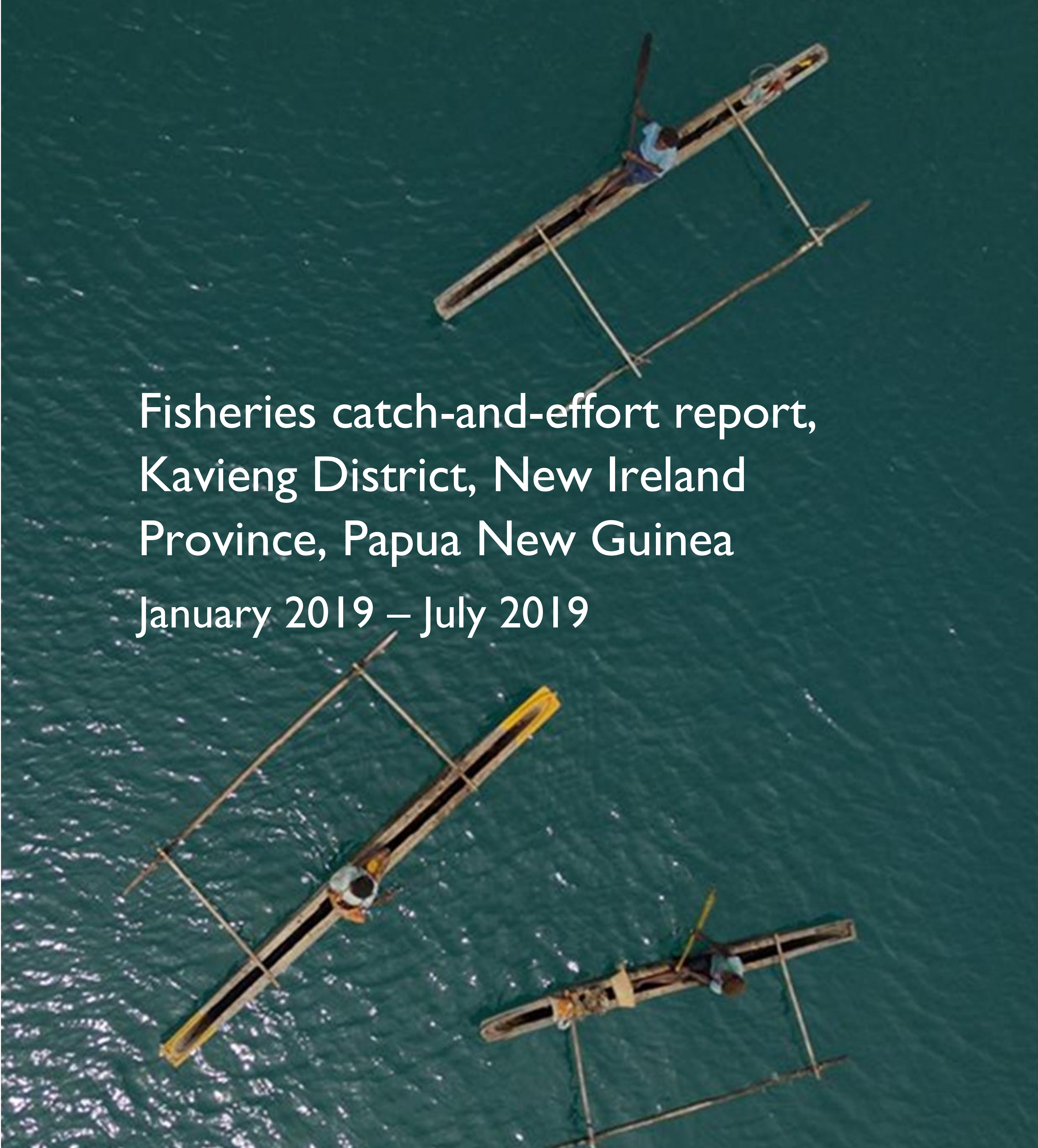

Fisheries catch-and-effort report, Kavieng District, New Ireland Province, Papua New Guinea

January 2019 – July 2019

DFAT

Department of Foreign Affairs and Trade

Oceans 5

Wildlife Conservation Society

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January 2019 – July 2019

Project title: Building rural communities' resilience to climate change in the Bismarck Sea and Forest, Papua New Guinea

Funded by the Australia Department of Foreign Affairs and Trade (DFAT) and Oceans 5

COMMUNITIES: Bangatan, Kavitongong, Kavulik, Kulibang, Limanak, Mamion, Nonovaul, Salapiu, Sosson, Tsoilik, Tugolop, Ungakum, Ungalabu

Cover photo: Fishers in canoes, New Ireland Province (Elodie Van Lierde)

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Executive summary

The Department of Foreign Affairs and Trade (DFAT) (with co-funding from Oceans 5) allocated funds to build community resilience to climate change in the Bismarck Sea, Papua New Guinea. Part of the project was implemented by the Wildlife Conservation Society (WCS) Papua New Guinea Programme at thirteen coastal communities in Kavieng District, New Ireland Province. In addition, from 2016 to 2019, four waves of fisheries catch-and-effort data were collected at each community. In 2018, subsurface fish aggregating devices (FADs) were deployed in each community, which aim to transfer fishing effort from vulnerable reef fisheries to more resilient open water fish stocks, and fisheries management plans were implemented at each site. The catch-and-effort data can help indicate changes in fishing activity since the introduction of the fisheries management initiatives at each community.

Background and methods

Population increase, more efficient fishing methods and exposure to the cash economy, coupled with the projected threats from climate change, are contributing to declining fish stocks across the South Pacific. Coastal communities living around New Ireland Province, located in the Bismarck Sea, Papua New Guinea, have relied on the extraction of seafood for thousands of years. However, there are now concerns that many coastal communities around New Ireland Province will face increasing food scarcity during subsequent decades unless appropriate management measures are in place. Accordingly, there is now a need to conduct fisheries assessments around New Ireland Province to better understand local fish catch rates and other fishing trends. A simple and effective method for conducting fisheries assessments at the community level requires obtaining catch-and-effort data to enable catch-per-unit-effort (CPUE) to be calculated.

The DFAT project involved working with thirteen communities around Kavieng District, in western New Ireland Province, from January 2019 to May 2019 to obtain fisheries catch-and-effort data. The DFAT project involved building community resilience to climate change in each of the thirteen communities; thus, the data in this report is necessary for comparing changes in fishing trends and catch abundance during the lifespan of the project. Information concerning how much time and effort each fisher put into fishing, and also the species composition and total body sizes of the animals caught, were obtained. The objectives of this study were to understand:

1 – The diversity of harvested species
2 – The relative importance of harvested species and families
3 – The relative proportions of harvested to marketed catches
4 – The importance and preferences of different fishing methods
5 – Size selectivity of different fishing methods

Since 2015, WCS has collected three additional waves of catch-and-effort data, in in 2018, WCS deployed fish aggregating devices (FADs) for the communities to catch open water species. During this timeframe, WCS also implemented site-specific fisheries management plans in each community, with fisheries management rules and penalties decided by community members and enforced by community-elected marine management committees. Accordingly, the current 2019 data were compared to the previous three waves of collected data to see whether the FADs have changed fishing activities and trends in each community.

Results and summary

Mean CPUE outcomes varied across all thirteen communities, and were higher at the island communities in North-west Lavongai, including Ungalabu, Sosson and Kavitongong. The following points overview some of the key findings listed in this report:

- In total, 558 fishing trips were intercepted, which encompassed 1,568 fishing hours
- 10,359 marine animals were recorded: 9,310 fish and 1,049 invertebrates and turtles
- For finfish, a total of 30 families and 270 species were recorded
- The highest CPUE values were from Ungalabu, Mamion, Sosson, Nonovaul and Kavitongong
- The main fishing gears used in the region were spear-guns, hand-lines, and gill-nets
- The habitat types that had the highest CPUE values were open-water systems, deep water reefs and sea grass beds
- A high proportion of larger-bodied, more vulnerable reef fish species were captured as juveniles
- For many key fish families, fish destined for market sale were larger than those consumed by fishers and their dependents

From the catch-and-effort data, it is clear that Kavieng District supports diverse fisheries, which includes a variety of reef fish species. Data collection from the thirteen communities also indicated differences in how each community relied on their marine resources. Across all thirteen sites, the mean CPUE was 1.28 kg/person/hr, which is lower than the outcomes from similar studies conducted in the Pacific region. Due to the lower CPUE values, it is apparent that many reef fisheries around Kavieng District could be under pressure due to increasing rates of fishing activity.

Concerning gear types, some of the highest CPUE values were from fishers that used spear-guns. Spear-guns are efficient at targeting surgeonfish, rabbitfish and parrotfish, which graze on algae growing on the reef. The removal of algal grazers, such as through increased spear-gun usage, could lead to a shift from a coral-based habitat to an algae-dominated system; a phenomenon that could occur around Kavieng District if the current trends of fishing effort 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 thirteen communities, implementing such management methods requires the support of the whole community.

Although there was much variation in the data that was collected at each community during the four waves of data collection, there was a general increase in average CPUE values eight of the thirteen communities. There was also a large increase in CPUE from wave three of data collection through to wave 4, following the deployment of the FADs and the implantation of the fisheries management plans. Despite this, there was not a major increase in open water species biomass in the combined fish catches for each wave. This could be due to the recent deployment of the FADs, which did not give enough time for

It would be expected that there would be an increase in the number of pelagic fish species in the catch data from wave 3 to wave 4 of the surveys. However, the total fish catch biomass values for open water species did not vary too much across all four waves. Considering that the FADs were only introduced in 2018, it is possible that community fishers have not had sufficient time to make the transition from relying on reef-associated fish species to FAD caught open water fish. Accordingly, it is anticipated that the proportion of pelagic fish would increase during future waves of catch-and-effort data collection at all thirteen sites.

In short, the outcomes in this report indicate that more vulnerable reef fish species could be susceptible to localised population declines due to increased levels of recruitment overfishing.

Glossary of terms

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 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.

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.

Bivalve: Species that belong to a large class of aquatic molluscs that have a laterally flattened body and a hinged pair of shells. Bivalves are sedentary and use their gills for both gas exchange and extracting food particles from the water column. Bivalves include clams, mussels, cockles, oysters and scallops.

Carapace: A hard outer shell that protects certain marine animals, such as prawns, lobsters and turtles.

Carnivore: An animal that consumes other animals.

Cephalopod: Representatives of the class of molluscs that included the nautilus, cuttlefish, squid, octopuses and extinct ammonites. Cephalopods are predaceous carnivores that have an advanced brain, nervous system and eyes (which support retinas); the nervous system also controls skin colour changes, which are thought to provide a form of communication.

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.

Coefficient: A number or other known factor by which a variable quantity is multiplied.

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. Over 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 each eco-region.

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

Decapod: An order of crustaceans that are found mostly in marine or freshwater habitats. All have five pairs of walking legs, the first pair of which can be modified to form pincers. Following fertilisation by the males, the females usually carry the eggs until they hatch. Includes shrimps, prawns, crabs, crayfish, lobsters and woodlice (woodlice are terrestrial).

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

Exclusive economic zone: An area prescribed by the United Nations Convention on the Law of the Sea, 1982, allowing coastal states to assume jurisdiction over the exploration and exploitation of marine resources in the adjacent continental shelf up to 200 nautical miles from the national shoreline.

Family: In biological classification, the taxonomic group above genus; families are used to group organisms that belong to similar or closely related genera.

Fish aggregating device: 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.

Free, prior, informed consent: The collective right of the people within a community to give or with-hold consent to all activities, projects, administrative measures, and policies that take place in the community, or impact the land, resources or livelihoods of customary landholders and communities.

Gastropod: Members of a large class of molluscs, which have a well-developed head with tentacles, a large flattened muscular foot for locomotion, and a conical or coiled shell that is twisted. Includes limpets, snails, whelks, conches, slugs, and sea slugs (slugs and sea slugs secondarily lost their shells).

Gear: Equipment for a particular task; in fishing, gears can include nets, hand-lines and spear-guns.

Gleaning: To gather; such as to gather edible invertebrates from an area of shallow reef.

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

Herbivore: An animal that consumes vegetation.

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

Juvenile: An immature stage during the life cycle 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.

Larva: The initial stage during the life cycle 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.

Life history: The series of biological events from birth through reproduction and death; includes the growth and maturation characteristics of a species.

Mangrove: Tropical evergreen trees and shrubs with aerial roots that form dense thickets along coastlines. One of the few plants to adapt to living in the marine environment.

Maturity: The stage when an organism is fully developed – an adult – and capable of reproduction.

Melanesia: A region of western Oceania, characterised by the darker skin pigmentation of the 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 often 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 over-exploitation where fish stocks are reduced to below sustainable levels. Occurs when more fish are caught than the population can replace through 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: Small, open water organisms that drift passively with the current of an ocean, sea or lake. Plankton form a key food source for other aquatic life. Includes phytoplankton (algae that photosynthesise) and zooplankton (small animals or larval animals that feed on phytoplankton).

Population: A group of individuals of the same species (or other taxonomic division) within a community or a given area. Various factors – including density, sex ratio, birth rates, death rates, immigration and emigration – influence the nature of a population.

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

Reptile: A group of cold-blooded vertebrate animals (with a backbone) that have scaly skins and usually lay shelled eggs. Includes turtles, tortoises, crocodiles, lizards and snakes.

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

Spawn: To lay 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 to spawn, usually at designated areas within the marine environment often at a time determined by the lunar cycle and associated influence of the tides.

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

Standard error: A measure of the statistical accuracy of an estimate.

Tenure: The ancestral rights to live in an area and to use the local land and coastal resources. Over 97% of Papua New Guinean land is held under customary ownership, through traditional tenure.

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

Trolling: To fish by dragging a lure through the water.

Yield: To produce or bear.

List of acronyms

CAE	Catch-and-effort
CCA	Community conservation area
CF	Community facilitator
CPUE	Catch-per-unit-effort
DFAT	Department of Foreign Affairs and Trade
EEZ	Exclusive Economic Zone
FAD	Fish aggregating device
FPIC	Free, prior, informed consent
L	Length
LLG	Local Level Government
LMMA	Locally managed marine area
MMC	Marine management committee
MPA	Marine protected area
NGO	Non-governmental organisation
PNG	Papua New Guinea
SE	Standard error
W	Weight
WCS	Wildlife Conservation Society

Foreword

Just below the equator – in the biologically rich waters of the Bismarck Sea – New Ireland forms one of the maritime provinces of Papua New Guinea. Surrounded by a number of smaller islands and a wealth of marine habitats, the coastal waters of New Ireland support an abundance and variety of flora and fauna, including up to seventy percent of all known hard coral species and as much as thirty-five percent of the world's documented reef fish species.

For millennia, human communities living around New Ireland Province have relied on their local marine resources for sources of protein and income, a trend that continues to today. Even so, many coastal habitats and locally important fish stocks are now threatened by rapid modernisation, human population growth, and the use of more efficient fishing methods. This emphasises the need to better understand local fisheries and fishing practices within the New Ireland region to enable the implementation of site-specific management methods at the community level.

Despite such threats, there is limited understanding of the status of many local fish populations at the community level in New Ireland Province. Indeed, it may come as a surprise that an area of such biodiversity and ecological importance remains poorly studied. However, considering the thousands of New Ireland residents that directly or indirectly depend on coastal resources, fishery assessments are necessary to enable the application of the best possible adaptive management approaches.

