The small-scale fisheries of Timor-Leste and the impacts of the COVID-19 pandemic

Sarah Jørgensen Veillat

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Department of Biology
University of Bergen
Norway

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Abstract

Small-scale fisheries (SSFs) of developing countries are an important yet neglected part of the world's capture fisheries. The general lack of fisheries dependent and independent data makes it difficult to predict the impact of future crises on SSFs, and thus to prepare for them. This research focusses on the SSF of the small island developing state Timor-Leste. Timor-Leste is a newly independent country, with a still underdeveloped fishery. WorldFish, a non-profit research organisation based in Penang, carries out projects that focus on promoting the fish production of the country to combat malnourishment. One of the ongoing projects is a new catch and effort monitoring program that has been active since 2016. This thesis will be the first to explore and analyse this dataset to give a descriptive analysis of the SSF of Timor-Leste. Simultaneously, the data is used to examine the possible impact of the COVID-19 pandemic, to give insight on how the fisheries cope under the pressure of such a health emergency. The SSF of Timor-Leste has the characteristics of a typical small-scale fishery, having small inshore boats and crews and catching multiple species. The climate and other occupations such as agriculture determine the seasonality pattern of the fisheries. The catch is sold locally and what cannot be traded is kept for own consumption. The results suggest that the SSF of Timor-Leste is quite resilient against the COVID-19 crisis. While experiencing a decline in the market value of the catch, it does not appear to have been as impactful as in other SSFs, where a decrease in fishing effort has been measured as well. It is possible that the limited export and modest tourism sector of Timor-Leste have sheltered the fisheries from enduring the same shock that other SSFs have. It will thus be important to put a significant amount of effort into preserving the resilience of the fisheries when promoting and developing the sector. This thesis contributes to filling the data gap present of small-scale fisheries, and hopefully incites an increase of descriptive analyses of SSFs.

Foreword

It is with pleasure that I hereby present to you my thesis on the small-scale fisheries of Timor-Leste in Southeast Asia, which is the final work of my Master study in Fisheries Biology and Management at the University of Bergen.

Originally, my thesis was not supposed to be about a small-scale fishery in a developing country, but a study on different sampling methods of tropical fish communities. However, as most people, I had not foreseen what the year 2020 would have in store for us. The COVID-19 pandemic and the resulting travel restrictions made it impossible to perform the required fieldwork, and the subject of the thesis had to be changed accordingly. WorldFish, a non-profit international research organisation under the Consortium of International Agricultural Research Centres (CGIAR), which provided the data this thesis is based on, had piloted a new catch and effort monitoring program in Timor-Leste a few years prior, that had yet to be explored and analysed. This now desk-based thesis proved to be the perfect opportunity to perform this exploration, and with the ongoing crisis it could simultaneously be used to test if the pandemic had impacted the fisheries in Timor-Leste. This change in topics sparked an interest for a subject I had not initially thought to pursue. Small-scale fisheries were introduced to me in a different light, and I became intrigued by the complexity of the subject. One cannot claim to be properly informed on the biology and management of small-scale fisheries without comprehension of the local generational fishing culture, especially in developing countries. As I have always taken an interest in social and cultural sciences, this interdisciplinary aspect of the field is something that I believe fits me as a glove. My goal was to include such an aspect to this thesis, and with the help of Dr. Jacqueline Lau (James Cook University, Australia), which to whom I am extremely grateful, I had made a framework for a focus discussion group where fishers and traders could discuss their experiences with the pandemic. This discussion group was supposed to be held by enumerators in situ, however at that time Timor-Leste had to cope with a severe COVID-19 outbreak as well as devastating floods. Unfortunately, but understandably, the discussion groups had to be postponed and could therefore not be a part of this research. I have nonetheless tried my best to include sociological and cultural viewpoints to this thesis by gaining information through literature and anecdotes of experts on the topic.

I am extremely grateful for the help and support I have received from countless people. This thesis could not have been written without you. First and foremost, I would like to thank my supervisor Dr. Jeppe Kolding of the University of Bergen for his guidance throughout this process. Thank you for going out of your way to

make sure I was doing okay and did not get lost in the stress of writing a thesis. I will truly miss our lengthy meetings where a significant amount of time was spend talking about past and future experiences. These conversations always left me with a new sense of confidence and motivation. I would like to equally thank my external supervisor Dr. Alexander Tilley of WorldFish, without whom this thesis would not have existed, as he was the one to suggest the new subject. Thank you for your support and guidance, and for answering my countless questions about Timor-Leste. My sincere thanks to Joctan Dos Reis Lopes of WorldFish, for having been willing to conduct the focus discussion groups and for keeping me informed about the current situation of the Timorese fisheries. I would like to thank Ir. Paul van Zwieten of the University of Wageningen and Fernando Cagua of WorldFish for their help with the statistical analysis. Special thanks to Dr. Richard Telford of the University of Bergen, who hosted the weekly R clubs of which I became a resident. I will now have to come up with new activities to fill my Friday afternoons. Lastly, I am extremely grateful for the unconditional support and love I have received from my friends and family. Thank you for sticking with me through it all.

My sincere hope for this thesis is that it will spark the interest of the reader as much as it has mine. I wish you a happy reading.

Sarah Jørgensen Veillat

Amsterdam, August 02, 2021

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List of Abbreviations and Acronyms

CPUE . . . . Cath per unit effort

ENSO . . . . El Niño-Southern Oscilation

FAD . . . . Fish aggregating device

GDP . . . . Gross domestic product

IOD . . . . Indian Ocean Dipole

PDS trackers . . . . . . GPS trackers manufactured by Pelagic Data Systems Inc. (San Francisco, CA)

PeskAAS . . . . Tetum word for fisheries (*Peskas*) + Automated Analytics System

SIDS . . . . Small island developing state

SSF . . . . Small-scale fishery

SST . . . . Sea surface temperature

1. Introduction

Small-scale fisheries (SSFs) are an important part of the global fish production, contributing around half of the total annual catch of capture fisheries (World Bank et al., 2012). Of the several million people engaged in SSFs, over 90% live in developing countries and small island developing states (SIDSs), for whom it is an essential source of food and income (Mills et al., 2011; World Bank et al., 2012). SSFs in developing countries and SIDSs are at risk due to high poverty levels and climate change, and are simultaneously being put under pressure to conform to western management strategies (Béné & Friend, 2011; Islam, 2011; Kolding & Van Zwieten, 2011; Kolding et al., 2014; Macusi et al., 2020). These management strategies are often based on limited information, as there is clear underrepresentation of SSF in the literature considering their importance (Gill et al., 2019; Kolding et al., 2014; Pauly & Zeller, 2014; Smith et al., 2019). While making the effort to improve management of small-scale fisheries is not inherently bad, doing it with a lack of fisheries dependent and independent data and without understanding the social and cultural elements can result in doing more harm than good (Kolding & Van Zwieten, 2011). Filling these gaps in our knowledge should be a priority, as to determine their level of resilience against crises and, if necessary, strengthen them.

One of the latest and arguably one of the biggest crises our world has faced is the COVID-19 pandemic. It has had substantial economic, social and health impacts on the entire world (World Bank, 2020a; World Trade Organization, 2020). While most SIDSs benefit from a remote location which can delay and limit the spread of COVID-19, it also implicates that any foreign help during the crisis will be more problematic (Filho et al., 2020). Furthermore, foreign aid and tourism, which are often a vital part for the economy and wellbeing of SIDSs, have dwindled due to international travel and trade restrictions (Feeny & McGillivray, 2010; Filho et al., 2020; Pratt, 2015). As mentioned, SSFs are an important source of food and income for people living in SIDSs, and it is thus important to know if and how the pandemic and the consequential global lockdown has impacted these fishing communities.

In this thesis, the focus will be on the small-scale fisheries of the Democratic Republic of Timor-Leste. Timor-Leste, also known as East Timor, is a SIDS in Southeast Asia. The official languages are Portuguese and Tetum, but there are many other indigenous languages in use (Taylor-Leech, 2009). It is at long-term high risk from the COVID-19 crisis due to its fragile economic and health conditions (CARE, 2020). The history of Timor-Leste has not been peaceful and is still a controversial topic, but outside the scope of this thesis. It is however important to recognize that the country has only recently been declared a sovereign state by the United Nations in May 2002, after having suffered two brutal civil wars in 1979 and 1999 and a 24-year long occupation by Indonesia (Braithwaite et al., 2012; Ingram et al., 2015). These calamities have left the country with high poverty rates, poor health services and infrastructure, and 36% of the population experiences chronic food insecurity due to low quality and quantities of food intake (CARE, 2020; Casado & Alonso, 2019; National Directorate of Food Security and Cooperation, 2019). While during the Indonesian occupation the commercial fishery played a significant role in the economy of Timor-Leste, after the civil war in 1999 this completely plummeted as the infrastructure of the country was destroyed (Barbosa & Booth, 2009). Hereafter, the SSF became the dominant fishery in Timor-Leste. Presently, the fish consumption of the Timorese population is low, both in the coastal communities as well as in the inland areas (17 and 5.2 kg/capita/year, respectively), especially compared to other SIDS in the Pacific (30–118 kg/capita/year in Melanesia, 62–115 kg in Micronesia and 50–146 kg in Polynesia) (FAO, 2014; López Angarita et al., 2019; Mills et al., 2013). Agriculture is responsible for most of the food production, with 90% of rural households engaged in it (FAO, 2015; Ximenes et al., 2018). Most families involved in fishing have diverse livelihoods, where most of their time and energy is spend on agriculture and livestock farming (Mills et al., 2013). WorldFish, an international non-profit research organisation based in Penang, Malaysia, carry out development projects that focus on boosting the fisheries production in Timor-Leste to help combat malnutrition, specifically in terms of micronutrient deficiency (López Angarita et al., 2019). These projects include: deploying nearshore fish aggregating devices (FADs) as a way for small-scale fishers to access nutritious and sought-after small-pelagic species using their normal gear types; building stronger market chains by improving the facilities and promoting innovations to extend the market to inland areas; and educating the population on the nutritional value of fish (López Angarita et al., 2019; Tilley et al., 2019). One of the main issues however is the lack of information on the SSF of Timor-Leste. WorldFish has therefore piloted a new catch and effort monitoring program, called PeskAAS, to fill this data gap (Tilley et al., 2020). PeskAAS is a pseudo-acronym, combining the Tetum word for fisheries (*peskas*) and the abbreviation for Automated Analytics System. It is an interactive web-hosted application in which one can access databases containing catch and trip records, with the goal of facilitating data exploration and decision-making processes for small-scale fisheries. The data sampling for this database started in 2016 and has yet to be explored, analysed, and visualised for the broader public. In this thesis, this new dataset will be scrutinised and investigated, to give a descriptive analysis of the fisheries of Timor-Leste. Furthermore, it will be used to analyse the potential effect of the COVID-19 pandemic on the fisheries, primarily on the effort, the landings, and the market value of the produce.

2. Background Information

2.1 Geographic and demographics

Timor-Leste is surrounded by Indonesia to the west, north and east, and Australia to the south with the Timor Sea in between (fig. 2.1). It has a coastline of 783 km and a total land area of around 14.954 km^2, including two islands: the larger Atauro island and the smaller, uninhabited Jaco island (Lopes et al., 2019). Atauro island, with a land area of around 140 km^2, is located approximately 30 km north of the capital Dili and has a population of around 10,000 (General Directorate of Statistics, 2015; Lopes et al., 2019). Jaco island is located just off the coast of the eastern end of Timor-Leste and has a land area of around 10 km^2. The country counts around 1.3 million citizens which is expected to triple by 2050 (Molyneux et al., 2012). Most cities, including the capital Dili, are located on the north coast. Consequently, this is where the majority of the people are situated: over 60% of the total population lives on the north coast and around 20% on the south coast (General Directorate of Statistics, 2015). Most economic activity is centred around Dili, and the rural population experience higher poverty rates than people living in urban areas (Moxham & Carapic, 2013).

2.2 Climate and marine landscape

Timor-Leste has a tropical climate, with temperatures at the coast ranging from 25 to 30 degrees Celsius all year round and with a pronounced wet (December to May) and dry season (June to November) (fig. 2.2) (Timor-Leste National Directorate of Meteorology and Geophysics et al., 2015). This seasonality pattern of the rainfall experiences between-year fluctuations, caused by both the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) (Australian Bureau of Meteorology & CSIRO, 2014). The ENSO and the IOD are climate phenomena which are driven by anomalies in the sea surface temperature (SST) (NOAA, 2021; Saji et al., 1999). When the SST around Timor-Leste is cooler than usual (during El Niño or positive phase of IOD), it creates a dryer climate with prolonged droughts and shorter wet seasons (Timor-Leste National Directorate of Meteorology and Geophysics et al., 2015). When the opposite is the case and the SST around Timor-Leste is warmer than normal (during La Niña or negative phase of IOD), there is more rainfall and longer lasting wet seasons, accompanied by an increase in floods and landslides (Timor-Leste National Directorate of Meteorology and Geophysics et al., 2015). The mountain range separating the northern coast of the southern (fig. 2.1) causes different rainfall patterns on the two coasts (Asian Development Bank, 2014).

The west part of the southern coast is wetter than the rest of the country, whereas some parts of the north coast experience dryer weather. Wind-driven waves are usually weak on the north coast, while waves on the south coast are more high-energy, especially during the period April – November (Australian Bureau of Meteorology & CSIRO, 2014; Tomascik et al., 1997). The south coast experiences rougher seas due to cyclones coming from the Indian Ocean, which are intensified during La Niña (Asian Development Bank, 2014). The marine landscape differs around the country (fig. 2.3). The south coast has a shallow slope, while the north coast has a very steep slope, quickly descending to several kilometres depth. The coral reefs are predominantly fringing reefs, located for the most part on the north coast and around Atauro island (Asian Development Bank, 2014). The absence of any large settlements of coral reef on the south coast are likely due to high rates of erosion and sedimentation from the rivers, as well as the different climate and wave and current activity (Alongi et al., 2009; Asian Development Bank, 2014).

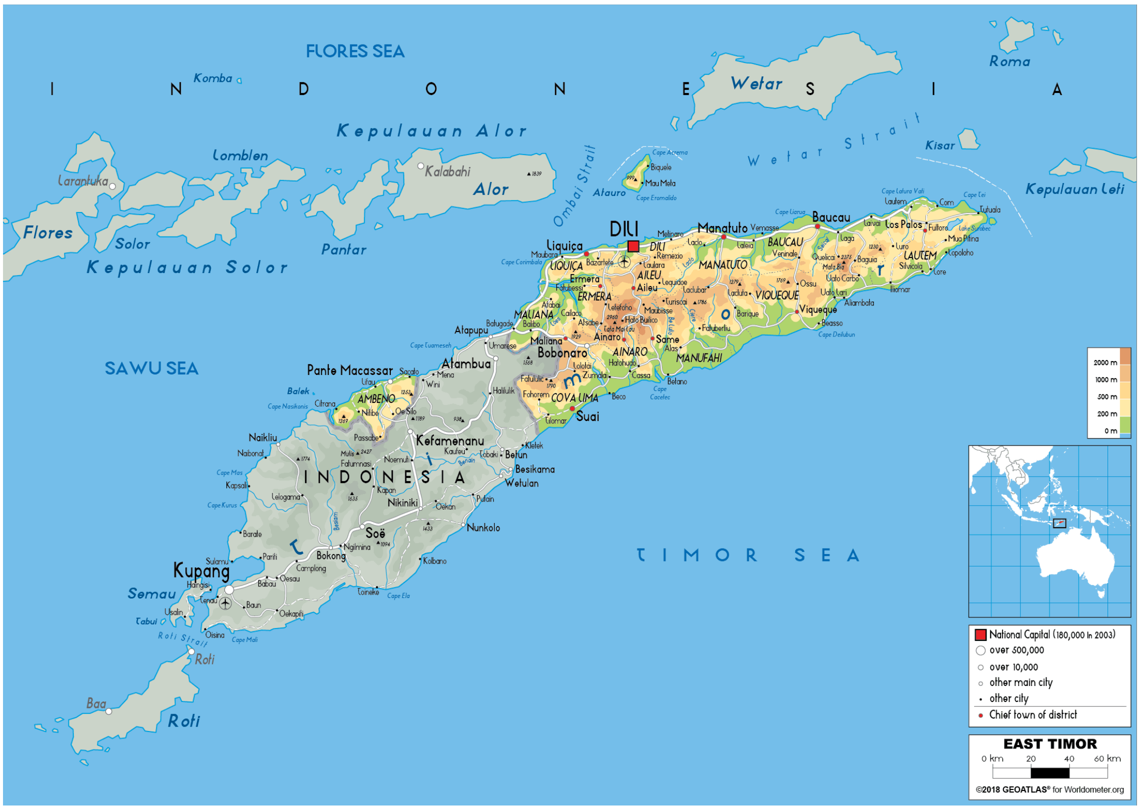

Figure 2.1: **Map of Timor-Leste and its surroundings.** The colours show the elevation from 0 meters above sea-level (green) to 2000+ meters above sea-level (orange-brown). The size of the points show the size of the cities. The small map on the right side shows the placement of the country compared to the rest of Southeast Asia and Australia. Source: Geoatlas (2018)

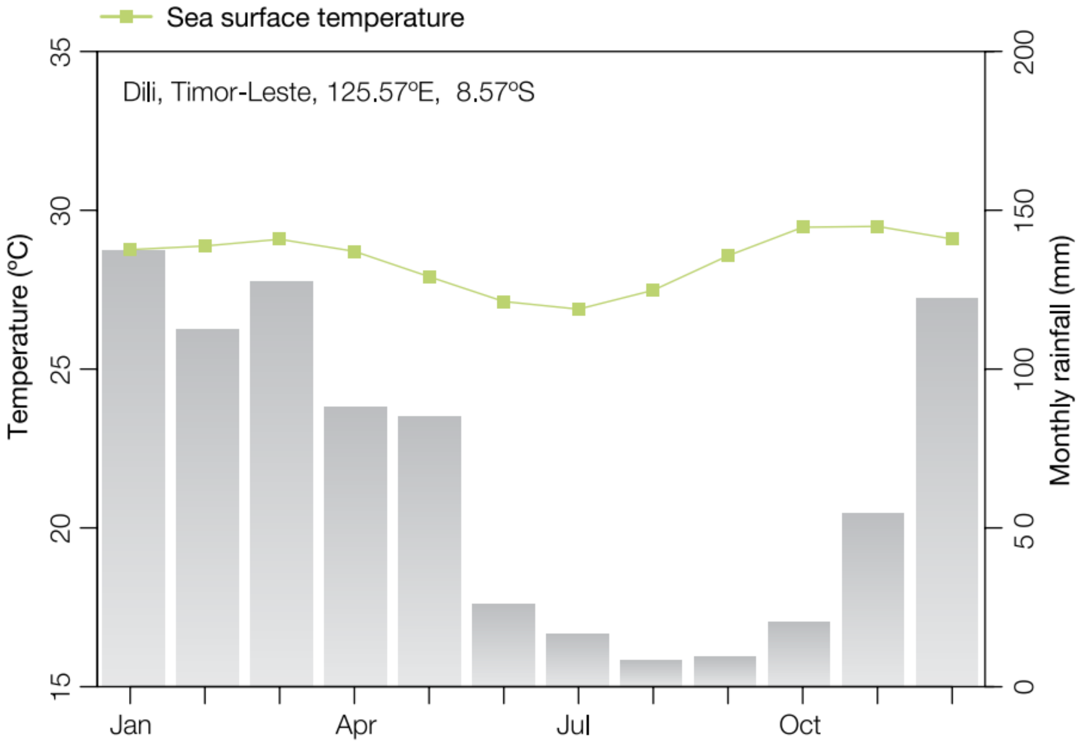

Figure 2.2: **Seasonal rainfall and sea surface temperature in Timor-Leste.** Seasonal rainfall and sea surface temperature in Timor-Leste, measured in Dili. Source: Timor-Leste National Directorate of Meteorology and Geophysics et al. (2015)

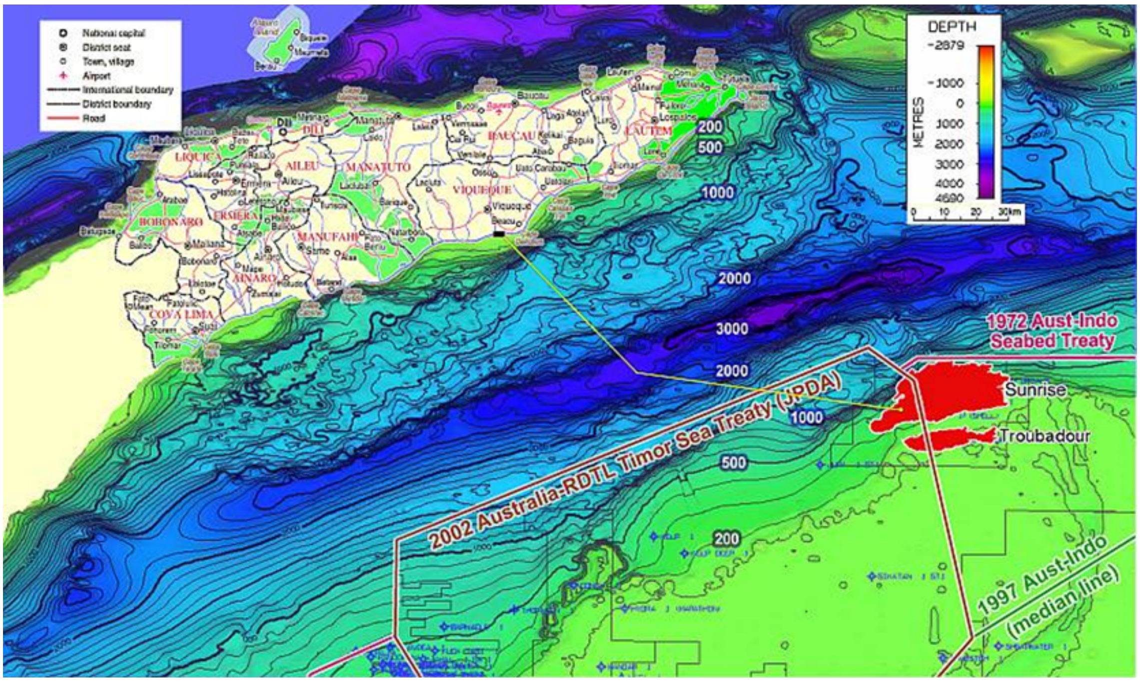

Figure 2.3: **Depth chart of the surrounding waters of Timor-Leste.** The shading shows the depth (metres) of the seabed going from 0 metres below sea-level (green) to 4690 metres below sea-level (dark purple). Source: Hoffmann (2007)

2.3 COVID-19 development and measures

The first COVID-19 case in Timor-Leste was announced on March 21st, 2020, and on March 28th the government issued a state of emergency (Timor-Leste, 2020). During this state of emergency, a travel ban was enacted, public transportation was shut down, social distancing was required, and professional and educational activities had to be conducted from home if possible. It was prohibited to have any type of gathering (religious, social, or political), however markets and street venders were authorised if the rules for social distancing, face masks and hygiene were followed. The state of emergency has been renewed multiple times during the year and is still in force at the beginning of 2021. In 2020, there have been no major outbreaks of the virus nor any confirmed deaths caused by COVID-19 (World Health Organization, 2021).

3. Material and Methods

3.1 Study area

The study was conducted in Timor-Leste. The country consists of 13 municipalities, of which only Aileu and Ermera do not have a coastline (fig. 3.1). Atauro island, situated 30 km from the north coast, is part of the Dili municipality.

The coastal municipalities were grouped into three statistical areas for the purpose of this study: Atauro island, the north coast, and the south coast (fig. 3.1: blue, yellow, and green, respectively). The landing sites of Manatuto and Lautém are located on the north coast and have therefore been assigned to the north coast strata, even though the municipalities border both coasts. The municipalities Ermera and Aileu do not have a coastline and are thus not included. These areas were chosen due to their difference in rainfall pattern, wave activity, marine landscape, and demographics.

Figure 3.1: **A map of Timor-Leste and its municipalities.** The dots represent the landing sites where catch and trip information were recorded*. The colours represent the different strata: Atauro island (blue), north coast (yellow), and south coast (green). Source: Tilley et al. (2020). *Not all landing sites are shown on this map, only the ones where enumerators are presently active.

3.2 Data collection

For this study the new national fisheries monitoring system PeskAAS was used (Tilley et al., 2020). The PeskAAS database can be compartmentalised into two parts: the catch and effort data collected by enumerators at the landing sites (shown in fig. 3.1) and the trip data collected by solar-powered GPS units installed on a part of the fishing boats. These GPS units are produced by Pelagic Data Systems Inc. (San Francisco, CA) and are hereafter referred to as PDS trackers.

In this thesis, only the specifics of the PeskAAS system relevant to this study are discussed. See Tilley et al. (2020) for a more detailed explanation of the PeskAAS monitoring system.

3.2.1 Data sampling by enumerators

Of all the registered fishing boats in Timor-Leste, 14% were sampled on average (table 3.1). Over the period of 10 September 2016 to 12 April 2021, 37,470 fishing trips were recorded: 13,347 from Atauro island, 15,333 from the north coast, and 8,790 from the south coast (fig. 3.2). A fishing trip is defined as the moment the fishing boat leaves the dock for the purpose of fishing, to the moment the boat returns. In case of shore-based fishing, a trip is defined as the time the fishermen are spending actively fishing. There is an increase in sampling effort over the years, which is due to a gradual increase in sampling areas and enumerators (fig. 3.3; see Appendix A for the names of the places of the station codes and the exact number of samples). Enumerators document information about the boats used, the trip, catch and selling price (table 3.2). The sampling was done at the landing station right after a fishing trip was finished, and the information recorded on the market value and destination of the catch are therefore estimations of what will happen. Note that not all recorded trips had a boat ID documented, and it is thus possible that more boats were sampled than shown in table 3.1.

Table 3.1: **Total number of sampled and registered fishing boats per strata.** Information on the number of registered fishing boats was obtained from the Timor-Leste Ministry of Agriculture and Fisheries (2018).

Strata	# sampled boats	# registered fishing boats	% boats sampled
Atauro Island	89	348	25.6%
North Coast	129	1463	8.8%
South Coast	105	466	22.5%
Total	323	2277	14.2%

Table 3.2: **Information recorded by enumerators for every fishing trip.**

Information documented		Unit	Description
Trip	Duration	Rounded to nearest hour	-
	Number of fishers	Count	Men, women, and/or children engaged in fishing trip
	Gear type	-	Gill net, hand line, long line, spear gun, cast net, manual collection, beach seine, seine net and trap
Catch	Species	-	53 different categories*
	Fork length	Centimetres	-
	Number of fish	Count	-
	Weight of fish**	Grams	-
	Destination of catch	-	Own consumption, sold on market, or both
	Market value	USD	-
Boat	Boat ID	-	Unique ID number per boat
	Boat type	-	Canoe, motorboat, or shore-based
	Boat length	Metres	-
	Material	-	Fiberglass or wood
	Engine type (if motorboat)	-	Outboard or inboard

* see Appendix B for a detailed list of the species categories
** the weight of the fish was measured per species and length group, not per individual fish

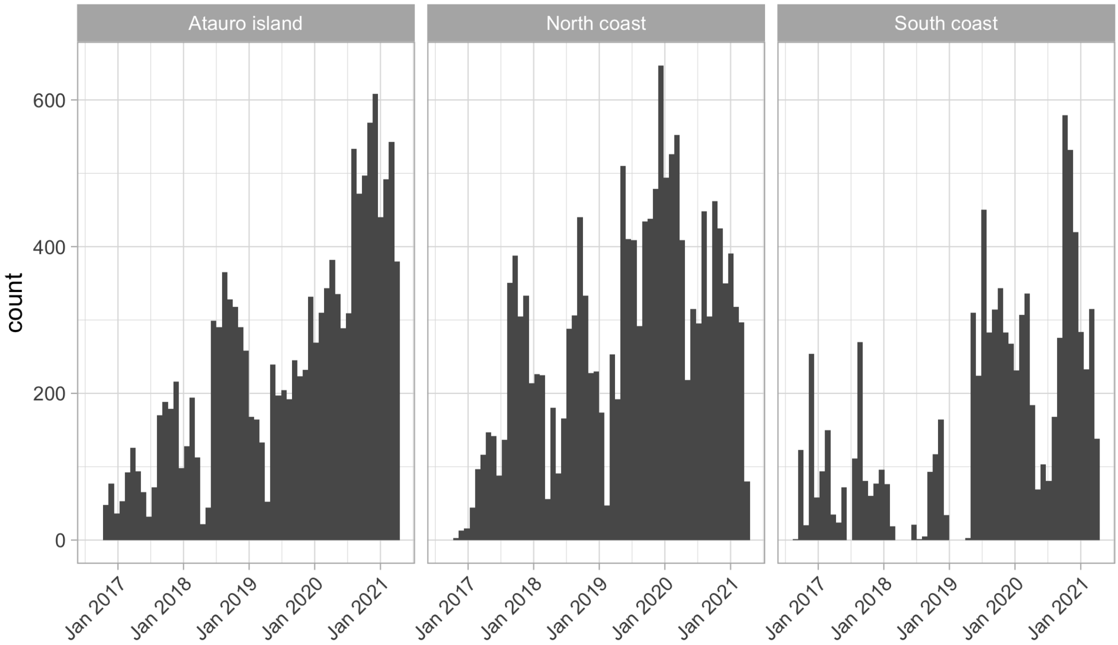

Figure 3.2: **Number of fishing trips recorded by enumerators.** Number of fishing trips recorded per month by the enumerators in Atauro island, north coast, and south coast, for the period of September 2016 to April 2021.

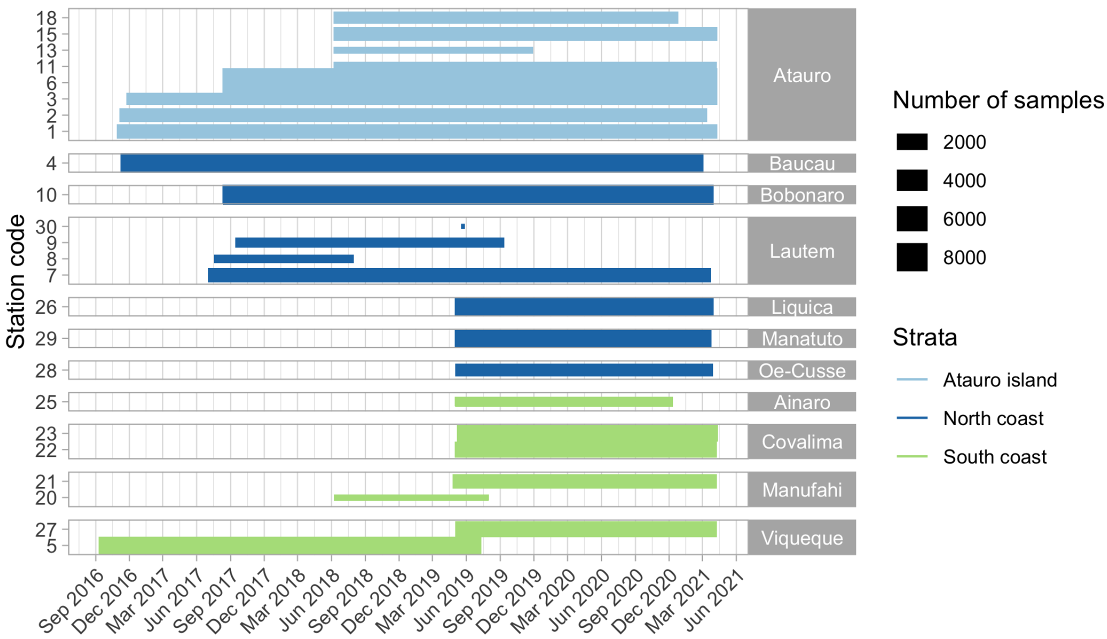

Figure 3.3: **Timeline of the sampling of fishing trips by enumerators in each station code.** The station codes are grouped by municipality. The colours show the strata (light blue for Atauro island, dark blue for north coast, green for south coast) and the thickness of the bar shows the total number of samples taken on a continuous scale

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3.2.2 Data sampling by PDS trackers

PDS trackers were installed on fishing boats to track the number of trips and to visualise geospatial fishing effort. In the period of 7 February 2018 to 14 March 2021, 55,929 fishing trips were tracked: 9,422 in Atauro island, 20,429 in the north coast, and 23,501 in the south coast (fig. 3.4). During a fishing trip, the location was automatically recorded every 5 seconds. The trackers were installed in batches over the course of two years, with a gradual attrition of total active number due to wear and tear, and loss for various reasons (fig. 3.5). This has resulted in a fluctuation of the number of boats being tracked during the sampling period of February 2018 to April 2021 (fig. 3.6).

The boats sampled by the enumerators and the boats with a PDS tracker installed are not always the same. An effort has been made to link the two datasets through a unique IMEI code (International Mobile Equipment Identity), however it was only possible to match 14% of the trips recorded by the enumerators through this method. Therefore, the decision was made to treat the two datasets as separate.

