that were sampled were considered to be juveniles

- Not all clan leaders were present during the clam farming activities: Communication with the ward councillors and community leaders before the site visit, specifically to specify the dates and times of the clam gardening workshop, is necessary to ensure all relevant stakeholders are present.
- Collecting giant clams for the clam gardens: It was advised to place twenty giant clams in each pen; the clams were taken from either known clam sites that were previously collected by the Andra and Ponam residents, or from wild populations. Efforts had to be made not to remove too many wild clams from a particular site to ensure enough clams remained to allow for future spawning.
- Restricted time for completing the terrestrial gardening work: Gardening trials and training took time to complete; accordingly, additional time would have assisted the gardening team.
- Obtaining climate resilient plants and seeds: All the seeds and African yam tubers that were distributed to each community were obtained from Morobe province in mainland PNG through the National Agricultural Research Institute (NARI); forward planning to ensure all the planting materials arrived on time was necessary

Table 10: Overview of the problems and mitigation measures encountered during the implementation of Objective IV of the ADB Subproject at ten community sites around Manus Island, from October 2016 to April 2017. The table has been arranged according to the components of the fourth subproject objective. An evaluation of the mitigation and alleviation measures has also been provided, accompanied by a colour-coded impact effect that is based on the success of the mitigation and alleviation measures. Lessons learned from the encountered problems are provided in the final column. For further details of the colour-coded impact effects outcomes, refer to Appendix I.

OBJECTIVE IV: TRIAL AND REPLICATE LIVELIHOOD AND CLIMATE CHANGE ADAPTATION INITIATIVES

OBJECTIVE COMPONENT	PROBLEMS ENCOUNTERED	MITIGATION & ALLEVIATION	EVALUATION	IMPACT EFFECT	LESSONS LEARNED
Clam farming trials undertaken (Andra and Ponam).	Selecting the best sites for the clam farms to be distributed; at Ponam there were some disputes concerning where the pens should be located.	The six Andra pens were positioned in proximity to major clan areas, There were four pens for Ponam, positioned according to suitable habitats; yet the Ponam residents took time to decide on the locations so WCS had to assist with pragmatic advice.	It is important for the communities to make their management decisions, especially concerning the locations of clam pens and FADs, and for WCS to provide technical assistance where necessary.	**STRONG EFFECT**	The communities must work with WCS when management decisions need to be made; the main role of WCS is to provide technical assistance where necessary.
	Absence of some clan leaders at the Andra and Ponam clam gardening workshops.	Information was given to clan leaders that were present; the aim was for such information to be disseminated to other leaders.	All stakeholders should be aware of what is happening during project implementation and the associated management decisions.		All clan leaders, councillors and other community stakeholders should be informed prior to the establishment of the clam gardens.
	Collecting sufficient numbers of giant clams.	Clams were collected from other regions of the reef.	It is important not to remove too many wild clams to ensure the population is not heavily impacted.		Clams should be available from the community gardens, which do not impact wild populations.

Community level clam farming training (Andra and Ponam).	Other activities were taking place at Andra while the clam gardening training was set to happen.	The clam training sessions began after the other activities (in this case, a regional female football tournament) had finished.	It is necessary to be adaptable and flexible so that community activities do not clash with the activities of the subproject.	**STRONG EFFECT**	Flexibility is important, and schedules often need to be adjusted according to the current situation within each community.
Purchase of equipment for clam farming (Andra and Ponam).	Logistics in delivering clam pen materials to the WCS office.	All materials were ordered in advance to ensure they arrived in time.	Forward planning was necessary to make sure the clam pens could be constructed in time.	**STRONG EFFECT**	Making sure clam pen materials are sourced locally can help reduce shipping times and other logistical constraints.
Produce project document on lessons learned.	Limited time frame for completing the document.	Keeping a record of all the activities of the subproject, and any problems that arose, allowed the document to be completed.	Prioritisation and planning was necessary to ensure the plans were completed in time.	**STRONG EFFECT**	Careful note-taking and planning is vital, especially for compiling final lessons learned reports.
Conduct a needs and capacity assessment at all sites.	Complaints regarding how the data will be used.	Presentations, made prior to the surveys, were given to explain the project, and also to explain how the data will be used.	Residents who attended the presentations saw the need of the project and were therefore keener to take part in the project.	**STRONG EFFECT**	During the opening presentations, the importance of the data collection surveys and community involvement should be stressed.
	Requests for data repatriation.	All of the data was repatriated to the communities.	Data repatriation was welcomed by the community members.		All data must be repatriated via *PowerPoint* presentations and reports.
Secure climate resilient planting materials.	It took time for the planting materials to arrive; problems in relying on external sources (it took four months for the seeds and tubers to arrive in Manus from Morobe province).	All planting materials were ordered in advance to make sure everything was ready on time.	Careful planning and prioritising enabled the various components of the gardening activities to be completed on time.	**STRONG EFFECT**	All planting and gardening materials should be purchased and imported during the early stages of project implementation to make sure they arrive on time.