This report aims to assist the New Ireland Provincial Government, fisheries scientists and other stakeholders and policy makers in making sensible fisheries decisions at the artisanal level based on fisheries catch-and-effort data. Such data were obtained during four waves of catch-and-effort data collection at thirteen communities around Kavieng District, north-western New Ireland Province, from January 2019 to May 2019. The information and analysis presented in this report outlines major fishing trends for the 2019 data that were collected, and a summary of changes in fishing activity occurred over the last four years, during which fish aggregating devices (which can help relive fishing pressure in coral reef areas) were installed in the communities.

The data in this report could be used to inform coastal fisheries management decisions. Future fisheries catch-and-effort assessments and similar studies will be conducted during subsequent years to enable temporal catch-and-effort comparisons to be made among the thirteen communities around Kavieng District, which should assist with the safeguarding of local marine resources for future generations to utilise and enjoy.

1.0 Introduction

In tropical regions, coral reef fisheries support over 6 million residents, providing sustenance, livelihoods, income and other key services (Delany *et al.*, 2017; Hair *et al.*, 2019). In Papua New Guinea (PNG), 97% of all land and inshore waters are owned by communities through traditional tenure systems and customary land ownership, allowing coastal communities to access marine and inshore resources (Lam, 1998). However, recent population growth in the coastal zone, coupled with rising exposure to the cash economy, is placing pressure on near shore fisheries and coastal environments (Barclay & Kinch, 2013). To help manage marine resources, the Fisheries Management Act, 1998, included the potential to regulate area closures and catch restrictions for certain commercial species within PNG's Exclusive Economic Zone (EEZ) (Kumoru & Koren, 2007). Size limits, for example, included size restrictions on certain coral reef species, such as sea cucumbers, reef lobsters and groupers, which are profitable for export and can be exploited at the community level (Kinch *et al.*, 2008; McClanahan & Cinner, 2008). Despite this, there are few national or provincial-level regulations on small-scale artisanal or subsistence fisheries at the community level, which is how the majority of coastal Papua New Guineans harvest marine resources (Lam, 1998).

From 1960 to 2019, the population of PNG increased from 2 million to over 8.5 million people. The national population is expected to reach over 10 million by 2030 and as such the demand for coastal fisheries is expected to double (Bell *et al.*, 2015). In 2007, estimated coastal fisheries production for PNG was 35,000 tonnes, with 80% of all harvested fish originating from subsistence fisheries, while maximum coastal fisheries productivity was estimated at 98,760 tonnes per year. Recent studies indicate that a projected increase in fish demand of 169,100 tonnes by 2035 will not be met if appropriate fisheries management methods are not implemented, especially if the marine environment is degraded (Bell *et al.*, 2015). In New Ireland Province, 77% of the population lives within the coastal zone and are therefore reliant of marine resources for sustenance and livelihoods. The maritime province has experienced recent population growth: In 2002, there were 118,315 people in New Ireland, while in 2011 there were 194,067 people (PNG Census, 2011) – an 86% population increase in nine years, placing further pressure on inshore marine resources. Accordingly, the future extraction of fisheries resources in many coastal areas of PNG may not be sustainable, especially considering the projected threats of anthropogenic climate change (Bell *et al.*, 2013), underscoring the need to better understand the health of local reef fisheries.

The collection of fisheries catch-per-unit-effort data can be conducted at relatively low costs and has become a standard practice for both commercial fisheries (Richardson *et al.*, 2006; Klein *et al.*, 2008) and artisanal and subsistence fisheries in developing nations (Frijlink, 2018). Fisheries CPUE outcomes can: (i) assess local fishing pressure; (ii) provide information that can be compared spatially and temporally to demonstrate the status of inshore fisheries; (iii) identify trends in resource exploitation or recovery (Kuster *et al.*, 2006); and (iv) monitor the effectiveness of local fisheries management initiatives (Sugiyama, 2005). Long-term CPUE assessments – such as on a decadal timespan – may also indicate whether marine protected areas (MPAs), such as locally managed marine areas (LMMAs) or community conservation areas (CCAs), have enhanced local fisheries through increased recruitment or spill over (Russ *et al.*, 2004).

From January 2019 to May 2019 WCS worked with thirteen coastal communities around Kavieng District, north-western New Ireland Province, to collect detailed fisheries catch-and-effort (CAE) data in order to conduct CPUE analysis. Moreover, from late-2015 to 2018, three previous waves of CPUE data were collected, enabling temporal comparisons to be made. In 2018, subsurface fish aggregating devices (FADs) were deployed in eleven of the thirteen communities (three of the thirteen communities – Kavitongong, Sosson Ungalabu) comprise one ward, and as such one FAD was deployed in this region), which aim to transfer fishing effort from vulnerable coral reef fisheries to more resilient pelagic fish species (Figure 1). In addition, LMMAs were also set up in each community, with locally-elected marine management committees (MMCs) to enforce site-specific rules and penalties, allowing communities to manage their marine resources. Such management measures should help increase local ecosystem resilience, and improve regional fisheries recruitment.

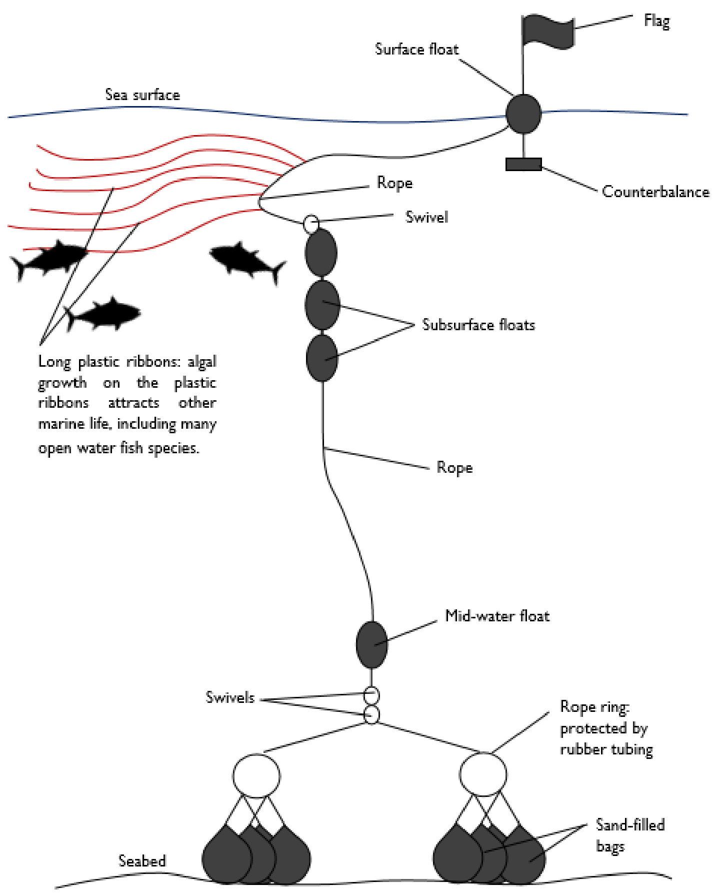

Figure 1: Typical structure of a subsurface fish aggregating device (FAD). Located in deeper waters, a FAD consists of a series of weights, ropes and floats, the upper region of which is positioned below the water's surface. Plastic streamers are attached to the upper region of the FAD, and are bathed in sunlight to enable the growth of algae. The algae provides a food source for bait fish, which open water fish species, such as tuna, predate on. The FAD thus creates an artificial open water habitat for fishers to target, transferring fishing effort from less resilient coral reef fisheries. (Image not to scale)

1.1 Objectives

The sub-objectives of this study have been grouped into two sections. Part I of the study assesses the data collected in 2019, while Part II compares the 2019 data with three former waves of data that were collected in 2015-16, 2017 and 2018, respectfully, to detect whether the deployment of the FADs has altered fishing effort in each of the thirteen communities.

The sub-objectives of this study are to assess:

I. The diversity of harvested species
II. The relative importance of harvested species and families
III. The relative proportions of harvested and marketed catches
IV. The relative preferences of different fishing methods and habitats
V. Changes in fishing effort following the deployment of the FADs in each community

2.0 Materials and methods

2.1 Study region

Located in the eastern region of the Coral Triangle and Western Pacific Ocean, Papua New Guinea (PNG) is the largest independent nation of Melanesia. To the north and north-east of mainland PNG lie five island provinces and many smaller islands, including New Ireland Province. Forming the northern boundary of the Bismarck Sea, mainland New Ireland and the adjacent smaller islands lie 280 km east of Manus Province and 340 km north-east of Madang. The southern coastline of New Ireland forms part of the Bismarck Seascape, one of the most biologically-enriched areas of the Coral Triangle; to the north of the province lies the Pacific Ocean (Figure 2). Formed by recent tectonic activity, the rugged limestone terrain of New Ireland supports rainforest and low-lying tropical vegetation. The New Ireland shoreline includes areas of sandy beach, uplifted reefs and mangroves, while the inshore waters are characterised by shallow seas that drop off into deeper water. To the west of mainland New Ireland is the island of Lavongai, and many small communities inhabit islands and atolls to the north-east and north-west of Lavongai. Between Lavongai and mainland New Ireland are the Tigak Islands, which are separated by mangroves, sheltered lagoons, coral reefs and sea grass beds.

In 2011, the population of New Ireland Province was 194,067 and spoke 22 distinct languages. Lavongai and the adjacent smaller islands form part of the Lavongai Local Level Government (LLG), while the Tigak Islands are part of the Tikana LLG. Table 1 includes some of the major geographical and demographic details of New Ireland Province. Since 2015, thirteen coastal communities in Kavieng District (western New Ireland Province) agreed to take part in a number of marine management initiatives, facilitated by the Wildlife Conservation Society (WCS), including the collection of catch-and-effort (CAE) data, the deployment of subsurface fish aggregating devices (FADs), and the establishment of locally managed marine areas (LMMAs). These communities were: (i) Limanak, (ii) Nonovaul, (iii) Salapiu, (iv) Bangatan and (v) Tugalop in the Tikag Islands; (vi) Kavulik, (vii) Ungakum, (viii) Kulibang, (ix) Mamion and (x) Tsoilik in the Tsoi Island chain that lies to the north-east of Lavongai; and (xi) Kavitongong, (xii) Sosson and (xiii) Ungalabu, which are located in the Ungalabu Harbour on the north western coast of Lavongai (Figure 1). The three small island communities in north-west Lavongai (Kavitongong, Sosson and Ungalabu) comprise one ward and are geographically within close proximity to each other. Accordingly, one fisheries management plan was developed for all three communities, and one FAD was deployed in the area for fishers to use. In addition, only one LMMA was established for all three communities.

Table 1: Total land and sea areas for New Ireland Province, Papua New Guinea, as well as information concerning the regional demographics for the province, according to data presented in the 2011 National Population and Housing Census.

Total land area	Total sea area	Total population	Population density	Total males	Total females	Total households
9,557km^2	230,000km^2	194,067	23 people per km^2	102,494	91,573	29,634

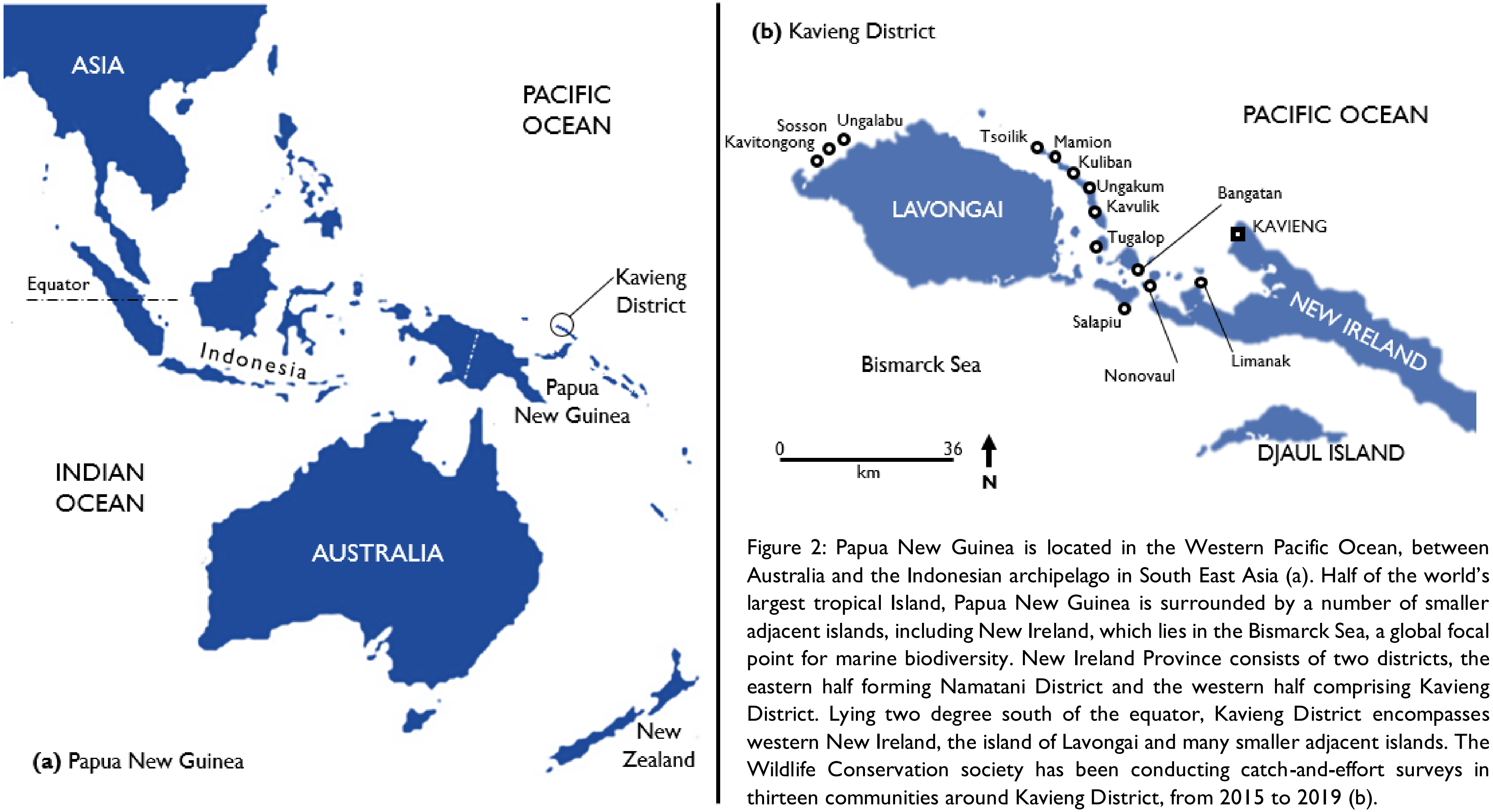

Figure 2: Papua New Guinea is located in the Western Pacific Ocean, between Australia and the Indonesian archipelago in South East Asia (a). Half of the world's largest tropical Island, Papua New Guinea is surrounded by a number of smaller adjacent islands, including New Ireland, which lies in the Bismarck Sea, a global focal point for marine biodiversity. New Ireland Province consists of two districts, the eastern half forming Namatani District and the western half comprising Kavieng District. Lying two degree south of the equator, Kavieng District encompasses western New Ireland, the island of Lavongai and many smaller adjacent islands. The Wildlife Conservation society has been conducting catch-and-effort surveys in thirteen communities around Kavieng District, from 2015 to 2019 (b).