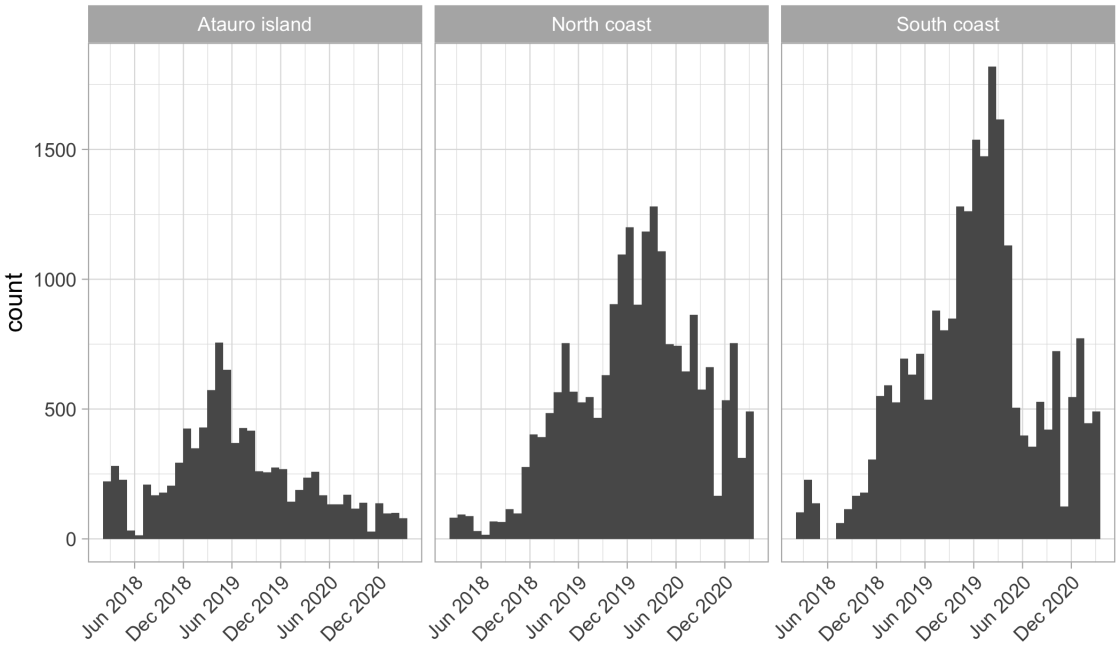

Figure 3.4: **Number of fishing trips recorded per month by the PDS trackers.** Number of fishing trips recorded per month by the PDS trackers in Atauro island, north coast, and south coast, between February 2018 and March 2021.

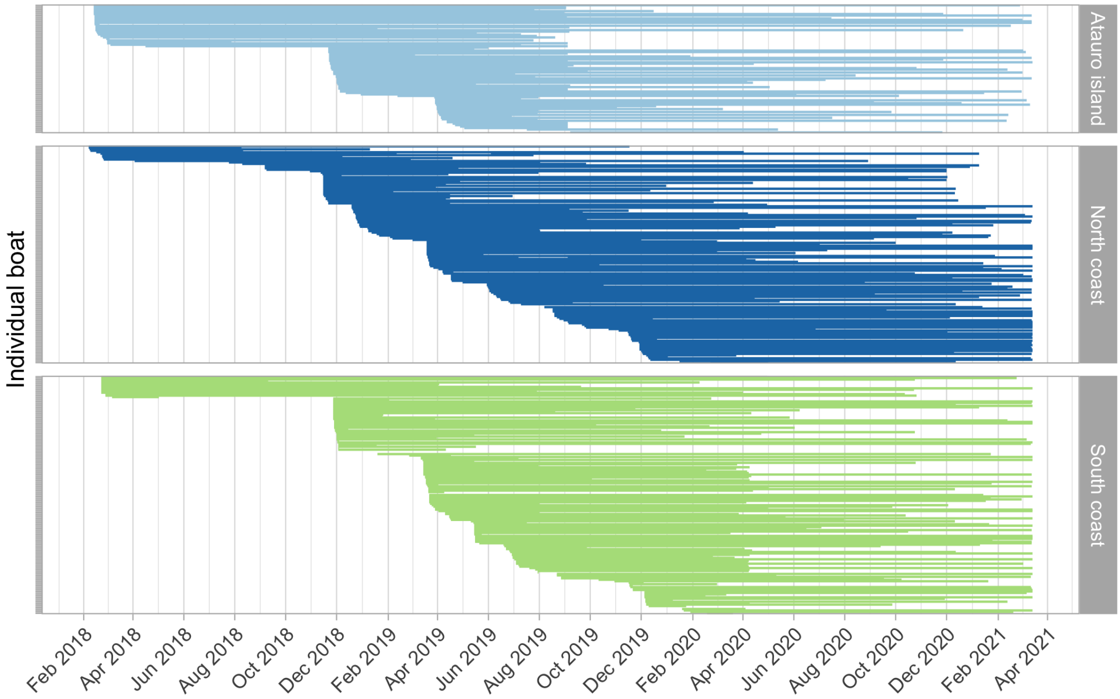

Figure 3.5: **Operation time for installed PDS trackers.** Operation time for installed PDS trackers in Atauro island (light blue), north coast (dark blue), and south coast (green), from February 2018 to April 2021. Every line on the y-axis signifies a single boat with a PDS tracker. Operation time goes from the time of the first tracked trip until the time the PDS tracker was last detected.

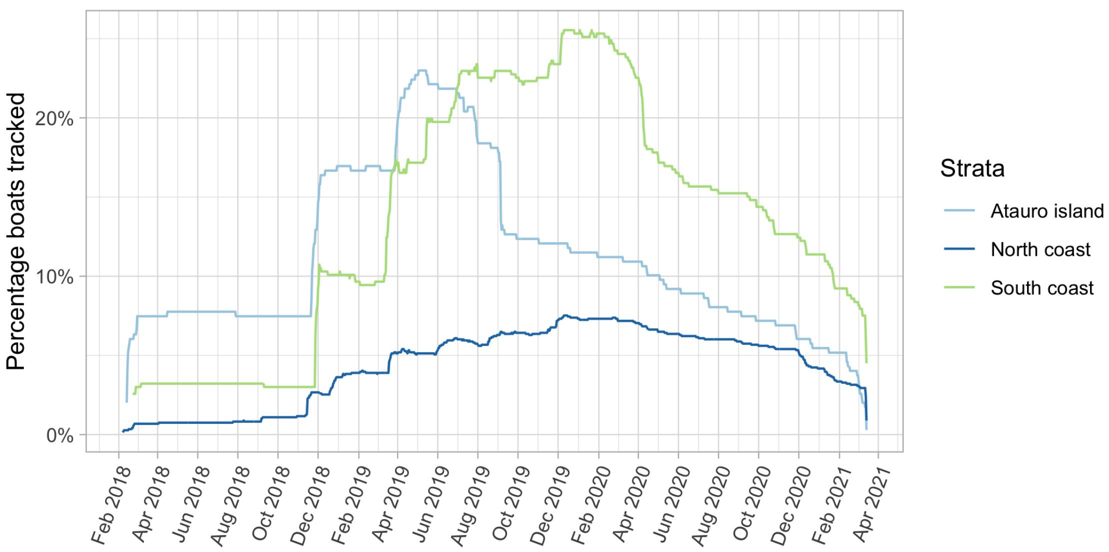

Figure 3.6: **Percentage of boats installed with a working PDS tracker.** Percentage of boats installed with a working PDS tracker in Atauro island (light blue), north coast (dark blue) and south coast (green), from February 2018 to April 2021. The percentage of boats being tracked was calculated using a fixed number of total fishing boats (table 3.1) for the entire sampling period.

3.3 Data handling

3.3.1 Species classification

A total of at least 53 identified different species were caught, excluding the species classified under "unknown" and "other". To facilitate the data handling and to keep the results comprehensible, the species were divided into 10 functional groups: small pelagics, large pelagics, small demersal, large demersal, shark and rays, crustaceans, shrimp, cephalopods, molluscs and unknown (See Appendix B for a detailed list of the species classification).

3.3.2 Scrutinising and cleaning of data

The data was extensively scrutinised for mistakes and outliers. To account for missing or unreasonable values in the dataset, estimations were made to fill the missing data and to change unreasonable values. Of the 37,470 trips recorded, 354 (0.9%) had values altered, a total of 12 (0.03%) had values discarded and changed to NAs, and a total of 1803 (4.8%) had missing values filled (see Appendix C for details on the changes made).

3.3.3 Index of Relative Importance

The index of relative importance (IRI) is an equation which calculates the relative importance of a species within a fisheries, by taking into consideration the weight, abundance (numbers) and frequency of occurrence all at once (Kolding, 1989). The equation 3.1 reads as follows:

$$\%IRI_i = \frac{(\%W_i + \%N_i) * \%F_i}{\sum_{j=1}^{S}(\%W_j + \%) * \%F_j} * 100 \tag{3.1}$$

Where $\%W_i$ equals the percentage weight and $\%N_i$ the percentage number of each species of the total catch, $\%F_i$ equals the percentage frequency of occurrence of each species in the total number of fishing trips, and S equals the total number of different species. This index can either be shown as a percentage ($\%IRI$) or as a rectangle, where the percentage number of fish ($\%N$), the percentage weight ($\%W$), and the percentage of the frequency of occurrence ($\%F$) are separately displayed relative to all other species.

While the original function of the equation is to calculate the index of importance of the species caught in a fishery, in this paper it was applied to functional groups and the gear use.

3.3.4 Effort

Estimation of total number of trips

The total number of trips per week was calculated using the trips sampled by the PDS trackers. As only a percentage of the total boats are being tracked (fig. 3.6), an estimation had to be made for the total number of fishing trips taken per week (equation 3.2):

$$\textit{Total Number Of Trips Per Week} = \frac{\textit{Number Of Trips Tracked Per Week}}{\textit{Percentage of Boats Being Tracked}} * 100 \tag{3.2}$$

Trip effort

To calculate the trip effort the duration of a trip (hours) was multiplied with the number of fishermen (including women and children), resulting in an effort unit of fisher-hours.

3.3.5 Catch per unit effort

In fisheries sciences, catch per unit effort (CPUE) is used as an indicator for the biomass status in a fishery. This basic assumption stems from the widely used catch equation (3.3) that assumes a relation between the catch (C) and the stock abundance or biomass (B):

$$C = f * q * B \tag{3.3}$$

Where f is the fishing effort and q is the catchability coefficient.

Rearranging this results to equation 3.4:

$$\frac{C}{f} = q * B \tag{3.4}$$

Where C/f is the catch per unit effort (CPUE). If catchability q is assumed constant, the CPUE is proportional to the standing biomass of the stock.

In this thesis, a CPUE with a standardised unit of effort was used (equation 3.5):

$$CPUE = \frac{1}{n} \sum C_i * \frac{SU}{U_i} * \frac{TU}{T_i} \tag{3.5}$$

Where n is the number of samples (fishing trips), C_i is the catch (weight or numbers) of fishing trip i, SU is the standard relative effort unit of the trip duration (1 hour), U_i the actual relative effort of the trip duration of fishing trip i, TU is the standard relative effort unit of the number of fishermen (1 fishermen), T_i the actual relative effort of the number of fishermen of fishing trip i.

3.3.6 Calculating total monthly landings

To estimate the total monthly catch, the equation 3.6 was used (Tilley et al., 2020):

$$C = CPUE * EPT * VAC * N * 0.001 \tag{3.6}$$

Where C equals the total monthly catch (in metric tons), $CPUE$ equals the mean monthly catch per unit effort (in kg per fisher-hour), EPT equals the median effort per trip of a month (in fisher-hours), VAC equals the vessel activity coefficient (average number of trips per month per boat), and N equals the total number of boats.

The total monthly landings per capita were calculated using the World Bank population statistics (table 3.3) (World Bank, 2021). As there is not yet any information on the population number of 2021, the value for 2020 was used.

Table 3.3: **Population statistics of Timor-Leste.** Population statistics of Timor-Leste used for analysis. The value of 2020 was used for 2021 as well. Source: World Bank (2021)

Year	# Population
2018	1,267,797
2019	1,293,120
2020	1,318,442
2021	1,318,442

3.3.7 Market value

To analyse the market value of the catch, the dataset was subset to only include catches which destination was to be sold on the market. Furthermore, there was no documentation of the market value before 15-04-2019 and until 01-07-2019 the data showed unreasonable values. Therefore, the analysis of the market value started at 01-07-2019, leaving 18,472 trips (49.5% of all recorded trips) to be considered.

In the peskAAS dataset, the market value of the catch was given per fishing trip instead of per caught species. To be able to estimate the market value per functional group, the data was filtered to only include trips where the weight of the catch consisted at least 95% of one functional group (fig. 3.7a). This was the case for 79.6% of the trips with information on the market value. The same process was done for the different species caught (fig. 3.7b), where 72.2% of the trips had a catch consisting 95% of one species (in weight). The assumption was made that the 5% weight of the other species or functional group in the catch was negligible with respect to the market value of the entire catch of that fishing trip.

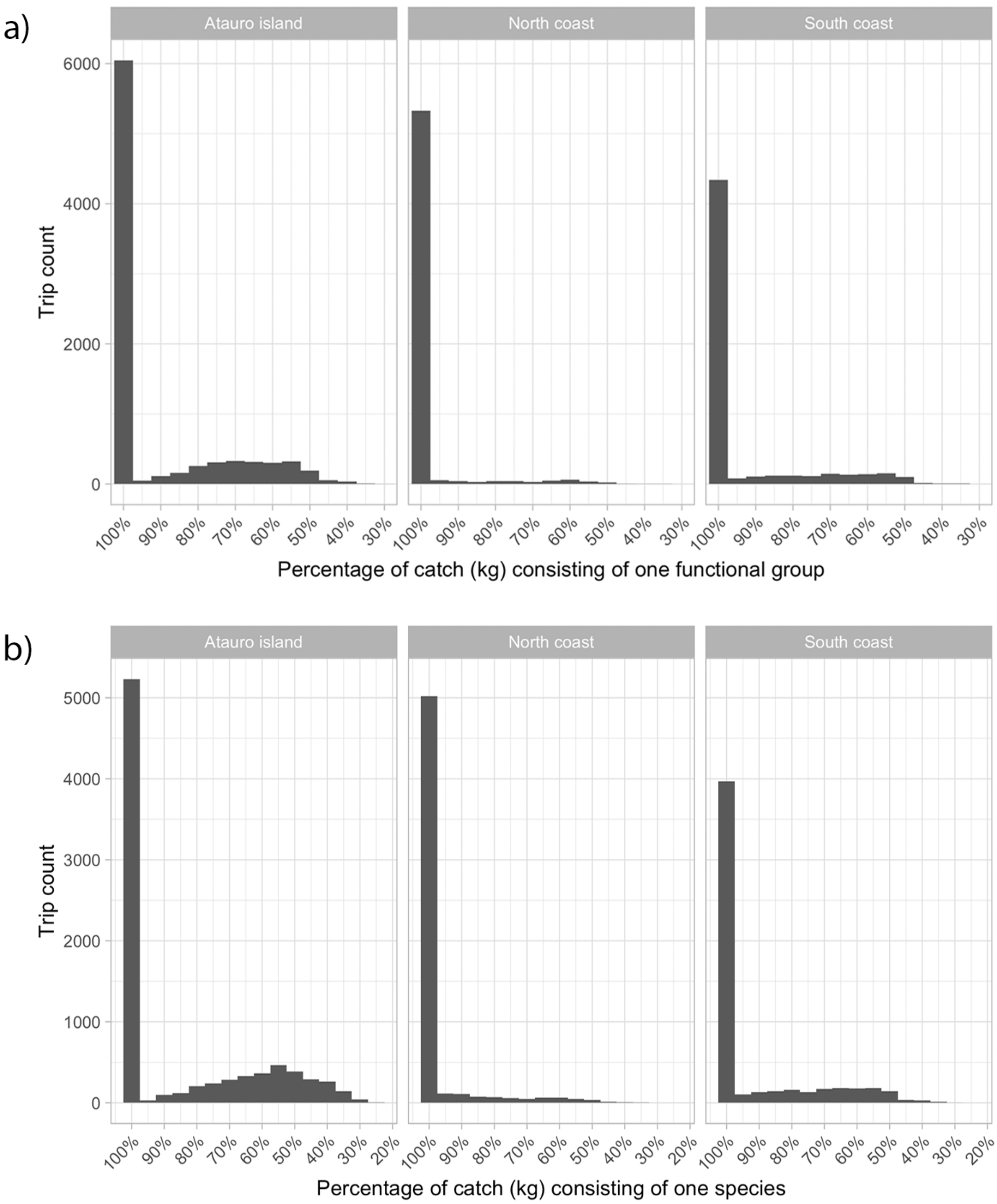

Figure 3.7: **Percentage of catch consisting of one functional group or species.** Histogram of the percentage of the catch (kg) of a trip consisting of one (a) functional group or (b) species.

3.4 Statistical analyses

All statistical analyses were performed in R 3.6.2 (R Core Team, 2019). Generalised linear models and generalised linear mixed effect models (Gaussian family) were carried out using the lme4 and nlme packages, and modelled means were computed using the emmeans package (Bates et al., 2015; Lenth, 2021; Pinheiro et al., 2019). All plots were created with the ggplot2 package (Wickham, 2016).

Prior to modelling, the data was subset into two years: pre-COVID-19-lockdown (29-02-2019 to 28-02-2020) and post- COVID-19-lockdown (29-02-2020 to 28-02-2021). Furthermore, station codes and gear types with a low sample count were removed to create balanced models (see Appendix C for details on the changes made). The independent variables gear type and boat type showed interaction, and therefore these two variables were not used together in a model. When a mixed effect model was used, the station code was put as random effect. The dependent variables tested were the number of trips taken per week per boat, the monthly landings (tons) and the market value of the catch (USD). The number of trips taken and the monthly catch were tested against strata and the lockdown stage. The market value was tested against strata, gear or boat type, and the lockdown stage. All dependent variables were log-transformed during the modelling and transformed back for the visualisation (see Appendix D for the frequency plots of the dependent variables before and after transformation). A p-value of 0.05 was chosen as the threshold for significance.

3.4.1 Model selection

The model selection of each dependent variable was based on the AICc, (Akaike Information Criterium), the AICc weight and the adjusted pseudo-R-squared (Akaike, 1998; Cameron & Windmeijer, 1997; Wagenmakers & Farrell, 2004). The AICc is a number that estimates the goodness of fit of a model, relative to other models of the same dataset. The AICc uses the maximum likelihood estimation, which is a measure of how likely a model will show the same values as the observed data. At the same time, it penalises models on complexity. The model with the lowest AICc is the model with the best and most parsimonious fit. The AICc weight uses the AICc to show the probability that a model is the true model, assuming that one of the given models is the truth. The adjusted pseudo-R-squared is another method of testing the goodness of fit of a model, that imitates the function of an actual adjusted R-squared. The common adjusted R-squared shows how much of the variance in the observed data can be explained by the independent variables given in your model. Therefore, the higher the value of the R-squared, the better of a fit the model is. This can however only be calculated for a linear regression model. For other types of models, such as generalised linear models, pseudo-R-squared has been developed. The difference is that it does not give a true representation of the proportion of your data that can be explained by the model and can only be used in comparison to pseudo-R-squared of other models using the same data and variables. A higher pseudo-R-squared relative to the other tested models shows a better fit.

4. Results

4.1 Descriptive information on the fishery

4.1.1 Fishing boats

Boat composition

Of the 89 registered boats on Atauro Island, 46% are paddle driven canoes and 54% are motorboats (fig. 4.1). In the north coast, of 129 registered boats 20% are canoes and 80% are motorboats, and of 105 registered boats in the south coast 71% are canoes and 29% are motorboats.

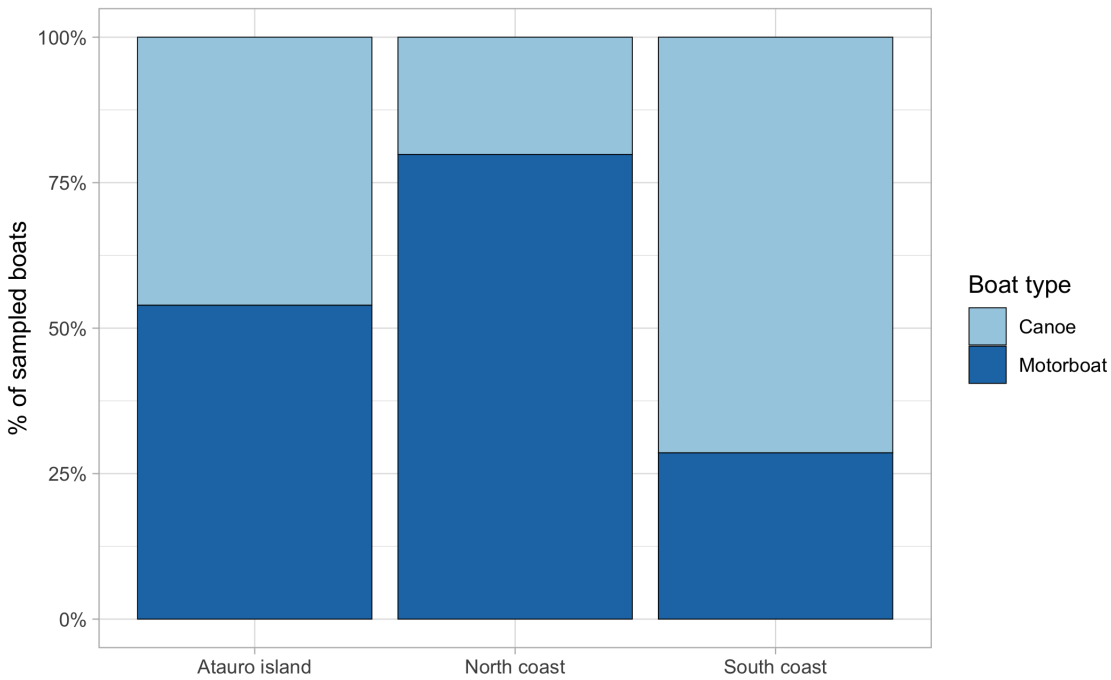

Figure 4.1: **Percentage of motorboats and canoes.** Percentage of paddle-driven canoes (light blue) and motorboats (dark blue) of the sampled boats on Atauro island, north coast, and south coast

Number of fishermen per boat type

Atauro island appears to have more active fishermen per trip than the north coast and south coast, both on canoes and on motorboats (fig. 4.2).

Trip duration per boat type

When making a fishing trip using canoes, the south coast seems to go out for the longest period (fig. 4.3). Fishing trips using motorboats have the longest duration on both the north and the south coast.

Boat length

Of the sampled boats, Atauro island has the highest median canoe and motorboat length, followed by the north coast and then the south coast (fig. 4.4).

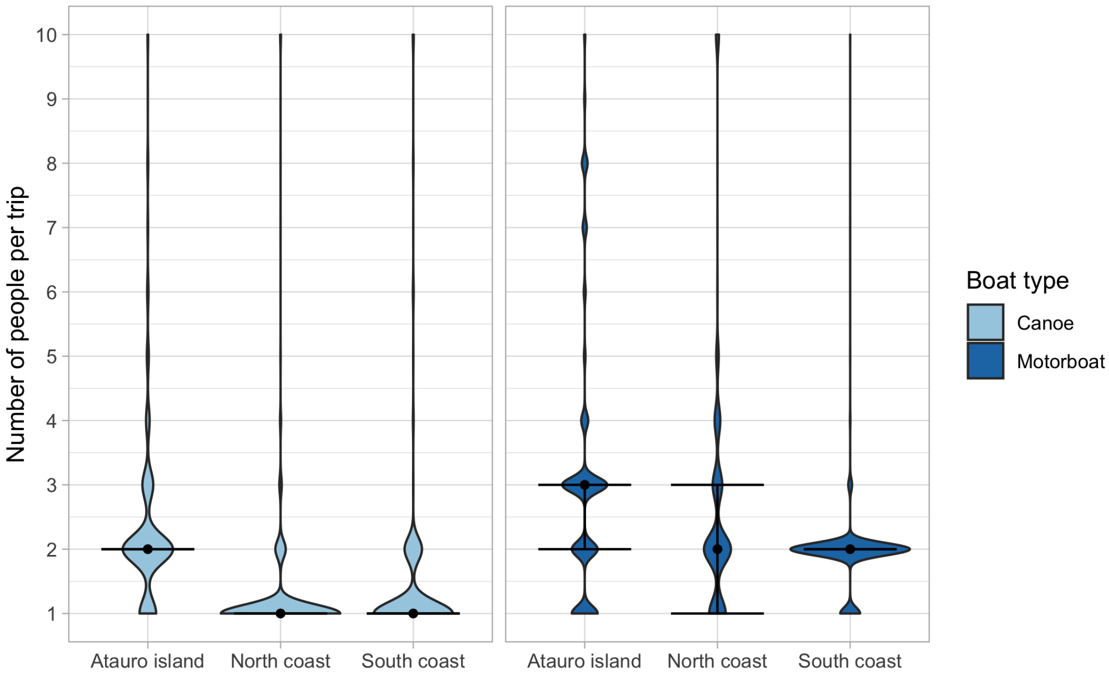

Figure 4.2: **Violin plots of the number of fishermen active per trip.** Violin plots of the number of fishermen active per trip on canoes (light blue) and motorboats (dark blue) in Atauro island, north coast, and south coast. The dot represents the median and the variance bars the first and third quartile.

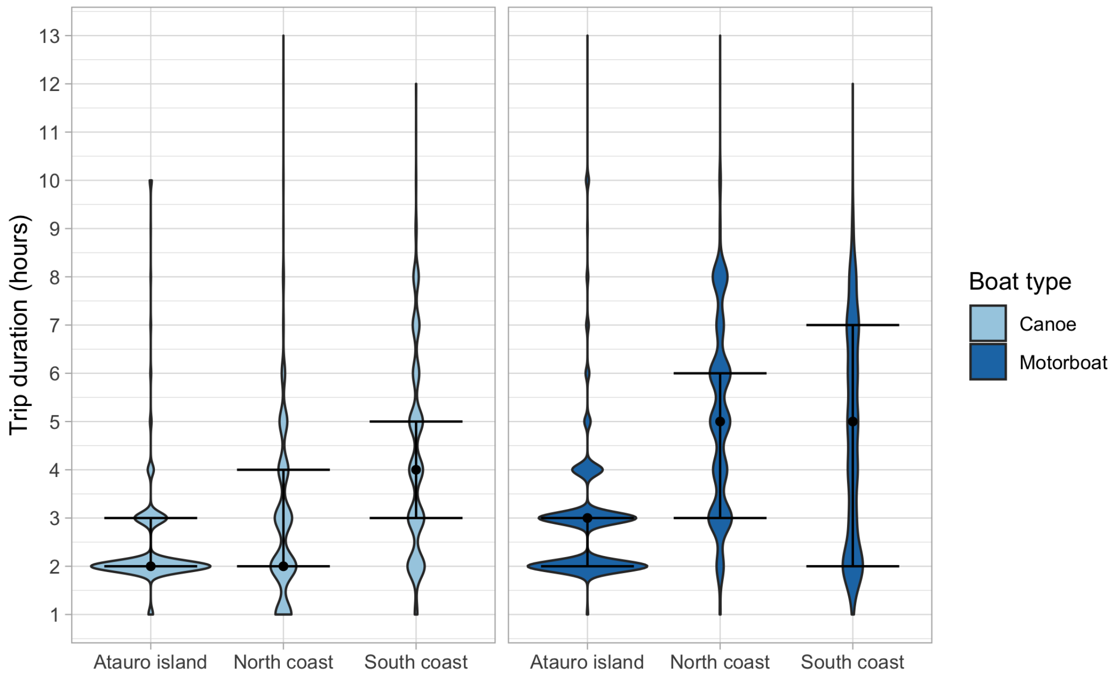

Figure 4.3: **Violin plots of the trip duration.** Violin plots of the trip duration (hours) for canoes (light blue) and motorboats (dark blue) in Atauro island, north coast, and south coast. The dot represents the median and the variance bars the first and third quartile.

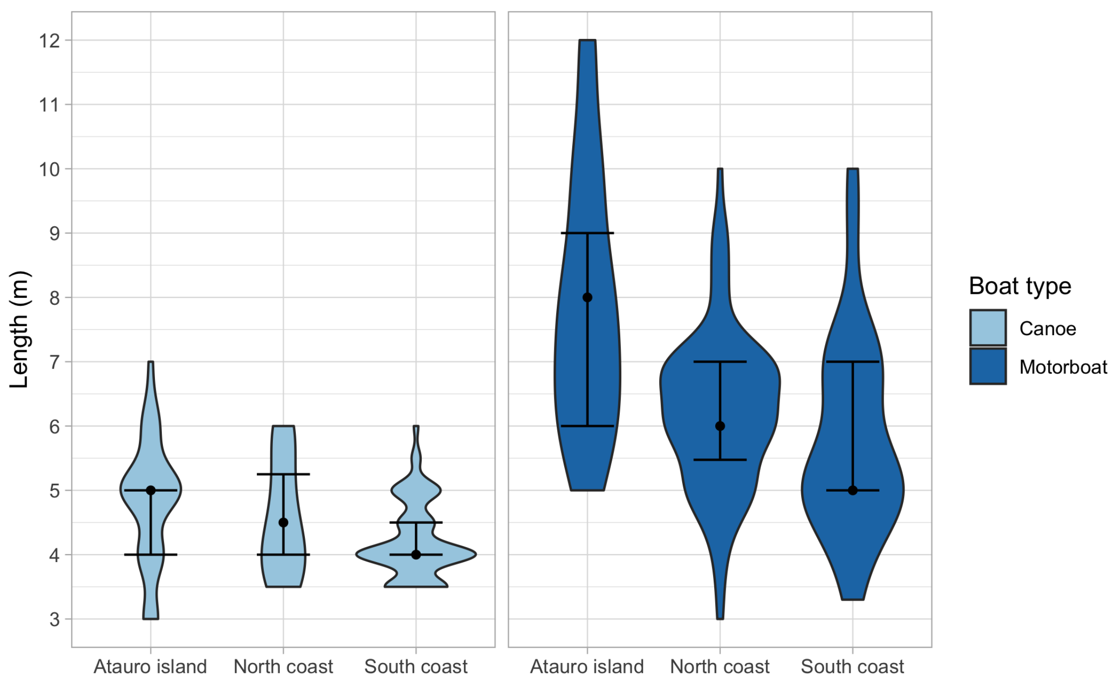

Figure 4.4: **Violin plots of the length (m) of sampled boats** Violin plots of the length (m) of sampled canoes (light blue) and motorboats (dark blue) in Atauro island, north coast, and south coast. The dot represents the median and the variance bars the first and third quartile.

Boat material

Almost all sampled canoes appear to be made of wood, except for one (2.4%) on Atauro island which is made of fiberglass (fig. 4.5). Of the sampled motorboats, the north coast has the highest percentage made of fiberglass (34 boats, 33.0%), followed by the south coast (4 boats, 13.3%), and then Atauro island (3 boats, 6.3%).

Engine type

Atauro island has mostly outboard engines on their sampled motorboats (95.8%), whereas the north coast and the south coast have a mixture of both engine types (34.0% inboard, 55.3% outboard, and 40.0% inboard, 46.7% outboard, respectively; fig. 4.6).

Boat use over time

On Atauro island and on the north coast the use of motorboats exceeds the use of canoes over time, while on the south coast the canoe stays the dominant choice of fishing boat (fig. 4.7). Shore-based fishing only counts for a small part of the fisheries and is no longer sampled around the beginning of 2019 for all three strata.

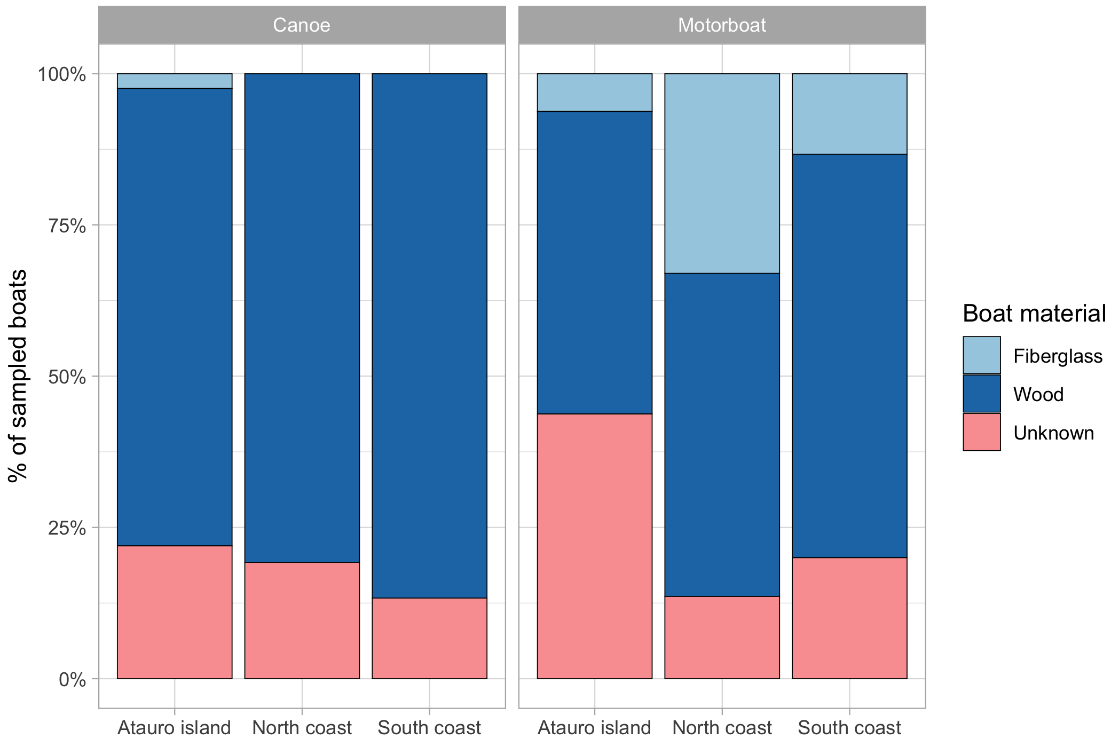

Figure 4.5: **Material of sampled boats.** Percentage of the sampled canoes and motorboats made of fiberglass (light blue) or wood (dark blue) on Atauro island, north coast, and south coast. Boats without information on the material are shown in red.