Distribute crops for propagation and provide training for farmers.	Time delays for the training to take place, due to bad weather or a death at a community.	Training and crop distribution trips took place throughout the weeks of January and February, which included weekends, to ensure all sites received the crops and training despite the delays due to existential circumstances.	Commitment by the CFs ensured that all the crop distributions and training sessions took place at all sites.	**STRONG EFFECT**	Flexible timetables and a strong work ethic ensured all the relevant tasks took place and on time.
	At Andra and Ponam, not all the seedlings germinated due to the alkaline soil conditions on the islands.	Additional training was provided, which focused on improving soil fertility and productivity.	Soil pH and other conditions vary from one place to another. Training in different methods for adjusting soil acidity was given.		Training and the provision of seeds and tubers should increase local crop yields and improve food security. Model farmers were also enlisted, who recorded the number of successful seeds and tubers that germinated: the outcomes could be used to determine the crop hybrids that were the most successful for each site, which would assist with future projects within each area.
	Some community members asked for more seeds and tubers.	Additional seeds were provided where possible. Communities were advised to replant seeds from the adult plants.	Enthusiasm for the gardening activities was evident when requests for further seeds were made.		
	Insufficient time for the model farmers to conduct performance assessments.	The model farmers will continue with their experimental plots following project completion.	The enthusiasm of the model farmers should enable long-term performance assessments to occur.	**QUITE STRONG EFFECT**	Performance assessments are necessary for determining which crops are most suited to a certain site. Yet time is required for long-term performance assessments to occur.
Performance assessment of garden trials.	Limited timeframe for completing a long term assessment.	Model farmers were enlisted to monitor the growth of their seeds and tubers. The results were used to assess crop hybrid success. Voluntary assessments should continue after project completion.	Ideally, additional site visits would be required to continue monitoring the success of the crop hybrids at each site.	**QUITE STRONG EFFECT**	The enthusiasm of some villagers was evident, and it is likely that monitoring will continue on a voluntary basis. To effectively assess the performance of the garden trials, regular monitoring of seed and tuber germination, and subsequent crop yields, would occur during the months and years following project completion.

5.0 GUIDELINES FOR COASTAL ZONE MANAGEMENT AND MONITORING

Various challenges and constraints were encountered during the implementation of the ADB Subproject. Such problems, together with the logistical difficulties that can be encountered when working within an isolated island province in Papua New Guinea, led to the lessons learned that have been presented in this report. The following section expands upon the lessons that were learned during the implementation of the ADB Subproject, and suggests guidelines for integrated coastal zone management (ICZM), as well as general suggestions for future monitoring plans, for all of the sites following subproject completion. It is hoped that such guidelines for ICZM will also be implemented during similar projects that occur around Manus province or elsewhere in Papua New Guinea, and that an adaptive monitoring plan will be applied to each of the ten sites following subproject completion.

5.1 Ecosystem-based approach to fisheries management

An ecosystem-based approach to fisheries management, which forms a key part of the Coral Triangle Initiative (CTI), can encourage sustainable fisheries practices at the artisanal level (Flower *et al*., 2013). In recognition of the importance of managing community-level fisheries, an amendment to the Fisheries Management Act 1998 was made in 2013 to enable the implementation of ecosystem-based approaches to fisheries management within PNG (Govan, 2013). To ensure such approaches are successful, public awareness is vital in order to mobilise and educate clan leaders and community members, who can take relevant actions to enable sustainable fisheries to develop. In addition, working with stakeholders, including Local Level Governments (LLGs) and Ward Level Governments (WLGs), as well as other non-governmental organisations (NGOs) in the region, can assist in introducing sustainable fisheries knowledge to each community (Lokani *et al*., 2013).

Resource management requires tribal leaders to negotiate resource access according to the needs of each community, which can then be used to develop fisheries management guidelines that are amenable to local customs. Gear-based management can also be employed, which can be based on current management practices (McClanahan & Cinner, 2008; Cinner *et al*., 2009). Simple management approaches can also be introduced to each community such as the model developed by Cinner *et al*. (2009) presented in Figure 9. If such approaches are used, however, it is necessary to make sure tribal leaders, local fishers and other community members understand the concepts: simple language, diagrams, and words in the local vernacular may assist with information dissemination.

Conservation awareness programmes can also be established at each community, which could include school visits and school lesson plans, media development programmes, community workshops, and interactions with local church communities. As well as the communities, other target groups may include schools, church groups, conservation organisations, journalists and funding donors.