2.2 Data collection

The catch-and-effort data used in this report were collected from all thirteen communities between January 2019 and May 2019. A further three waves of catch-and-effort data were collected in 2015-2016, 2017 and 2018. The 2015-2016 data were collected at ten communities while the 2017 to 2019 waves of data were collected at thirteen communities (Kavitongong, Sosson and Ungalabu joined the WCS projects in 2017). CAE surveys require catch information (such as scientific, common and local names of the species caught, as well as animal length measurements (in centimetres), and details concerning how the fish catch will be utilised) and effort information (including a description and location of the fishing area, the number of fishers involved, fishing methods used, and transport modes to and from the fishing sites). Data collection at each site was carried out daily for two weeks during the five month period by community facilitators (CFs) stationed at each site (see Appendix III for the dates of data collection). Data were acquired by intercepting fishers as they returned from their fishing trips upon the fishers' consent.

Length measurements for finfish (including sharks) involved measuring from the tip of the snout to the middle of a forked-tail or end of a rounded-tail, depending on the morphology of fish species. Crustacean length was quantified by measuring across the width of the carapace for crab species, or length of the carapace for lobster species (lobster total body length was not recorded during this survey). For conical gastropods, such as trochus snails, length measurements were obtained by measuring the basal diameter of the shell; for other molluscs, such as bivalves and cephalopods, length was recorded along the longest axis the animal (for squid and octopuses, the longest axis included the extended tentacles, rather than body – also known as mantle – length). For rays, the total disc length was taken by measuring across the breadth of the body, while for turtles, total shell length was recorded (Figure 3).

At each site, the CFs used a 100 cm fish measuring board to collect length data. For fish identification, the following fish taxonomy books were used: *Identification guide to the common coastal food fishes of the Pacific Islands region* (Moore & Colas, 2016); *Marine fishes of tropical Australia and South-East Asia* (Allen *et al*., 2002); and *Reef fish identification: Tropical Pacific fishes* (Allen *et al*., 2003). Separate laminated identification cards were developed for invertebrate identification. Where possible handheld digital cameras or Smartphones were employed to capture images of unknown species for later identification.

When a fisher returned from a fishing trip, the fish catch was grouped into taxonomic families; once grouped, the different animals were identified to family and species level (scientific, common and – where possible – names in the local vernacular were obtained) and counted. For the catch data, individual counts for each species were recorded; however, if the count exceeded twenty animals, a sample of the first twenty animals – selected at random – were measured (although the total number of individuals was recorded on the datasheet). All species that were represented by less than twenty individuals in each catch were measured and recorded.

For the effort data component, the following information was collected:

- Duration of fishing trip: The amount of time spent on the fishing trip, plus travel time to and from the fishing site to calculate actual time spent fishing.
- Habitat type fished: To gain insight into which habitats receive the most fishing pressure.
- Fishing method: When more than one fishing method was used, fishers were asked to indicate the relative time allotted to each fishing activity.
- Number of fishers: When multiple people were involved during a single fishing trip, the data collector ascertained whether each person was actively involved in using different fishing gears. If they were, the amount of fishing effort was multiplied by the number of active fishers.

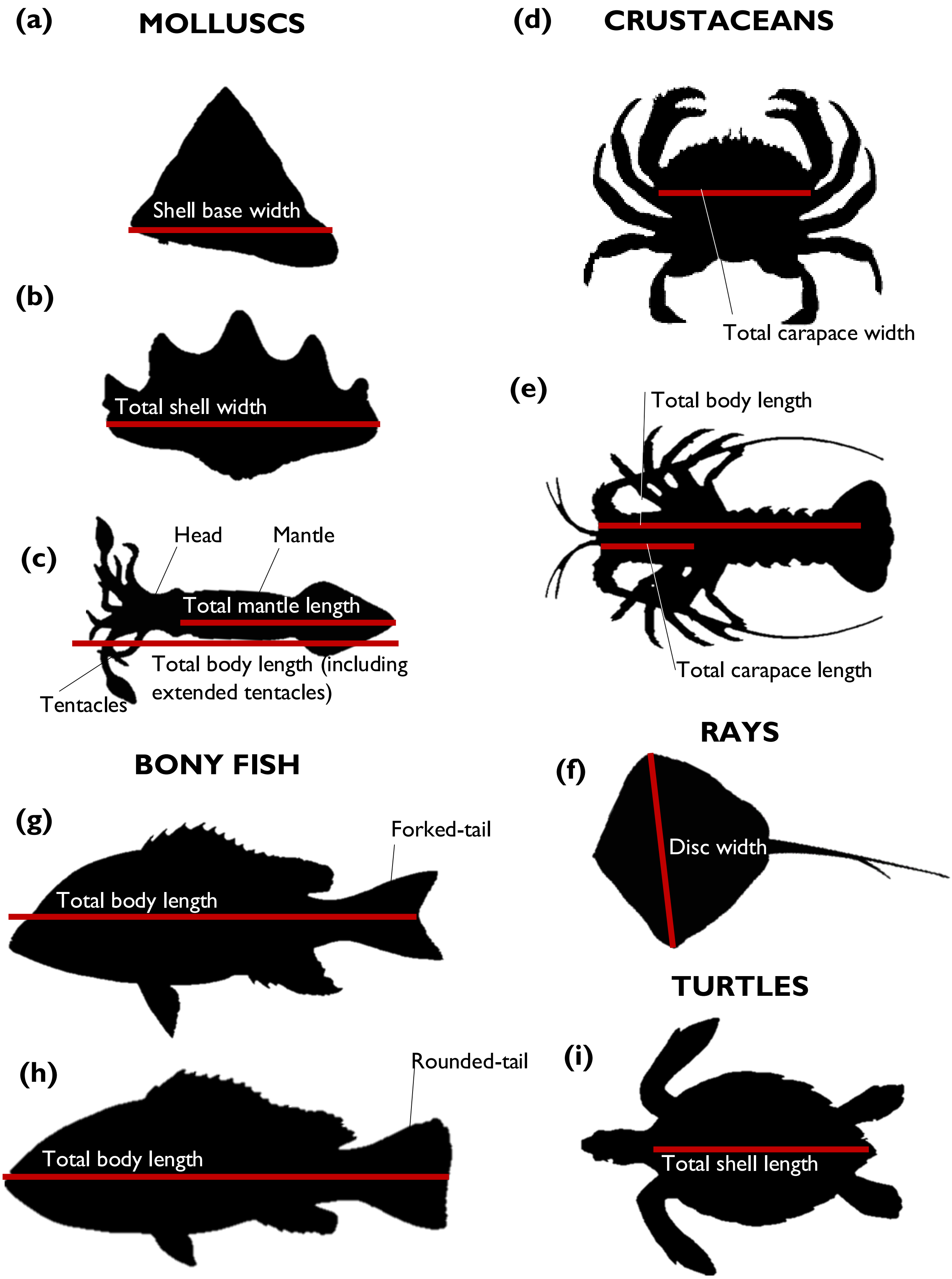

Figure 3: Approaches for measuring different marine organisms typically targeted by communities around New Ireland Province, Papua New Guinea. Examples include: Molluscs: (a) trochus snails, (b) giant clams and other bivalves, (c) squid and other cephalopods; crustaceans: (d) crabs, (e) lobsters and crayfish; cartilaginous fish: (f) rays (sharks are measured in the same manner as bony fish); bony fish: (g) fish with forked-tails, (h) fish with rounded-tails; and reptiles: (i) turtles.

- Net details: When nets were used, the number of nets, plus their length, depth, mesh sizes and soak times were recorded.
- Method of transport to the fishing site: To gain insight into the most common transport modes used by local fishers.

2.3 Data analysis

The biomass of each finfish individual was calculated using the recorded length (*L*) measurements of each individual animal, along with published values obtained from *Fishbase* (Froese & Pauly, 2009) in the standard length-weight (*L-W*) expression

$$W = aL^b$$

with *a* and *b* coefficient parameter values selected from sites closest to Papua New Guinea. If no length-weight conversion factor was available for the species, the parameters for a species of similar morphology in the same genus was used (Jennings & Polunin, 1996). Invertebrate and turtle biomass was not calculated due to the lack of accessible parameter values for each species; accordingly, catch-per-unit-effort (CPUE) could not be calculated for invertebrates or turtles. Biomass was converted to kilograms (kg) and CPUE (kg/person/hr) was calculated by dividing total catch weight by the number of active fishers by the number of hours spent fishing. For gillnet usage, CPUE was expressed as the weight of fish (kg) that were harvested per $1m^2$ of fishing net per hour of net deployment (also known as soak time).

Comparisons of CPUE and fish biomass data, collected during all four waves of data collection, were made, which included assessing changes in the proportion of pelagic fish species compared to reef associated fish species across all sites before and after the deployment of the fish aggregating devices (FADs). Because of the variability among the number of fishing trips at each community across each wave of data collection, the data were not normalised so a non-parametric test was conducted on the data using *R* version 3.5.2. A Kruskall-Wallis Rank Sum test was performed on the data to determine any significant differences between all four waves of data collection.

2.4 Limitations and constraints

Only two weeks were allocated to collecting catch-and-effort data within each community, resulting in a limited timeframe for intercepting fishers (see Appendix III for a list of the dates of data collection). Poor weather conditions and other events within each community – including community deaths – led to delays and a reduction in local fishing activity. Not all communities regularly go fishing; for example, Kavulik Island is surrounded by mangroves that supply shellfish and crabs for residents to collect regularly. There were only a small number of data collectors, and there were some uncertainties regarding fish and invertebrate identification. It was not possible to obtain biomass parameter values for invertebrates or marine turtles, preventing CPUE analysis from being conducted on invertebrate or turtle catches. There was some hesitation among local fishers, regarding the data collection procedures and why the data were being collected; further instructions and assurance from the data collectors helped to alleviate any concerns. During the first three waves of data collection, incentives were given to community fishers to encourage community participation; in 2019, no incentives were given, which could have influenced the data that were collected.

3.0 Results

PART I: Outcomes from the 2019 study

3.1 Sampling summary

For the 2019 dataset, a total of 558 fishing trips were intercepted across all thirteen communities, which encompassed a total of 10,359 individual animals that were captured and sampled. The majority (90%) of all the sampled animals were finfish (9,310 in total). Table 2 outlines the number of fishing trips that were intercepted during the 2019 survey at all thirteen communities, and the different organisms that were sampled, including the number of families and species' measured. Figure 4 presents the number of finfish caught at each community in 2019. For a breakdown of all the fish families that were sampled, and details concerning the number of species from each family that were measured, refer to Table 3.

Across all sites, 770 fishers spent a total of 1,568.84 hours fishing. The communities that had the lowest number of intercepted fishing trips were Kulibang (a total of 26 trips), Bangatan (28 trips), and Kavitongong (28 trips). In contrast, the island communities of Tsoilik (101 fishing trips), Salapiu (57 trips) and Sosson (55 trips) provided the most opportunities to intercept fishers. The pooled data revealed that the sites with the highest number of fishers were the island communities of Tsoilik (131 fishers), Sosson (87 fishers), and Mamion (80 fishers). The communities with the lowest number of intercepted fishers were Limanak (30 fishers), Kavulik (33 fishers), and Kulibang (37 fishers). The highest number of total fishing hours per site came from Tsoilik (276 fishing hours), Salapiu (234 hours), and Ungakum (166 hours). The lowest number of pooled fishing hours came from Bangatan (54 hours), Ungalabu (67 hours) and Mamion (79 hours) (Table 4).

3.2 Catch-per-unit-effort results by community and habitat type

In 2019, across all thirteen communities, the average catch-per-unit-effort (CPUE) was 1.28 kg/person/hr. The highest CPUE value was from Ungalabu (n=32), which had a mean CPUE of 3.66 kg/person/hr. In contrast, the lowest average CPUE value was at Tsoilik (n=101), yielding 0.61 kg/person/hr. Mamion, Sosson and Nonovaul also had high CPUE values, while Tugalop, Salapiu and Ungakum had low CPUE. (Figure 5). Total biomass of captured fish also varied at each site. All sites harvested less than 500kg of finfish during the study. The sites with the highest catch biomass were Bangatan (487kg), Tsoilik (469kg), and Sosson (293kg). The lowest catch biomass outcomes were for Kavulik (18kg), Kulibang (79kg) and Limanak (134kg) communities (Table 4 includes the sample size for each site).

Table 2: Summary of the catch-and-effort data that was collected at thirteen coastal communities around New Ireland Province, Papua New Guinea. The data were collected between January 2019 and May 2019. (*Invert = invertebrates).

Fishing trips	Animals	Fish	Fish families	Fish species	Inverts*	Invert* families	Invert* species
558	10,359	9,310	30	270	1,049	13	14

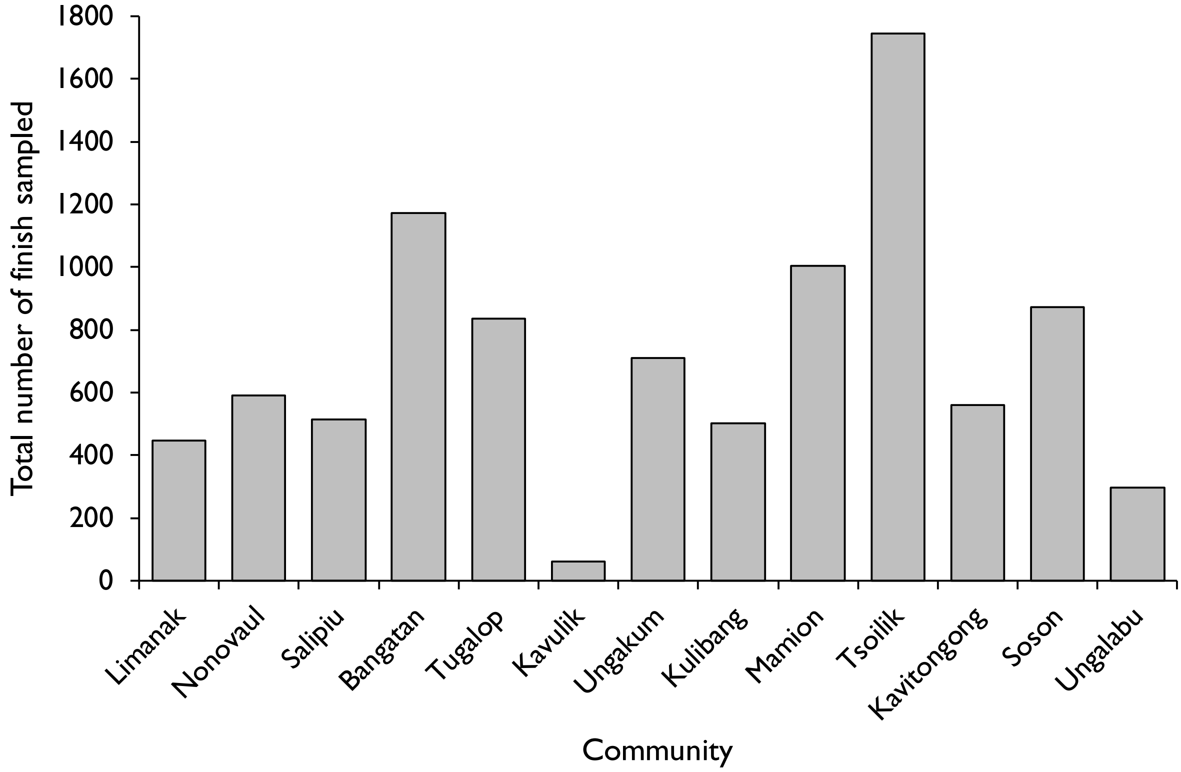

Figure 4: The total number of fish that were sampled in each community during the catch-and-effort data collection.