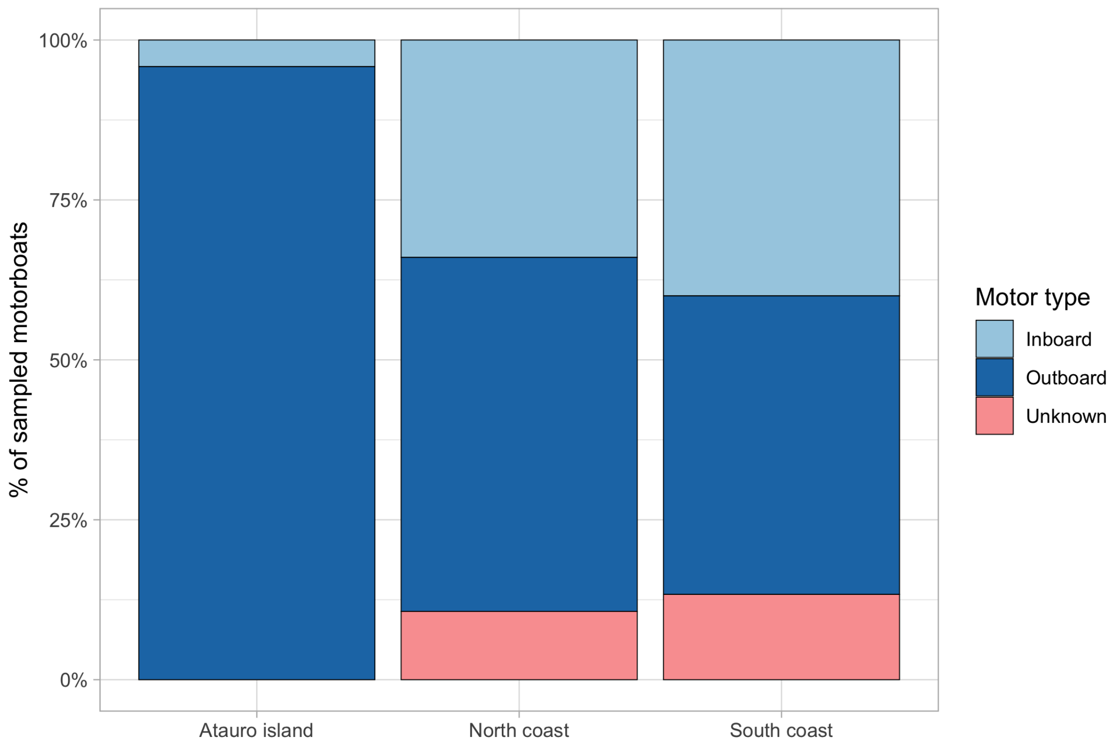

Figure 4.6: **Engine type on sampled motorboats.** Percentage of the sampled motorboats with an inboard (light blue) or outboard engine (dark blue) on Atauro island, north coast, and south coast. Boats without information on the engine type are shown in red.

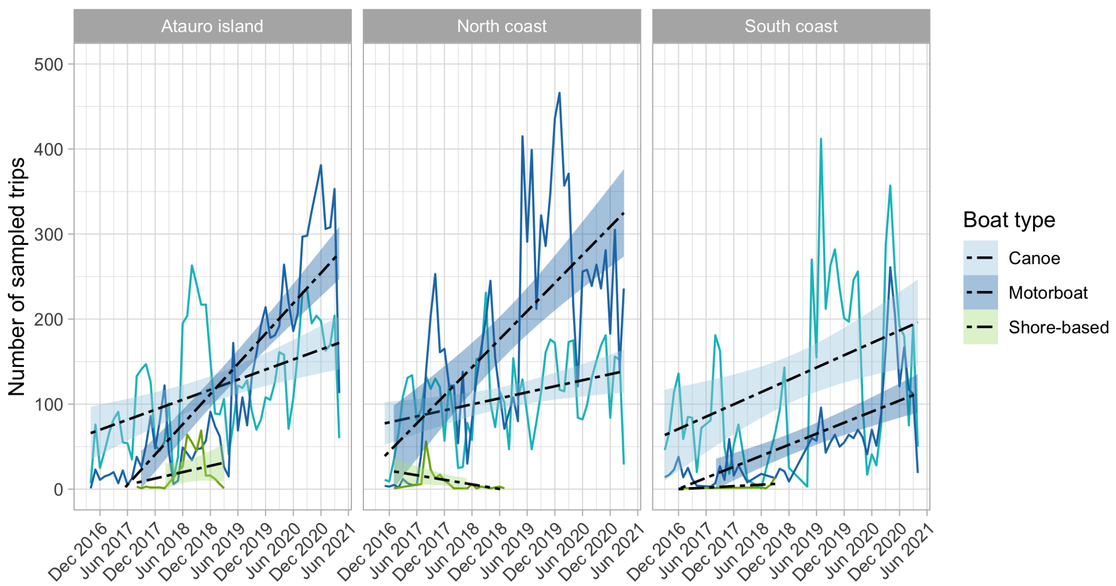

Figure 4.7: **Boat use over time.** Count per month of canoes (light blue) and motorboats (dark blue) used for the fishing trips and shore-based fishing (green) recorded by enumerators on Atauro island, north coast, and south coast in the period of October 2016 to April 2021. The dashed line shows the linear regression with 95% confidence intervals for each boat type.

4.1.2 Gear composition

Index of Relative Importance

Gill nets are the most used gear on Atauro island (fig. 4.8) as well as the gear that catches the highest percentage of the catch in weight (64% and 88%, respectively) and numbers (71% and 96%, respectively). Spear guns, seine nets and hand lines also play a part in the fishery of Atauro island, collectively yielding 32% of the total weight of the catch and 28% of the total catch in numbers.

The fishery of the north coast is also dominated by gill nets, catching 88% of the total catch in weight and 96% of the total catch in numbers (fig. 4.9). Hand lines are used somewhat frequently, but only results in a small part of the yield.

On the south coast long lines are the most frequently used gear, catching 73% of the total catch in weight and 51% of the total catch in numbers (fig. 4.10). In addition, 14% and 10% of the total catch in weight and 18% and 27% of the total catch in numbers are caught by hand lines and gill nets, respectively.

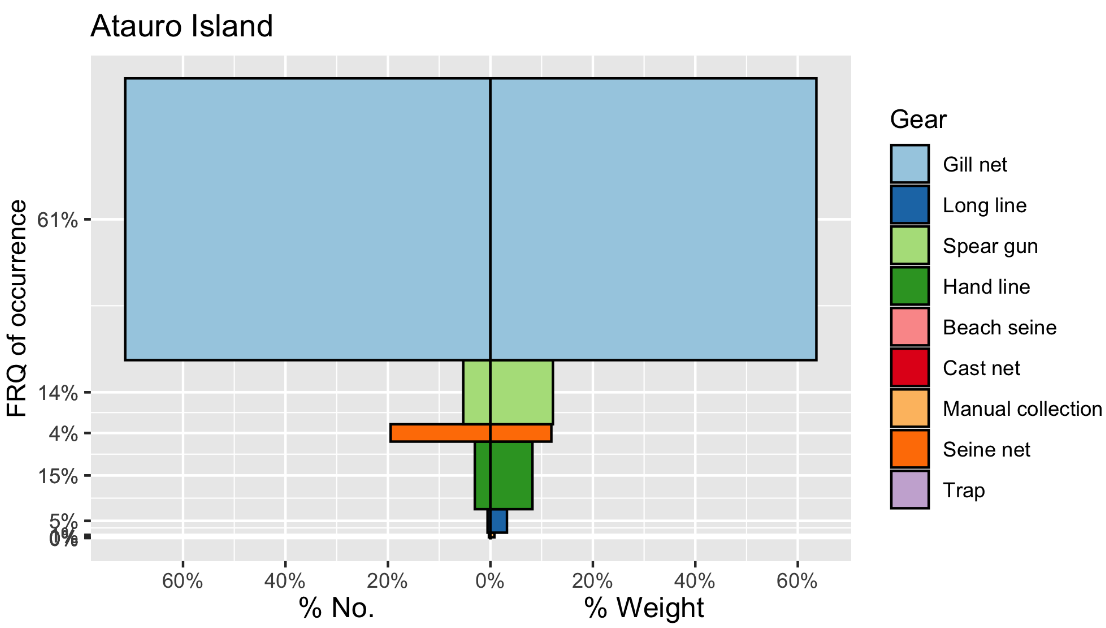

Figure 4.8: **Gear composition of Atauro island using the Index of Relative Importance (IRI).** Gear composition using the Index of Relative Importance (IRI) of the landings of Atauro island from September 2016 to April 2021. The IRI considers the weight and the number of fish caught per gear type, and the frequency of occurrence (FRQ) of a gear type.

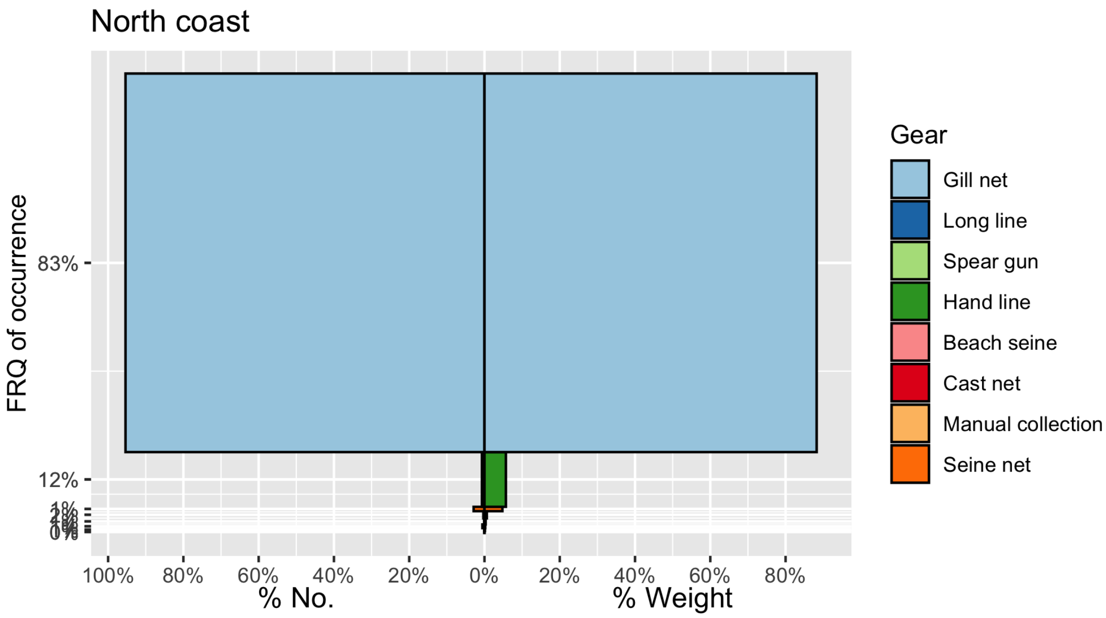

Figure 4.9: **Gear composition of north coast using the Index of Relative Importance (IRI).** Gear composition using the Index of Relative Importance (IRI) of the landings of north coast from September 2016 to April 2021. The IRI considers the weight and the number of fish caught per gear type, and the frequency of occurrence (FRQ) of a gear type.

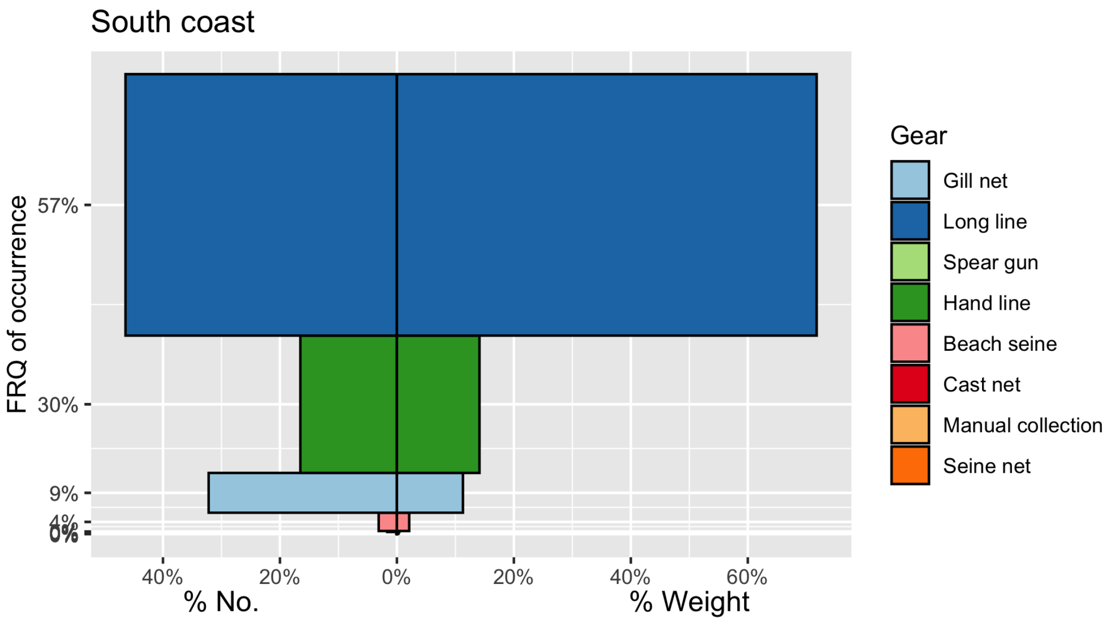

Figure 4.10: **Gear composition of south coast using the Index of Relative Importance (IRI).** Gear composition using the Index of Relative Importance (IRI) of the landings of south coast from September 2016 to April 2021. The IRI considers the weight and the number of fish caught per gear type, and the frequency of occurrence (FRQ) of a gear type.

Gear use over time

On Atauro island the use of gill nets decreases over time, with an increase of the use of spear gun, hand line and seine net (fig. 4.11). Conversely, in the north coast an increase of gill nets is seen and a decrease of hand line, long line and beach seine. The south coast shows a shift from hand line to long line in 2019, and around that same time the use of beach seine is apparently disappearing, and gill nets appear (see appendix E for the gear composition over time of each municipality of the north and south coast).

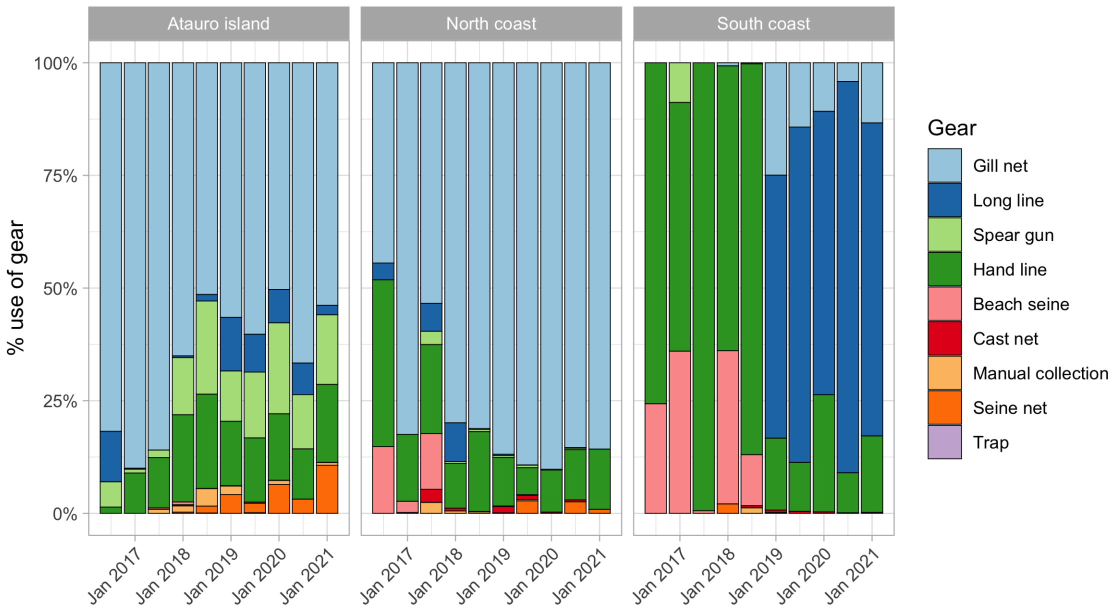

Figure 4.11: **Gear use over time.** The gear composition per 6 months of Atauro island, north coast, and south coast for the period of September 2016 to April 2021 (the last bar only consists of 4 months). The y-axis shows the percentage of times a gear has been used.

4.1.3 Catch composition

Index of Relative Importance per strata

Atauro island shows the most diverse catch composition of the three sampling strata (fig. 4.12; fig. 4.13; fig. 4.14). It is dominated by small pelagics in weight and numbers, while small demersal are the most frequently caught.The catch composition of the north and the south coast are both dominated by small pelagic species. In the south coast the large pelagics are also caught relatively frequently (33%) and contribute to 31% of the weight of the catch (see Appendix F for the species composition of the catch within the functional groups).

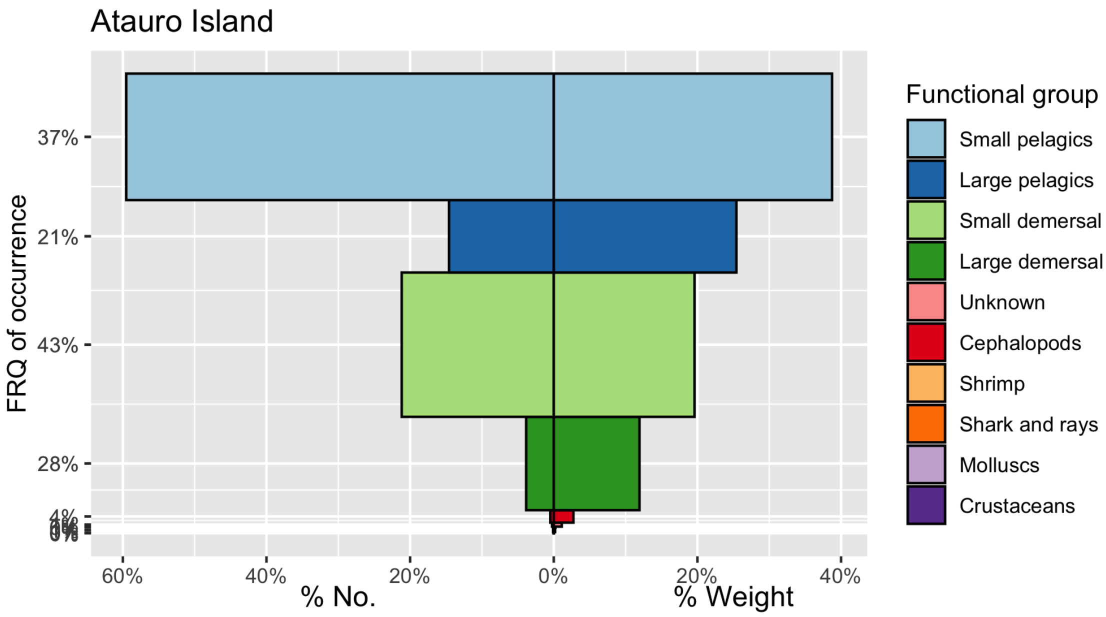

Figure 4.12: **Catch composition on Atauro island using the Index of Relative Importance (IRI).** Catch composition using the Index of Relative Importance (IRI) of the landings of Atauro island for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

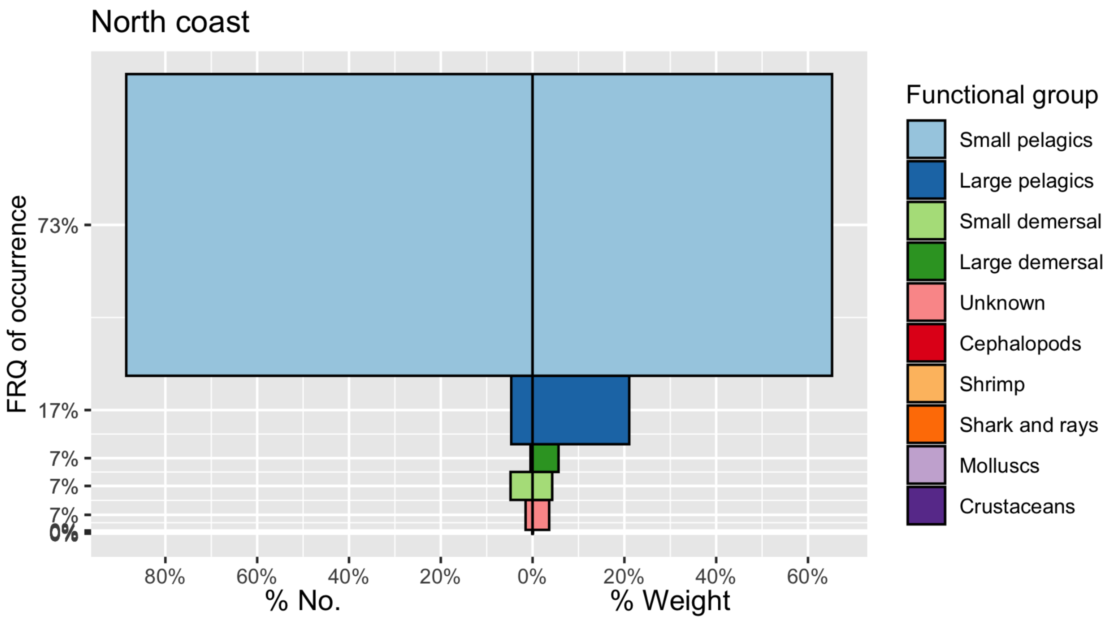

Figure 4.13: **Catch composition on the north coast using the Index of Relative Importance (IRI).** Catch composition using the Index of Relative Importance (IRI) of the landings of the north coast for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

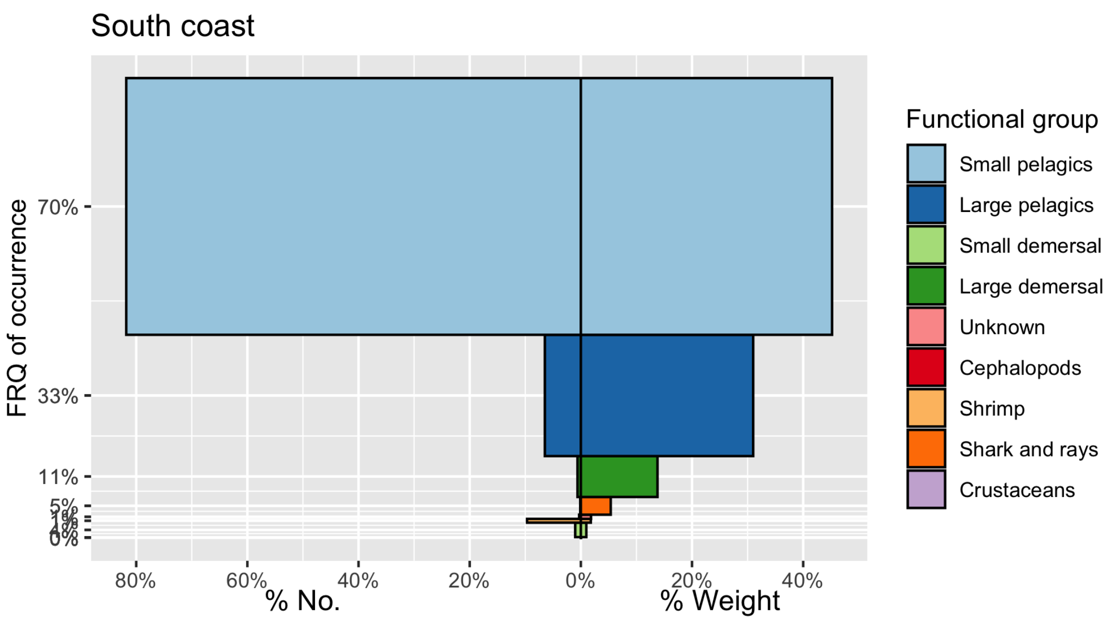

Figure 4.14: **Catch composition on the south coast using the Index of Relative Importance (IRI).** Catch composition using the Index of Relative Importance (IRI) of the landings of the south coast for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

Index of Relative Importance per gear type

Gill nets catch primarily small pelagic species, both in weight and number (fig. 4.15). The weight of the catch of the hand line is dominated by large pelagics and large demersal, whereas the small pelagics dominate the catch in numbers (fig. 4.16). When long lines are used pelagic fish are primarily caught, of which large fish account for most of the weight of the catch, and small fish account for most of the catch in numbers (fig. 4.17). The catch of spear guns consists largely of demersal fish, with again the large fish accounting for most of the weight of the catch, and small fish accounting for most of the catch in numbers (fig. 4.18). Cephalopods are caught in one fifth of the fishing trips where spear guns are used.

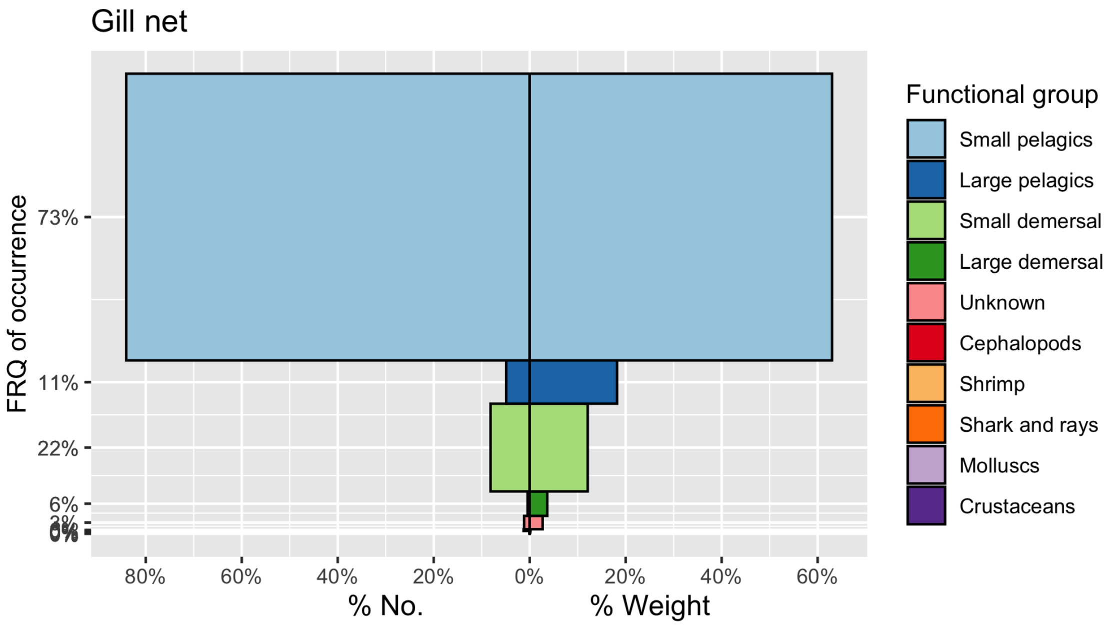

Figure 4.15: **Catch composition of gill nets using the Index of Relative Importance (IRI)** Catch composition using the Index of Relative Importance (IRI) of the landings of gill nets for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

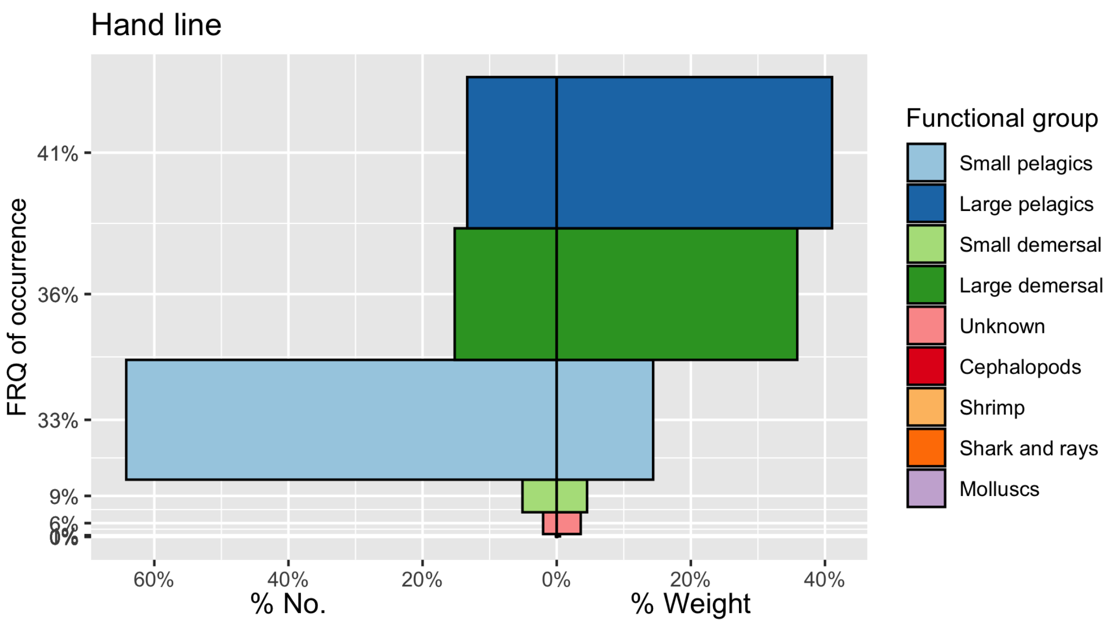

Figure 4.16: **Catch composition of hand lines using the Index of Relative Importance (IRI)** Catch composition using the Index of Relative Importance (IRI) of the landings of hand lines for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

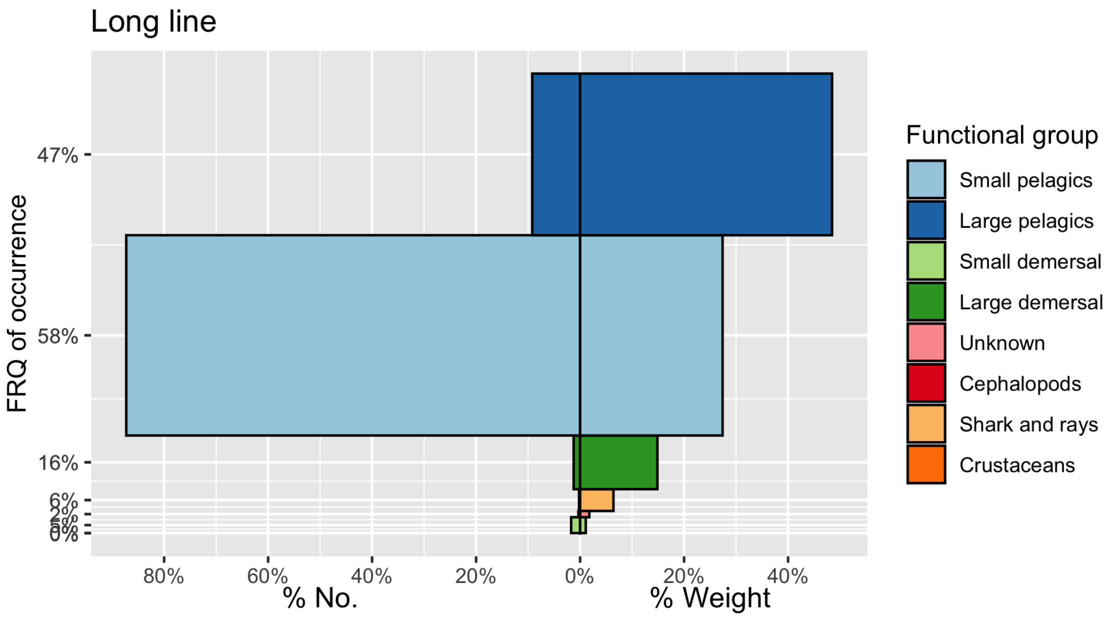

Figure 4.17: **Catch composition of long lines using the Index of Relative Importance (IRI)** Catch composition using the Index of Relative Importance (IRI) of the landings of long lines for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

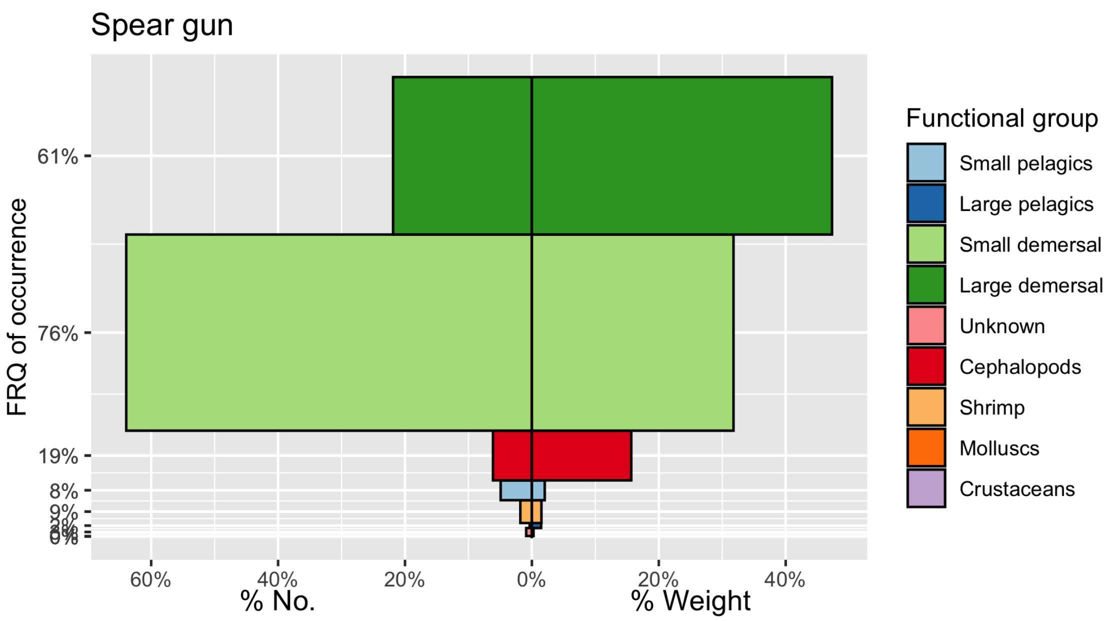

Figure 4.18: **Catch composition of spear guns using the Index of Relative Importance (IRI)** Catch composition using the Index of Relative Importance (IRI) of the landings of spear guns for the period of September 2016 to April 2021. The IRI considers the weight, the number, and the frequency of occurrence (FRQ) of a functional group.