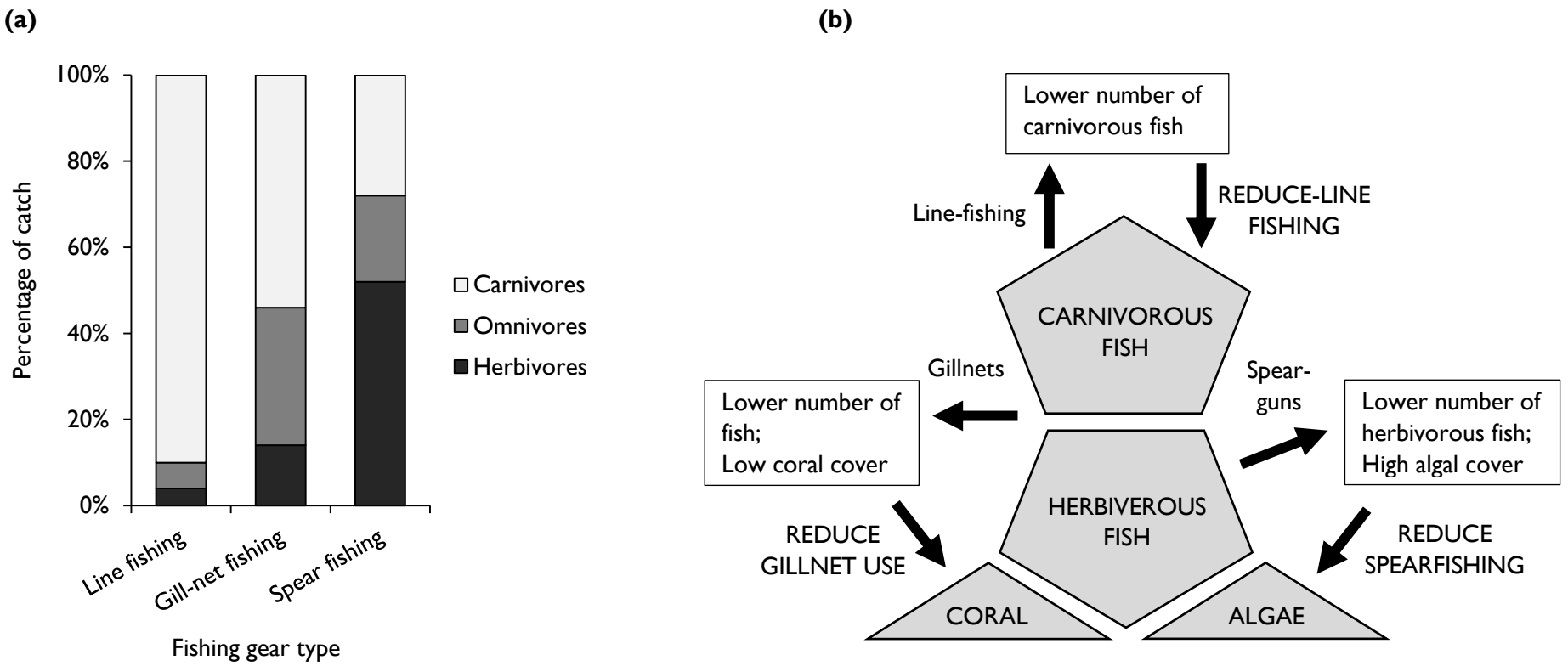


Figure 10: The percentages of fish groups classified according to major feeding type (a), which were harvested in Papua New Guinea with fishing lines, gillnets and spear-fishing methods at nine sites in 2008 (adapted from Cinner *et al*., 2009; a total of 2,145 fish were sampled). Fishing lines typically catch carnivorous fish, gillnets tend to catch carnivorous and omnivorous fish, and spear-fishing targets herbivorous and omnivorous fish. A model (b) developed by McClanahan & Cinner (2008) to enable fishing communities to make suitable fisheries management decisions based on observable catch composition trends and the condition of the adjacent coral reef system. For instance, if fishers notice an increase in algal cover on local reef areas coupled with a reduction in captured herbivorous fish, a recommended management option would be to reduce the intensity of spear-fishing until there is an observable reduction in algal cover and the recovery of herbivorous fish numbers (adapted from McClanahan & Cinner, 2008). Such ecosystem-based management methods can provide inspiration for the communities, and enable self-governance through the Marine Management Committee.

Community-based conservation awareness programmes can include information concerning the following topics:

- Marine ecosystems
- Sustainable marine fisheries
- Fisheries management tools and approaches
- Resource and waste management
- Marine law and community rights
- Climate change
- Endangered marine species and the live aquarium trade
- Biological classification

Once villagers increase their capacity and start managing their own resources – and especially once the benefits of sustainable fisheries management can be witnessed – it is likely that: (i) the communities will independently agree to set aside management areas; (ii) attitude changes that favour sustainable fishing practices may arise; (iii) there may be an increase in local students entering professions that protect the environment; and (iv) local women may be empowered and take leading conservation roles in their localities.