During the 2019 catch-and-effort data collection, fishers were asked to describe the main habitat type in which they went fishing. The various habitat types were grouped into six categories: (i) shallow coral reef areas (*n*=262), (ii) deep coral reef areas (*n*=56), (iii) sea grass beds (*n*=112), (iv) sand flats (*n*=58), (v) open water (*n*=8), and mangroves (*n*=5). According to habitat type, the highest combined mean CPUE values were from areas of open water (2.65 kg/person/hr) and regions of deep coral reef (2.15 kg/person/hr). The lowest pooled mean CPUE values for habitat type were from mangrove areas (0.76 kg/person/hr) and sand flats (1.06 kg/person/hr). The mean CPUE values for habitat type are presented in Figure 7a.

Catch biomass also varied across the different habitat types. The largest combined catch biomass came from open water environments (an average of 7.86kg across all trips). The lowest catch biomass came from mangroves (with a combined average of 3.92kg) and sand flats (with a mean of 3.71kg across all communities). Figure 7b provides the total finfish biomass for all thirteen communities for each habitat type.

3.3 Catch-per-unit-effort results for transport and gear type used

In 2019, across all thirteen sites, four main methods of accessing fishing grounds were used: (i) by motor boat (*n*=20), (ii) by canoe (*n*=354), (iii) by walking (*n*=106), and (iv) by swimming (*n*=24). (For convenience, throughout this report, all four methods will be referred to as modes of transport). The fishers that travelled to a fishing ground by motor boat had the highest combined mean CPUE

Table 4: The total number of individual fish species from all the taxonomic families that were sampled during catch-and-effort data collection at thirteen communities around New Ireland Province, Papua New Guinea (including the total number of families, and the total number of individual organisms from each family). The data were collected between January 2019 and May 2019. The families are arranged in taxonomic order; phyla and classes are also included as well as the common names of each family. The thirteen communities have been arranged geographically: Limanak, Nonovaul, Salapiu, Bangatan, and Tugalop are in the Tigak Islands, which lie between the New Ireland mainland and the island of Lavongai. Kavulik, Ungakum, Kulibang, Mamion and Tsoilik are all in the Tsoi Island chain, which lies to the north-east of Lavongai; Kavitongong, Sosson and Ungalabu are three small island communities that form one ward of the north-west of Lavongai. Table 4 continues over the next two pages.

TAXONOMIC CLASSIFICATION					TOTAL NUMBER OF INDIVDUALS BY SITE												
PHYLUM	CLASS	FAMILY	FAMILY COMMON NAME	TOTAL NUMBER	Limanak	Nonovaul	Salapiu	Bangatan	Tugalop	Kavulik	Ungakum	Kulibnag	Mamion	Tsoilik	Kavitongong	Sosson	Ungalabu
		Carcharhinidae	Requiem sharks	4	-	1	-	-	-	-	-	1	-	1	1	-	-
	Chondrichthyes	Urolophidae	Stingarees	2	-	-	-	-	-	-	-	-	-	1	-	-	1
		Dasyatidae	Sting rays	9	-	-	-	-	1	-	1	-	1	2	1	1	2
		Belonidae	Garfishes	87	5	4	50	1	4	-	5	-	6	3	2	6	1
		Hemiramphidae	Needle fishes	7	-	-	-	-	4	-	1	-	1	-	1	-	-
		Holocentridae	Soldier fishes	76	2	9	49	1	1	-	2	1	-	5	4	2	1
Chordata		Serranidae	Groupers	200	3	18	19	5	25	1	39	4	11	35	5	-	35
		Terapontidae	Grunters	1	-	-	-	-	-	-	-	-	1	-	-	-	-
	Actinopterygii	Carangidae	Trevallies	369	70	25	18	8	47	1	69	-	36	42	7	35	11
		Lutjanidae	Snappers	636	159	45	54	20	17	4	38	21	26	93	61	62	36
		Haemulidae	Sweetlips	90	1	9	6	3	14	3	22	2	8	1	-	5	16
		Caesionidae	Fusiliers	3	-	-	3	-	-	-	-	-	-	-	-	-	-
		Lethrinidae	Emperors	1,724	89	214	86	115	86	7	36	80	144	543	171	123	30
		Sparidae	Breams	3	-	-	-	3	-	-	-	-	-	-	-	-	-

TAXONOMIC CLASSIFICATION					TOTAL NUMBER OF INDIVIDUALS BY SITE												
PHYLUM	CLASS	FAMILY	FAMILY COMMON NAME	TOTAL NUMBER	Limanak	Nonovaul	Salapiu	Bangatan	Tugalop	Kavulik	Ungakum	Kulibang	Mamion	Tsoilik	Kavitongong	Sosson	Ungalabu
Chordata	Actinopterygii	Nemipteridae	Breams	56	7	15	5	-	-	-	-	3	4	15	1	2	4
		Gerreidae	Biddies	753	-	2	-	247	122	4	20	102	93	49	31	83	-
		Mullidae	Goatfishes	507	1	9	14	7	10	-	5	64	283	48	4	51	11
		Monodactylidae	Diamond fishes	3	-	-	-	-	-	-	-	-	3	-	-	-	-
		Kyphosidae	Drummers	25	1	4	1	5	2	4	12	-	-	-	-	7	4
		Scatophagidae	Scats	6	3	-	3	-	-	-	-	-	-	-	-	-	-
		Chaetodontidae	Butterfly fishes	3	-	-	1	-	-	-	-	-	1	1	-	-	-
		Pomacentridae	Damsel fishes	62	14	15	23	-	-	-	5	2	1	-	1	-	1
		Mugilidae	Mullets	836	2	20	6	226	201	-	40	11	26	1	130	170	3
		Sphyraenidae	Barracudas	26	7	2	-	-	9	-	-	-	-	-	-	4	4
		Labridae	Wrasses	137	16	5	10	19	3	4	10	10	6	34	9	7	4
		Scaridae	Parrotfishes	576	-	8	31	41	53	1	95	11	21	174	1	69	44
		Ephippidae	Batfishes	6	1	-	1	-	1	2	1	-	-	-	-	-	-
		Siganidae	Rabbitfishes	2,390	66	165	65	427	172	13	66	151	292	547	171	229	26
		Acanthuridae	Surgeonfishes	591	1	19	46	30	47	14	219	14	30	124	-	3	44
		Scombridae	Tunas	24	-	-	2	6	10	-	-	1	-	-	-	-	5
		Balistidae	Triggerfishes	125	-	2	6	10	3	3	22	26	11	29	1	-	12
		Ostraciidae	Boxfishes	1	-	-	-	-	-	-	-	-	-	-	-	-	1

Table 5: Overview of the number of intercepted fishing trips, the number of fishers, and the number of fishing hours from each of the thirteen communities. The average length (hours) of individual fishing trips (±SE) are also provided for each community.

Community	Total number of fishing trips	Total number of fishers	Total number of hours fishing	Average fishing trip length in hours (±SE)
Limanak	30	31	106.66	3.56 (±0.64)
Nonovaul	35	39	112.37	3.21 (±0.56)
Salapiu	57	63	234.03	4.11 (±0.37)
Bangatan	28	62	54.48	1.95 (±0.24)
Tugalop	40	49	117.75	2.94 (±0.23)
Kavulik	33	32	124.88	3.78 (±0.48)
Ungakum	50	73	165.84	3.46 (±0.25)
Kulibang	26	37	45.75	1.44 (±0.28)
Mamion	41	83	78.98	2.13 (±0.38)
Tsoilik	102	132	276.12	2.73 (±0.17)
Kavitongong	28	40	84.32	3.01 (±0.71)
Sosson	55	85	100.31	1.82 (±0.14)
Ungalabu	33	49	67.33	2.10 (±0.22)
TOTAL	558	775	1568.82	2.79 (±0.23)

(11.89 kg/person/hr) across all sites. In contrast, swimming yielded the lowest average CPUE for all fishers from all sites (1.72 kg/person/hr). For the combined mean CPUE values from all sites, see Figure 8a.

Travelling by motor boat also resulted in the highest combined mean fish catch biomass (2.12 kg) across all sites. In contrast, swimming resulted in the lowest mean fish biomass across all thirteen communities (1.11 kg). Concerning total finfish biomass, travelling by canoe resulted in the highest total fish catch biomass (1,793 kg), while swimming (41 kg) and travelling by motor boat (238 kg) resulted in the lowest total fish catch biomass across all the communities (Figure 7b).

Across all thirteen study sites, six major gear types were used: (i) hand-lining (n=100 trips), (ii) trolling (n=11), (iii) spear (including hand spears and spear-guns) fishing (n=154), (iv) dive fishing for invertebrates (n=76), (v) fishing with nets (n=146), gleaning (n=19), plus other types of fishing methods (n=5). The combined average CPUE values for spear-gun fishing (2.79 kg/person/hr) and dive fishing (2.44 kg/person/hr) provided the largest CPUE across all thirteen communities. In contrast, the use of gill-nets (0.23 kg/person/hr) resulted in the lowest mean CPUE values from the combined datasets (Figure 8a).

Concerning total catch biomass for each gear type, gill-net usage (1,178 kg), spear-gun usage (694 kg), and dive collecting (374 kg) provided the highest catch biomass across all the communities. In contrast, trolling yielded a catch biomass of 80 kg, and other types of fishing yielded only 14 kg of finfish (Figure 8b).

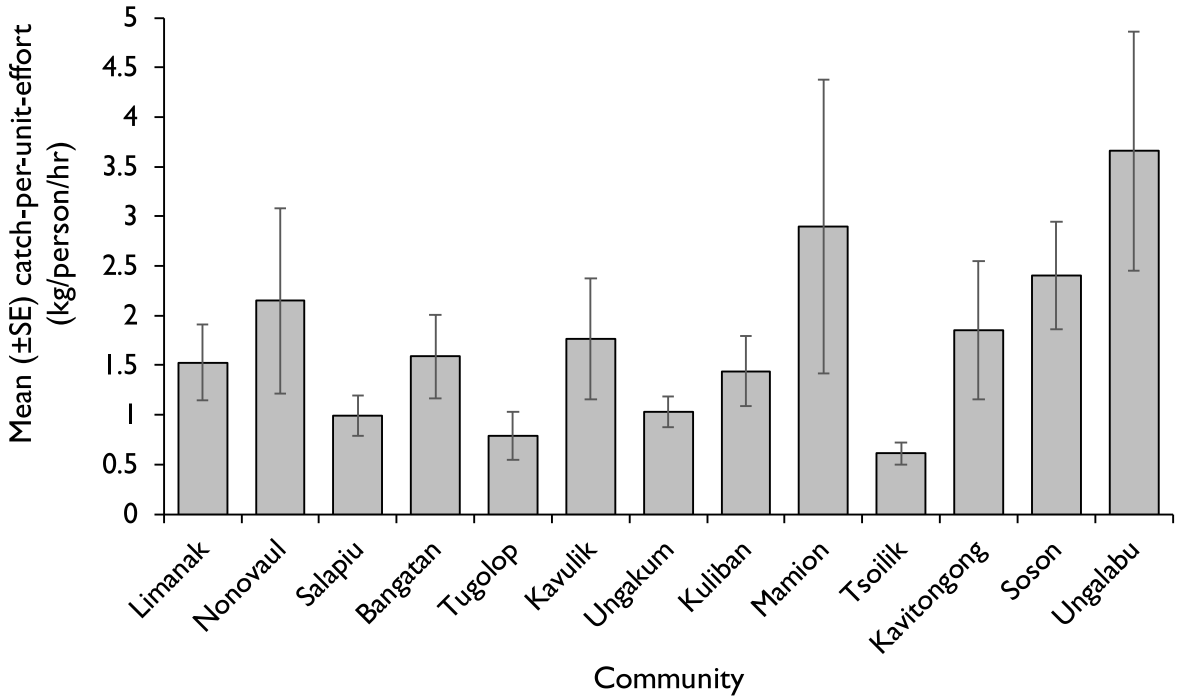

Figure 5: Mean (± SE) catch-per-unit-effort (kg/person/hr) for all thirteen communities around Kavieng District, New Ireland Province, Papua New Guinea.

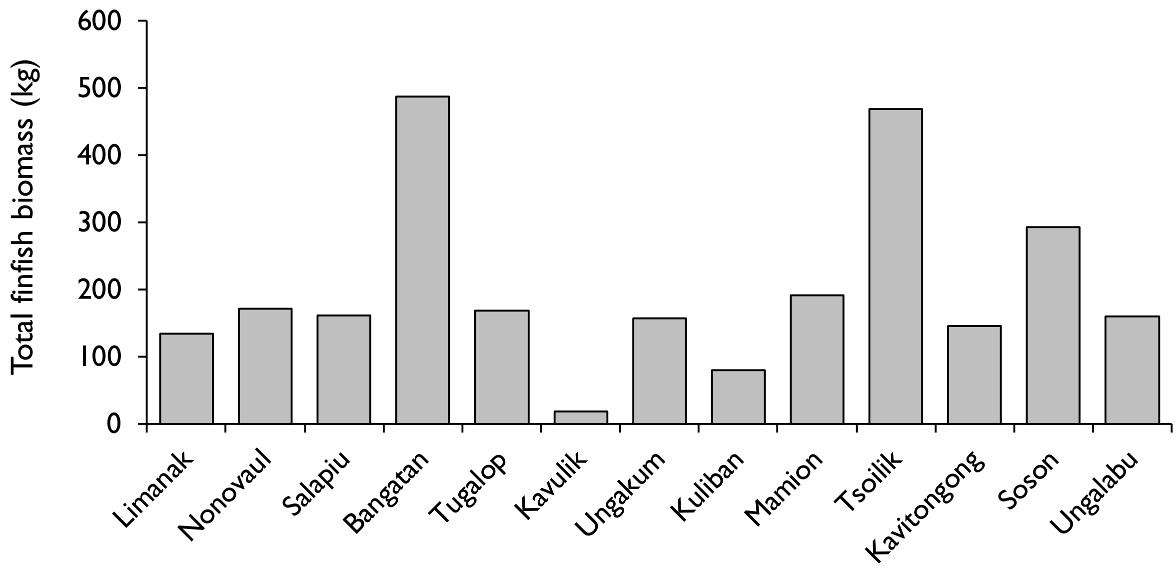

Figure 6: The total finfish biomass (kg) that was sampled in thirteen communities around Kavieng District, New Ireland Province, Papua New Guinea. The data were collected between January 2019 and May 2019.