Catch composition over time

On Atauro island the catch of small pelagics decreases during the sampling period, while the catch of demersal, both small and large, increases (fig. 4.19). On the south coast there is an increase large pelagics being caught from 2018 and onwards. The north coast does not show a clear change in the catch composition over time, however in the first two half years most of the catch is labelled as unknown.

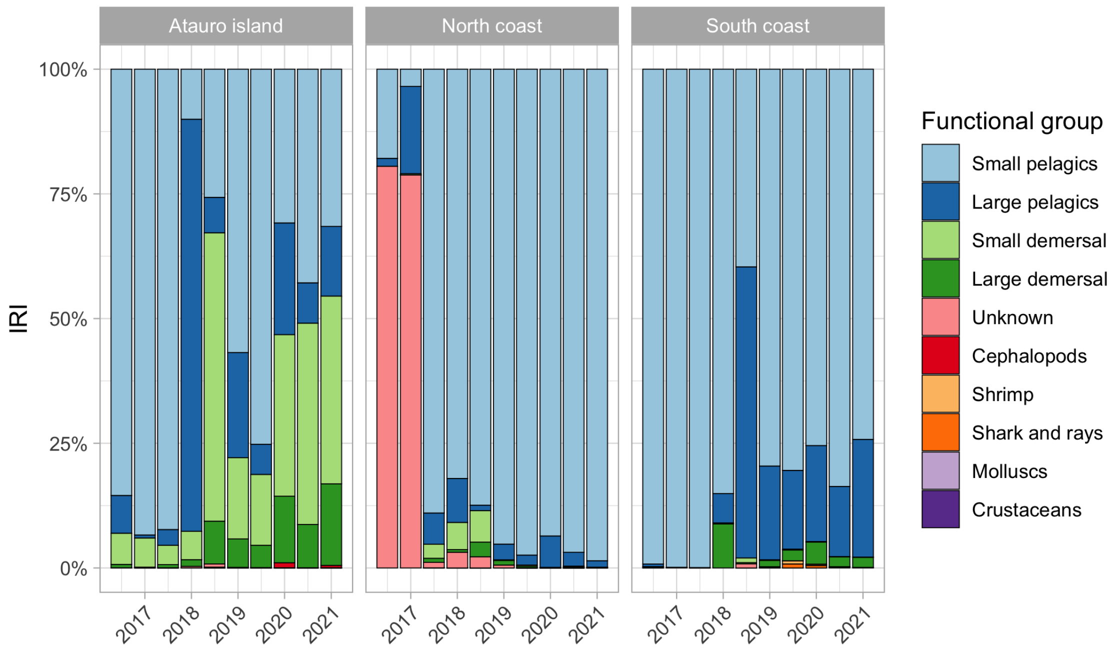

Figure 4.19: **Catch composition over time.** The catch composition per 6 months of Atauro island, north coast and south coast, divided in functional groups for the period of September 2016 to April 2021 (the last bar only consists of 4 months). The y-axis shows the Index of Relative Importance (IRI) of the functional groups, which is calculated using the weight, number, and frequency of occurrence of a functional group.

Length composition of functional groups

The small pelagics and the cephalopods caught on Atauro island appear to be marginally bigger than on the north and south coast, whereas the large demersal caught on the south coast seem slightly bigger than on Atauro island and the north coast (fig. 4.20).

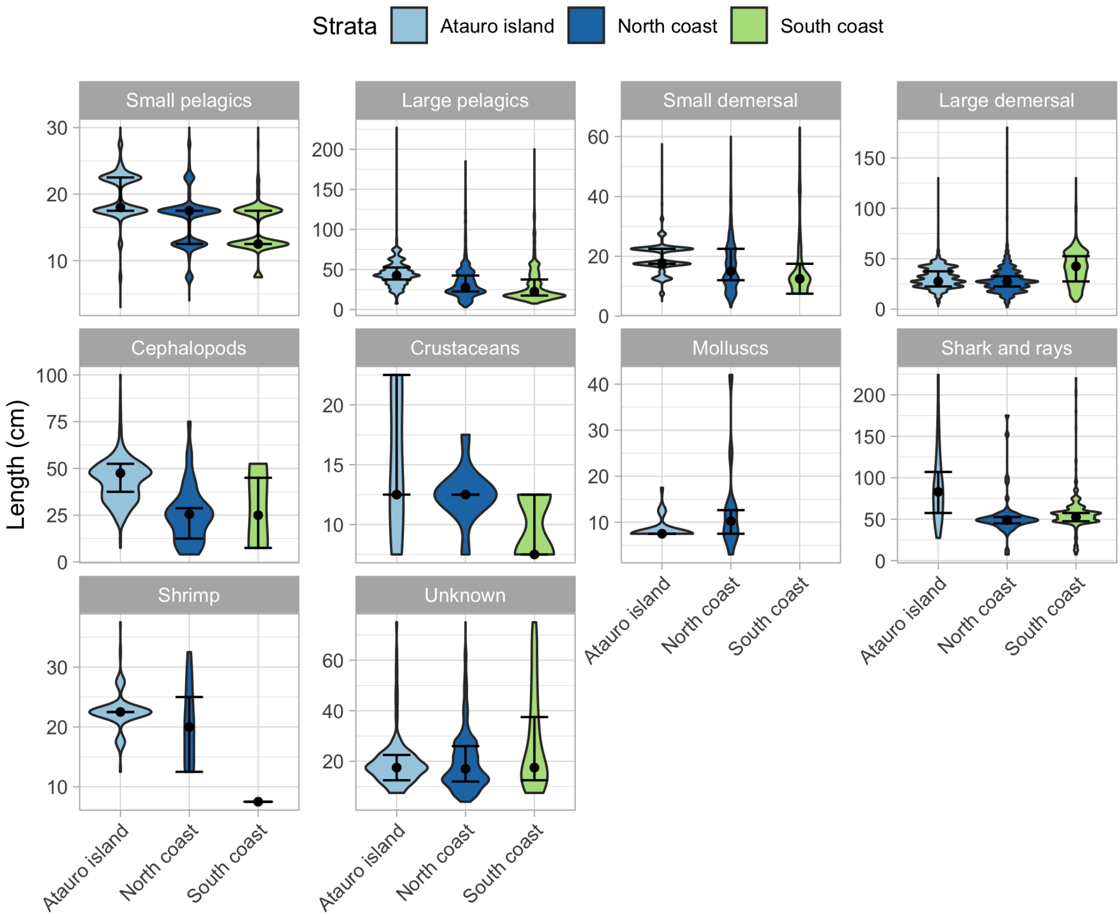

Figure 4.20: **Length composition of the functional groups.** Violin plots of the length (cm) of the catch for every functional group for Atauro island (light blue), north coast (dark blue), and south coast (green). The y-axis has free scaling for every functional group. The dot represents the median and the variance bars the first and third quartile.

4.1.4 Effort

Geospatial fishing effort

Most of the fishing trips are concentrated around the landing sites and close to the coast (fig. 3.1; fig. 4.21). On the west side of the north coast, it appears the fishermen go out further than on the rest of the coastline of Timor-Leste or Atauro island.

Figure 4.21: **Heat map of Timor-Leste visualizing the geospatial fishing effort.** A heat map of Timor-Leste visualizing the geospatial fishing effort of 80163 trips using the tracking information sampled by the PDS trackers during the period of February 2018 to July 2021. High effort is represented by red dots on the map, with orange to yellow to white representing a decreasing effort. Source: Daniel Suchomel, Pelagic Data (2021).

Number of trips per week

There are considerably more fishing trips taken per week on the north coast than on Atauro island and the south coast (fig. 4.22). Within each stratum the number of fishing trips taken per week appear to remain quite constant over time.

A pattern of seasonality is observed for the total number of trips taken per week in all three strata, with the strongest trend seen in the south coast (fig. 4.23). The total number of trips per week decrease around April/May and increase again around September/October.

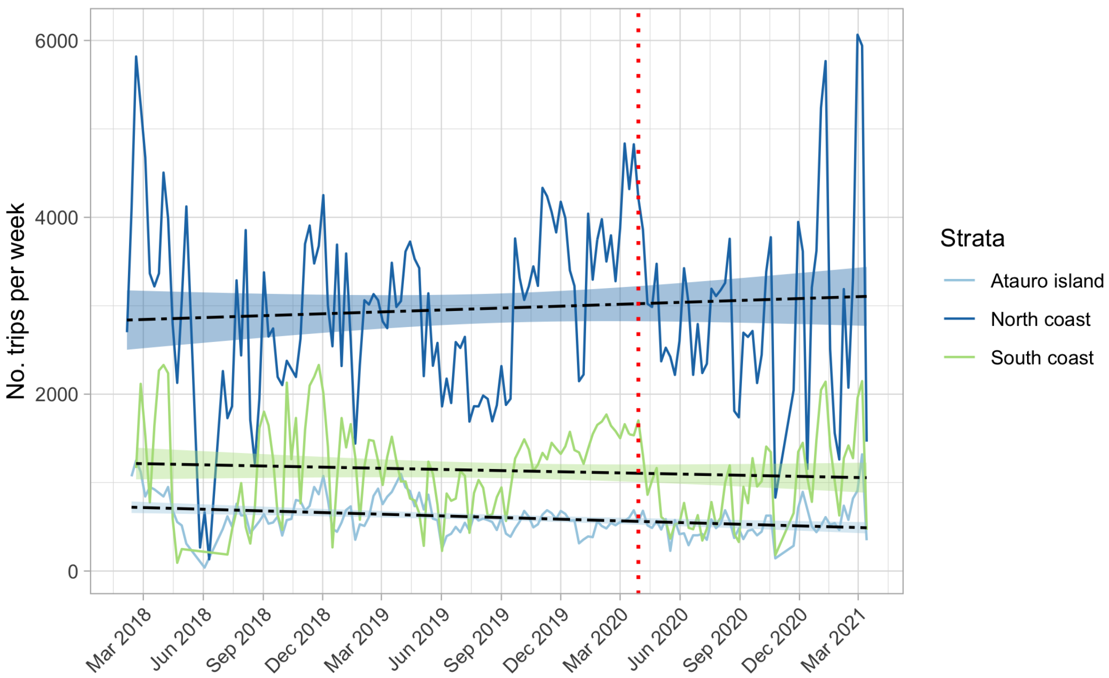

Figure 4.22: **Estimated total number of trips per week.** Estimated total number of trips per week for Atauro island (light blue), the north coast (dark blue) and the south coast (green), in the period of February 2018 to April 2021. The dashed lines show the linear regression with 95% confidence intervals for each stratum. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

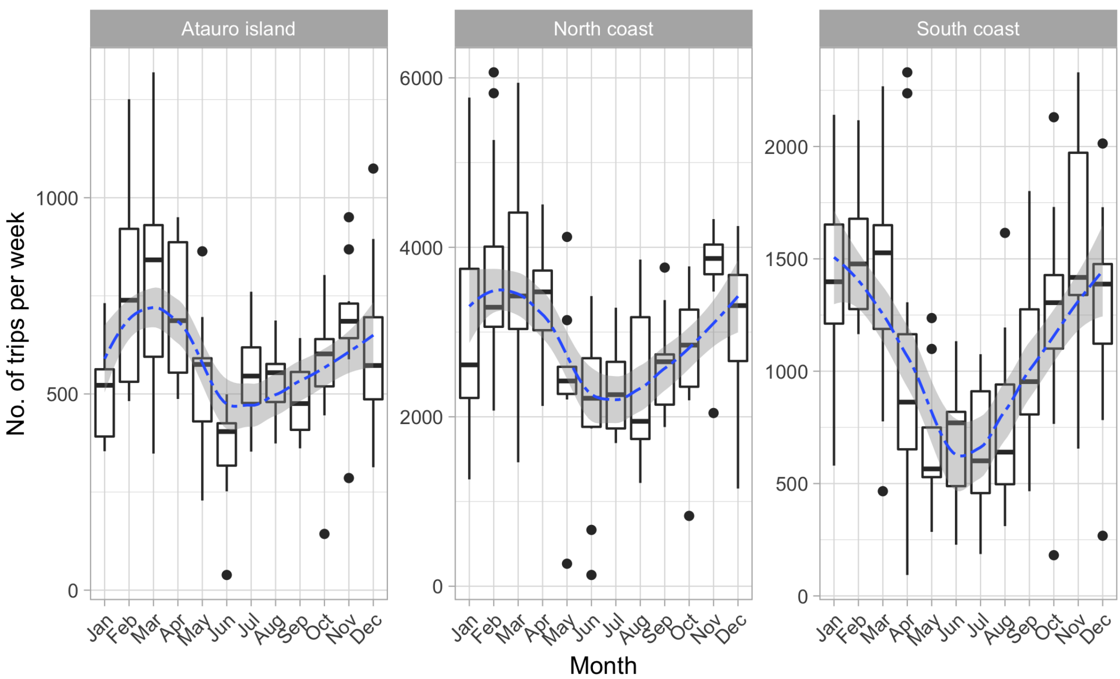

Figure 4.23: **Seasonality of trips per week** Box plots of the estimated number of trips per week for every month (2018-2021) for Atauro island, north coast, and south coast. The y-axis has a free scale for each stratum. The dashed line shows a loess regression with 95% confidence intervals.

Trip effort

The trip effort (fisher-hours) of the three strata appears to be quite similar (fig. 4.24a). The trip effort mostly ranges between two to ten fisher-hours, with some peaks reaching up to 28 fisher-hours. There seems to be no change in trip effort over time for Atauro island and the north coast, while the south coast shows a slight increase (fig. 4.24b). There is no sign of a seasonality pattern (fig. 4.25).

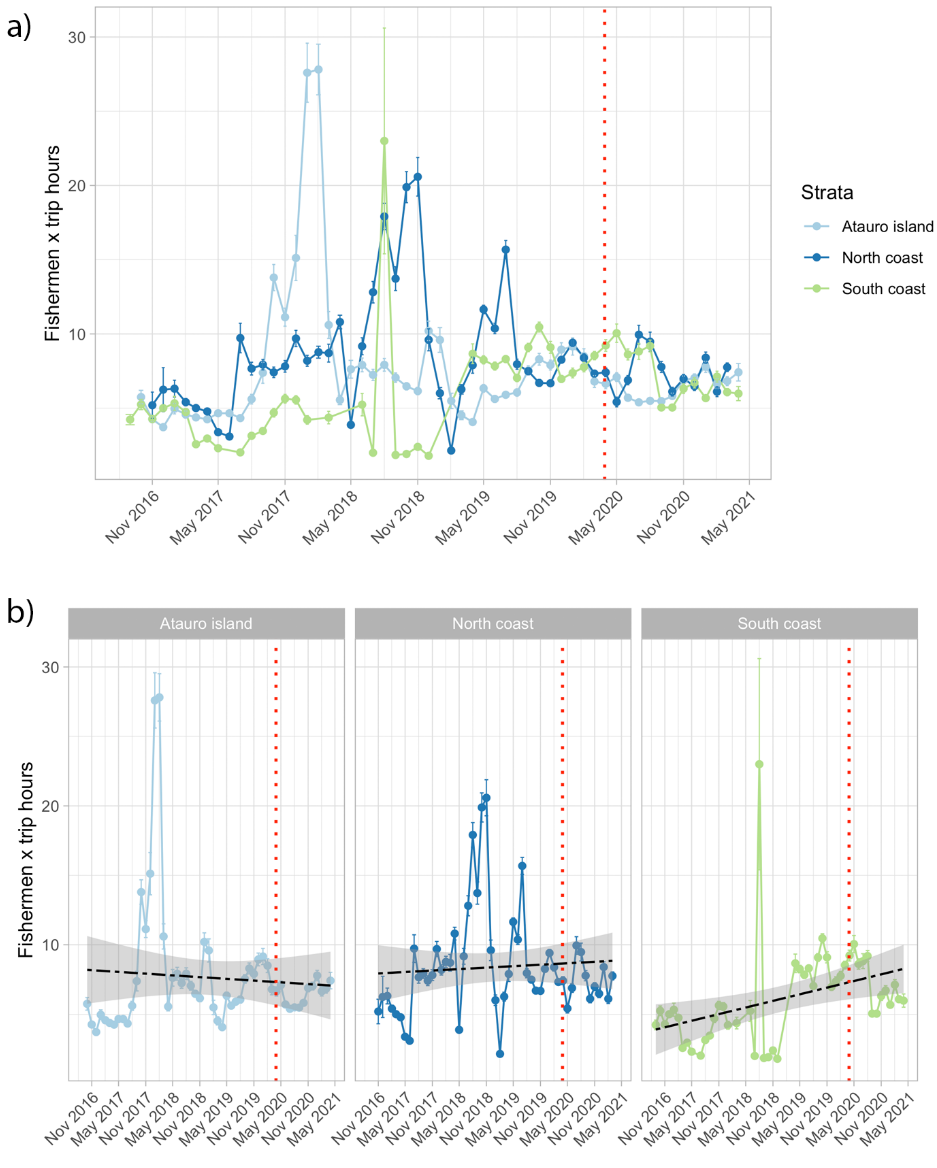

Figure 4.24: **Mean trip effort.** The mean effort (fishermen * hours) of a fishing trip in Atauro island (light blue), north coast (dark blue) and south coast (green) for the period of September 2016 to March 2021, with the strata plotted (a) together in one plot and (b) separately. The error bars represent the standard error. The dashed line shows the linear regression with 95% confidence intervals. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

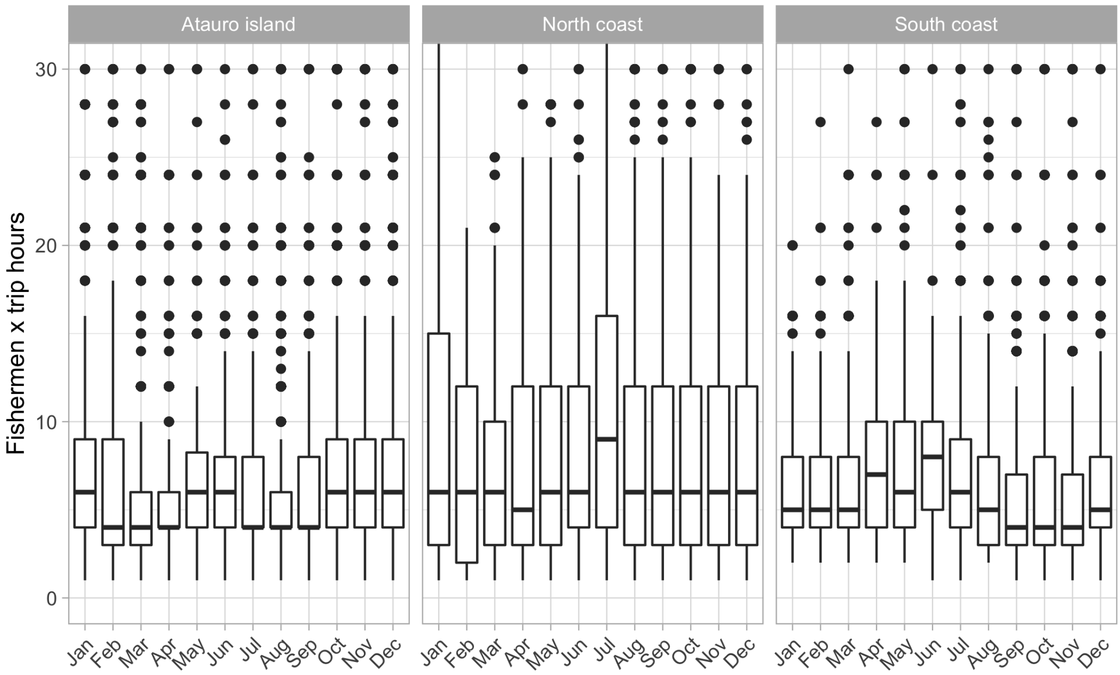

Figure 4.25: **Seasonality of trip effort.** Box plots of the trip effort (fishermen * hours) for every month (2016-2021) for Atauro island, north coast, and south coast. The limits for the y-axis are set from 0 to 30.

Catch per unit effort

The catch (kg) per unit effort (CPUE) of Atauro island and the north coast are quite similar, whereas the north coast has more high peaks (fig. 4.26). The south coast appears to generally have a lower CPUE (kg) than Atauro island and the north coast. The CPUE (kg) of Atauro island seems to increase over time. The north and south coast show no apparent change of CPUE over time. There is also no sign of a seasonality pattern (fig. 4.27).

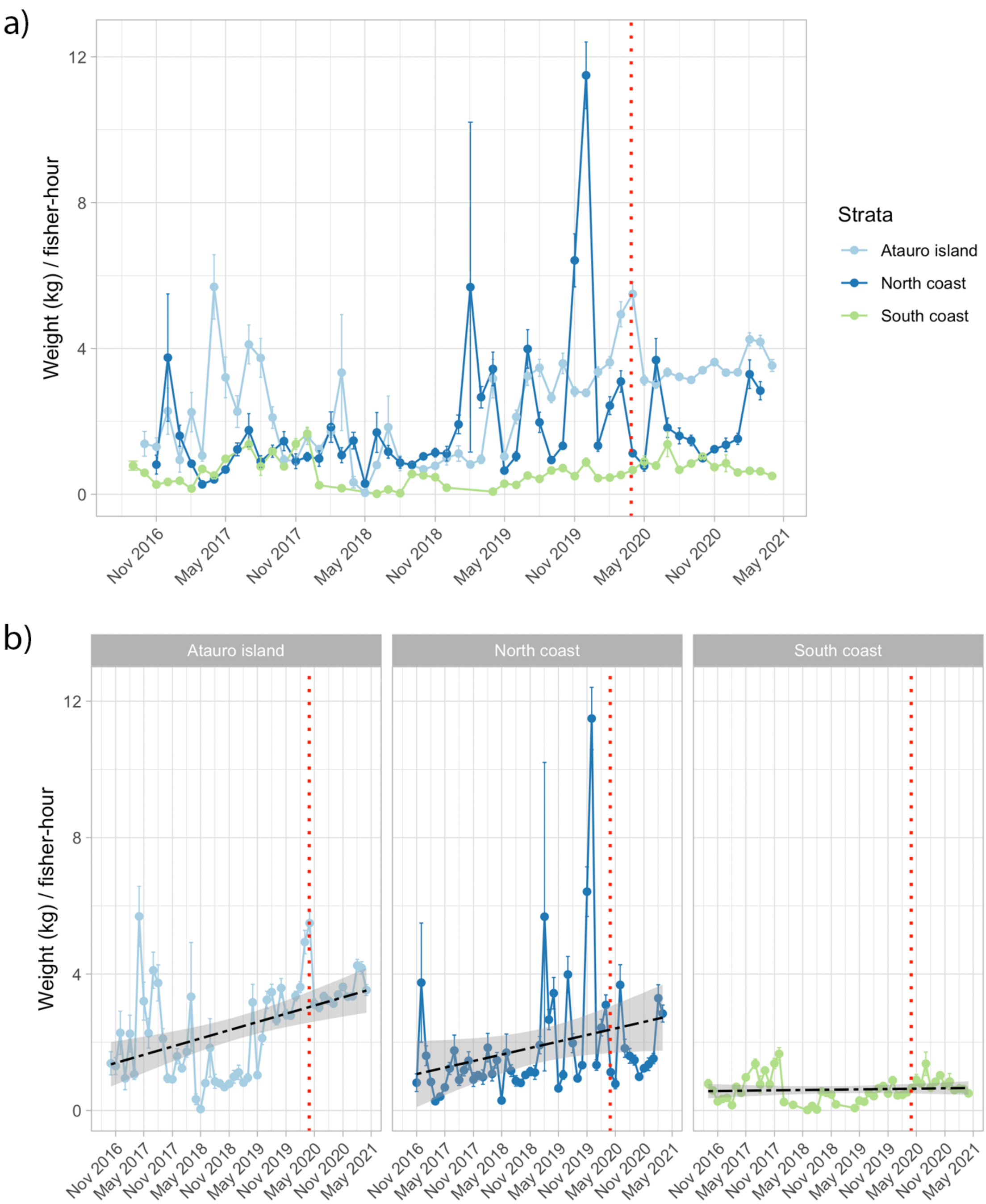

Figure 4.26: **Mean CPUE.** The mean catch (kg) per unit effort (fisher-hour) in Atauro island (light blue), north coast (dark blue) and south coast (green) for the period of September 2016 to March 2021, with the strata plotted (a) together in one plot and (b) separately. The error bars represent the standard error. The dashed line shows the linear regression with 95% confidence intervals. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

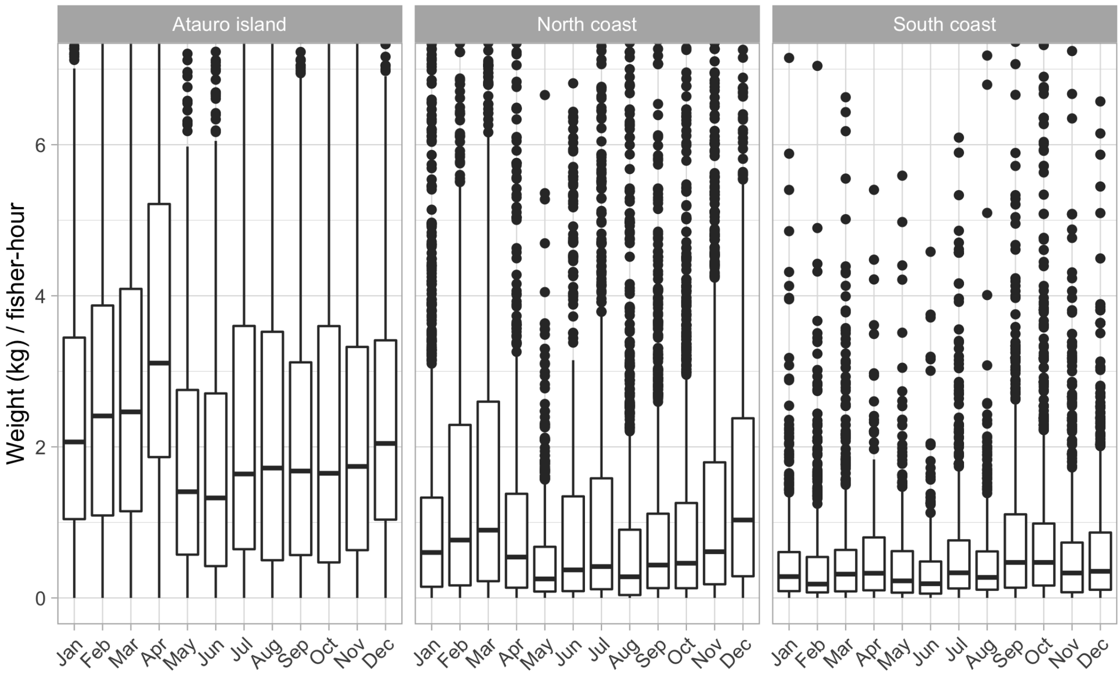

Figure 4.27: **Seasonality of CPUE.** Box plots of the catch (kg) per unit effort (fisher-hour) for every month (2016-2021) for Atauro island, north coast, and south coast. The limits for the y-axis are set from 0 to 7.

4.1.5 Total landings

The estimated total monthly landings of all of Timor-Leste averaged 145.1 tons per month (SE = 28.5) in 2018, 312.3 tons per month (SE = 95.5) in 2019, 191.3 tons per month (SE = 32.0) in 2020 and 220.6 tons per month (SE = 24.9) in 2021. The total monthly catch per capita of Timor-Leste averaged 0.11 kg/month/capita (SE = 0.02) in 2018, 0.24 kg/month/capita (SE = 0.07) in 2019, 0.15 kg/month/capita (SE = 0.02) in 2020 and 0.17 kg/month/capita (SE = 0.02) in 2021.

The estimated total monthly landings (tons) of the north coast are generally higher and with more peaks than on Atauro island and the south coast (fig. 4.28). The landings seem to increase over time on the south coast, while remaining constant on Atauro island and north coast. There seems to be a slight indication of seasonality (fig. 4.29).

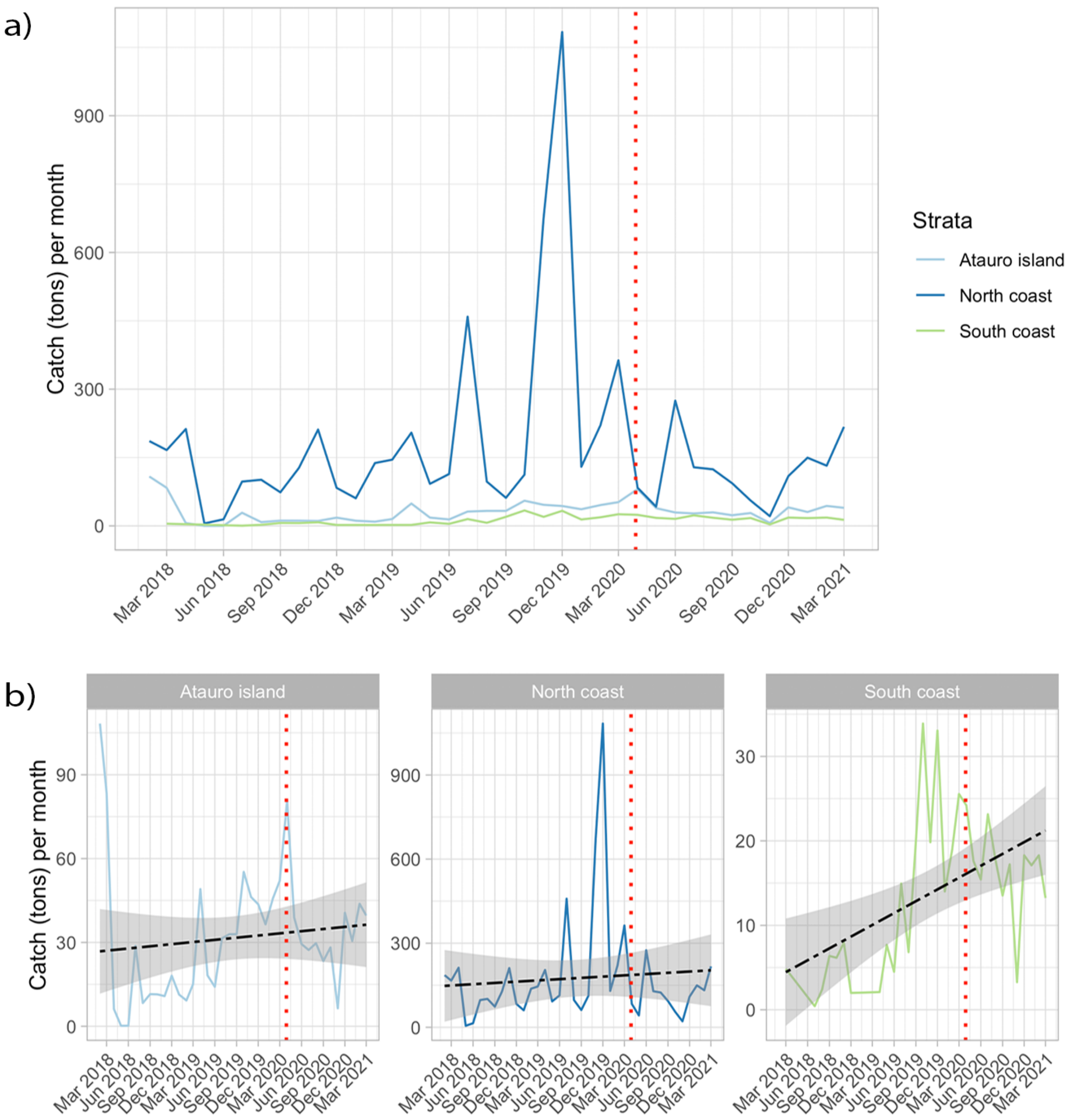

Figure 4.28: **Estimate of total monthly catch (tons).** Estimate of the total monthly catch (tons) for Atauro island (light blue), north coast (dark blue) and south coast (green), during the period of February 2018 to March 2021, with the strata plotted (a) together in one plot and (b) separately. The dashed line shows the linear regression with 95% confidence intervals. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

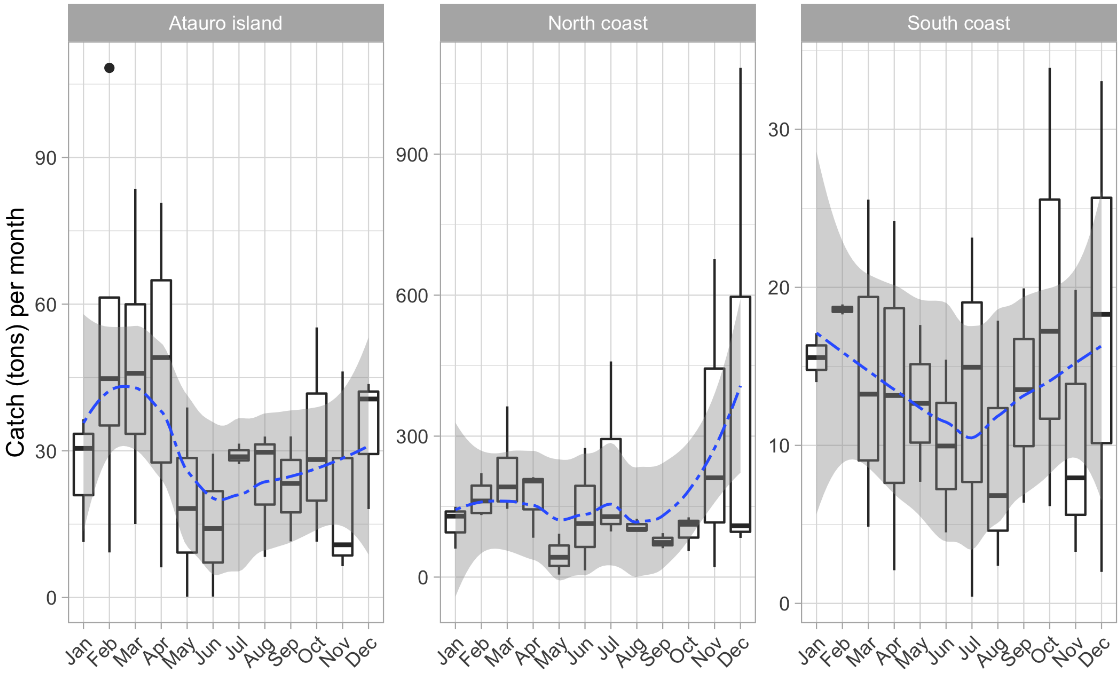

Figure 4.29: **Seasonality of total monthly catch (tons).** Box plots of the estimated total catch (tons) for every month (2018-2021) for Atauro island, north coast, and south coast. The y-axis has a free scale for each stratum. The dashed line shows the loess regression with 95% confidence intervals.