5.2 Using lessons learned as guidelines for integrated coastal zone management

The following points have been developed from the lessons that were learned from the ADB Subproject, which was conducted around Manus Island from October 2016 to April 2018. The following guidelines can be used to assist with similar community-based fisheries management projects around Manus Island or within the other maritime provinces of Papua New Guinea.

Technical components

- Educational awareness programmes should be established to build capacity and to inform communities about the importance of sustainable fisheries and safeguarding marine resources and ecosystems
- Gaining an understanding of local key fisheries, according to the views of the community members, will assist with the development of site-relevant fisheries management plans
- Fisheries management tools should be suggested to the communities, and each community can select tools that they think are appropriate; information concerning each management method should be provided via presentations
- Questionnaires can provide valuable socio-economic and food security data; yet communities need to be aware of why the data is being collected and about data privacy; the questionnaires should also be short and simple, and without questions concerning personal details
- All data should be repatriated to the communities through reports and presentations; data should be presented in a simple and visually interesting way
- Ecological surveys should be conducted (with sufficient replicates) in areas that communities claim are regularly fished and in areas that are not regularly fished, to determine differences in

benthic community structure; the non-fished areas can provide baseline data for subsequent temporal comparisons to be made

- Regular monitoring, including the monitoring of local community catch rates and compositions (and where possible socio-economic, catch-and-effort, and ecological surveys), is required to detect changes in fishing activity, catch rates, and fish sizes, as well alterations in community demographics and coral reef community structure, following the initiative implementation
- The work of the model farmers at each site should allow for the continued monitoring of crop germination success and final yields

Community engagement and project management

- Initial community engagement should present the subproject in a simple manner, so that community leaders and councillors can understand the relevance and importance of the project, and thus pass such information on to other community members, furthering interest within the community
- Community facilitators must be equipped with project-relevant knowledge, in order to disseminate information about:
    - Marine ecosystems
    - Protected areas and no-take zones
    - Climate change
    - Community rights
    - Fishing impacts
    - Resource management
    - Local marine law
    - Taxonomy and identification
- Community facilitators need to take an approach that is culturally appropriate and be aware of ethnic diversities, such as:
    - Having an awareness of the customary land and sea boundaries of each community
    - Gaining an understanding of what fishing activities take place at each site
    - Appreciating what is culturally taboo or inappropriate for each community
    - Using local vernacular to allow residents to be comfortable in asking questions
- There is a need for further coordination amongst the local governments (LLG and WLG), other NGOs, public awareness organisations, and regional stakeholders
- Different awareness techniques need to be employed, which present information in a clear and interesting manner, and which is site-relevant and easy to understand
- The Marine Management Committee (MMC) can empower their community and inspire villagers to manage their own resources; however, the MMC should:
    - Be locally elected and include representatives of each major clan
    - Select relevant committee member positions, including a chairman and secretary
    - Plan to convene on a quarterly basis
    - Set penalties, agreed on by all community members, for rule breakers
    - Choose relevant penalties, which may include community work
    - Adapt the plans according to observed fishery, community or ecological changes
    - Ensure all information is disseminated to the community
    - Remain in contact with WCS for further guidance and technical support
- All materials for constructing FADS, as well as large-meshed gillnets, clam pens and gardening supplies, should be purchased in advance
- Funding should be available to enable the programme to continue, which should incorporate monitoring plans

5.3 Future monitoring plans for the ten ADB sites around Manus Island

A structured monitoring plan, which is conducted at regular intervals following the implementation of an ecosystem-based management approach, is necessary to determine the success of the management measures that are used, and also to indicate areas for adaptive management. Although there was insufficient time during the ADB Subproject to conduct rigorous monitoring following project completion, a basic outline of a monitoring plan has been provided (Table 11) in the event that future opportunities to monitor the effects of the fisheries management plans should arise. Some key points from the monitoring plan are:

- The Marine Management Committee should record observations and simple count data in dated logbooks
- Population increase can be quantified through a community census (conducted every four years) to determine changes in local population demographics; immigration and emigration should be included
- Record the use of efficient fishing gears, such as spear-guns, which can be limited to a certain number per household; also monitor gillnet usage and gillnet mesh sizes to ensure larger meshed nets are used
- Monitor the catch numbers, body sizes, and catch species diversity of fish caught with larger-meshed gillnets and from around the community FADs, and also following the implementation of other management tools, such as no-take zones, rotational fishing areas, and minimum catch size limits; additional monitoring of the giant clam pens can be made at Andra and Ponam
- Assess changes that may occur to local coral reef habitats in areas now designated as no-take zones, and compare the diversity and abundance of major coral types within the no-take zones to areas that remain open fishing grounds
- If possible, continue the catch-and-effort surveys at each site
- Monitor the quality and quantity of climate-resilient crop harvest yields, and the fertility and quality of the associated soil structure; continue the monitoring work of the model farmers at each site

WCS will continue to remain in contact with each of the ten ADB communities (through the Marine Management Committees), and will also continue to provide technical guidance and support when required. This includes advice with the monitoring plans, and – if sufficient funding should arise – WCS would be keen to carry out all (in an adapted form, where necessary) of the monitoring plans listed in this section.