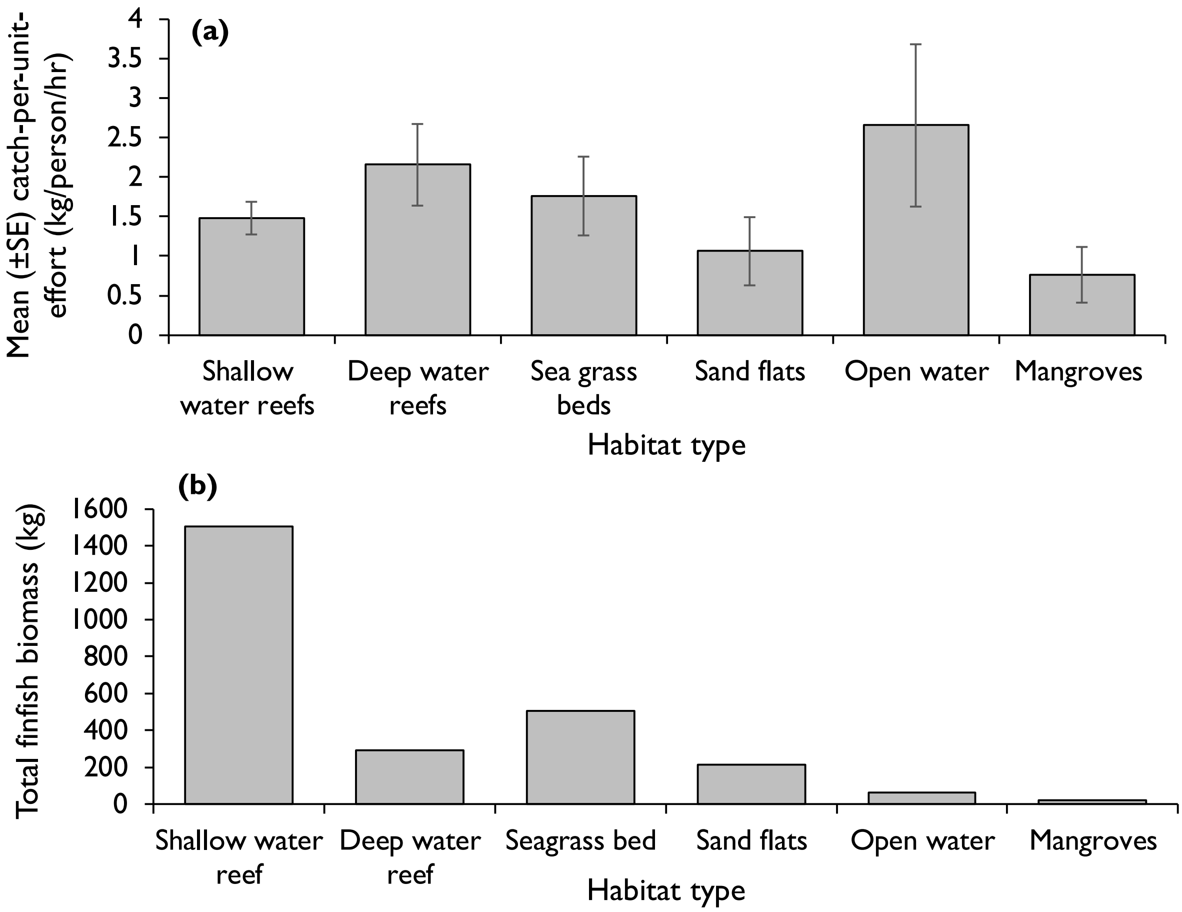

Figure 7: (a) The mean (± SE) catch-per-unit effort (kg/person/hr) values for different habitat types. (b) The total biomass (kg) of fish that were caught in each habitat type area.

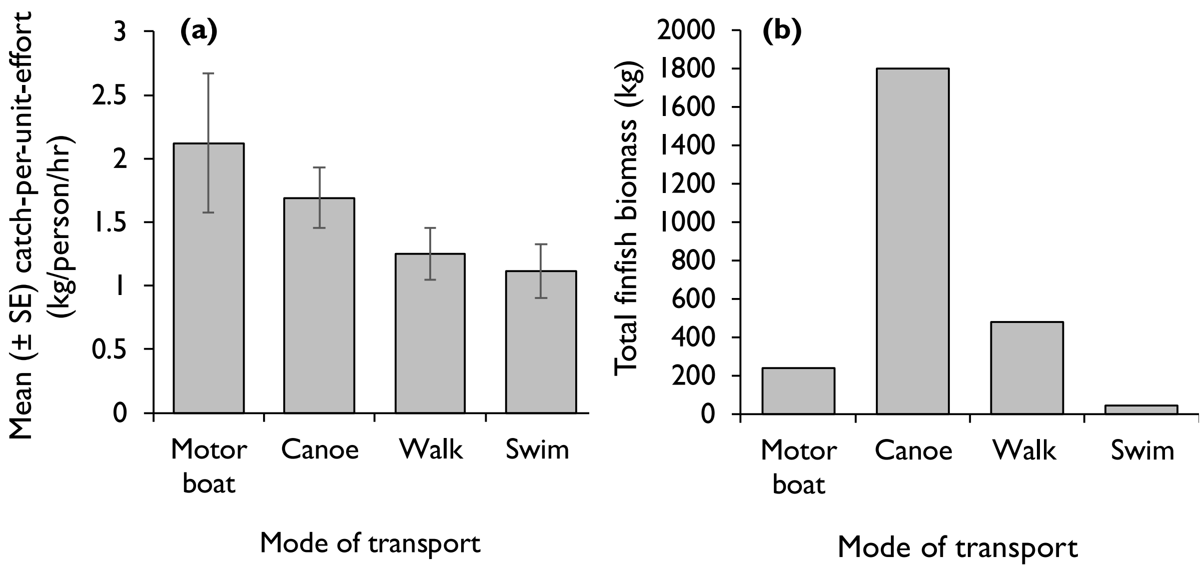

Figure 8: (a) The mean (± SE) catch-per-unit effort (kg/person/hr) values for different transport types, including walking and swimming. (b) The total biomass (kg) of fish that were caught during fishing trips via the different modes of transport.

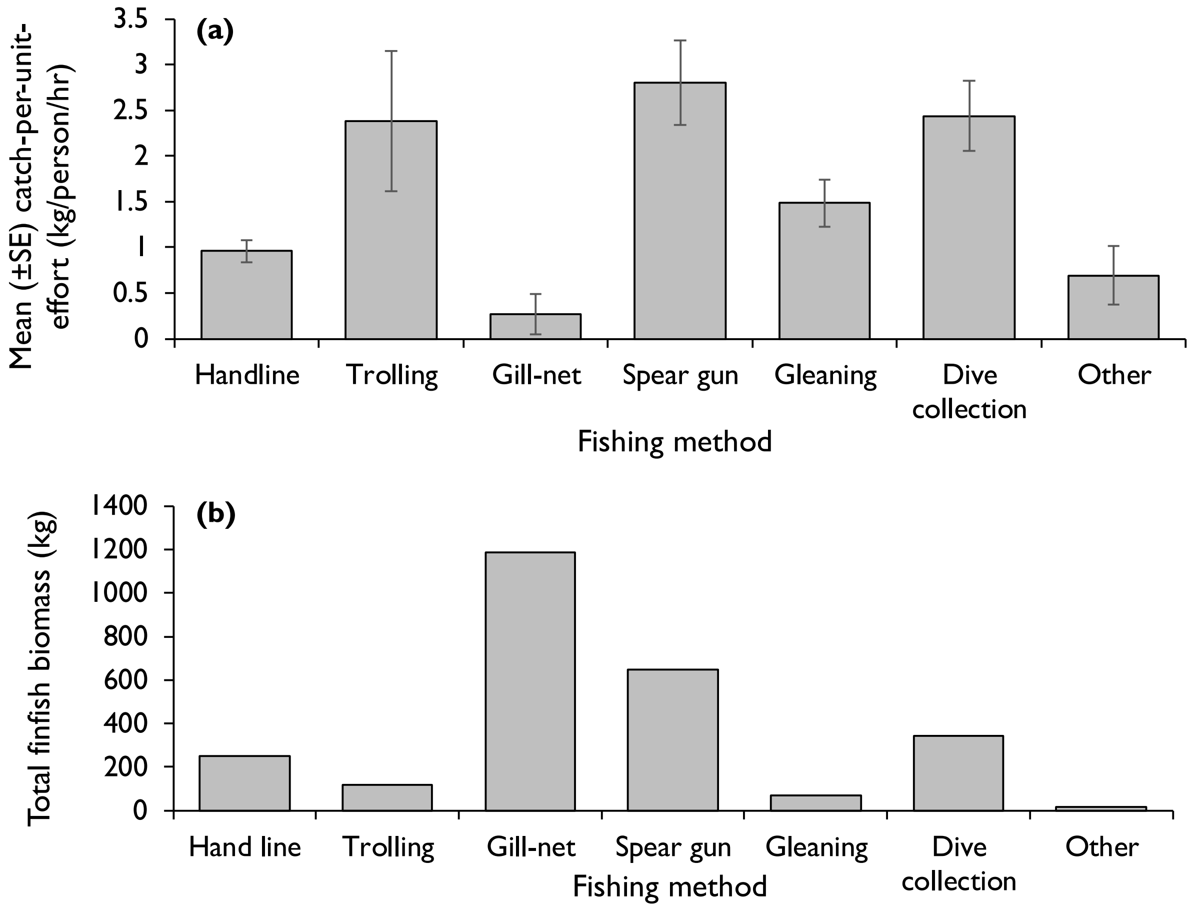

Figure 9: (a) The mean (± SE) catch-per-unit effort (kg/person/hr) values for different fishing methods that were used. (b) The total biomass (kg) of fish that were caught during the fishing trips, according to the different methods that were used. The data were collected from thirteen sites around Kavieng District, New Ireland Province, Papua New Guinea. The data were collected from January 2019 to May 2019.

3.4 Catch utilisation

The fishers who took part during the catch-and-effort data collection stated that the fish they caught were to be utilised in three main ways: (i) for home consumption (*n*=4,158 of the fish that were sampled), (ii) for market sales (*n*=6,168), and (iii) for trade (*n*=77). In addition, three fish were destined to be used as bait, and the future use of 30 more fish was unknown. To determine whether the fish sold at market were larger than fish destined for home consumption, the average fish lengths of ten key fish families were calculated. The fish families included reef fish and pelagic fish groups, which were among the most abundant across all thirteen sites.

Table 5 presents the number of fish from all thirteen sites that were destined for either home consumption, market sales, or for trade; the average lengths of each captured fish group are also included. Even though the majority of fish (51%) were to be sold at market, for five of the ten fish families, the larger sized individuals were consumed at home. Figure 10 presents the average lengths of fish destined for home consumption and fish intended for market sale. Five of the fish families were, on average, larger when sold at market than those eaten at home; however, more of the larger lethrinids (emperors), lutjanids (snappers), mugilids (mullets), mullids (goatfish) and serranids (groupers) were eaten at home, rather than sold at market (Figure 10).

3.5 Catch by fish family

Certain fishing gears typically target particular fish families. For example, it is unlikely that many herbivorous fish, including siganids (rabbitfishes), scarids (parrotfishes) and acanthurids (surgeonfishes and unicorn fishes), will be caught with hand-lines because such fish feed on algae growing on the reed and therefore, will not be attracted to bait. In contrast, other fishing gears, such as gill-nets, can be more general and catch various fish that have different life histories. Table 6 shows the number of fish from the ten most abundant fish families that were captured in 2019 across all thirteen communities by certain fishing gears, as well as their average lengths. In total, across all sites, 432 lethrinids (emperors) and 402 lutjanids (snappers) were caught by fishers with hand-lines; no acanthurids (surgeonfishes), scarids (parrotfishes) or siganids (rabbitfishes were captured by hand-lines due to their herbivorous life histories. In contrast, the most targeted fish families for spear-gun fishers were the acanthurids and siganids. Gill-nets targeted various fish families, including 1,414 Siganidae individuals, 1,044 lethrinids, and 783 mugilids (mullets), which were the most targeted fish families across all thirteen communities.

3.7 Overview of invertebrates and turtles

In total, 1,046 invertebrates and three turtles[1] were sampled across all thirteen communities, which encompassed 13 families and 14 different species (Table 7). The biomass of the invertebrates and turtles was not obtained, preventing CPUE analysis from being carried out. Table 7 provides an overview of the different invertebrate and turtle species that were captured at the thirteen communities. At Kavulik, 152 mud crabs (Family Portunidae) were collected, which were the main fishery for this community. 521 trochus snails (Family Trochoidae) were collected at Ungakum and were all destined for trading.

[1]Turtles are reptiles, not invertebrates. However, because turtles are measured across the length of the upper shell, rather than the length of the whole body, they have been grouped with the invertebrates.

Table 5: The number of fish from selected from the most abundant fish families that were caught across all thirteen communities that were destined for home consumption, market sales or for trade. The average (±SE) lengths (cm) of fish intended for home consumption or market sales are also included. The catch-and-effort data were pooled from thirteen sites around Kavieng District, New Ireland Province, Papua New Guinea.

Family	Common name	Total number of fish	Number of fish eaten	Fish eaten (%)	Number of fish sold	Fish sold (%)	Number of fish traded	Fish traded (%)	Average size of fish eaten	±SE	Average size of fish sold	±SE
Acanthuridae	Surgeonfishes	591	413	69%	178	30%	-	-	16.93	0.24	20.4	0.42
Carangidae	Trevallies	368	125	34%	242	66%	-	-	32.44	1.04	34.1	0.66
Gerreidae	Biddies	768	322	42%	446	58%	-	-	19.99	0.29	20.82	0.18
Lethrinidae	Emperors	1,724	570	33%	1,150	66%	-	-	22.55	0.26	22.09	0.14
Lutjanidae	Snappers	636	258	41%	375	59%	-	-	23.90	0.57	21.59	0.27
Mugilidae	Mullets	836	313	38%	499	60%	-	-	31.97	0.22	29.29	0.25
Mullidae	Goatfishes	506	169	33%	269	53%	68	13%	19.01	0.31	19.27	0.20
Scaridae	Parrotfishes	549	374	68%	175	31%	-	-	22.77	0.34	26.64	1.12
Serranidae	Groupers	209	151	72%	49	23%	9	4%	22.74	0.63	23.98	0.97
Siganidae	Rabbit fishes	2,347	822	35%	1,524	65%	-	-	20.21	0.14	22.76	0.10

SE = standard error

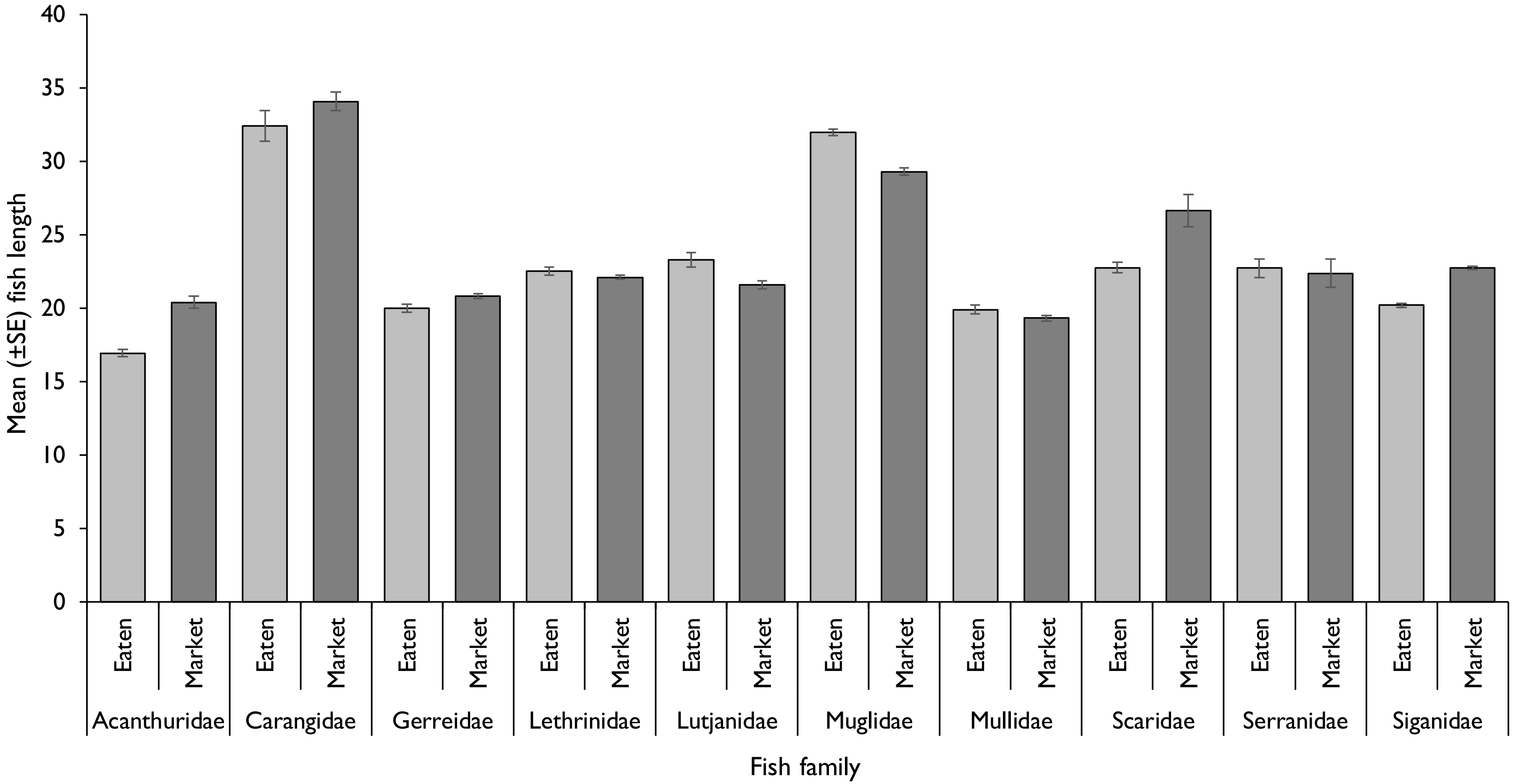

Figure 10: Mean (± SE) lengths (cm) of key fish families destined for home consumption (light grey bars) or market sales (dark grey bars). The data were pooled from all thirteen communities from around Kavieng District, New Ireland Province, Papua New Guinea. The data were collected between January 2019 and May 2019.