4.1.6 Destination of catch

On average, 96.2% of the sampled catch on Atauro island is sold on the market, 3.4% is kept for own consumption and 0.4% is used for both (fig. 4.30). On the north coast, 56.5% goes to the market, 1.8% is used for own consumption and 41.7% is used for both. On the south coast 91.7% is sold on the market, 2.0% is kept for own consumption and 6.3% is used for both. The amount (kg) used for own consumption does not appear to change over time (fig. 4.31).

Most of the fish being kept for own consumption are smaller sized fish and fish species, with some exceptions such as the Cobia (*Rachycentron canadum*) and the Moray eel (*Gymnothorax spp.*) (fig. 4.32; fig. 4.33).

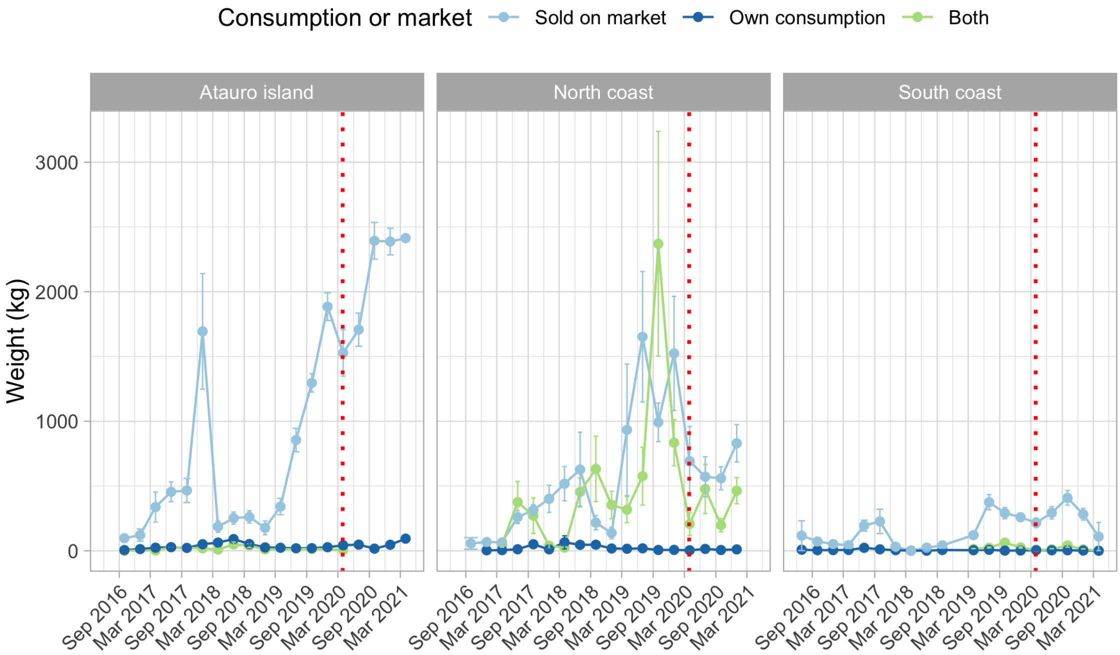

Figure 4.30: **Destination of catch over time.** The mean weight (kg) per week of the sampled catch being sold on market (light blue), kept for own consumption (dark blue), or both (green) on Atauro island, north coast, and south coast in the period of September 2016 to March 2021. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

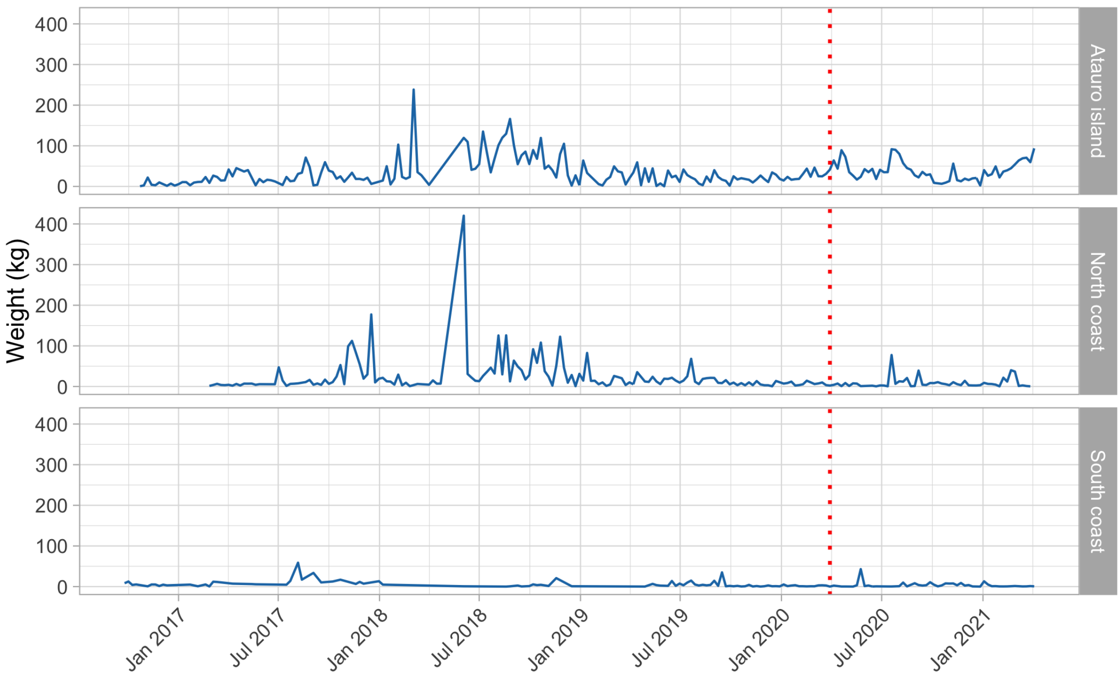

Figure 4.31: **Amount of catch used for own consumption over time.** The weight (kg) per week of the sampled catch being kept for own consumption on Atauro island, north coast, and south coast in the period of September 2016 to March 2021. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

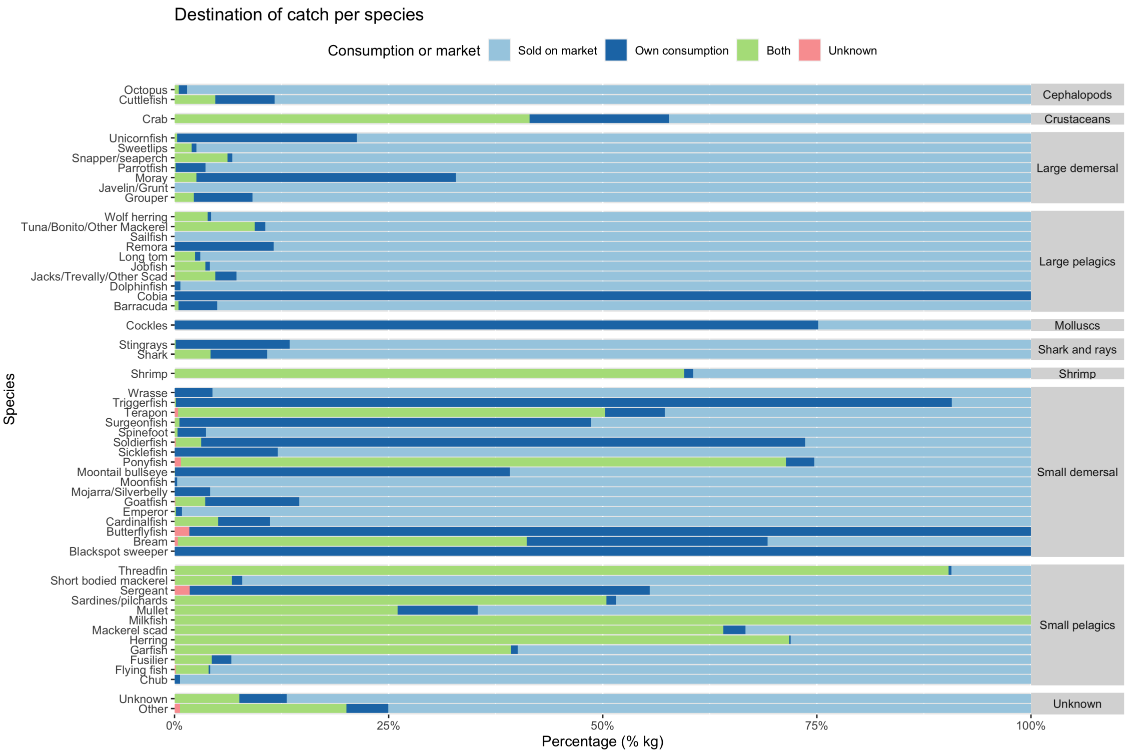

Figure 4.32: **Bar plot of the destination of the catch per species.** The y-axis shows individual species grouped by functional group and the x-axis shows the percentage of the catch in weight (kg) being sold on the market (light blue), held for own consumption (dark blue), or used for both (green). Entries without any information on the destination of the catch is shown in red.

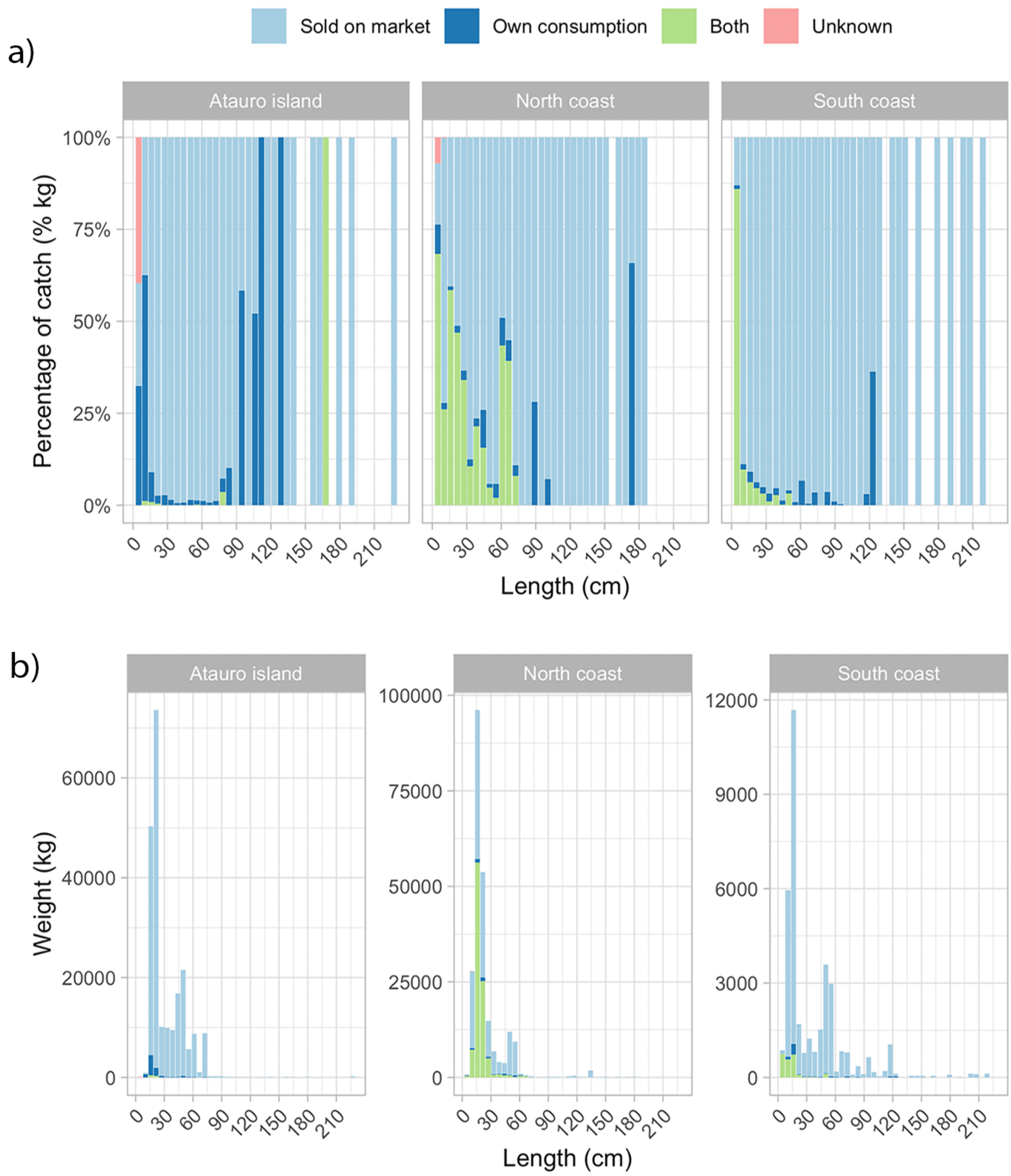

Figure 4.33: **Bar plot of the destination of the catch per length groups.** (a) Percentage of the catch and (b) weight (kg) of the catch being used to sell on market (light blue), for own consumption (dark blue), or both (green) versus the size (cm) of the fish caught. The catch is divided into 50 length groups. Entries without any information on the destination of the catch is shown in red.

4.1.7 Market value of catch

The selling price (in USD) per kg of the catch is highest in the south coast, followed by the north coast and lastly Atauro island (fig. 4.34). The market price of the catch of Atauro island seems to decline over time, which does not appear to be the case in the north or south coast.

The catch in hand lines yields the highest price (USD) per kg of the different gear types, followed by long lines (fig. 4.35). Gill nets and spear guns generate the lowest price per kg.

The large pelagics and large demersal yield the highest price (USD) per kg Of the different functional groups (fig. 4.36). The cephalopods bring in the lowest price per kg, followed by the small pelagics and small demersal.

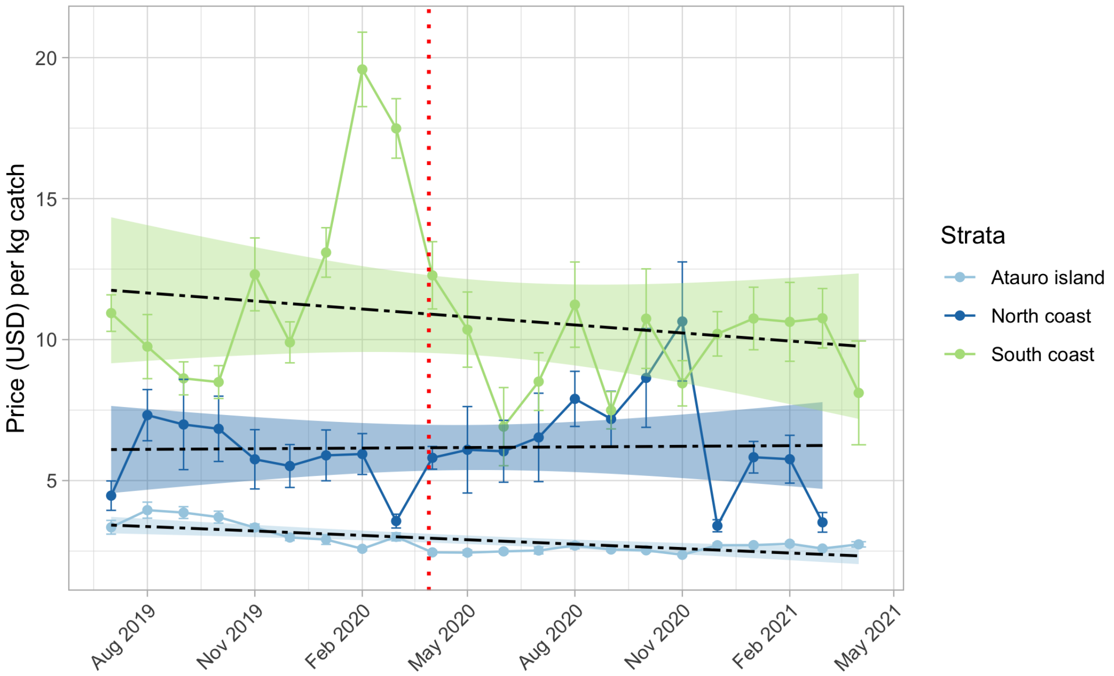

Figure 4.34: **Mean market value (USD) per kg of the catch.** Mean market value (USD) per kg of the catch for Atauro island (light blue), north coast (dark blue) and south coast (green), during the period of July 2019 to April 2021. The error bars represent the standard error. The dashed line shows the linear regression with 95% confidence intervals for each stratum. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

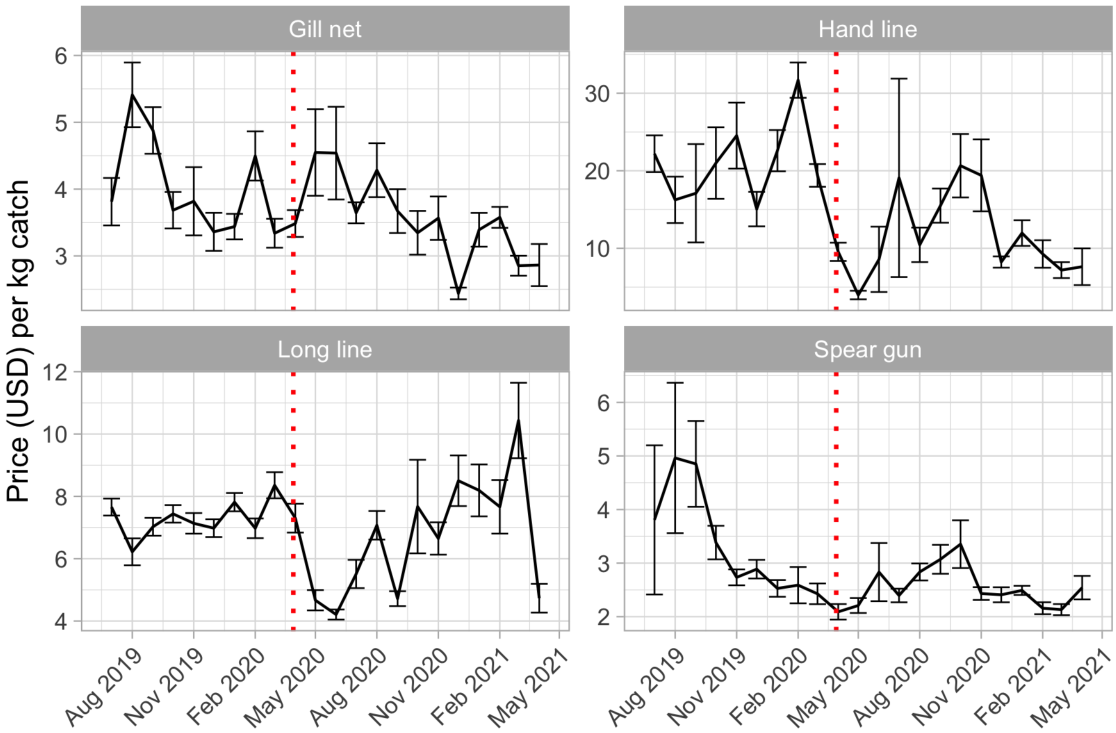

Figure 4.35: **Mean market value (USD) per kg of the catch of the most used gear types.** Mean market value (USD) per kg of the catch in gill nets, hand lines, long lines, and spear guns during the period of July 2019 to April 2021. The error bars represent the standard error. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020. The y-axis has free scaling for every gear type.

Figure 4.36: **Mean market value (USD) per kg of the cath of the most frequently caught functional groups.** Mean market value (USD) per kg of the cath of the most frequently caught functional groups in Atauro island (light blue), north coast (dark blue) and south coast (green), during the period of July 2019 to April 2021. The error bars represent the standard error. The y-axis has free scaling for every functional group. The dotted red line signifies the start of the COVID-19 lockdown on 28 March 2020.

4.2 Models

4.2.1 Model selection

To choose the model with the best degree of explanatory power, several model combinations were performed and compared to each other based on the AICc, the AICc weight and the adjusted pseudo-R-squared (table 4.1). The three dependent variables tested were the number of trips taken per week per boat, the estimated monthly landings (tons) and the market value (USD). For the landings model there was little difference between the AICc, the weight and the pseudo-R-squared, and no significant difference ($p = .08$) between the model with interaction and without interaction between the independent variables strata and lockdown. Therefore, the simplest model of the two was chosen.

Table 4.1: **Results of model selection comparing different fixed effects and their combination.** The model with a * in the front represents the chosen model for the analysis. The different model types used are generalised least squared models (GLS), generalised linear models (GLM) and generalised linear mixed effect models (GLMM). AR1 correlation accounts for autocorrelation. AICc is the Akaike Information Criterium and gives the goodness of fit of a model, where a lower value equals a better fit. Weight shows the probability that a model is the true model, with the assumptions that one of the given models is the truth. The adjusted pseudo-R-squared also gives the goodness of fit, where a higher value equals a better fit.

Dependent variable	**Model type**	**Model**	**AICc**	**Weight**	**Adjusted pseudo-R^2**
Trips taken per week per boat	GLS	*Strata + Lockdown + AR1 correlation	-236	1	0.19
	GLS	(Strata + Lockdown)^2 + $AR1correlation$	-226	0	0.20
	GLM	Strata + Lockdown	-194	0	0.12
	GLM	Lockdown	-167	0	0.02
	GLM	Null model	-162	0	0
Landings	GLM	*Strata + Lockdown	40	0.42	0.86
	GLM	(Strata + Lockdown)^2	39	0.58	0.89
	GLM	Lockdown	113	0	0.01
	GLM	Null model	112	0	0
Market value	GLMM	*(Gear type + Lockdown)^2	8147	1	0.48
	GLMM	Gear type + Lockdown	8365	0	0.47
	GLMM	Strata + Gear type + Lockdown	8368	0	0.52
	GLMM	Boat type + Lockdown	9271	0	0.51
	GLMM	Lockdown	9332	0	0.50
	GLMM	Null model	9490	0	0

4.2.2 Fishing trips taken per week

During the lockdown, there was a non-significant average decline of 13.0% in number of fishing trips taken per week per boat over the three strata ($F_{1,296} = 3.54$, $p = .06$) (table 4.1; fig. 4.37). Stratum had a significant effect on the number of trips taken per week per boat ($F_{2,296} = 35.28$, $p < .0001$), where the north coast and the south coast have a higher trip count than Atauro island (28% more trips ($p = < .0001$) and 36% more trips ($p = < .0001$), respectively). There is no significant difference between the north and the south coast ($p = .14$).

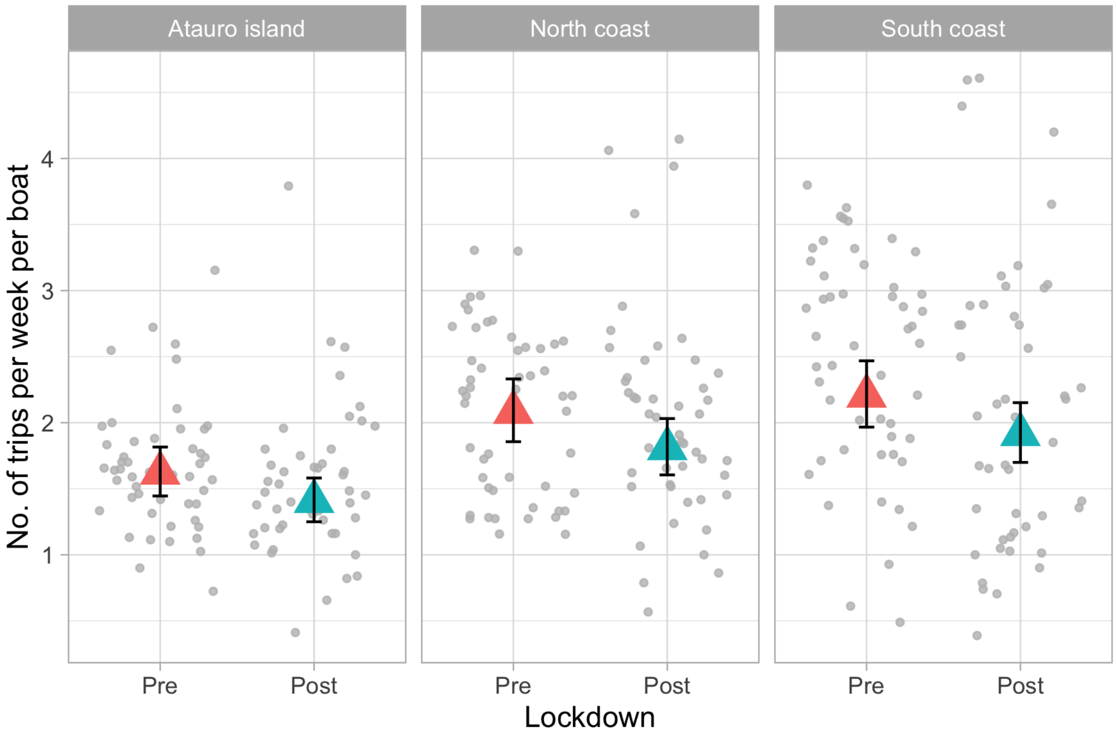

Figure 4.37: **Modelled number of fishing trip taken per week per boat.** Number of fishing trip taken per week per boat pre-lockdown (red; 28 March 2019 to 27 March 2020) and post-lockdown (blue; 28 March 2020 to 27 March 2021). The triangular points show the modelled means (using a generalised least squares model) with 95% confidence interval error bars. The grey points show the raw data points.

4.2.3 Monthly landings

During the lockdown, there was a non-significant average decline of 3.4% in the estimated total monthly landings (tons) over the three strata ($F_{1,68} = 2.10$, $p = .15$) (table 4.1; fig. 4.38). Stratum had a significant effect on the monthly landings (tons) ($F_{2,68} = 66.82$, $p < .0001$), where the north coast has the highest monthly catch (11.5% higher than Atauro island ($p < .0001$), and 63% higher than south coast ($p < .0001$). Atauro island catches 14.8% more per month than the south coast ($p < .0001$).

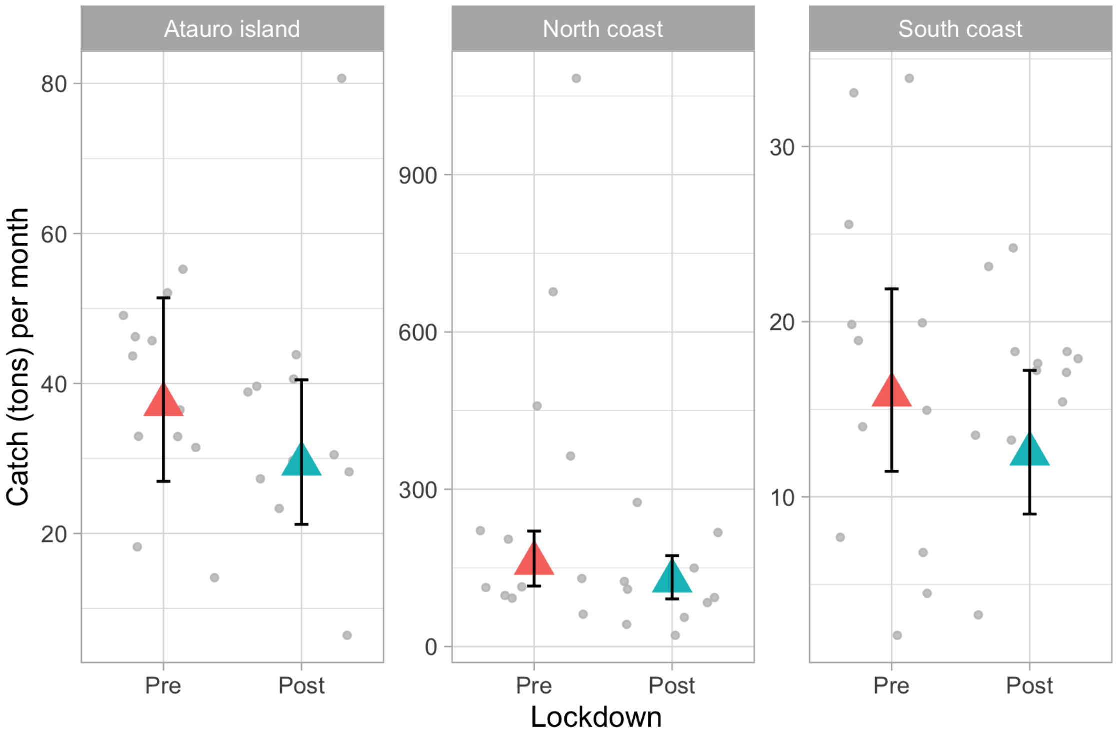

Figure 4.38: **Modelled total monthly catch (tons).** Estimated total monthly catch (tons) pre-lockdown (red: 28 March 2019 to 27 March 2020) and post-lockdown (blue: 28 March 2020 to 27 March 2021) for Atauro island, north coast, and south coast. The triangular points show the modelled means (using a generalized linear model) with 95% confidence interval error bars. The grey points show the raw data points. The y-axis has free scaling for each stratum.

4.2.4 Market value

The gear type, the lockdown and the interaction between these variables appear to have a significant effect on the market value (USD) of the catch ($F_{3,18715} = 342.24$, $p < .0001$; $F_{1,18715} = 189.90$, $p < .0001$; $F_{3,18715} = 82.19$, $p < .0001$, respectively) (table 4.1; fig. 4.39). The price (USD) the produce was sold for per kilogram during the lockdown showed a decline of 20.3% for fish caught by hand line ($p < .0001$), 21.9% for fish caught by long line ($p < .0001$), and 31.6% for fish caught by spear gun ($p < .0001$). The value of the fish caught by gill nets did not appear to have changed during the lockdown ($p = .73$).