The fisheries management plans and other documents that have been produced as part of the ADB Subproject have been specially devised so that they are adaptable, according to changes and events that may happen in the near future. The Marine Management Committees can adapt the plans to what they feel necessary, and can also enlist advice from WCS on such matters. Adaptive capacity is necessary: Indeed, with the current trends of population increase coupled with better fishing practices and the projected threats of climate change, ensuring adaptive resilience across the socio-ecological system at each of the ten sites is of immediate importance, not only for safeguarding food security and marine resource availability, but also for enabling ecosystem-based approaches to integrated coastal zone management to continue to be practiced, which should help to ensure a more sustainable future for generations to come.

Table 11: Proposed monitoring plan for each of the ten communities around Manus Island, Papua New Guinea, which were part of the ADB Subproject from October 2016 to April 2018. The monitoring plan focused on key procedures that occurred during the subproject, and includes details of how frequent the monitoring action should occur, as well as potential constraints that may arise, and an evaluation of the monitoring procedure with a colour-coded impact effect based on how beneficial the monitoring action will be for the community and whether additional technical guidance and support would be required (see Appendix I for more details regarding the impact effects).

SOCIO-ECOLOGICAL COMPONENT	SOURCES OF IMPACTS	MONITORING PLAN	POTENTIAL CONSTRAINTS	EVALUATION AND SUGGESTIONS	IMPACT EFFECT
Population increase and an increased rate of fishing activity and invertebrate collecting.	A larger population will require more seafood for protein and market sales, and will also result in more people that can go fishing.	Preferably, socio-economic questionnaires (to determine demographic changes) and catch-and-effort surveys can be conducted on an annual basis. Simpler methods include an annual census and monthly fish catch counts by the MMC, which can be monitored during the years following project completion to see catch number changes.	The MMC are unlikely to have the time or technical skills for scientific studies. Recording catch numbers in logbooks provides a basic snapshot of fishing activity, and can show major trends if continued over time.	Questionnaires and catch-and-effort studies take time and require volunteers to collect data, technical skill to analyse data, and computer facilities to analyse and store data. A basic method is to record catch numbers on the first day of each month, with records kept by the MMC, in order to monitor trends.	**MEDIUM EFFECT**
Perceived increase in efficient fishing methods, such as spear-gun usage, dive fishing methods or small-meshed gillnet usage.	Efficient and modern fishing methods can increasing fish catch rates, including an increase in the number of juvenile fish (needed for a sustainable fishery) and herbivorous fish (which manage algal growth on the reef) that are caught.	Monitoring the number of spear-guns and snorkelling sets per household. An agreed set limit of spear-guns and snorkelling sets, enforced through the MMC, could be decided. Monitor gillnet mesh sizes and usage of gillnets.	Not all households will be keen to give information about spear-gun and snorkelling set numbers. Residents can be reluctant in using only larger-meshed gillnets.	The MMC, representing all clans, should disseminate information regarding both the management plan rules and the importance of such rules to all community members. Thus, fishing gear limits and gear monitoring can be achieved.	**QUITE STRONG EFFECT**