Table 6: Catch numbers and average lengths (cm) of the most abundant fish families that were captured across all thirteen sites, and the fishing gears they were caught with. The data were collected from thirteen coastal communities around Kavieng District, New Ireland Province, Papua New Guinea. The data were collected between January 2019 and May 2019.

	FISHING GEAR	HAND-LINING			TROLLING			SPEAR-GUN FISHING			NETTING		
FISH FAMILY	COMMON NAMES	(*n*)	Average length*	±SE	(*n*)	Average length*	±SE	(*n*)	Average length*	±SE	(*n*)	Average length*	±SE
Acanthuridae	Surgeonfishes	-	-	-	-	-	-	399	18.97	1.26	192	17.64	0.34
Carangidae	Trevallies	85	39.56	0.91	87	35.26	0.75	49	29.12	1.40	144	29.72	0.86
Gerreidae	Biddies	31	14.33	0.53	-	-	-	102	18.96	0.55	635	21.02	0.16
Lethrinidae	Emperors	432	21.17	0.24	6	19.87	0.46	222	21.72	0.40	1,044	22.83	0.16
Lutjanidae	Snappers	402	21.22	0.30	-	-	-	122	24.78	0.69	99	22.46	0.42
Mugiilidae	Mullets	36	23.19	0.83	-	-	-	17	30.44	1.14	783	30.49	0.18
Mullidae	Goatfishes	3	18.33	1.76	-	-	-	118	21.04	0.50	385	19.06	0.15
Scaridae	Parrotfishes	-	-	-	-	-	-	198	27.47	1.01	345	22.07	0.33
Serranidae	Groupers	85	22.51	0.64	3	21.5	0.87	100	23.44	0.89	21	19.50	1.59
Siganidae	Rabbit fishes	-	-	-	-	-	-	933	20.21	0.12	1,414	22.96	0.11

SE = standard error

Table 7: The total number of each invertebrate and turtle family that were captured during data collection at thirteen communities around Kavieng district, New Ireland Province, Papua New Guinea. The total number of organisms caught in each community are also included. The data were collected between January 2019 and May 2019.

TAXONOMIC CLASSIFICATION					TOTAL NUMBER OF INDIVIDUALS BY SITE												
PHYLUM	CLASS	FAMILY	FAMILY COMMON NAME	TOTAL NUMBER	Limanak	Nonovaul	Salapiu	Bangatan	Tugalop	Kavulik	Ungakum	Kulibang	Mamion	Tsoilik	Kavitongong	Sosson	Ungalabu
Mollusca	Gastropoda	Trochoidae	Trochus snails	529	-	-	-	1	-	-	521	-	7	-	-	-	-
		Strombidae	Conches	2	-	-	-	-	-	-	-	-	-	-	-	-	2
	Bivalvia	Tridacnidae	Giant clams	6	-	-	1	-	3	-	2	-	-	-	-	-	-
		Cyrenidae	Mud clams	81	-	-	-	-	-	81	-	-	-	-	-	-	-
	Cephalopoda	Loligidae	Squids	1	-	-	-	1	-	-	-	-	-	-	-	-	-
		Octopodidae	Octopuses	9	-	-	-	-	-	-	1	-	3	5	-	-	-
Arthropoda	Crustacea	Gecarcinidae	Semi-terrestrial crabs	139	-	-	-	36	-	102	-	-	-	1	-	-	-
		Thalamita	Swimming crabs	4	-	-	-	-	-	-	-	-	-	4	-	-	-
		Portunidae	Mud crabs	262	-	-	57	26	17	152	5	1	4	-	-	-	-
		Coenobitidae	Coconut crabs	1	-	-	-	-	-	1	-	-	-	-	-	-	-
		Palinuridae	Lobsters	10	-	-	-	-	5	-	-	-	-	5	-	-	-
		Scyllaridae	Mitton lobsters	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Chordata	Reptilia	Cheloniidae	Turtles	3	-	-	-	2	-	-	-	-	-	-	-	-	1

PART II: Comparing catch and effort data, 2015-2019

3.8 Results summary

In total, four waves of catch-and-effort data have been collected in Kavieng District, New Ireland Province. In late-2015 and early 2016, catch-and-effort data was collected in ten communities, while an additional three communities (Kavitongong, Sosson and Ungalabu) were included in the data collection during subsequent surveys (in 2017, 2018 and 2019, respectfully). During the first three waves of data collection, incentives were given to fishers to encourage participation in the surveys. In 2019, no incentives were given, which could have influenced the data that were collected. Table 8 provides an overview of the catch-and-effort data from all four waves.

3.9 Catch-per-unit-effort across all four waves of data collection

Although there was much variation in the number of fishing trips that were intercepted each year, there was a general increase in the mean CPUE values during the four-year timeframe in each community (Figure 12). The mean CPUE per community outcomes for wave 1 (44.7 kg/person/hr) was almost three times lower than the subsequent three waves of data collection; in general, the mean CPUE values per community for each wave of data collection increased from 2015 to 2018, before levelling off in 2019 (Figure 13(a)). When the average CPUE values per catch analysed for each wave of data collection (Figure 13(b)), there was a significant increase in the average CPUE from the first three waves of data collection to wave 4 (Kruskall-Wallis: χ^2=24.5, d.f.=3, p<0.001).

Table 8: Summary of the catch-and-effort data that were collected during four waves of data collection in Kavieng District, New Ireland Province, Papua New Guinea. The data were collected at thirteen communities from late-2015 to 2019.

Community	Number of communities	Total number of fishing trips	Total number of fishers	Total number of hours fishing	Total number of fish sampled
Phase 1: 2015-2016	11	443	609	1,631	7,158
Phase 2: 2017	13	1,073	1,390	3,036	15,238
Phase 3: 2018	13	1,411	1,675	3,937	13,047
Phase 4: 2019	13	509	721	1,380	9,299
TOTAL	13*	3,437	4,396	9,986	44,742

*A total of 13 communities were involved in the data collection

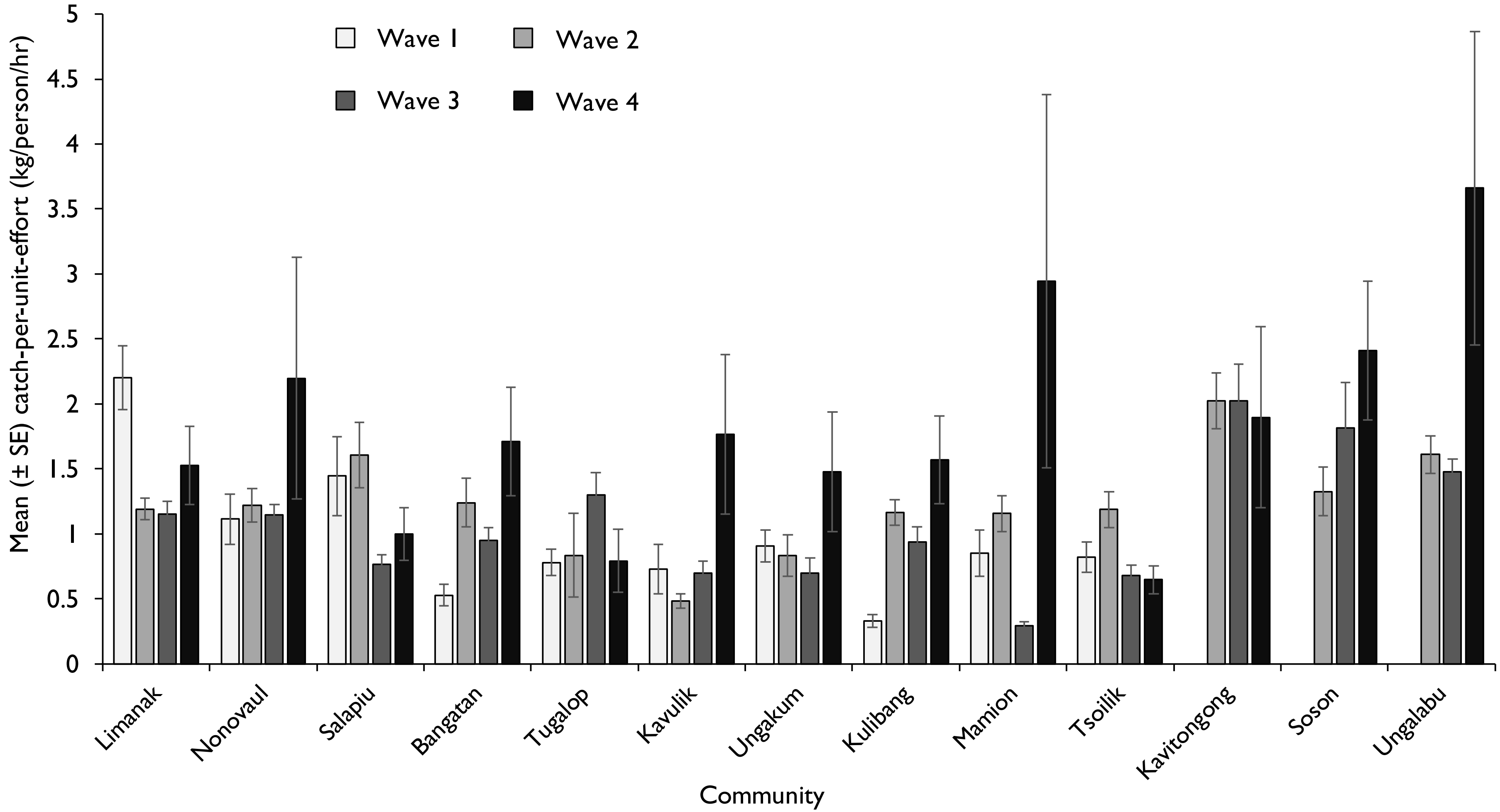

Figure 11: Average (± SE) combined catch-per-unit-effort values for all thirteen communities according to data collection wave. The data were collected in thirteen communities in Kavieng District, New Ireland Province, Papua New Guinea. Wave 1 was collected from late-2015 to early 2016, wave 2 was collected in 2017, wave 3 in 2018 and wave 4 in 2019. During wave 1 of the data collection, Kavitongong, Sosson and Ungalabu communities were not included in the survey.

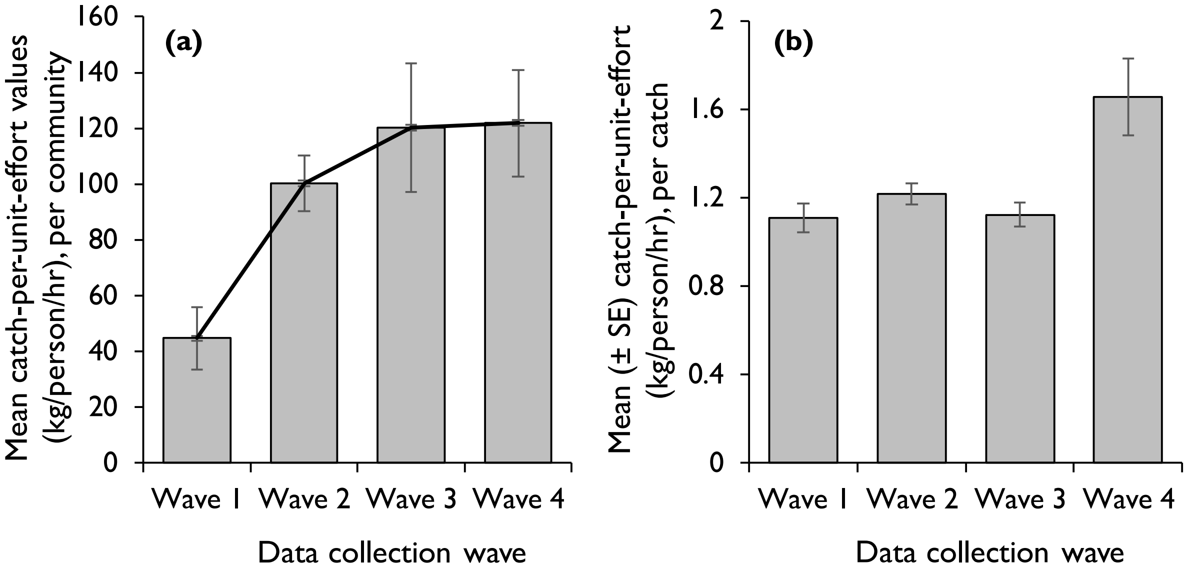

Figure 12: Mean (± SE) catch-per-unit-effort values per community for all four waves of data collection (a), and the mean (± SE) catch-per-unit-effort values per catch (b) for each of the four waves of catch-and-effort data collected across thirteen communities in Kavieng District, New Ireland Province, Papua New Guinea. Wave 1 was collected in 2015-2016 at eleven communities, while the subsequent three waves of data were collected at thirteen communities in 2017, 2018 and 2019, respectfully.