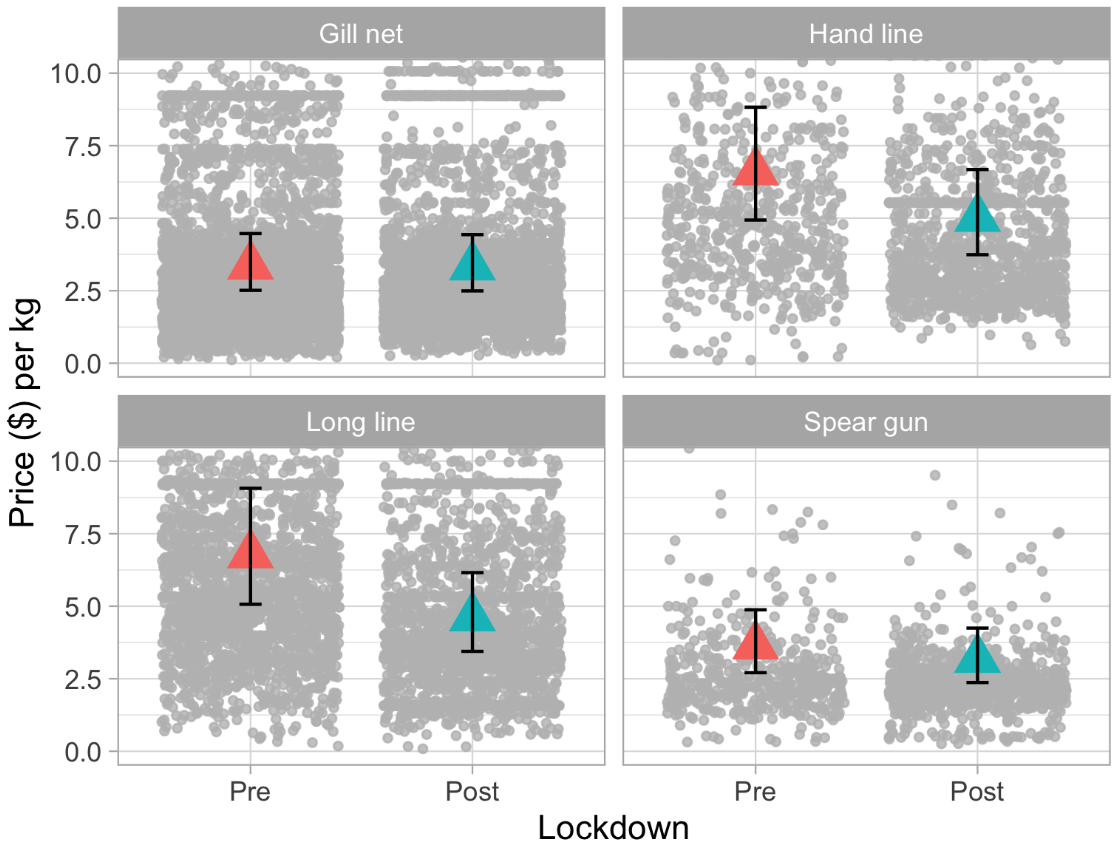

Figure 4.39: **Modelled market value (USD) of the catch per kilogram.** Market value (USD) of the catch per kilogram pre-lockdown (red: 1 July 2019 to 27 March 2020) and post-lockdown (blue: 28 March 2020 to 27 March 2021) in Timor-Leste. The triangular points show the modelled means (using a generalized linear mixed-effect model) with 95% confidence interval error bars. The grey points show the raw data points

5. Discussion

5.1 Characteristics of the fishery

5.1.1 Boat, gear and catch composition

The fishery of Timor-Leste is a characteristic small-scale fishery. The boats used are small, open canoes or lightly engine motorboats, and most fishing trips only have one or two active fishers, staying close to the shore and lasting about half a day. The catch consists of multiple species and the fishing gear used is comparable to the gear choice of other SSFs (Herrón et al., 2020; Pelletier & Ferraris, 2000).

The choice of boat and gear type are influenced by social, cultural, economic, geographic and climate factors, which is shown in the different composition of the strata (Herrón et al., 2020). First, a particular fishing gear has to be available and preferably also commonly used in the area. If it is not a traditional fishing gear, it will be difficult to get access to the gear or to find someone who has experience fishing with it. For instance, while Atauro island and the north coast have approximately the same marine habitat, the fishers on Atauro island catch less pelagic fish, as the gear needed to fish on the open ocean is uncommon on the island (Mills et al., 2013). It also needs to be financially feasible for a fishing family to pay for the entry costs and the maintenance of certain fishing gears and boats. The north coast is for example clearly the richer region, as many can invest in motorboats, some even made of fiberglass. By contrast, the south coast predominately fishes in paddle-driven canoes, which is presumably a result of the poor infrastructure and the higher poverty rates of that part of the country (Braithwaite et al., 2012; Ingram et al., 2015; Moxham & Carapic, 2013). Investing in a motorboat will likely not be an option for most. This also limits the gear choice, as with the rougher weather conditions on the south coast they will not be able to go out very far on paddle-driven canoes or use heavy fishing gear. If, after having met all these conditions, a fisher is still left with options, the choice in fishing gear will likely be made according to desired targets, tradition, as well as revenue.

The choice in gear and boat type is reflected in the catch composition of each area. The high frequency of occurrence of demersal fish in the catch of Atauro island reflects the scarcity of pelagic fishing gear on the island, as well as the use of spear guns. Both the south coast and Atauro island catch larger-sized fish than the north coast, which is likely due to their more common use of long lines, hand lines and spear guns.

There are some notable differences over time in boat and gear use. There appears to be a surge in motorboats compared to paddle-driven canoes on Atauro island and north coast, a cease in shore-based fishing, an increase in the use of spear guns on Atauro island, and a sudden shift from hand lines to long lines on the south coast. While it could be attempted to find economic, social, or biological reasons, these phenomena could also be due to sampling biases. For example, the shift in fishing gear on the south coast is likely due to a change and the addition of sampling sites. At the time of the shift, Covalima was added to the sampling design, where long lines are the predominant gear choice. Around the same time, the enumerators active in Viqueque and Manufahi changed landing sites for the sampling.

5.1.2 Effort and landings

While there are some slight differences between the number of fishers active and the trip duration between the strata, there is no apparent difference in the resulting trip effort (in fisher-hours). The CPUE of the different strata are initially within the same range, but there appears to be an increase on Atauro island and north coast over time (although the increase seen on the north coast could be debated due to the large error margins), resulting in the south coast having the lowest CPUE. Possibly the long lines and hand lines need more effort to produce the same yield as gill nets, however the productivity of fishing gears are dependent on many factors (Angelsen & Olsen, 1987; Misund et al., 2002). The highest number of trips taken per week are on the north coast, which is a direct reflection of that area having the highest number of fishing boats registered and also where the majority of the population of Timor-Leste lives (General Directorate of Statistics, 2015).

This large difference in trips taken per week is what mainly drives the difference in the estimated total monthly landings (kg) in each area. The increase in landings observed on the south coast is likely due to the increase in trip effort. However, the first years of the south coast were poorly sampled (only two stations were sampled on the entire south coast up until May 2019), which could explain this trend. The north coast has high variations in the CPUE and therefore in the estimated landings. These high peaks could likely be actual windfall catches of sardines, which are the primary species of small pelagics caught on the north coast. These fish often migrate in large schools, which can result in big hauls if one comes across such a school (Hunnam et al., 2021). This hypothesis is strengthened by the fact that these observed high catches occur during the wet season, when sardines are mostly present (Hunnam et al., 2021). The use of FADs could also play a role in the fluctuations present, as fishing near one increases the chances of encountering big schools of fish (Tilley et al., 2019).

There seems to be no indication of the SSF of Timor-Leste to be overexploiting the fish stock. There is no significant decrease in landings or increase in effort, and the CPUE, which is often used as an indicator for the biomass status in a fishery, shows no sign of decline. There appears thus to be room to further develop the fishing sector, which is a positive outcome when it comes to improving the food security in Timor-Leste. However, it would be recommended to conduct fishery-independent studies for more certitude.

As for the geospatial effort, the fishing seems to be concentrated inshore around the coast. This is probably because most marine productivity is in the surf zone, and thus where most fish can be found (Alongi et al., 2009). There is some activity recorded between Atauro island and the mainland as well as to the Indonesian island Wetar, situated north of Atauro. These are most likely taxiing and trading trips, and not for fishing. The same is probably the case for the activity seen in the west part of the north coast, where they are headed to Indonesia or trade with Indonesian fishers at sea.

5.1.3 Market

When looking at the data the destination of the catch and the market value, it is important to keep in mind that the information is acquired before the selling has taken place. It is a prediction made by the fisher and does not necessarily align with reality. These assumptions are however made on prior knowledge and thus if a fisher sold less fish and for a low price for a longer period of time, the assumption will be made that the next catch will follow this pattern.

The catch is usually sold on the road, on the water (e.g. to Indonesian fishers/traders), or to a trader, which then sells the fish on the market (Población, 2013). Selling the catch to traders is the safest option however less profitable than if sold directly to the consumer. Fishers will try to sell as much of their catch as they can and keep what is left. This is seen in the data of the north coast, where a large part of the catch is documented as being used for both own consumption as well as being sold. The same practice most likely happens on Atauro island and the south coast as well, even though it is not reflected in the data. Why there is this difference in documenting between the strata is not clear. It could be that the fishers of the north coast are more realistic with the outcome of the selling, or that the fishers of Atauro island and the south coast have a better understanding of which fish will sell and which will not and therefore can be more precise in their answering. It could also be because of a difference in the nuance of the question asked by the enumerators. The fish kept for own consumption are usually the smaller fish. Large-size fish and fish species are often easier to sell, as they look more appetising and are in demand by the restaurants and urban population (Venugopa & Shahidi, 1995). These are consequently the fish that sell for the highest price per kg. The south coast appears to receive the highest value for their fish, which could possibly be because they catch larger-sized fish species. It is however still somewhat counter-intuitive. The south coast has a poor infrastructure and is located further from the places with high demand (such as Dili), and you would therefore expect the traders to pay less as they need to compensate for the costs made for transport facilities and preservation of the produce (Población, 2013). Atauro island selling for the lowest price per kg is also doubtful. According to Mills et al. (2017), fish from Atauro island has a higher standing among the Dili-based middle class, as well as easy accessibility. Fishers from Atauro island also do not appear too worried about being able to sell their catch (Mills et al., 2017). One should anyhow be hesitant in making a comparison between the strata, as there have been differences in how the enumerators record the pricing between the areas and over time.

5.1.4 Patterns of seasonality

There is a clear pattern of seasonality seen in the number of fishing trips taken per week, especially prevalent on the south coast. This is likely explained by the weather conditions, as well as due to the diverse livelihood of most Timorese households. The fishers on the south coast make less trips when the seas are at their roughest, from April to September (Tomascik et al., 1997). The seasonality in fishing activity seen on Atauro island are in line with the findings of Mills et al. (2017), who found that there was reduced fishing activity in August and the months around August due to the rough seas caused by the south-easterly monsoon.

Fishing is for many households however not their only or even primary source of income (Mills et al., 2013). Instead, the vast majority name having their own crops and livestock as their main economic activity. It would therefore not be bold to assume that the seasonality of agricultural activities has an influence on the fishing activity. The harvesting of the two primary crops, maize and rice, happens from February to April and April to July (FAO, 2021). The period with the highest food insecurity is in the months before the harvesting, which is also when we see the highest fishing activity on the mainland (Gorton, 2018). This pattern is less prevalent on Atauro island, where there is a stronger fishing culture and half of the fishers consider it to be their main livelihood (Mills et al., 2017).

5.2 Effect of COVID-19 pandemic

The most apparent impact of the COVID-19 pandemic appears to be on the market value of the fish. The reported selling price of the fish caught by hand lines, long lines, and spear guns, which include the larger-sized fish, seems to have decreased quite significantly. This could partially be explained by the collapse in the tourism industry as a result of closing the international borders. During the lockdown, the tourism sector experienced a 95% decline in their revenues and many businesses depending on international travellers had to partially or completely close (Rajalingam et al., 2021). The fish favoured by restaurants are often the larger-sized species, and a collapse of the tourism sector will likely affect the demand and thus value of these fish. Furthermore, Timor-Leste experienced an overall economic shock due to the pandemic and earlier political uncertainty, and as a result the gross domestic product (GDP) of Timor-Leste is expected to decrease by 6.8%, leaving the local people with less money to spend (World Bank, 2020b). Due to the social distancing rules, the urgent request to work from home, and potential fear for the virus, there will have been less people present on the markets and less traffic to sell to along the roads. All these factors have likely contributed to driving down the selling price of the fish. Interestingly, the results do not indicate that a bigger part of the catch is kept for own consumption. Possibly, if there is a large part of the catch that cannot be sold on markets or on roads, it would be shared or bartered with relatives or friends.

Altogether, the pandemic and the resulting lockdown do not appear to have had as large an impact on the fisheries of Timor-Leste as it has had on other SSFs around the world, where the loss of revenue and decline in fishing activity has been substantial (Belton et al., 2021; Bennett et al., 2020; Campbell et al., 2021; Ferrer et al., 2021; Fiorella et al., 2021; Knight et al., 2020; Mangubhai et al., 2021; Plagányi et al., 2021). This could be explained by the still underdeveloped nature of the SSF of Timor-Leste. Other SSFs around the world lost a large part of their revenue due to the disruption of the international export market and the global supply chains (Belton et al., 2021; Knight et al., 2020; Plagányi et al., 2021). This will not have affected the fisheries of Timor-Leste in a similar manner, as the goods are generally sold locally, and there is minimal export except for some trade with Indonesians (Barbosa & Booth, 2009). Furthermore, the tourism sector of Timor-Leste is underdeveloped compared to other SIDS, as it accounts only for 0.5% of the GPD in Timor-Leste, while it accounts for more than 20% of the GDP in two fifths of the SIDS (Rajalingam et al., 2021; UNWTO, 2014). Whereas in most SSFs the decline in income for fishers has resulted in a decrease in fishing effort, as the costs started to outweigh the profit, this does not appear to be the case in Timor-Leste (Ferrer et al., 2021; Mangubhai et al., 2021). Another, more direct impact of the pandemic and the restrictions on the fishing activity of most SSFs is the required social distancing and the fear of catching the virus (Mangubhai et al., 2021; Okyere et al., 2020). Many fishers had to restrict the size of their crew to be able to maintain the necessary distance on the boat, resulting in a decrease in effort (Mangubhai et al., 2021). Landing sites are often crowded, and during the landing of the fish it is difficult to keep 2 metres distance from one another (Okyere et al., 2020). The fear of getting sick, which is a genuine concern for many in developing countries where health care is poor, constrains people in their movement and keeps some from going out fishing altogether (Lau et al., 2020). The fishers of Timor-Leste usually operate with small crews of one to three people, and these restrictions will therefore likely not have affecting them as much.

It appears that the underdevelopment of the fisheries of Timor-Leste is one of the reasons for its resilience against the COVID-19 crisis. It is therefore important that when putting effort in promoting and developing the fisheries, there is an equal amount of effort being put into building the resilience of the fisheries and creating safety nets for future crises, as more people's livelihood will depend on it. OECD (2021) and Love et al. (2021) propose several methods on how to accomplish this.

It is important to remember that there are other factors besides the pandemic that may influence changes in the fisheries. For instance, the climate plays an important role when it comes to yearly fluctuations. In 2020 a La Niña took place, while in 2019 there was an El Niño (NOOA, 2020). The ENSO can influence the wave energy, causing an increase or decrease in fishing activity (Hemer et al., 2010). Furthermore, La Niña can cause water temperatures to rise, which can affect the behaviour and thus catchability of target species (Dunstan et al., 2018). According to the Fisheries and Agriculture Organisation (FAO), the average landings in the western central Pacific Ocean increase during El Niño and decrease during La Niña (FAO, 2020). Another factor possibly playing a role is the success of other income and food sources. As mentioned, almost all households have multiple professions, of which agriculture is often the primary livelihood (Mills et al., 2013). If there is a bad harvesting year, this might increase the fishing activity of households to compensate for the income and food loss. During the pandemic, Timor-Leste experienced a higher level of food insecurity than during other years, partially due to the virus and the associated restrictions and partially due to droughts and crop pests (Timor-Leste Department of Food Security et al., 2020). It could thus be expected that households engaging in both fishing and agriculture would turn more to fishing when the crops are poor, reinforced by the fact that people felt that agricultural activities were more affected by the restrictions than fishing activities (Timor-Leste Department of Food Security et al., 2020).

5.3 Limitations

When a new dataset is being analysed, one is bound to discover some flaws and mistakes. This has also been the case for PeskAAS. Quite some records had missing information, and there were some occasional unreasonable values given. Considerable effort has been made to remove sampling errors, however due to the size of the datasets some will have remained unnoticed. As for the missing data, assumptions had to be made and a large part has been filled with educated estimations. Furthermore, as there were less enumerators and PDS trackers initially, the sample count of the earlier years is quite low, making outliers more prevalent and harder to determine any trends. Another setback when initially exploring the data, was the inability to match the data acquired from the trackers with the data sampled by the enumerators. If this would have been possible, it would potentially have been achievable to create geospatial maps showing the fishing effort, catch and gear composition, and landings of different areas.

As has already been mentioned, some of the trends seen in the results could be caused by sampling bias. Human error is always an element to consider, and so for this study. All the recorded information, except for what comes from the PDS trackers, is based on choices and estimations made by the fishers and the enumerators. If there is not a clear protocol and uniform routine on how to sample the data, then this will likely result in biases between the stations. The choice on which fishing trips are sampled are likely also not random, as enumerators will prefer to work with fishers that they know are reliable and cooperative. The accuracy of the estimations should however have increased over time, due to training and getting more experienced.

To increase the confidence in the results, specifically of the effect of the COVID-19 pandemic, a plan was made to compliment the quantitative analyses with a qualitative study. However, due to circumstances beyond control the qualitative study had to be postponed and could therefore not be included in this research (see Appendix G for the set-up of the focus discussion groups that were meant to be conducted).

While there is a growing interest in SSFs and an increasing number of studies being conducted on the matter, the lack of descriptive data still proved to limit the possibilities of comparing the characteristics of the Timorese fisheries with other SSFs. This is unfortunate, as it would have given a greater opportunity to put the results into perspective. Hopefully, this research will have proved the importance of "simple" descriptive analyses of SSFs and incited an increase in these types of studies.

5.4 Further research

As for Timor-Leste, this thesis only describes and analyses a part of the fishery. PeskAAS includes large amounts of information, making it possible to conduct more in-depth analyses on specific matters. For instance, the length distribution of the catches could be studied, to assess the fishing pattern by sizes. As the monitoring program will remain active, it will also be possible to conduct studies over longer time periods, making it easier to discover trends. Furthermore, it is recommended to continue analysing the impact of the COVID-19 pandemic and other drivers on the fisheries. This study only includes data up to March 2021, and until that date there were no significant outbreaks nor any deaths due to the virus in Timor-Leste (World Health Organization, 2021). However, since then the country has suffered their first serious outbreak, and to date (28 July 2021) there have been 10,535 cases and 26 deaths confirmed (World Health Organization, 2021). During the same period, Timor-Leste also had to grapple with severe floods and landslides caused by heavy rains (UN RCO, 2021). These calamities will have had a serious impact on the health and economy of the country, and the impact on the fisheries should be closely monitored.

6. Conclusion

This paper is the first to give a detailed descriptive overview of the small-scale fisheries of Timor-Leste. There are variations in the characteristics of the fisheries within the country, caused by social, cultural, economic, geographic and climate differences. The north coast is the richest and most dense area. They can invest in more expensive fishing equipment and are responsible for most of the landed fish, primarily small pelagic species. The south coast is poorer, and fishing is mostly by paddle-driven canoes. They also experience harsher weather conditions at sea without being well equipped against it, resulting in a discernible seasonality pattern of the fishing activity. Fishing is often not the main economic activity of households on the mainland, as agriculture and livestock farming are the preferred occupations. Atauro island has in that sense a stronger fishing culture, as more identify themselves primarily as fishers. Fishing equipment for catching pelagic fish is not easily accessible on the island, and therefore there are relatively more demersal species caught. Timorese fishers sell their catch locally, and what they cannot manage to trade they will keep for own consumption. Compared to other SSFs, Timor-Leste appears to be quite resilient against the impact of the COVID-19 pandemic. The fishing activity does not seem to be significantly affected, and the impact is mostly observed in the decline of the market value of the catches. Timor-Leste does however not rely on tourism and export as much as many other SSFs, and the impact is therefore less. It is important that as the fisheries of Timor-Leste are being developed and promoted, attention is given to preserving the resilience of the fisheries and creating safety nets for possible future crises, so the food security will not be put in danger.

Although the PeskAAS monitoring program is still developing and improving, it contains a lot of information which has enabled a description and analysis of a hitherto quite unknown fishery. Timor-Leste is a pilot study area for a wider implementation of PeskAAS, and hopefully this paper can be used as a steppingstone to further develop and improve the monitoring system, so it can be deployed in other countries to increase our knowledge of SSFs around the world.

References

Akaike, H. (1998). Information Theory and an Extension of the Maximum Likelihood Principle. In (pp. 199–213). Akademiai Kiado. doi: 10.1007/978-1-4612-1694-0{_}15

Alongi, D., Amaral, A., Carvalho, N., McWilliam, A., Rouwenhorst, J., Tirendi, F., ... 2009 (2009). *River Catchments and Marine Productivity in Timor Leste: Caraulun and Laclo Catchments; South and North Coasts* (Tech. Rep. No. 6).

Angelsen, K. K., & Olsen, S. (1987, 7). Impact of fish density and effort level on catching efficiency of fishing gear. *Fisheries Research*, *5*(2-3), 271–278. doi: 10.1016/0165-7836(87)90046-4

Asian Development Bank. (2014). *State of the Coral Triangle: Timor-Leste.*

Australian Bureau of Meteorology, & CSIRO. (2014). *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports.*

Barbosa, M., & Booth, S. (2009). Timor-Leste's fisheries catches (1950-2009): Fisheries under different regimes. In *Fisheries catch reconstructions: Islands, part i* (pp. 39–52).

Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015, 10). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1). doi: 10.18637/jss.v067.i01

Belton, B., Rosen, L., Middleton, L., Ghazali, S., Mamun, A. A., Shieh, J., ... Thilsted, S. H. (2021, 7). COVID-19 impacts and adaptations in Asia and Africa's aquatic food value chains. *Marine Policy*, *129*, 104523. doi: 10.1016/j.marpol.2021.104523

Béné, C., & Friend, R. M. (2011). Poverty in small-scale fisheries: Old issue, new analysis. *Progress in Development Studies*, *11*(2), 119–144. doi: 10.1177/146499341001100203

Bennett, N. J., Finkbeiner, E. M., Ban, N. C., Belhabib, D., Jupiter, S. D., Kittinger, J. N., ... Christie, P. (2020). The COVID-19 Pandemic, Small-Scale Fisheries and Coastal Fishing Communities. *Coastal Management*, *48*(4), 336–347. doi: 10.1080/08920753.2020.1766937

Bohnsack, J. A., & Harper, D. D. (1988). *Length-Weight Relationships of Selected Marine Reef Fishes from Southeastern United States and the Caribbean.* Retrieved from `https://scholar.google.de/scholar?q=amante+eakins+2009&btnG=&hl=de&as_sdt=0,5#6`

Braithwaite, J., Charlesworth, H., & Soares, A. (2012). *Networked Governance of Freedom and Tyranny : Peace in Timor-Leste.* doi: 10.26530/oapen{_}459392

Cameron, A. C., & Windmeijer, F. A. (1997). An R-squared measure of goodness of fit for some common nonlinear regression models. *Journal of Econometrics*, *77*(2), 329–342. doi: 10.1016/s0304-4076(96)01818-0

Campbell, S. J., Jakub, R., Valdivia, A., Setiawan, H., Setiawan, A., Cox, C., … Box, S. (2021, 2). Immediate impact of COVID-19 across tropical small-scale fishing communities. *Ocean and Coastal Management*, *200*, 105485. doi: 10.1016/j.ocecoaman.2020.105485

CARE. (2020). *COVID-19 Crisis: Analysis of Risk in Australia's Neighborhood* (Tech. Rep.).

Casado, A., & Alonso, I. D. (2019). *2019 Global Hunger Index: The Inequalities of Hunger* (Tech. Rep.). Retrieved from http://www.globalhungerindex.org

Dunstan, P. K., Moore, B. R., Bell, J. D., Holbrook, N. J., Oliver, E. C., Risbey, J., … Bennett, N. J. (2018, 2). How can climate predictions improve sustainability of coastal fisheries in Pacific Small-Island Developing States? *Marine Policy*, *88*, 295–302. doi: 10.1016/j.marpol.2017.09.033

FAO. (2014). *Global Blue Growth Initiative and Small Islands Developing States (SIDS).*

FAO. (2015). *Agriculture Trends In Timor-Leste From 2010-2015* (Tech. Rep.). Retrieved from http://www.statistics.gov.tl/wp-content/uploads/2019/10/FAO_TL_infographics_S_English-language.pdf

FAO. (2020). *El Niño Southern Oscillation (ENSO) effects on fisheries and aquaculture.* doi: 10.4060/ca8348en

FAO. (2021). *Special Report – 2021 FAO Crop and Food Supply Assessment Mission (CFSAM) to the Democratic Republic of Timor-Leste.* doi: 10.4060/cb5245en

Feeny, S., & McGillivray, M. (2010). Aid and growth in Small Island developing states. *Journal of Development Studies*, *46*(5), 897–917. doi: 10.1080/00220381003623889

Ferrer, A. J. G., Pomeroy, R., Akester, M. J., Muawanah, U., Chumchuen, W., Lee, W. C., … Viswanathan, K. K. (2021). Covid-19 and small-scale fisheries in southeast asia: Impacts and responses. *Asian Fisheries Science*, *34*(1), 99–113. doi: 10.33997/j.afs.2021.34.1.011

Filho, W. L., Lütz, J. M., Sattler, D. N., & Nunn, P. D. (2020, 7). Coronavirus: COVID-19 transmission in pacific small island developing states. *International Journal of Environmental Research and Public Health*, *17*(15), 1–8. doi: 10.3390/IJERPH17155409

Fiorella, K. J., Bageant, E. R., Mojica, L., Obuya, J. A., Ochieng, J., Olela, P., … Okronipa, H. (2021, 5). Small-scale fishing households facing COVID-19: The case of Lake Victoria, Kenya. *Fisheries Research*, *237*. doi: 10.1016/j.fishres.2020.105856

Froese, R., & Pauly, D. (2021). *FishBase.* Retrieved from https://fishbase.se/search.php

Gautam, K., Nazar, A. R., Ganesh, E. A., Mahendran, S., & Mahadevan, G. (2014). Study of Length and Weight Relationship of Litopenaeus Vannamei (Boone , 1931) From East Coast of India. *International Journal of Science Inventions Today*, *3*(4), 365–376. Retrieved from https://www.researchgate.net/publication/339788630_STUDY_OF_LENGTH_AND_WEIGHT_RELATIONSHIP_OF_LITOPENAEUS_VANNAMEI_BOONE_1931_FROM_EAST_COAST_OF_INDIA

General Directorate of Statistics. (2015). 2015 Timor-Leste Population and

Housing Census: Data Sheet. *Statistics Timor-Leste*, 1. Retrieved from http://www.statistics.gov.tl/wp-content/uploads/2016/11/Wall-Chart-Poster-Landscape-Final-English-rev.pdf

Gill, D. A., Oxenford, H. A., Turner, R. A., & Schuhmann, P. W. (2019, 3). Making the most of data-poor fisheries: Low cost mapping of small island fisheries to inform policy. *Marine Policy*, *101*, 198–207. doi: 10.1016/j.marpol.2017.10.040

Gorton, C. (2018). Food and Nutrition Security in Timor-Leste: Challenges and Prospects. *Future Directions International*(August).

Hemer, M. A., Church, J. A., & Hunter, J. R. (2010, 3). Variability and trends in the directional wave climate of the Southern Hemisphere. *International Journal of Climatology*, *30*(4), 475–491. doi: 10.1002/joc.1900

Herrón, P., Kluger, L. C., Castellanos-Galindo, G. A., Wolff, M., & Glaser, M. (2020, 4). Understanding gear choices and identifying leverage points for sustainable tropical small-scale marine fisheries. *Ocean and Coastal Management*, *188*, 105074. doi: 10.1016/j.ocecoaman.2019.105074

Hunnam, K., Carlos, I., Hammer, M. P., Dos Reis Lopes, J., Mills, D. J., & Stacey, N. (2021, 5). Untangling Tales of Tropical Sardines: Local Knowledge From Fisheries in Timor-Leste. *Frontiers in Marine Science*, *8*, 470. doi: 10.3389/fmars.2021.673173

Ingram, S., Kent, L., & McWilliam, A. (2015). *A New Era? Timor-Leste after the UN.* doi: 10.26530/oapen{_}578881

Islam, M. M. (2011). Living on the Margin: The Poverty-Vulnerability Nexus in the Small-Scale Fisheries of Bangladesh. In *Poverty mosaics: Realities and prospects in small-scale fisheries* (pp. 71–95). Springer, Dordrecht. doi: 10.1007/978-94-007-1582-0{_}5

Knight, C. J., Burnham, T. L., Mansfield, E. J., Crowder, L. B., & Micheli, F. (2020). COVID-19 reveals vulnerability of small-scale fisheries to global market systems. *The Lancet Planetary Health*, *4*(6), e219. doi: 10.1016/S2542-5196(20)30128-5

Kolding, J. (1989). *The fish resources of Lake Turkana and their environment* (Doctoral dissertation). Retrieved from https://agris.fao.org/agris-search/search.do?recordID=XF2015017717

Kolding, J., Béné, C., Bavinck, M., Garcia, S. M., Rice, J., & Charles, A. (2014). Small-scale fisheries - importance, vulnerability, and deficient knowledge. In *Governance of marine fisheries and biodiversity conservation: Interaction and co-evolution* (pp. 317–331). doi: 10.1002/9781118392607

Kolding, J., & Van Zwieten, P. A. (2011). The tragedy of our legacy: How do global management discourses affect small scale fisheries in the south? In *Forum for development studies* (Vol. 38, pp. 267–297). doi: 10.1080/08039410.2011.577798

Lau, J., Sutcliffe, S., & Hungito, W. (2020). *Lived experiences of Covid-19: impacts on an atoll island community, Papua New Guinea* (Tech. Rep.). Townsville, Australia: James Cook University.

Lenth, R. V. (2021). *emmeans: Estimated Marginal Means, aka Least-Squares Means.* Retrieved from https://cran.r-project.org/package=emmeans

Lopes, S., Mendes, H. H., De Araujo, V. S., Martins, A., de Fatima Mesquita, M., de Jesus, S., ... Dili, S. (2019). *Título Title Timor-Leste em Número* (Tech.

Rep.). Impressão.

López Angarita, J., Hunnam, K., Pereira, M., Jonathan Mills, D., Pant, J., Shwu Jiau, T., ... Tilley, A. (2019). Fisheries and aquaculture of Timor-Leste in 2019: Current knowledge and opportunities. *WorldFish*, 2019–15.

Love, D. C., Allison, E. H., Asche, F., Belton, B., Cottrell, R. S., Froehlich, H. E., ... Zhang, W. (2021). Emerging COVID-19 impacts, responses, and lessons for building resilience in the seafood system. *Global Food Security*, *28*(February), 100494. doi: 10.1016/j.gfs.2021.100494

Macusi, E. D., Macusi, E. S., Jimenez, L. A., & Catam-isan, J. P. (2020, 5). Climate change vulnerability and perceived impacts on small-scale fisheries in eastern Mindanao. *Ocean and Coastal Management*, *189*, 105143. doi: 10.1016/j.ocecoaman.2020.105143

Mangubhai, S., Nand, Y., Reddy, C., & Jagadish, A. (2021, 6). Politics of vulnerability: Impacts of COVID-19 and Cyclone Harold on Indo-Fijians engaged in small-scale fisheries. *Environmental Science and Policy*, *120*, 195–203. doi: 10.1016/j.envsci.2021.03.003

Mills, Abernethy, K., King, J., Hoddy, E., Teoh, S., Larocca, P., ... Fernandes, A. (2013). *Developing Timor-Leste's coastal economy: assessing potential climate change impacts and adaptation options* (Tech. Rep.).

Mills, Westlund, L., De Graaf, G., Kura, Y., Willman, R., & Kelleher, K. (2011). Under-reported and undervalued: Small-scale fisheries in the developing world. *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*(June 2014), 1–15. doi: 10.1079/9781845936075.0001

Mills, D. J., Tilley, A., Pereira, M., Hellebrandt, D., Pereira Fernandes, A., & Cohen, P. J. (2017). Livelihood diversity and dynamism in Timor-Leste; insights for coastal resource governance and livelihood development. *Marine Policy*, *82*(April), 206–215. doi: 10.1016/j.marpol.2017.04.021

Misund, O. A., Kolding, J., & Fréon, P. (2002). Fish Capture Devices in Industrial and Artisanal Fisheries and their Influence on Management. In *Handbook of fish biology and fisheries* (Vol. 2, pp. 13–36). doi: 10.1002/9780470693919.ch2

Molyneux, N., Da Cruz, G. R., Williams, R. L., Andersen, R., & Turner, N. C. (2012, 12). Climate change and population growth in Timor-Leste: Implications for food security. *Ambio*, *41*(8), 823–840. doi: 10.1007/s13280-012-0287-0

Moxham, B., & Carapic, J. (2013). Unravelling Dili: The Crisis of City and State in Timor-Leste. *Urban Studies*, *50*(15), 3116–3133. doi: 10.1177/0042098013487774

National Directorate of Food Security and Cooperation. (2019). *The First IPC Analysis Report on the Chronic Food Insecurity Situation in Timor-Leste. Evidence and Standards for Better Food Security and Nutrition Decisions* (Tech. Rep.).

NOAA. (2021). *El Niño & La Niña (El Niño-Southern Oscillation).* Retrieved from `https://www.climate.gov/enso`

NOOA. (2020). *ENSO: Cold & Warm Episodes by Season.* Retrieved from `https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php`

OECD. (2021). *COVID-19 pandemic: Towards a blue recovery in small island developing states* (Tech. Rep.).