Effects of the community FAD on fish catch composition and catch numbers.	A FAD should relive pressure on adjacent coral reef fisheries; accordingly, there should be an increase in more resilient pelagic fish species that are caught around the FAD.	Ideally, catch-and-effort studies would continue, using the initial data collected during the subproject as baseline data. The feasibility of this in the field, carried out by the MMC, however, is unlikely. Rather, fish catch numbers recoded from FAD fishing trips, and also reef fishing trips, can be logged by the MMC on the first day of each month to monitor change.	Catch-and-effort studies require time and involve data analysis. Future WCS projects at each community could allow this; yet at the community level, recording catch numbers (and if possible, fish types) can permit basic temporal and spatial comparisons.	An MMC logbook, arranged with simple tables that record the date, fishing location (FAD or reef), number of fish caught, and types of fish caught (reef fish or pelagic fish) can provide an indication of fishing trend changes. The data should be collected on the first day of each month. Monitoring the numbers over time can be indicative of change.	**MEDIUM EFFECT**
Compliance with the gillnet exchange programme (where applicable).	Larger-meshed gillnets (exchanged for small-meshed nets) should reduce the number of juvenile fish that are caught, increasing the reproductive potential of the fishery. Thus, there should be an decrease in smaller-sized fish that are caught.	Recording the number of gillnets per household and checking the mesh sizes (which to be sustainable should be 2.5 inches or more).	Residents may be keen to use small-meshed nets because smaller fish can be captured, which will be perceived as more food, despite the ecological ramifications.	As well as enforcing rules, the MMC should also educate and build capacity within their community and respective clans, especially concerning the importance of sustainability and why it is necessary to manage a fishery (such as not targeting juvenile fish with small-meshed gillnets).	**STRONG EFFECT**
Effectiveness of the rotational fishing zones or no-take areas.	No-take zones can increase spill-over, as fish migrate from protected areas to fished areas. A change in fish community structure could be detected.	Catch-and-effort surveys, conducted every three to six months, would provide reliable data. Such methods are unfeasible for the MMC, so comparisons of logged values from previous catch recordings should be made.	It is unlikely that scientific assessments can be conducted by the MMC, so observations and recordings of catch numbers will be required.	Observations of catch compositions and catch counts, taken before and after the no-take zone is established, should indicate catch trend changes and whether the no-take zones have had beneficial impacts.	**MEDIUM EFFECT**

Consequences of the set minimum size limits for certain fish species.	Obeying minimum size limits should see a reduction in juvenile fish caught, and an increase in fish catch numbers as more adult fish are able to spawn.	With sufficient funding, the catch-and-effort and LB-SPR assessments could continue, using data collected during the subproject as baseline data. Otherwise, observations of fish sizes that are caught can be made, and logged by the MMC.	It is unfeasible to check the sizes of all caught fish, especially when species have different minimum sizes; size limits for the ten LB-SPR species could be maintained and monitored by the MMC. NFA size restrictions must be kept.	For ten the LB-SPR species, a board fitted with the appropriately-sized holes for each species could be made, enabling fisheries to monitor size; if a certain fish fits through the gap, it is below minimum size limit. For other fish, general rules could be suggested, such as returning fish smaller than 10cm in length.	**QUITE STRONG EFFECT**
Changes in coral reef ecosystems following the implementation of the management plans.	Implementing no-take zones, together with a greater consideration for local coral reefs (such as not breaking corals while catching octopuses), should lead to reef recovery, such as an increase in coral cover and species diversity.	Replicate ecological surveys, such as conducting transect lines in certain areas, can determine rates of reef recovery. Yet technical knowledge and analysis would be required, which is out of reach for the communities. Snorkel observations can allow for a visual assessment of reef community changes.	It is unrealistic to expect rigorous ecological studies to be conducted.	If funded opportunities arose for further ecological studies, WCS would repeat more robust ecological studies on the reefs adjacent to each community to monitor rates of change or recovery between the no-take zones and the regularly fished zones.	**LOW EFFECT**
Diligence and commitment of the Marine Management Committee (MMC).	An effective MMC will enforce the management rules, convene regularly to decide on adaptive measures, and impose penalties for rule breakers, ensuring the plans are applied.	The MMC is responsible for monitoring all future findings: the biological monitor and socio-economic monitor have such duties. The MMC can complete basic marine management plan evaluations, and at the start of each year, new members can be elected.	MMC members should continue with their responsibilities in safeguarding food security for the rest of the community.	An active and engaged MCC, representing all major clans, is imperative for the future success of the subproject. MMC members should remain proactive, and should continue inspire and inform the community.	**STRONG EFFECT**

Success of the giant clam gardens for improving food security and clam spawning (Andra and Ponam communities).	The clam gardens should result in a sustainable source of giant clams for consumption, and an increase in wild giant clam abundance within the vicinity of the clam pen, due to the close proximity of the clams within the pen, which can increase spawning potential.	Size limits for clams should be set; when clams are harvested, they can be measured to ensure the size limits are maintained. Keen volunteers can snorkel around the reefs to monitor any changes in clam abundance, the outcome from which can be logged by the MMC and compared to past recordings.	Some residents might be keen to collect clams while they are still small; the MMC should inform such residents that larger clams produce more eggs and sperm, resulting in more clams on the reef for the future.	Clam size measurements (across the widest point of the shell) can be taken while harvesting the animals. Monitoring the clams on the reef can be taken three times a year; although this is not a robust way to assess the population, the results can be indicative of the wild clam population.	**QUITE STRONG EFFECT**
Success of the gardening approaches for food security and soil fertility.	Increased crop yields and improved soil fertility; less areas of forest need to be cleared due to improved soil conditions at each plot.	Crop harvests and yields can be monitored, both visually and if possible, through counting. The model farmers can continue with their recordings and observations on a voluntary basis. The quality and firmness of the soil can also be monitored, and adapted accordingly.	Gardeners can directly count the crop harvest (such as number of germinating seeds, or yam and bean pod yields) and check the soil quality, in a similar approach to what the model farmers are doing.	The MMC can keep note of the number of seeds that germinated and crops that were harvested. If soil quality deteriorates, trial the methods introduced during the gardening workshops can be used.	**STRONG EFFECT**

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The World Bank: Data

http://data.worldbank.org/country/papua-new-guinea

6.1 Photograph credits

Unless otherwise stated, all photographic images used in this report are the property of the Wildlife Conservation Society: Papua New Guinea.