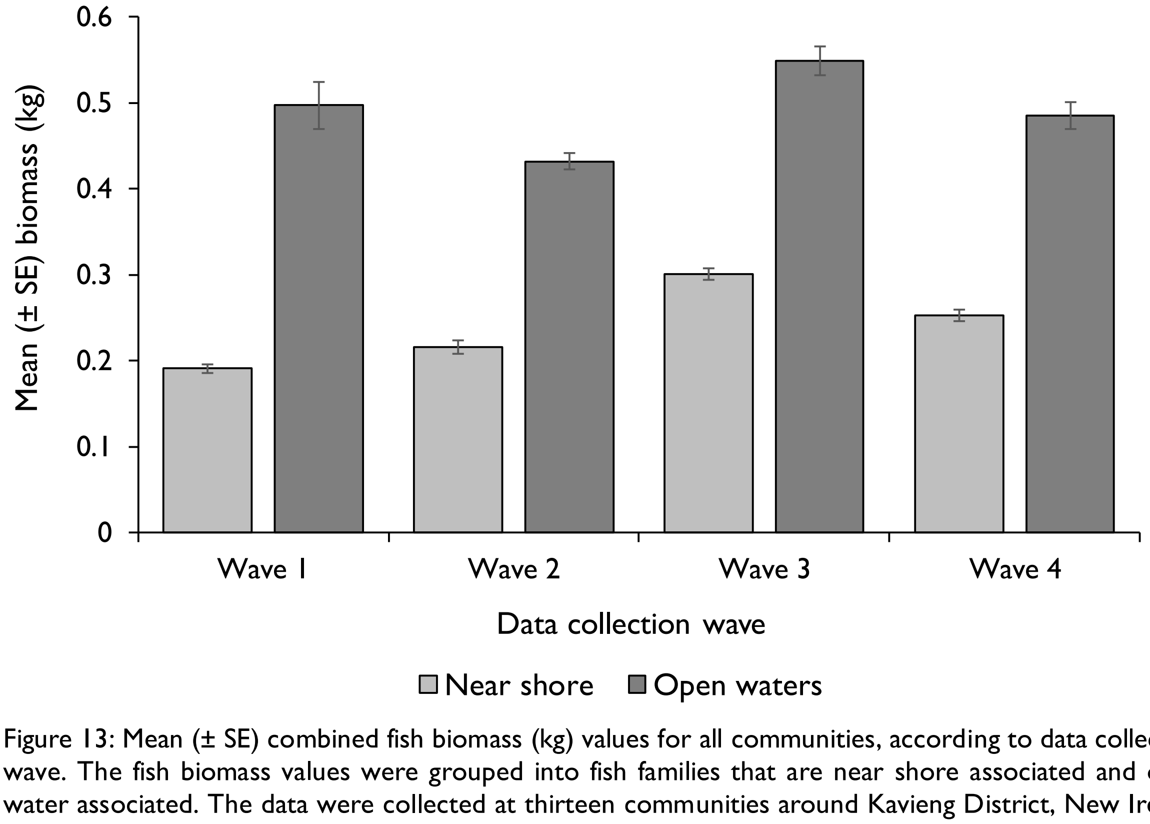

Figure 13: Mean (± SE) combined fish biomass (kg) values for all communities, according to data collection wave. The fish biomass values were grouped into fish families that are near shore associated and open water associated. The data were collected at thirteen communities around Kavieng District, New Ireland Province, Papua New Guinea. Wave 1 was collected from late-2015 to early 2016, wave 2 was collected in 2017, wave 3 in 2018 and wave 4 in 2019. During wave 1 of the data collection, Kavitongong, Sosson and Ungalabu communities were not included in the survey. The text that accompanies Figure 14 continues on page 37.

3.10 Impact of the fish aggregating devices

In 2018, subsurface fish aggregating devices (FADs) were deployed at eleven communities (a single FAD was deployed in north-west Lavongai for all residents in the Kavitongong, Sososn and Ungalabu communities to utilise). FADs attract open water fish species, and as such it would be expected that communities that regularly use FADs for fishing should have a larger proportion of open water species compared to near shore species. Only biomass values could be used to determine the differences in proportion of near shore and open water associated fish species. The average biomass values for fish families that typically inhabit near shore areas were lower than the biomass outcomes for fish families that are more associated with open water environments (Figure 14, page 36). See Appendix III for a list of the fish families and the predominant environments they are most associated with (near shore and open water regions).

4.0 Discussion

4.1 Overview of all thirteen communities

The catch-and-effort data collected around Kavieng District, New Ireland Province, indicated diverse fisheries across the region, including a variety of reef associated fish species that coastal communities rely on for sustenance and livelihoods. The catch-per-unit-effort (CPUE) outcomes from all thirteen communities also indicated differences in how each community relies on their marine resources. The CPUE analysis suggested that the communities of Ungalabu, Mamion and Sosson had among the highest CPUE values of all thirteen locations, whereas Tsoilik, Tugalop and Salapiu were represented by some of the lowest CPUE values. Across all thirteen communities, the mean CPUE outcome was 1.58 kg/person/hr. According to studies conducted by Dalzell (1996) and Meyer (2007), the average spearfishing CPUE values that were estimated from a number of reef fisheries in the South Pacific ranged from 0.4 to 2.41 kg/person/hr, with a mode of 1.21 kg/person/hr. Therefore, the mean CPUE for the thirteen Kavieng District communities was marginally above the CPUE mode taken from the combined Dalzell (1996) and Meyer (2007) studies. A further CPUE study conducted by Cakacaka *et al.* (2010), which encompassed four coastal sites in Fiji, found the mean CPUE ranged from 3 to 13 kg/person/hr, values that were greater than all thirteen communities around Kavieng District, with the exception of Ungalabu. Due to the lower CPUE outcomes at twelve of the thirteen New Ireland communities, it is apparent that many reef fisheries could be under growing pressure due to increased rates of fishing activity.

The catch data indicated that the highest biomass of captured finfish were from Tsoilik, Bangatan and Mamion, while the lowest total catch biomass values were from Ungalabu and Kavulik. The low biomass outcomes for Kavulik were likely due to the high proportion of mud crabs and other invertebrates that were harvested during the surveys. Although Tsoilik had the highest catch biomass, the community had the lowest CPUE value when compared to the other sites; this could be due to the widespread use of gill-nets in Tsoilik, which – despite yielding high fish catch biomass values – had on average lower CPUE values when compared to other fishing gear types (see Section 4.2 for further details). There were also differences in the transport modes used to go fishing. The highest CPUE values were derived from fishers that used motor boats to harvest fish, followed by those that used canoes. However, the highest fish biomass values were from fishers that used canoes, followed by walking. Concerning habitat type, fishers that caught fish in open water and deep water reefs yielded higher CPUE values than the other habitat types, although shallow reefs and sea grass beds had the highest fish biomass values. Such outcomes indicate the reliance local fishers have on near shore marine environments, including vulnerable shallow reefs, while more resilient open water systems are less exploited. Since 2017, the Wildlife Conservation Society (WCS) deployed fish aggregating devices (FADs) at all thirteen communities. FADs aim to transfer fishing effort from vulnerable reef communities to more resilient pelagic fisheries, and it is therefore anticipated that future catch-and-effort studies in the same communities should see a shift from targeting near shore reef fish species to more resilient open water fisheries, including tunas that feed on plankton. Other fisheries management methods, such as locally managed marine areas (LMMAs) – a form of marine protected area (MPA) – can also be established and enforced in areas of critical habitat, such as fish spawning aggregation sites, allowing larval and juvenile fish to spill over into fishing grounds and increase localised stocks.

4.2 Fisheries and fish sizes

Across Kavieng District, subsistence and artisanal fishers rely on certain fishing gear types for catching fish, which can be somewhat species specific, such as hand-lines that target carnivores, or more general, such as gill-nets. Concerning fishing gear usage, the highest CPUE values were obtained from the use of spear-guns, dive collection methods and trolling, while the lowest CPUE values came from the use of gill-nets; conversely, the highest biomass values came from the use of gill-nets. Spear-guns were especially efficient at targeting surgeonfish (Family Acanthuridae) and rabbitfish (Family Siganidae) (Meyer, 2007). Surgeonfish and rabbitfish are herbivores and graze on algae growing on the reef, providing a key functional group within the reef ecosystem and maintaining the resilience of the reef environment (Hughes *et al.*, 2007). The removal of algal grazers through increased spear-gun usage, could lead to an ecological shift from a coral- to an algal-dominated system (Cakacaka *et al.*, 2010); a phenomenon that could occur if the current trends of fishing effort and population increase continue. Accordingly, spear-gun management, such as bans on night-time spear-gun usage during full or new mood phases, when many marine animals spawn, could be a simple and pragmatic measure to introduce. For most fish families assessed in this report, it was evident that the larger animals were, on average, destined for market sales, demonstrating the high market value for larger individuals; a trend that could provide an incentive for targeting larger animals. In short, the outcomes from this report indicate that some of the more valuable reef fish species could be susceptible to localised population declines due to increased levels of recruitment overfishing.

4.3 Temporal catch-and-effort trends

There was variation among the data that were collected in each community over the four-year period, and during the first three waves of data collection, incentives were given to encourage community fishers to take part in the survey. Despite this, there appears to be a general increase in average CPUE values during the four years that the surveys took place, and especially at Nonovaul, Bangatan, Kavulik, Ungakum, Kulibang, Mamion, Sosson and Ungalabu (Figure 11). Similarly, there was an increase in average CPUE values for each data collection wave, and particularly from wave 3 to wave 4, when the catch data were combined for each community. Reasons for this could be the introduction of fisheries management plans and the establishment of marine management committees (MMCs) in each community during 2018, and the implementation of site-relevant fisheries management tools. Moreover, in 2018 subsurface fish aggregating devices (FADs) were deployed in eleven of the communities (one FAD was deployed in the waters between Kavitongong, Sosson and Ungalabu, for all three communities to use). It would be expected that there would be an increase in the number of pelagic fish species in the catch data from wave 3 to wave 4 of the surveys. However, the total fish catch biomass values for open water species did not vary too much across all four data collection waves. Considering the FADs were only introduced in 2018, it is possible that community fishers have not had sufficient time to make the transition from relying on FAD-caught open water fish in comparison to reef-associated species. Accordingly, it is anticipated that the proportion of pelagic fish would increase during future waves of catch-and-effort data collection at all thirteen sites.

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5.1 Internet sources

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

http://www.wikimediacommons.com

http://www.fishbase.se

5.2 Photograph credits

Unless otherwise stated, all photographic images used within the current report were the property of the Wildlife Conservation Society: Papua New Guinea.

Front cover photograph courtesy of Elodie Van Lierde

Base maps that were included in the current report were obtained from *Google Earth*, 2016.

APPENDIX

Appendix I: effort data sheet

Effort data sheet used by the data collectors in the field at all ten sites

EFFORT INFORMATION

Date: ___________ Trip Number: ___________

1. Village: ___________________________ Name of Recorder: ______________________

2. Time: Depart ______________AM/PM Return ______________ AM/PM

Travelling time to area fished: ___________ and to return: ______________

3. Description and location of area fished:

Shallow reef ☐ Deep reef ☐ Sea grass ☐ Sand ☐ Blue water ☐ Mangrove ☐

Grid: ______________________

4. Number of fishers: _______

Number of lines:_____

5. Fishing Method: Spearfishing ☐ Trolling ☐ Dive collection ☐ Hand-lining ☐ Gillnetting ☐ Other netting ☐ Gleaning ☐ Other _________________________

Number of nets: _____

Net lengths: ______m ______m _____m ______m

Net depth: _____m _____m _____m ______m

Mesh size: ______cm/in _____ cm/in _____cm/in _____cm/in

(Total) soak times: ____hrs ____hrs ____hrs _____hrs

Hook Size:_________

Hook height:_______ mm

Hook width:________mm

6. Effort by Method: (only if more than one method was indicated):

Hand-lining ______ hrs Trolling ______hrs Spearfishing ______hrs

Dive Collection ______hrs Netting ______ hrs Gleaning ______hrs

Other ________hrs

7. Transport to Fishing Area: boat with motor ☐ canoe ☐ swim ☐ walk ☐

Other ____________________

8. Comments

Appendix II: catch data sheet

Catch data sheet used by the data collectors in the field at all ten sites

CATCH DATA

Date: __________ Trip Number: ___________

Village: _________________________ Name of Recorder: ____________________

SPECIES	LOCAL NAME	LENGTH (CM)	SAMPLE Y/N	FISHING METHOD	UTILISATION			
					Market	Eaten	Trade	Bait

Comments:

Appendix III

The dates in which data were collected in each community for the fourth wave of data collection, from February to May 2019. The communities have been arranged in chronological order according to when the data were collected.

COMMUNITY	START DATE	END DATE
Tsoilik	19th February 2019	04th March 2019
Kavulik	05th February 2019	14th February 2019
Kulibang	06th February 2019	13th February 2019
Mamion	19th February 2019	01st March 2019
Limanak	13th March 2019	25th March 2019
Nonovaul	12th March 2019	25th March 2019
Tugalop	12th March 2019	26th March 2019
Salapiu	12th March 2019	26th March 2019
Ungakum	24th April 2019	06th May 2019
Ungalabu	24th April 2019	05th May 2019
Sosson	23th April 2019	06th May 2019
Kavitongong	24th April 2019	06th May 2019
Bangatan	15th May 2019	27th May 2019

Appendix IV

Fish families associated with near shore and open water environments. For convenience, the fish families have been arranged in alphabetical order.

Near shore associated fish families		Open water associated fish families	
Family name	Common name	Family name	Common name
Acanthuridae	Surgeonfishes	Aetobatidae	Eagle rays
Albulidae	Bonefishes	Belonidae	Needlefishes
Balistidae	Triggerfishes	Carangidae	Trevallies and jacks
Caesionidae	Fusiliers	Chanidae	Milkfishes
Carcharhinidae	Requiem sharks	Clupiedae	Herrings and sardines
Centropomidae	Barramundis	Hemiramphidae	Garfishes
Chaetodontidae	Butterfly fishes	Lobotidae	Tippletails
Cirrhitidae	Hawkfishes	Megalopidae	Tarpons
Dasyatidae	Sting rays	Mugilidae	Mullets
Diodontidae	Porcupinefishes	Polynemidae	Threadfins
Eleotidae	Herrings	Pomatomidae	Tailors
Ephippidae	Spadefishes	Sciaenidae	Croakers
Gerreidae	Biddys	Scombridae	Tunas and mackerels
Gobiidae	Gobies	Sphyraenidae	Barracudas
Haemulidae	Sweetlips		
Holocentridae	Soldierfishes		
Kyphosidae	Drummers		
Labridae	Wrasses		
Leiognathidae	Ponyfishes		
Lethrinidae	Emperors		
Lutjanidae	Snappers		
Malacanthidae	Tilefishes		
Monodactylidae	Moony fishes		
Mullidae	Goatfishes		
Muraenidae	Moray eels		
Nemipteridae	Thread-fin breams		
Ophichthidae	Snake eels		
Ostraciidae	Boxfishes		
Platycephalidae	Flatheads		
Pomacanthidae	Angelfishes		
Pomacentridae	Damselfishes		
Pseudochromidae	Blennies		
Rachycentridae	Cobias		
Scaridae	Parrotfishes		
Scatophagidae	Scats		
Serranidae	Groupers		
Siganidae	Rabbitfishes		
Sparidae	Breams		
Tetradontidae	Pufferfishes		
Urolophidae	Stingarees		

Appendix V: Full species list

Full list of the species that were measured during the catch-and-effort data collection at all thirteen communities around New Ireland Province, Papua New Guinea. The species have been grouped in taxonomic order by phyla and class. Common names have also been provided.