Okyere, I., Chuku, E. O., Ekumah, B., Angnuureng, D. B., Boakye-Appiah, J. K., Mills, D. J., ... Crawford, B. (2020, 12). Physical distancing and risk of COVID-19 in small-scale fisheries: a remote sensing assessment in coastal Ghana. *Scientific Reports*, *10*(1), 1–13. doi: 10.1038/s41598-020-79898-4

Pauly, D., & Zeller, D. (2014, 4). *Accurate catches and the sustainability of coral reef fisheries* (Vol. 7). Elsevier. doi: 10.1016/j.cosust.2013.11.027

Pelletier, D., & Ferraris, J. (2000). A multivariate approach for defining fishing tactics from commercial catch and effort data. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(1), 51–65. doi: 10.1139/f99-176

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & R Core Team. (2019). {*nlme*}*: Linear and Nonlinear Mixed Effects Models.* Retrieved from `https://cran.r-project.org/package=nlme`

Plagányi, , Deng, R. A., Tonks, M., Murphy, N., Pascoe, S., Edgar, S., ... Dutra, L. (2021, 6). Indirect Impacts of COVID-19 on a Tropical Lobster Fishery's Harvest Strategy and Supply Chain. *Frontiers in Marine Science*, *8*, 730. doi: 10.3389/fmars.2021.686065

Población, E. A. (2013). Fisheries and food security in Timor-Leste: The effects of ritual meat exchanges and market chains on fishing. *Food Security*, *5*(6), 807–816. doi: 10.1007/s12571-013-0308-2

Pratt, S. (2015, 5). The economic impact of tourism in SIDS. *Annals of Tourism Research*, *52*, 148–160. doi: 10.1016/j.annals.2015.03.005

R Core Team. (2019). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria.*

Rajalingam, G., Atwood, K., Miranda, A., Ximenes, J., Santo, G., da Conceição Teixeira, I., ... Bishop, A. (2021). *2020 Economic impact of COVID-19 on MSMEs and Timor-Leste's Tourism Sector* (Tech. Rep.). The Asia Foundation.

Saji, N. H., Goswami, B. N., Vinayachandran, P. N., & Yamagata, T. (1999). A dipole mode in the tropical Indian ocean. *Nature*, *401*(6751), 360–363. doi: 10.1038/43854

Smith, S. L., Battista, W., Sarto, N., Fujita, R., Stetten, D. C., Karasik, R., & Burden, M. (2019, 7). A framework for allocating fishing rights in small-scale fisheries. *Ocean and Coastal Management*, *177*, 52–63. doi: 10.1016/j.ocecoaman.2019.04.020

Taylor-Leech, K. (2009). *The language situation in Timor-Leste* (Vol. 10) (No. 1). doi: 10.1080/14664200802339840

Tilley, A., Dos Reis Lopes, J., & Wilkinson, S. P. (2020). PeskAAS: A near-real-time, open-source monitoring and analytics system for small-scale fisheries. *PLoS ONE*, *15*(11 November), 1–11. doi: 10.1371/journal.pone.0234760

Tilley, A., Wilkinson, S. P., Kolding, J., López-Angarita, J., Pereira, M., & Mills, D. J. (2019). Nearshore fish aggregating devices show positive outcomes for sustainable fisheries development in Timor-Leste. *Frontiers in Marine Science*, *6*(JUL), 487. doi: 10.3389/fmars.2019.00487

Timor-Leste Department of Food Security, Ministry of Agriculture and Fisheries, Oxfam, Mercy Corps, USAID, ADRA, ... WFP (2020). *Rapid Food Security Assesment 2020: Full Report - Timor-Leste* (Tech. Rep.).

Timor-Leste National Directorate of Meteorology and Geophysics, Australian Bureau of Meteorology, & Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2015). *Pacific-Australia Climate Change Science and*

Adaptation Planning Program: Current and future climate of Timor-Leste (Tech. Rep.).

Timor-Leste, G. o. (2020). *Measures for the Implementation of the Declaration of State of Emergency introduced by Decree of the Precident of the Republic (no. 29)* (Tech. Rep.).

Tomascik, T., Mah, A., Nontji, A., & Moosa, M. K. (1997). *The Ecology of the Indonesian Seas* (Vol. 7). Honkong, China: Periplus Editions (HK).

UN RCO. (2021). *Timor-Leste Floods - Flash update No. 1 (As of 5 April 2021)* (Tech. Rep.). Retrieved from `www.timorleste.un.org/`

UNWTO. (2014). *Tourism in Small Island Developing States (SIDS) – Building a more sustainable future for the people of Islands.* doi: 10.18111/9789284416257

Venugopa, V., & Shahidi, F. (1995, 9). Value-Added Products from Underutilized Fish Species. *Critical Reviews in Food Science and Nutrition*, *35*(5), 431–453. doi: 10.1080/10408399509527708

Wagenmakers, E. J., & Farrell, S. (2004). *AIC model selection using Akaike weights* (Vol. 11) (No. 1). doi: 10.3758/BF03206482

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis.* Springer-Verlag New York. Retrieved from `https://ggplot2.tidyverse.org`

World Bank. (2020a). *Food Security and Covid-19* (No. February 2019). Retrieved from `https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19.print`

World Bank. (2020b). *Timor-Leste Economic Report, October 2020: Towards a Sustained Recovery.* World Bank, Washington, DC. doi: 10.1596/34748

World Bank. (2021). *Population, total - Timor-Leste — Data.* Retrieved from `https://data.worldbank.org/indicator/SP.POP.TOTL?locations=TL`

World Bank, FAO, & WorldFish. (2012). *Hidden Harvests: the Global Contribution of Capture Fisheries, Economic and Sector Work* (Tech. Rep. No. 66469). Retrieved from `www.worldbank.org`

World Health Organization. (2021). *Timor-Leste: WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data.* Retrieved from `https://covid19.who.int/region/searo/country/tl`

World Trade Organization. (2020). Trade Statistics and Outlook: Trade set to plunge as Covid-19 pandemic upends global economy. *Wto.Org*, *2020*(April), 1–13. Retrieved from `https://www.wto.org/english/news_e/pres20_e/pr855_e.htm`

Ximenes, E. M., Yeros, M. C., Gusmão, C., Lopes, S., & Mendes, H. H. (2018). *Timor-Leste: Annual External Trade Statistics 2018* (Tech. Rep.).

Appendices

Appendix A

Information on the sampling sites

Table A1: **Detailed information of station codes.** Location of station codes, first and last sampling date and the total number of samples taken there.

Strata	Municipality	Station code	Location	Date of first sample	Date of last sample	Total number of samples
Atauro island	Dili	1	Adara / Atekru	29-10-2016	Ongoing	1231
		2	Beloi / Usu Bemasu	05-11-2016	Ongoing	1114
		3	Biqueli / Pala	24-11-2016	Ongoing	647
		6	Uaroana / Akrema	10-08-2017	Ongoing	8165
		11	Raiketa / Vila	07-06-2018	Ongoing	264
		13	Berao / Maquili	07-06-2018	29-11-2019	60
		15	Fatu'u / Doru / Iliana / Arlo	07-06-2018	Ongoing	1140
		18	Maquer	07-06-2018	26-12-2020	726
North coast	Baucau	4	Vemasse	07-11-2016	Ongoing	5323
	Bobonaro	10	Beacou / Sulilaran / Palaka	11-08-2017	Ongoing	3288
	Lautem	7	Com	02-07-2017	Ongoing	1198

		8	Tutuala	18-07-2017	31-07-2018	183
		9	Ililai	14-09-2017	11-09-2019	372
		30	Sentru / Liarafa / Sika / Rau Moko	18-05-2019	28-05-2019	3
	Liquica	26	Leopa / Do Tasi	02-05-2019	Ongoing	2184
	Manatuto	29	Comando	01-05-2019	Ongoing	1984
	Oe-Cusse	28	Oe-Cusse	03-05-2019	Ongoing	798
South coast	Ainaro	25	Bonuk / Fatumeta / Nunumera	02-05-2019	11-12-2020	298
	Covalima	22	We Hasan / We Inan	02-05-2019	Ongoing	1631
		23	Welateti	07-05-2019	Ongoing	1794
	Manufahi	20	Selihasan	08-06-2018	31-07-2019	19
		21	Betano	26-04-2019	Ongoing	1136
	Viqueque	5	Adarai	10-09-2016	11-07-2019	2073
		27	Beasu	03-05-2019	Ongoing	1839

Appendix B

Classification of functional groups

Table A2: **Classification of the different functional groups.**

Functional group	**Species code**	**Species name** (English)	**Species name** (Tetun)	**Family**
Cephalopods	41	Cuttlefish	Suntu	*Sepiidae*
	24	Octopus	Kurita	*Octopodidae*
Crustaceans	45	Crab	Kadiuk	-
Large demersal	12	Grouper	Garopa	*Serranidae*
	42	Javelin / Grunt	Talun	*Haemulidae*
	36	Moray	Samea / Tuna	*Muraenidae*
	15	Parrotfish	Niru	*Scaridae*
	10	Snapper / seaperch	Tanggalara / Kamera	*Lutjanidae*
	35	Sweetlips	Loloi	*Haemulidae*
	18	Unicornfish	Fafulu	*Acanthuridae*
Large pelagics	22	Barracuda	Alu-Alu / Taranu	*Sphyraenidae*
	44	Cobia	Badee / Gabus Laut	*Rachycentridae*
	46	Dolphinfish	Karonogo Metan	*Coryphaenidae*
	3	Jacks / Trevally / Other Scad	Sera Atan / Ikan Koku / Kombong Seluk	*Carangidae*

	20	Jobfish	Karungu / Talang-talang	*Lutjanidae*
	9	Long tom	Ikan Daun	*Belonidae*
	51	Remora	Ikan utu	*Echeneidae*
	43	Sailfish	Lanjara	*Istiophoridae*
	4	Tuna / Bonito / Other Mackerel	Tuna / Tongkol / Kasareta / Bulkumo / Sera seluk	*Scombridae*
	53	Wolf herring	Espada	*Chirocentridae*
Molluscs	50	Cockles	Sipu	*Cardiidae*
Shark and rays	34	Shark	Tubaraun	*Chaetodontidae*
	54	Stingray	Pari	-
Shrimp	38	Shrimp	Boek	-
Small demersal	47	Bannerfish	La pipi	*Chaetodontidae*
	30	Blackspot sweeper	Kadaheu	*Pempheridae*
	29	Bream	Bandeira / Kapapan	*Nemipteridae*
	39	Butterflyfish	Kalapepa	*Chaetodontidae*
	40	Cardinalfish	Ikan Serinding	*Apogonidae*
	13	Emperor	Uleu / Kapapan / Baduma	*Lethrinidae*
	31	Goatfish	Biz nga	*Mullidae*
	19	Mojarra / Silverbelly	Katarina	*Gerreidae*

	25	Moonfish	Baleu Belar Oan	*Menidae*
	26	Moontail bullseye	Kror Matan Fuan Boot	*Priacanthidae*
	28	Ponyfish	Bete-bete debe door	*Leiogthidae*
	55	Sicklefish	Kakehe	*Drepaneidae*
	8	Soldierfish	Karon	*Holocentridae*
	11	Spinefoot	Kitan	*Siganidae*
	14	Surgeonfish	Kafir	*Acanthuridae*
	33	Terapon	Bobi / Rongkado	*Terapontidae*
	16	Triggerfish	Papameta / Sungu	*Balistidae*
	52	Tripodfish	Ikan lisa	*Triacanthidae*
	21	Wrasse	Niru fatuk / Lamor	*Labridae*
Small pelagics	23	Chub	Spreo	*Kyphosidae*
	17	Flying fish	Ikan Manu	*Exocoetidae*
	5	Fusilier	Bainar	*Caesionidae*
	7	Garfish	Sardina kobi	*Hermiramphidae*
	27	Herring	Sardina kobi	*Elopidae*
	2	Mackerel scad	Kombon / Salar matan bo'ot	*Carangidae*
	48	Milkfish	Salmaun / Ikan be'e	*Chanidae*
	32	Mullet	Saltaun	*Mugilidae*

	6	Sardines / pilchards	Sardina	*Clupeidae*
	37	Sergeant	Blis	*Pomacentridae*
	1	Short-bodied mackerel	Bainar Mutin	*Scombridae*
	49	Threadfin	Kanase	*Polynemidae*
Unknown	300	Other	Seluk	-
	99	Unknown	La hatene naran	-

Appendix C

Data cleaning

<u>Dates</u>
One trip was entered with the date “1922-11-04”. Using the trip ID number to compare it to the dates of other trips, the trip was given the date “2018-12-07”.

<u>Trip duration</u>
The values of the trip duration were made absolute to remove negative values (one entry), and trips with a duration of zero hours were changed to one hour (10 entries). An upper limit of 13 hours was established, as the longest day-length of Timor-Leste is around 12 hours and 36 minutes. All entries with 14 trip hours or more were changed to the median trip duration for each stratum and boat type (125 entries; Table A7; fig. A1).

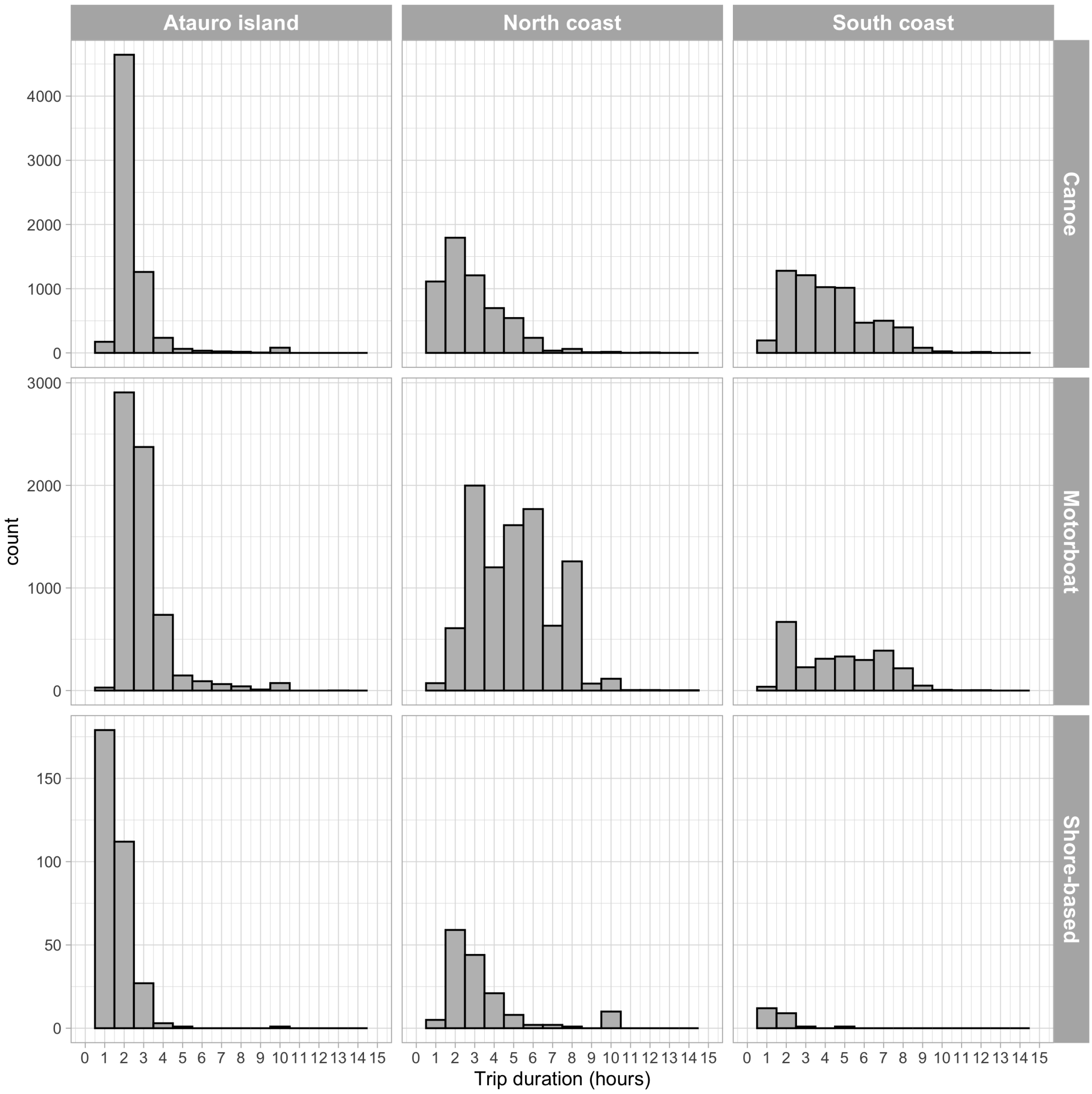

Figure A1: **Frequency plot of the trip duration (hours)** before data cleaning for canoes, motorboats, and shore-based fishery in Atauro island, north coast and south coast.

Number of fishermen

Entries with zero fishermen recorded were changed to one fisherman (26 entries). An upper limit of 10 fishermen for canoes and 10 fishermen for motorboats was established, and all entries above this limit were changed to the median number of fishermen for each stratum and boat type (189 entries; Table A8; fig. A2).

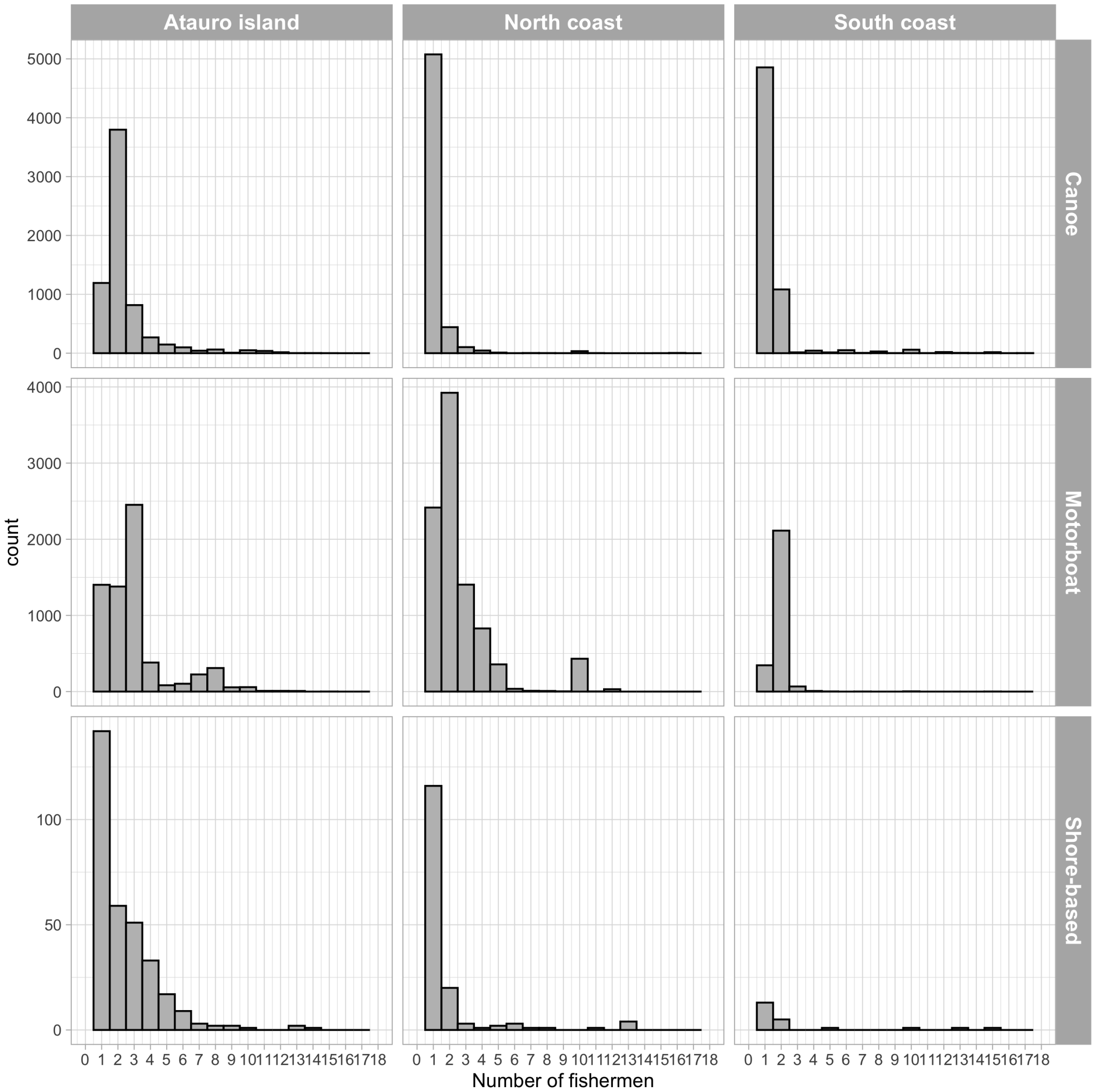

Figure A2: **Frequency plot of the number of fishermen** before data cleaning for canoes, motorboats and shore-based fishery on Atauro island, north coast, and south coast.

Abundance (number) of catch

Multiple changes were made concerning the number of fish caught and the weight of the catch. All entries were made absolute to remove negative values (two entries), and an upper limit was set of 10,000 fish caught in one trip. Trips where more fish were caught (9 entries), the abundance and the weight were changed to NA's.

Weight of catch

There were 1803 entries where no information on the weight of the catch was given. These were calculated using the following formula from Bohnsack and Harper (1988):

$$W = a * L^b * N \tag{1}$$

where W equals weight of catch (in gram), L equals fish size (in cm), N equals number of fish caught (of that species and length) and a and b equal constants per fish species. The constants a and b of most species were collected from Froese and Pauly (2021). For the shrimp, the a and b constants were collected from Gautam et al. (2014).

For some species groups (crab, cockles (*Cardiidae spp.*), and cuttlefish (*Sepiidae spp.*)) the a and b constants could not be found in the literature. For these species a length-weight relationship was plotted using the length and weight values that were present in the catch data, which was then used to derive the mean weight of the species for several length groups (fig. A3; fig. A4; fig. **??**)

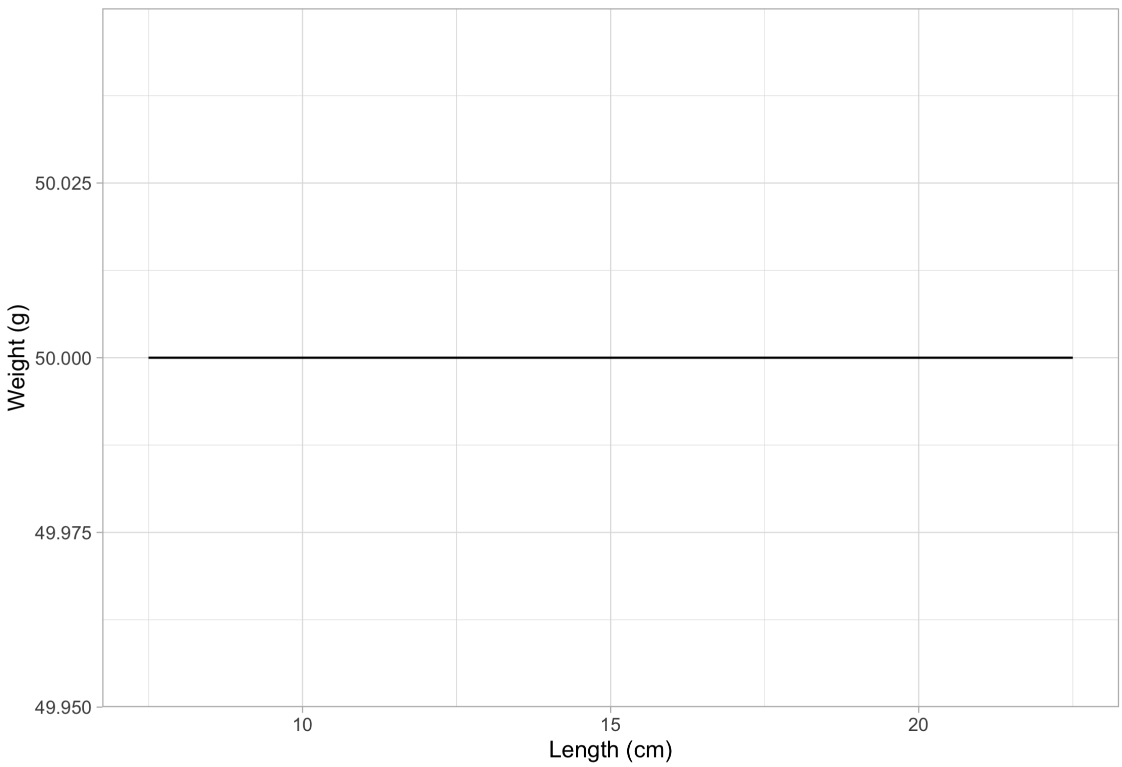

Figure A3: **Length-weight relationships of crab** using the length and weight values given in the catch data.

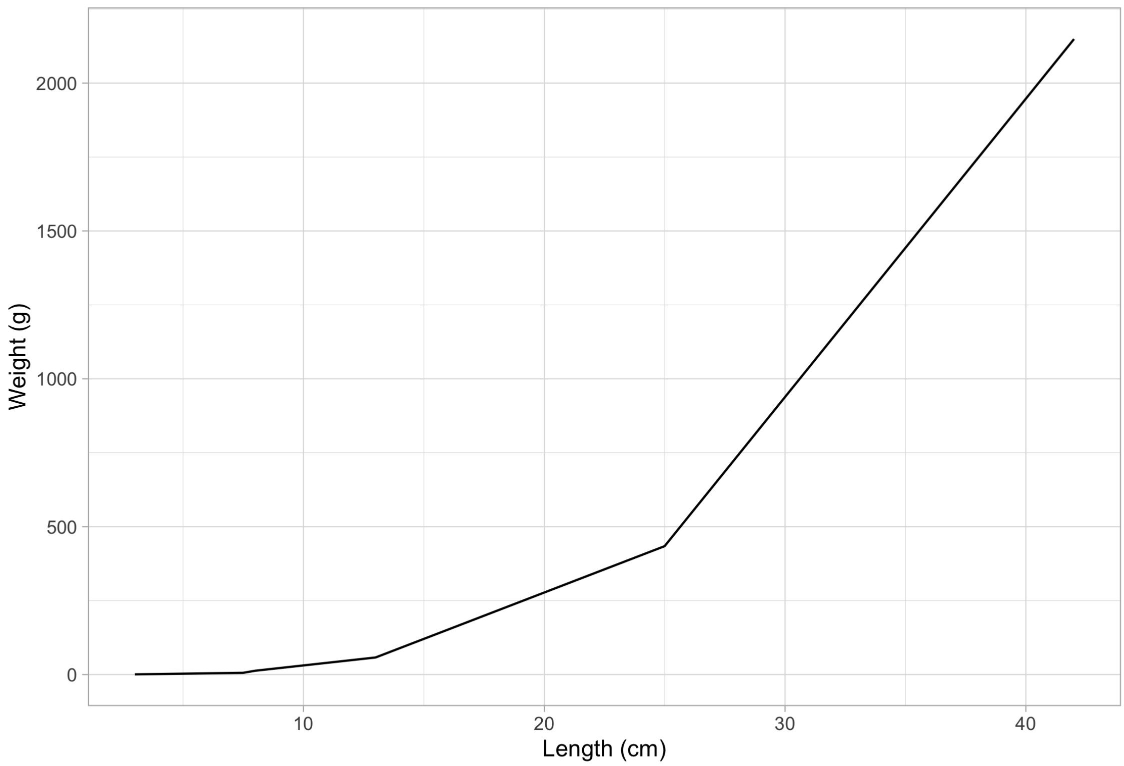

Figure A4: **Length-weight relationships of cockles (*Cardiidae spp.*)** using the length and weight values given in the catch data.

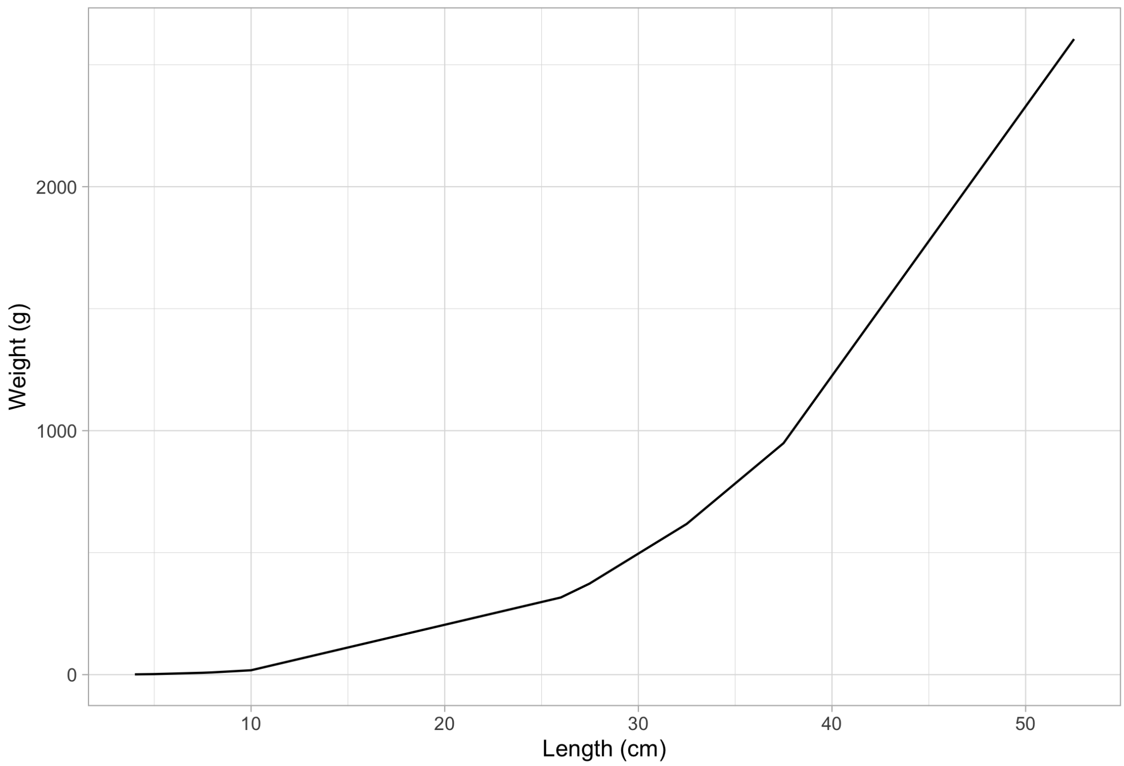

Figure A5: **Length-weight relationships of cuttlefish (*Sepiidae spp.*)** using the length and weight values given in the catch data.

Market value

Market value was given an upper limit of 2000 USD. Everything above this limit was changed to “NA” (3 entries).

Merging datasets

When merging the dataset which had the effort information for each trip with the dataset that included the catch information, a total of 121 entries were lost. This means that 121 trips did not have any information documented on the landings of those trips.

Subsetting data for modelling

For the modelling the gear types cast net, manual collection, beach seine, seine net and trap were removed, along with the station codes 5, 9, 13, 20 and 30 and the shore-based fishing

Appendix D

Frequency plots of the dependent variables untransformed and log-transformed

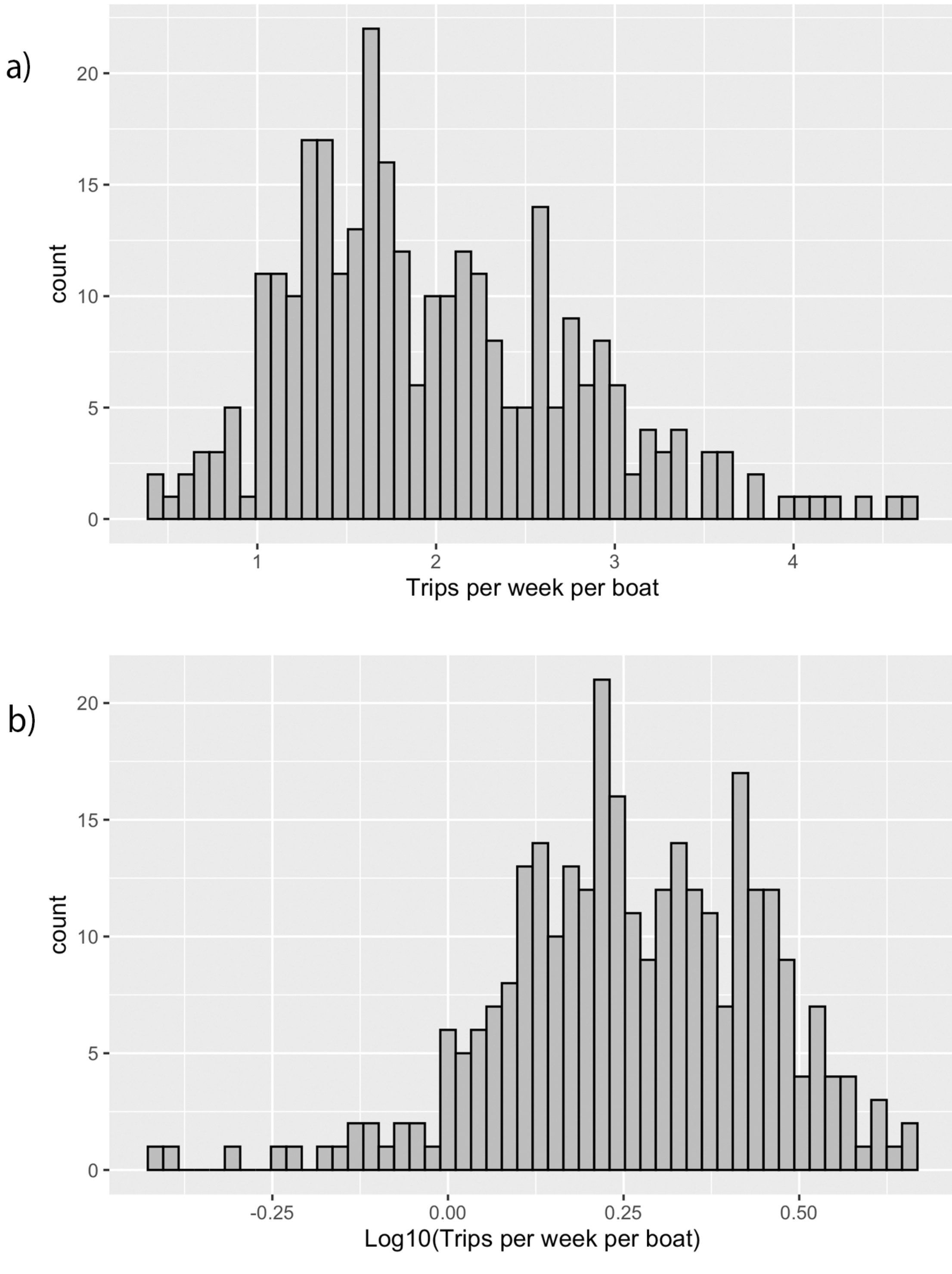

Figure A6: **Frequency plots of the fishing trips taken per week per boat** (a) before log-transformation and (b) after log-transformation.