Base maps included in this report were obtained from Google Earth, 2018.

APPENDIX

Appendix I

IMPACT EFFECTS KEY: Details concerning the colour-coded impact effects column used to assess the outcomes of the mitigation and alleviation measures that were employed in Table 7, Table 8, Table 9 and Table 10. Colour-coded impact effects were also used to assess the monitoring plans that are listed in Table 11 in order to determine the effects of potential monitoring procedures following project completion.

	NO EFFECT	NEGATIVE EFFECT	LOW EFFECT	MEDIUM EFFECT	QUITE STRONG EFFECT	STRONG EFFECT
MITIGATION AND ALLEVIATION MEASURES	The mitigation and alleviation measures that were employed had no detectable effects on the problem(s) that were encountered	The mitigation and alleviation measures that were employed exacerbated the encountered problem(s), leading to further complications and problems	The mitigation and alleviation measures that were employed had little effect on the outcomes of the problem(s) that were encountered	The mitigation and alleviation measures that were employed led to some positive change, yet further improvements could be made to alleviate the problem(s)	The mitigation and alleviation measures that were employed were successful, although such problems could arise again during later stages of the project	The mitigation and alleviation measures that were employed were successful, leading to positive change and project improvement
MONITORING PLANS	It is unlikely that the monitoring plans will have any positive or negative effect; technical guidance and support would be necessary	The monitoring plans will have a harmful effect on the community and environment; technical guidance and support is required	The monitoring plan will have a negligible effect in monitoring changes post project completion and will need further technical support	The monitoring plan will be useful, yet could be greatly improved with further technical support and assistance	The monitoring plans will be valuable, yet could benefit from additional technical guidance	The monitoring plan will be of benefit to the community by monitoring changes that occur following project completion

Appendix II

Form used to obtain Marine Management Committee (MMC) names, and also to develop the rules and associated penalties for the fisheries management plans. In addition, there is a final fisheries management plan feedback and evaluation table at the end of the form.

WILDLIFE CONSERVATION SOCIETY

Marine management committee responsibilities and fisheries rules, regulations and penalties form

NAME:	**COMMUNITY**:	**DATE**:

PART A: Give names and positions for the Marine Management Committee (MMC). Examples of positions have been provided, and other positions can also be included.

The MMC is responsible for enforcing the fisheries management rules, and for issuing penalties to residents that break the rules. The MMC should represent all major clans in the community to make sure all community members are included in the rule making process.

If the MMC and management plans are successful, there should be more fish for your community in the future.

MARINE MANAGEMENT COMMITTEE NAMES AND RESPONSIBILITIES		
POSITION	**CLAN GROUP**	**POSITION HOLDER**
Chairperson		
Secretary		
Treasurer		
Biological monitor		
Socio-economic monitor		
Marine enforcement officer		
Community spokesperson		
Clan representative		

PART B: Select management rules and regulations you believe will help your community. There is a separate section for each of the major management methods. You do not have to choose all the rules. If you want to introduce other rules, write them down in the spaces below each table.

GILLNET EXCHANGE PROGRAMME		Happy	Unhappy	Unsure
1	Use nets with a mesh size larger than 2.5 inches			
2	Control the number of gillnets in the community			
3	One gillnet for each house			
4	One gillnet for each community			
5	Not using gillnets during full or new moon periods			
6	Share gillnets with other community members			
7	Only using nets smaller than 2.5 inches for baitfish			
8				
9				
10				

Comments:

FISH AGGREGATING DEVICES (FADS)		Happy	Unhappy	Unsure
1	Do not anchor boats at the FAD site			
2	Maximum of 3-4 people on each boat at the FAD			
3	Only visit the FAD during good weather conditions			
4				
5				
6				
7				
8				
9				
10				

Comments:

NO-TAKE ZONES		Happy	Unhappy	Unsure
1	Do not enter the no-take zone			
2	Prevent all fishing along the no-take zone boundary			
3	Stop shellfish or coral collection in the no-take zone			
4	No boats or canoes to pass within the no-take zone			
5	No dynamite, poison rope or chemicals in the zone			
6	Anchor boats or canoes away from the no-take zone			
7	The MMC decides when monitoring takes place			
8	The monitoring team must consist of 3-5 people			
9				
10				
11				
Comments:				