PHYLUM MOLLUSCA

CLASS	FAMILY	SPECIES	COMMON NAME
Gastropoda	Tegulidae	*Rochia nilotica*	Trochus
	Strombidae	*Lambis lambis*	Spider conch
Bivalvia	Cardiidae	*Hippopus hippopus*	Bear paw giant clam
	Cyrenidae	*Polymesoda (Gelonia) erosa*	Mud clam
Cephalopoda	Octopodidae	*Octopus vulgaris*	Common octopus

PHYLUM ARTHROPODA

CLASS	FAMILY	SPECIES	COMMON NAME
Malacostraca	Portunidae	*Scylla serrata*	Mud crab
	Coenobitidae	*Birgus latro*	Coconut crab
	Gecarcinidae	*Cardiosoma carnifex*	Semi terrestrial crab
	Palinuridae	*Panulirus versicolor*	Painted rock lobster

PHYLUM CHORDATA

CLASS	FAMILY	SPECIES	COMMON NAME
Chondrichthyes	Carcharhinidae	*Carcharhinus albimarginatus*	Slivertip shark
		Carcharhinus melanopterus	Blacktip reef shark
		Triaenodon obesus	Whitetip reef shark
	Dasyatidae	*Himantura toshi*	Black-spotted whipray
		Neontrygon kuhlii	Bluespotted stingray
		Taeniura lymma	Ribbontail stingray
	Urolophidae	*Urolophus mitosis*	Mitotic stingraee
Actinopterygii	Belonidae	*Ablennes hians*	Barred longtom
		Platybelone argulus playtura	Flat-tail longtom

CLASS	FAMILY	SPECIES	COMMON NAME
		Strongylura incisa	Reef needlefish
	Belonidae	*Tylosurus crocodilus crocodilus*	Crocodile long-tom
		Tylosurus gavialoides	Stout Longtom
	Hemiramphidae	*Hemirhamphus far*	Black barred garfish
		Hyporhamphus affinis	Tropical Garfish
		Myripristis berndti	Blotcheye soldierfish
		Myripritis amaena	Brick soldierfish
		Myripristis murdjan	Crimson soldierfish
		Myriprisitis violacea	Lattice soldierfish
		Myripritis murdjan	Pinecone soldierfish
	Holocentridae	*Myripristis adusta*	Shadowfin soldierfish
		Neoniphon opercularis	Blackfin squirrelfish
		Sargocentron spiniferum	Sabre squirrelfish
		Sargocentron caudimaculatus	Silverspot squirrelfish
		Sargocentron tiereoides	Pink squirrelfish
		Sargocentron tiere	Bluestripe squirrelfish
		Cephalopholis cyanostigma	Bluespotted grouper
		Cephalopholis miniata	Coral grouper
Actinopterygii		*Cephalopholis microprion*	Dot-head rock cod
		Plectropomus leapardus	Leopard coral grouper
		Plectropomus oligacanthus	Highfin coral grouper
		Variola albimarginata	Whiteedge lyretail grouper
		Variola louti	Yellow-edged lyrtail
		Epinephelus areolatus	Areolated grouper
		Epinephelus caeruleopunctatus	Whitespotted grouper
	Serranidae	*Epinephelus corallicola*	Coral grouper
		Epinephelus fuscoguttatus	Brown marbled grouper
		Epineohelus lanceolatus	Giant grouper
		Epinephelus maculatus	Brown- spotted rock cod
		Epinephelus melanostigma	Oneblotch grouper
		Epinephelus merra	Honeycomb grouper
		Epinephelus spilotoceps	Foursaddle grouper
		Epinephelus socialis	Surge grouper
		Epinephelus tauvina	Greasy grouper
		Epinephelus polyphekadion	Camouflage grouper
		Epinephelus chlorostigma	Brownspotted grouper

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Actinopterygii	Serranidae	*Epinephelus hexagonatus*	Birdwire rock cod
		Epinephelus latifasciatus	Striped grouper
		Epinephelus magniscuttis	Specklefin grouper
		Epinephelus coioides	Orange-spotted grouper
		Epinephelus malabaricus	Malabar grouper
	Terapontidae	*Terapon jarbua*	Cresent bander grunter
	Centropomidae	*Psammoperca waigiensis*	Sand bass
	Carangidae	*Carangoides orthogrammus*	Island trevally
		Carangoides chrysophrys	Longnose trevally
		Carangoides bajad	Orange-spotted trevally
		Carangoides ferdau	Blue trevally
		Carax ignobilis	Giant trevally
		Crangoides plagiotaenia	Barcheek trevally
		Carax melampygus	Bluefin trevally
		Carax papuensis	Brassy trevally
		Carax sexfasciatus	Bigeye trevally
		Scomberoides lysan	Doublespotted queenfish
		Decapterus macarellus	Mackeral scad
		Gnathanodon speciosus	Golden trevally
		Elagatis bipinnulata	Rainbow runner
		Scomberoides tol	Needledscaled queenfish
		Selar crumenophthalmus	Bigeye scad
		Trachinotus blochii	Snubnose pompano
		Carangoides equula	Whitefin trevally
	Lutjanidae	*Lutjanus adetii*	Yellowbanded snapper
		Lutjanus argentimaculatus	Mangrove jack
		Lutjanus bohar	Red bass
		Lutjanus carponotatus	Spanish flag snapper
		Lutjanus ehrenbergi	Blackspot snapper
		Lutjanus fulviflamma	Dory snapper
		Lutjanus fulvus	Blacktail snapper
		Lutjanus gibbus	Humpback red snapper
		Lutjanus kasmira	Bluestiped snapper
	Lutjanidae	*Lutjanus lutjanus*	Bieye snapper
		Lutjaanus malabaricus	Saddletail snapper
		Lutjanus monostigma	One spot snapper

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Actinopterygii	Lutjanidae	*Lutjanus rivulatus*	Blubberlip snapper
		Lutjanus rufolineatus	Yellow lined snapper
		Lutjnaus sebae	Emperor red snapper
		Lutjanus semicinctus	Black banded snapper
		Macolor macularis	Midnight snapper
		Macolor niger	Black and white snapper
	Haemulidae	*Plectorhinchus chaetodonoides*	Harlequin sweetlips
		Diagramma labiosum	Painted sweetlips
		Plectorhinchus albovittatus	Twostriped sweetlips
		Plectorhinchus chrysotaenia	Yellowstriped sweetlips
		Plectorhinchus flavomaculatus	gold-spotted sweetlips
		Plectorhinchus gibbosus	Brown sweetlips
		Plectorhinchus lineatus	Yellowbanded sweetlips
		Plectorhinchus obscurum	Giant sweetlips
		Plectorhinchus picus	Painted sweetlips
		Plectorhinchus unicolor	Somber sweetlips
		Plectorhinchus vittatus	Oriental sweetlips
	Caesonidae	*Caesio cuning*	Redbelly yellowtail fusilier
	Lethrinidae	*Gnathodentex aurolineatus*	Striped large eye bream
		Gymnocranius grandoculus	Bluelined large eye bream
		Gymnocranius griseus	Grey large-eye bream
		Gymnocranius microdon	Blue spot large eye bream
		Lehtrinus harak	Thumbprint emperor
		Lethrinus atkinsoni	Pacific yellowtail emperor
		Lethrinus erythropterus	Longfin emperor
		Lethrinus erythracanthus	Orange spotted emperor
		Lethrinus genivittatus	Longspine emperor
		Lethrinus lentjan	Pink ear emperor
		Lethrinus miniatus	Sweetlips emperor
		Lethrinus nebulosus	Spangled emperor
		Lethrinus obsoletus	Orange stripe emperor
		Lethrinus olivaceus	Longface emperor
		Lethrinus ornatus	Ornated emperor
		Lethrinus rubrioperculatus	Spot cheek emperor
		Lehtrinus xanthocheilus	Yellowlip emperor

CLASS	FAMILY	SPECIES	COMMON NAME
Actinopterygii	Sparidae	*Acanthopagrus palmaris*	Northwest blackbream
	Nemipteridae	*Pentapodus trivittatus*	Three-striped whiptail
		Scolopsis bilineatus	Bridled monocle-bream
		Scolopsis lineata	Lined monocle-bream
		Scolopsis monogramma	Rainbow monocle bream
		Scolopsis temporalis	Bald spot monocle bream
		Scolopsis xenochrous	Oblique monocle bream
	Gerreidae	*Gerres oyena*	Common silver biddy
		Gerres filamentosus	Whipfin silver biddy
		Gerres longirostris	Longtail silver biddy
		Gerres oblongus	Slender silver biddy
		Gerres subfasciatus	Common silver biddy
		Gerres erythrourus	Deep-bodied silver biddy
		Pentaprion longimanus	Longfin silver biddy
	Mullidae	*Parupeneus barberinus*	Dash and dot goatfish
		Mulloidichthys flavolineatus	Yellow- lined goatfish
		Mulloidichthys vanicolensis	Yellowfin goatfish
		Parupeneus chrysopleuron	Yellow striped goatfish
		Parupeneus ciliatus	Whitesaddle goatfish
		Parupeneus crassilabris	Double bar goatfish
		Parupeneus heptacanthus	Cinnibar goatfish
		Parupeneus indicus	Yellowspot goatfish
		Parupeneus indicus	Indian goatfish
		Parupeneus insularis	Two saddle goatfish
		Parupeneus multifasciatus	Manybar goatfish
		Parupeneus pleurostigma	Goldband goatfish
		Parupeneus sundiacus	Ochreband goatfish
		Parupeneus trangular	Finstripe goatfish
	Monodactylidae	*Monodactylus argenteus*	Silver mooney
	Kyphosidae	*Kyphosus bigibbus*	Brown chub
		Kyphosus cinerascens	Blue sea chub
		Kyphosus vaigiensis	Brassy chub
	Ephippidae	*Platax boersii*	Golden Spade Fish
		Platax orbicularis	Orbicular Batfish
		Platax pinnatus	Shotfin Batfish
		Zabidius novemaculeatus	Shortfin batfish

CLASS	FAMILY	SPECIES	COMMON NAME
Actinopterygii	Scatophagidae	*Scatophagus argus*	Spotted scat
	Chaetodontidae	*Chaetodon auriga*	Threadfin butterfly fish
		Chaetodon ornatissimus	Ornate butterflyfish
	Chaetodontidae	*Chaetodon semeion*	Dotted butterflyfish
	Pomacanthidae	*Centropyge nox*	Midnight angelfish
		Pomacanthus xanthometopon	Blueface Angelfish
	Pomacentridae	*Dischistodus prosopotaenia*	Honeyhead damsel
		Hemiglyphidodon plagiometopon	Lagoon damsel
		Neoglyphidodon nigroris	Scarface damsel
	Mugilidae	*Crenimugil buchanani*	Bluetail mullet
		Crenimugil crenilabis	Fringelip mullet
		Ellochelon vaigiensis	Squaretail mullet
		Moolgarda seheli	Bluespot Mullet
		Planiliza macrolepis	Largescale mullet
	Sphyraenidae	*Sphyraena barracuda*	Great barracuda
		Sphyraena forsteri	Bigeye barracuda
		Sphyraena jello	Picklhandle barracuda
		Sphyraena qenie	Blackfin barracuda
		Sphyraena flavicauda	Yellowtail barracuda
	Labridae	*Bodianus loxozonus*	Blackfin pigfish
		Cheilinus chlorourus	Floral wrasse
		Cheilinus fasciatus	Redbreast wrasse
		Cheilinus oxycephalus	Snooty wrasse, red maori-wrasse
		Cheilinus trilobatus	Tripletail wrasse
		Cheilinus undulatus	Humphead wrasse
		Cheilio inermis	Sharpnose wrasse
		Choerodon anchorago	Orange-dotted tuskfish
		Choerodon rubescens	Baldchin groper
		Choerodon schoenleinii	Darkspot tuskfish
		Halichoeres argus	Argus wrasse
		Halichoeres melanurus	Hoeven's wrasse
		Halichoeres scapularis	Zigzag wrasse
		Halichoeres solorensis	Green wrasse
		Halichoeres trimaculatus	Threespot wrasse
		Hemigymnus melapterus	Blackeye thicklip

Actinopterygii	Labridae	*Oxycheilinus unifasciatus*	Ringtail maori wrasse
	Scaridae	*Bolbometopon muricatum*	Bumphead parrotfish
		Chlorurus bleekeri	Bleeker's parrotfish
		Chlorurus sordidus	Greenfin parrotfish
		Hipposcarus longiceps	Pacific longnose parrotfish
		Leptoscarus vaigiensis	Marble parrotfish
		Scarus chameleon	Chameleon parrotfish
		Scarus dimidiatus	Yellowbarred parrotfish
		Scarus ghobban	Blue-barred parrotfish
		Scarus globiceps	Globe head parrotfish
		Scarus niger	Swarthy parrotfish
		Scarus prasiognathus	Greenthroat parrotfish
		Scarus psittacus	Common parrotfish
		Scarus quoyi	Quoy's parrotfish
		Scarus rivulatus	Rivulated parrotfish
		Scarus rubroviolaceus	Blackvein parrotfish
		Scarus russellii	Eclipse Parrotfish
		Scarus spinus	Greensnout parrotfish
		Scarus tricolor	Tricolor parrotfish
		Scarus oviceps	Dark capped parrotfish
	Siganidae	*Siganus argenteus*	Forktail rabbitfish
		Siganus canaliculatus	Whitespotted rabbitfish
		Siganus corallinus	Blue-spotted spinefoot
		Siganus doliatus	Barred spinefoot
		Siganus fuscescens	Mottled spinefoot
		Siganus guttatus	Goldline rabbitfish
		Siganus lineatus	Goldenline spinefoot
		Siganus puellus	Masked rabbitfish
		Siganus punctatissimus	Peppered spinefoot
		Siganus punctatus	Goldspotted spinefoot
		Siganus spinus	Little spinefoot
		Siganus vermiculatus	Maze rabbitfish
		Siganus vulpinis	Foxface
	Acanthuridae	*Acanthurus albipectoralis*	Whitefin surgeonfish
		Acanthurus auranticavus	Orange-socket surgeonfish
		Acanthurus bariene	Black-spot surgeonfish
		Acanthurus blochii	Ringtail surgeonfish

Actinopterygii	Acanthuridae	*Acanthurus guttatus*	Whitespotted surgeonfish
		Acanthurus leucocheilus	Palelipped surgeonfish
		Acanthurus lineatus	Lined surgeonfish
		Acanthurus maculiceps	White-freckled surgeonfish
		Acanthurus nigricauda	Epaulette surgeonfish
		Acanthurus nigroris	Bluelined surgeonfish
		Acanthurus nubilus	Striped surgeonfish
		Acanthurus olivaceus	Orangespot surgeonfish
		Acanthurus pyroferus	Chocolate surgeonfish
		Acanthurus triostegus	Convict surgeonfish
		Acanthurus xanthopterus	Yellowfin surgeonfish
		Ctenochaetus striatus	Striated surgeonfish
		Ctenochaetus tominiensis	Orangetip bristtletooth
		Naso annulatus	White-margin unicornfish
		Naso brachycentron	Humpback unicornfish
		Naso brevirostris	Spotted unicornfish
		Naso fageni	Horseface unicornfish
		Naso lituratus	Orangestripe unicornfish
		Naso lopezi	Slender unicornfish
		Naso tonganus	Humpnose unicornfish
		Naso unicornis	Bluespine unicornfish
		Zebrasoma veliferum	Sailfin tang
	Scombridae	*Euthynnus affinis*	Kawa kawa
		Grammatorcynus bilineatus	Double-ined mackerel
		Rastrelliger kanagurta	Indian mackerel
		Sarda orientalis	Oriental bonito
		Scomberomorus commerson	Spanish mackerel
		Trachurus symmetricus	Chub mackerel
	Balistidae	*Balistapus undulatus*	Orangestripe triggerfish
		Balistoides viridescens	Titan triggerfish
		Melichthys niger	Black triggerfish
		Melichthys vidua	Pinktail triggerfish
		Pseudobalistes flavimarginatus	Yellowmargin triggerfish
		Rhinecanthus aculeatus	Hawaiian triggerfish
		Rhinecanthus lunula	Halfmoon triggerfish
	Balistidae	*Rhinecanthus verrucosus*	Blackpatch triggerfish
		Sufflamen bursa	Pallid triggerfish

Actinopterygii	Balistidae	*Sufflamen fraenatum*	Bridled triggerfish
	Ostraciidae	*Ostracion solorensis*	Striped boxfish
Reptilia	Cheloniidae	*Chelonia mydas*	Green turtle
		Eretmochelys imbricata	Hawksbill turtle