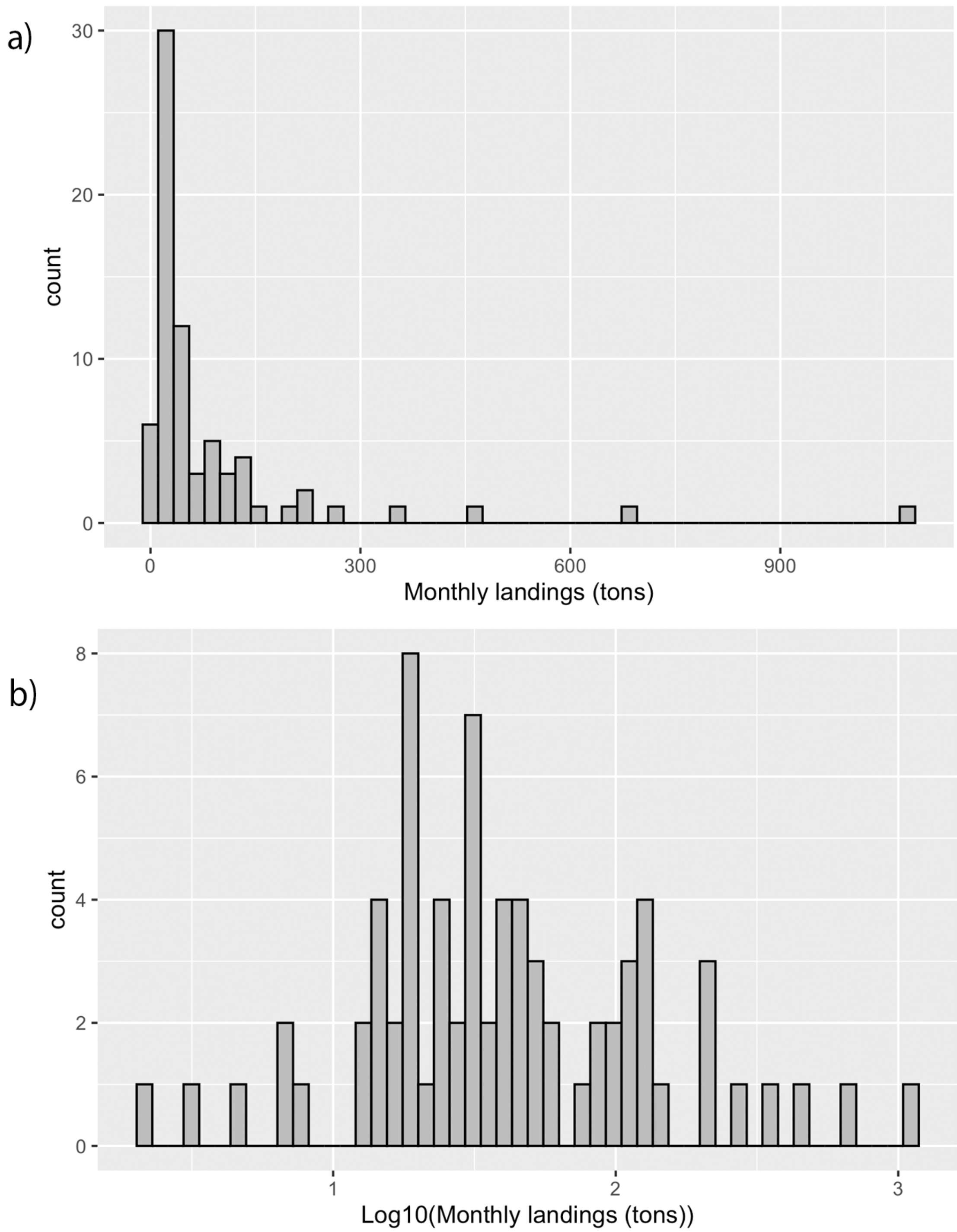

Figure A7: **Frequency plots of the estimated monthly landings (tons)** (a) before log-transformation and (b) after log-transformation.

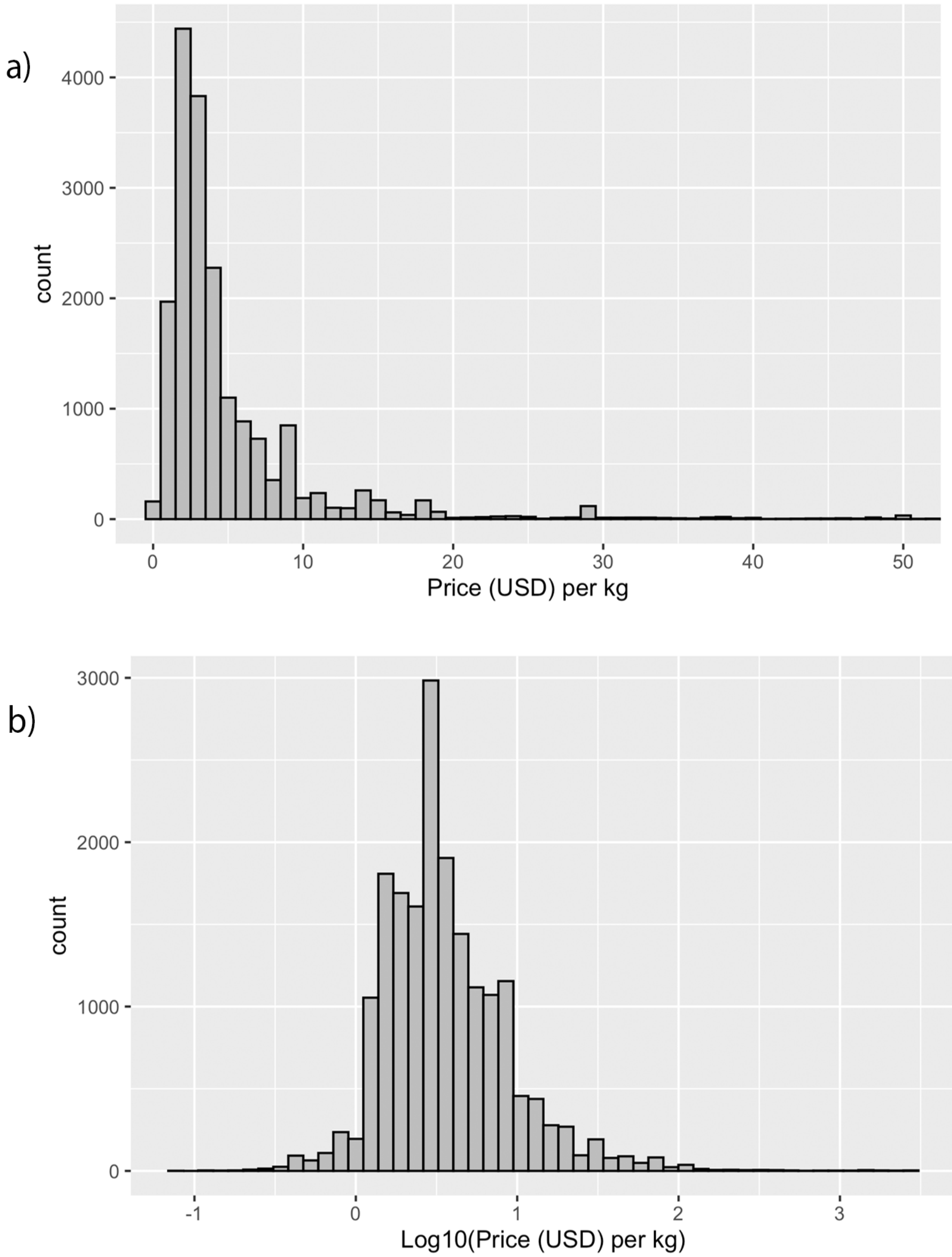

Figure A8: **Frequency plots of the value (USD) of the catch per kg** (a) before log-transformation and (b) after log-transformation.

Appendix E

Gear composition over time of municipalities in the north and south coast

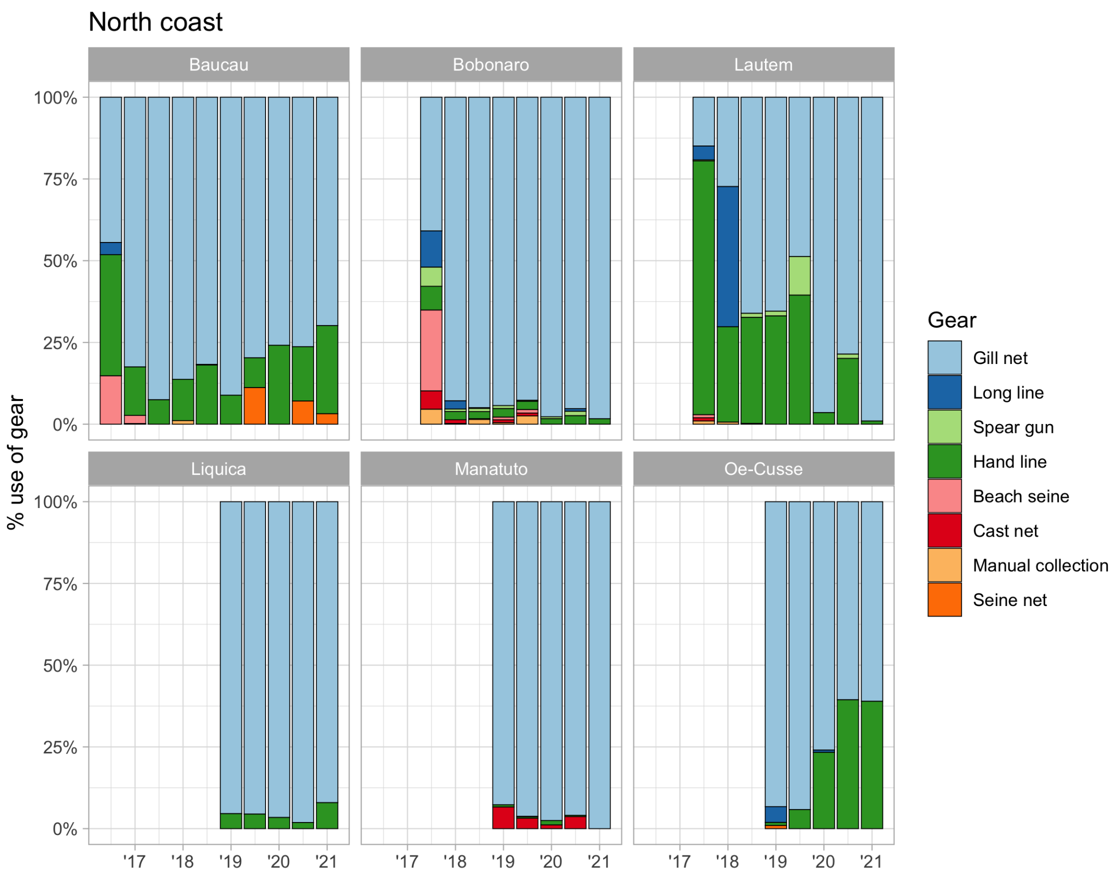

Figure A9: **Gear composition on the north coast over time.** The gear composition per 6 months of the municipalities on the north coast for the period of September 2016 to April 2021 (the last bar only consists of 4 months). The y-axis shows the percentage of times a gear has been used.

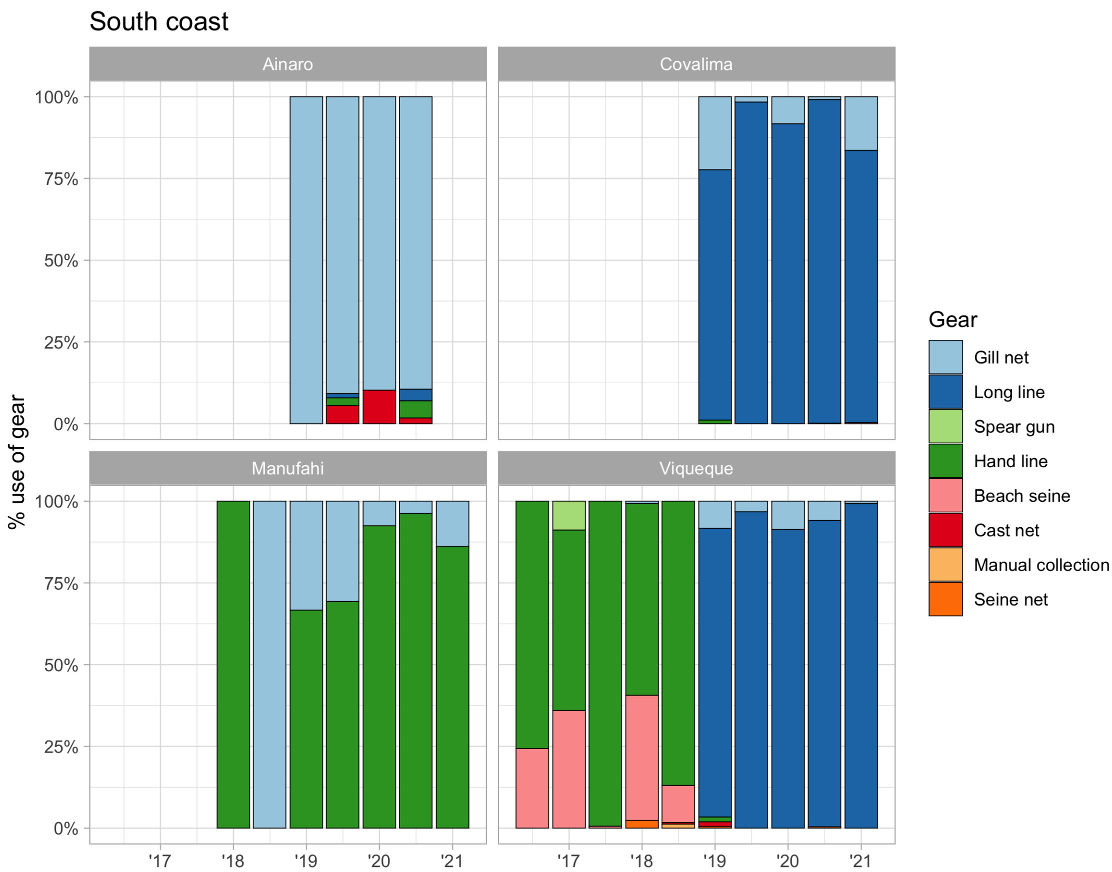

Figure A10: **Gear composition on the south coast over time.** The gear composition per 6 months of the municipalities on the south coast for the period of September 2016 to April 2021 (the last bar only consists of 4 months). The y-axis shows the percentage of times a gear has been used.

Appendix F

Species composition of the catch within the functional groups

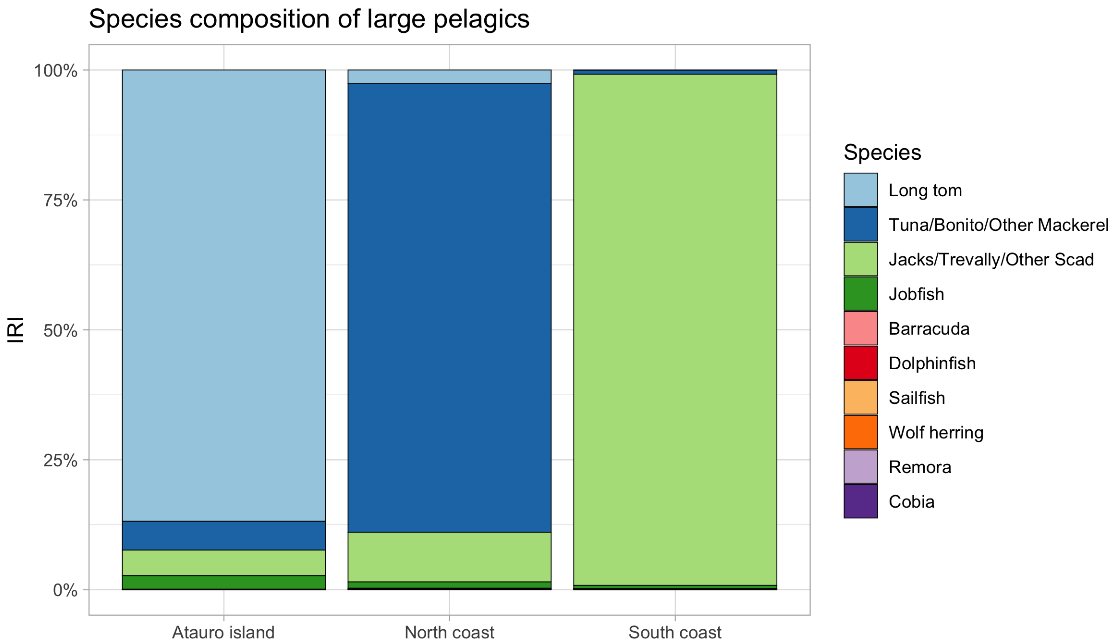

Figure A11: **Species composition of the catch of large pelagic species.** Species composition of the catch of large pelagic species on Atauro island, north coast and south coast. The y-axis shows the Index of Relative Importance (IRI), which is calculated using the weight, number, and frequency of occurrence of a species.

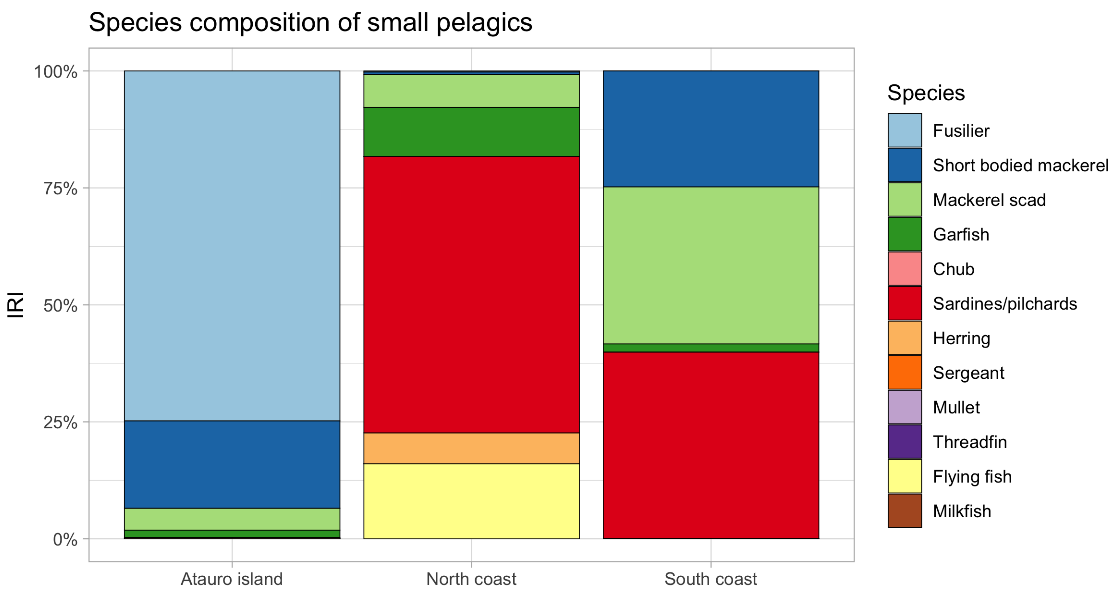

Figure A12: **Species composition of the catch of small pelagic species.** Species composition of the catch of small pelagic species on Atauro island, north coast and south coast. The y-axis shows the Index of Relative Importance (IRI), which is calculated using the weight, number, and frequency of occurrence of a species.

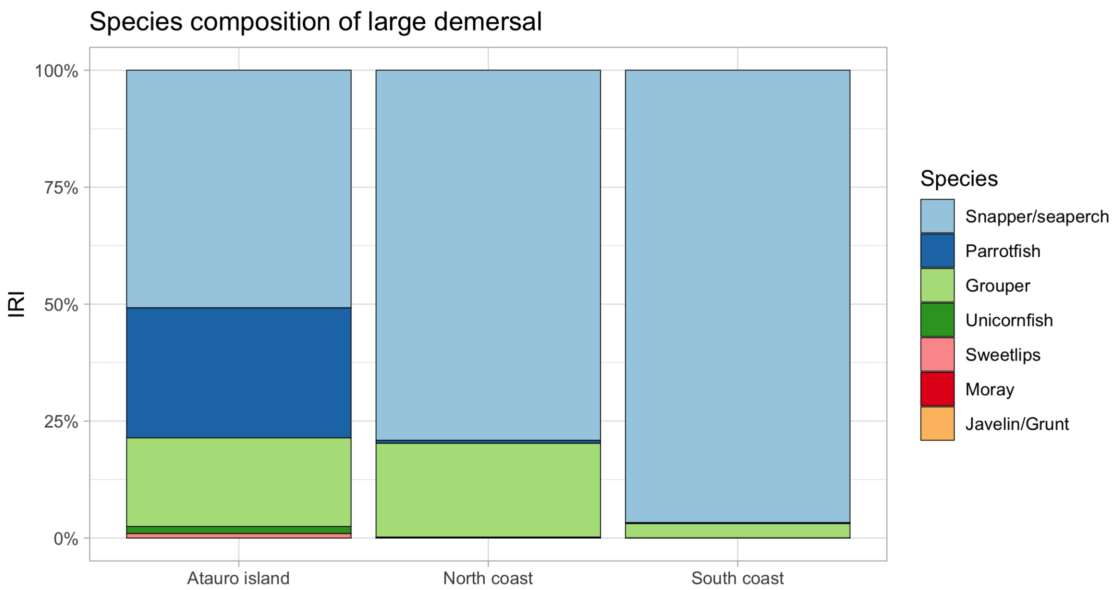

Figure A13: **Species composition of the catch of large demersal species.** Species composition of the catch of large demersal species on Atauro island, north coast and south coast. The y-axis shows the Index of Relative Importance (IRI), which is calculated using the weight, number, and frequency of occurrence of a species.

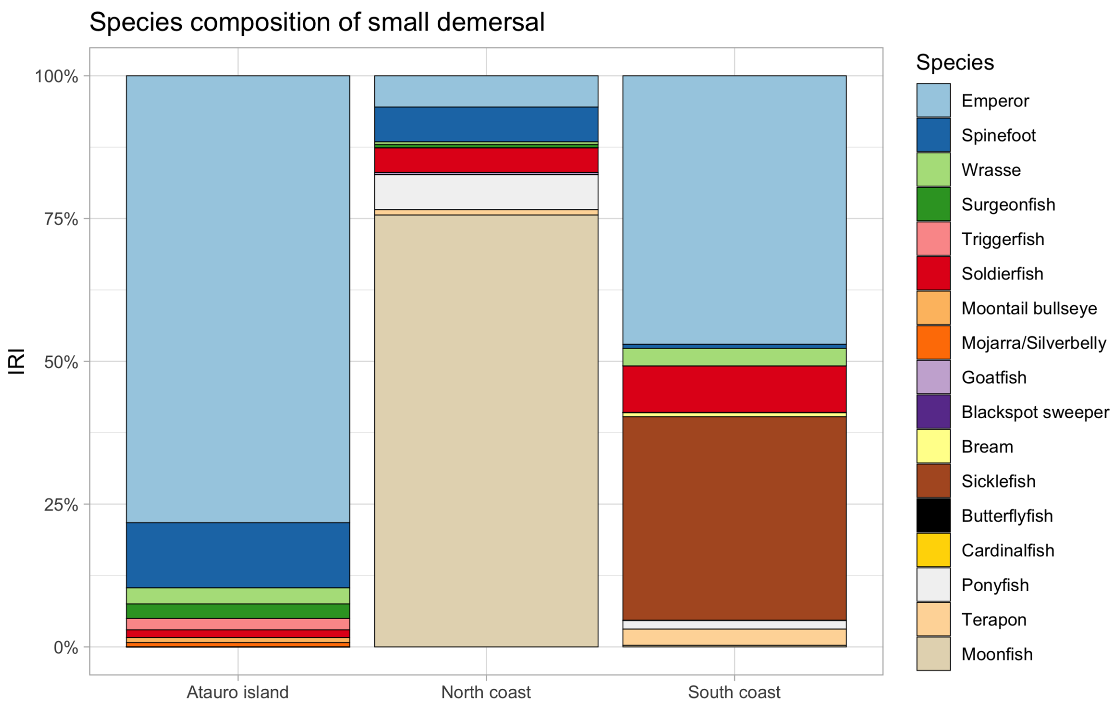

Figure A14: **Species composition of the catch of small demersal species.** Species composition of the catch of small demersal species on Atauro island, north coast and south coast. The y-axis shows the Index of Relative Importance (IRI), which is calculated using the weight, number, and frequency of occurrence of a species.

Appendix G

Set-up and template for the focus discussion groups

Set-up FDG Timor-Leste

Sarah Jørgensen Veillat

Type of interviews:
Focus Discussion Groups

Locations:
3 places:
North coast – Manatuto
South coast – Covalima
Atauro Island

People:
2 fishers and 2 traders

Duration:
+/- an hour

INSTRUCTIONS FOR ENUMERATORS

Background info
We're researching how the COVID-19 pandemic has affected fisheries in Timor-Leste. This part of the project seeks to understand the experiences of the fishermen and traders, including how COVID-19 impacted their fishing and marketing practices using focus group discussions (FGD) and a timeline activity. It will be focussed on the experiences of the last year during the pandemic. The findings will be used to better understand existing (quantitative) data on the fisheries gathered in catch surveys and from the tracking devices installed on some of the fishing boats.

Before the FDG

1. Go through the instructions beforehand to make sure you understand everything.

2. Fill in the major events/restriction section yourselves first (step 2 of the timeline activity), with your knowledge on what has happened the last year.

3. Do this in the output template given by me. This needs to be a separate document from the document that will be filled in with the information given by the participants.

4. The reason for this is so you can cross-reference the participants' answers with yours.

5. Prepare the activity for the participants (check the template for how it should look):

6. Gather several big sheets of paper (4x A3) and tape them together

7. Draw the timeline on it (as shown in the template), excluding the already given events.

8. Below the timeline, write down the different sections (as shown in the template).

Structure FDG

Open the FDG by giving the participants the background information and the reason they are here.

Script
Welcome! First of all, thank you all for your participation. This discussion group will last around an hour and we will be discussing your experiences of the last year during the COVID-19 pandemic. We will be doing one timeline activity, which we will explain in more detail once we begin, followed by some general discussion questions. The reason we are doing this is because we are doing a research into how the pandemic has affected the fisheries in Timor-Leste. The information we will gain from this discussion group will be used to better understand data we already have gathered from catch surveys and tracking devices installed on some of the fishing boats.

Start with main activity (timeline):

The main activity will be filling out a timeline of the last year (since 28 March 2020) with the experiences concerning their business and other aspects of their lives.

Structure of activity
We will go through the activity sequentially with the participants. Start by explaining one section, then do that section. Then explain the next section, then do that section... etc.

Step by step:

1. **Get out the drawn timeline and explain the general idea of the timeline activity**

Script:
As we talked about before, we want to understand how COVID-19 affected you and your fishery since March 2021. We'd like you to fill out this timeline with the major events you remember, and how these impacted your fishing practices and market access throughout the year (or how they impacted you and fishers you know). We'll talk through this together and fill out this timeline together. We will talk about what happened since March 2020, and we'd like you to describe the key events and what impact they had on fisheries, markets and your livelihoods.

2. **Start with the major events section**
   Go through the timeline periodically. Start with the first State of Emergency in March 2020.

   Intro script
   We are going to start by listing and discussing the events and restrictions related to COVID-19 that have taken place over the last year. We will start in March 2020 and work our way towards the present day. Some events have already been added to the timeline, and those we will discuss in more depth, but mostly we are going to recall the events and restrictions ourselves. These can be nation-wide restrictions and events, or just applicable for your community locally. We will illustrate how this works by starting with the first State of Emergency, put in place by the government in March 2020.

   Now start asking the participant these questions:

   (a) Can you recall the event/restriction?

   (b) Can you describe the event/restrictions?

   (c) Did the restrictions apply to your community?

      - *For example: government brought in social distancing rules, but they were not enforced here*

   After every discussed event, ask the question:
   What is the next major event/restriction related to COVID-19 you can recall?

   - If the next event is recalled by them, ask them question **b and c**
   - If the next event is an event given by me or by you, ask them question **a, b and c**

   Continue to do this until you have reached the end of the timeline. is okay to jump back and forth on the timeline if the participants start remembering events/restrictions later on.

3. **Next, start with the fishing activities section**

Intro script:
We're now going to talk about how these different events and restrictions we discussed impacted your and your communities' fishing activities. We'll start at the beginning of the timeline again.

Questions to ask the participants:

(a) Did the restrictions and events that took place in March have an effect on...

- ...the number of times you went fishing in a week compared to normal? Why?
- ... the amount of time you went out fishing on each trip compared to normal? Why?
- ... the way you fished? (going out at different times of the day than usual, fishing in different spots than usual, being with more or less people on the boat than usual). Why?

(b) How long did these changes last?

Continue asking these questions for the rest of the timeline, by replacing March with the next month, or a period of several months if that is more in line with the events that take place.

4. Next, the market access section

Intro script:
We're now going to talk about how these different events and restrictions we discussed impacted your communities' market access and activities. We'll start at the beginning of the timeline again.

Questions to ask the participants:

(a) Did the restrictions and events that took place in March have an impact on...

- ...the number of costumers at the markets compared to normal? Why? (specify which markets)
- ...the number of traders at the markets compared to normal? Why? (specify which markets)
- ...the amount of fish sold compared to normal? Why?
- ...the supply of fish compared to normal? (e.g. more fish than possible to sell) Why?

- …the demand for fish compared to normal (low or high demand)? Why?
- …the amount of fish you brought home for own consumption instead of selling compared to normal? Why?

(b) How long did these changes last?

Continue asking these questions for the rest of the timeline, by replacing March with the next month, or a period of several months if that is more in line with the events that take place.

5. **Next, the livelihood section**

> Intro script:
> *We're now going to talk about how these different events and restrictions we discussed impacted your and your communities' livelihoods. We'll start at the beginning of the timeline again.*

Questions to ask the participants:

(a) Did the restrictions and events that took place in March have an impact on…

- …how you brought food into the house compared to normal? Why?
- …how you brought money into the house compared to normal? Why?

(b) How long did these changes last?

Continue asking these questions for the rest of the timeline, by replacing March with the next month, or a period of several months if that is more in line with the events that take place.

6. **Next, the food security section**

> Intro script:
> *We're now going to talk about how these different events and restrictions we discussed impacted your and your communities' food security. We'll start at the beginning of the timeline again.*

Questions to ask the participants:

(a) Did the restrictions and events that took place in March have an impact on…

- ... the type, variety and quantity of food you ate at home compared to normal? Why?

(b) How long did these changes last?

Continue asking these questions for the rest of the timeline, by replacing March with the next month, or a period of several months if that is more in line with the events that take place.

7. **Lastly, notes that don't fit the above themes**

Intro script: *Lastly, we'd like you to add anything that we haven't discussed yet, but what you think is important for us to know.*

Question to ask the participants:

(a) Was there anything that happened or changed in March that we haven't discussed that you would like to add?

Continue asking these questions for the rest of the timeline, by replacing March with the next month, or a period of several months if that is more in line with the events that take place.

Start with activity 2: General discussion questions

Go through the last couple of questions listed below.
Write down the consensus of the answers, and anything else you think is important to note.

1. *Would you say you have invested more or less in your business than what you would usually do in a year? (e.g., the maintenance and/or upgrading of your boat and fishing gear). Why?*
2. *Have you or your community turned to any other techniques to find markets? If so, which ones?*
3. *Do you and your community agree with the measures taken by the government to prevent COVID-19? Why, why not?*
4. *How do you feel that you and your community coped with everything that happened last year?*
5. *Is there anything else you'd like to add?*

Outputs:

- The document with the events/restrictions filled in by the enumerators before the start of the FDG

- A translated version (English) of the filled-out table of the timeline activity by the participants in an excel document following the format given
  - Notes on observations made (e.g., there was a disagreement about...), also filled in the document following the format given
- A summary of the answers to the general discussion questions, translated to English, following the template.
  - Notes on observations made (e.g., there was a disagreement about...), also filled in the document following the format given
- Optional: photos of original (non-translated) filled-in timeline activity.