ROTATIONAL FISHING AREAS		Happy	Unhappy	Unsure
1	No entering the rotational areas during closed periods			
2	Stop fishing in the areas during new and full moons			
3	No dynamite, poison rope or chemicals in the area			
4	Night time diving and torch diving is not allowed			
5	Do not use nets within the rotational areas			
6	No breaking corals in the rotational areas			
7	Quota for each fisher in the area (20 fish per person)			
8	Anchor boats or canoes away from the rotational area			
9	Limit the number of fishers in the rotational areas			
10	Inform monitoring officer before entering the area			
11				
12				
Comments:				

MINIMUM FISH SIZE LIMITS		Happy	Unhappy	Unsure
1	Follow the suggested size limits for the key fish			
2	Return all fish smaller in size than an average hand-size			
3	Regulate hook size and gillnet mesh size before fishing			
4				
5				
6				
7				
8				
9				
10				
Comments:				

GENERAL RULES FOR HEALTHY SEAS		Happy	Unhappy	Unsure
1	Do not break corals when catching sea animals			
2	No using poison rope or harmful chemicals in the sea			
3	Do not use dynamite when catching fish			
4	Do not throw rubbish into the sea or on the beach			
5	Avoid using spears for catching crabs or lobsters			
6	Do not take female lobsters or crabs			
7	Do not catch sharks, turtles or dugongs			
8	Control fishing during full and new moon periods			
9	Do not go fishing at known fish spawning sites			
10				
11				
12				
13				
Comments:				

PART C: Select the clam gardening management rules and regulations you believe will be help your community. You do not have to choose all the rules. If you want to introduce other rules, write them down in the spaces in the table below.

CLAM GARDENING (ANDRA AND PONAM)		Happy	Unhappy	Unsure
1	Take clams of a certain size (more than 20cm wide)			
2	No boats or canoes over the clam gardens			
3	Do not harvest clams under the pens			
4	Avoid anchoring boats close to the pens			
5	Do not plant coral on the clam pens			
6	No fishing allowed near the clam pens			
7	Make clam farm maintenance every three months			
8	Do not throw rubbish near the clam pens			
9				
10				
11				
12				

Comments:

PART D: Select penalties for the management rules and regulations, which you believe will help your community to have more fish in the future. If you want to introduce other penalties, write them down in the spaces in the table below.

PENALTIES		Happy	Unhappy	Unsure
1	Cleaning the beach			
2	Planting ten mangrove saplings (or other coastal trees)			
3	Planting ten coral fingerlings to restore coral reefs			
4	Collect crown-of-thorns starfish			
5	Planting and maintaining gardens			
6	Do other community work			
7	Pay small fines (5 kina, 10 kina or 50 kina)			
8				
9				
10				
11				
12				
13				
14				
15				
16				

Comments:

PART E: Using the information from the tables above, please list the rules and regulations you think would help provide fish and seafood for your family and community in the future. Also list the penalties you think would be suitable for any community member who breaks the rules. You can write additional comments in the third column.

The rules and penalties must be practical and be of benefit to all community members.

FINAL RULES AND PENALTIES TABLE FOR THE FISHERIES MANAGEMENT PLANS

RULES AND REGULATIONS	PENALTIES	COMMENTS
GILLNET EXCHANGE PROGRAMME		
FISH AGGREGATING DEVICES (FADS)		
NO-TAKE ZONES		

RULES AND REGULATIONS	PENALTIES	COMMENTS
ROTATIONAL FISHING ZONES		
GENERAL RULES FOR HEALTHY SEAS		
OTHER SUGGESTIONS		

QUESTIONS AND ADDITIONAL COMMENTS: If you have other questions or comments, please write them in the box below:

PART F: Complete the final feedback and evaluation questions below, based on your understanding of the fisheries management plans and the work of WCS in your community. For question 8 and 9, please write your answers in the spaces provided. If you have any other questions or comments, please include them in the space below.

	FEEDBACK AND EVALUATION	**YES**	**UNSURE**	**NO**
1	Are you concerned about the future of your fish stocks and marine resources in your community?			
2	Do you think your community is responsible for managing your future fish stocks?			
3	Do you think the fisheries management plans will be successfully implemented in your community?			
4	Will the community be willing to follow the fisheries management rules?			
5	Do you think the Marine Management Committee will be able to enforce the management rules?			
6	How do you think your community and all the major clans will respond to the management rules?			
7	Are you happy with the WCS work within your community?			

8) Can you think of any problems or challenges that may occur when the management plans are introduced?

9) Is there anything additional that WCS should do to help manage fish in your community?

Questions or comments:

Thank you for completing the form

WILDLIFE CONSERVATION SOCIETY

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