CLIMATE CHANGE VULNERABILITY ASSESSMENTS IN SELECTED COASTAL COMMUNITIES IN MADAGASCAR

Draft final report

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APRIL 2022

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Acronyms and abbreviations

AEECL : Lemur Conservation Network
AHP : Analytical Hierarchy Process
AQUALMA : Aquaculture de la Mahajamba
BN-CCCREDD+ : Bureau National des Changements Climatiques, du Carbone et de la REDD+ (National Office for Climate Change)
BNGRC : National Office for Risk and Disaster Management
CCVA : Climate Change Vulnerability Assessment
CNGIM : National Commission for Integrated Mangrove Management
CNGIZC : National Committee for Integrated Coastal Zone Management
EWS : Early Warning System
FiTI : Fisheries Transparency Initiative
GEF : Global Environment Facility
GELOSE : Gestion Locale Sécurisée
GIZ : Deutsche Gesellschaft für Internationale Zusammenarbeit
GHG : Greenhouse Gases
HHs : Households
IAS : Integrated Agricultural Systems
IEC : Information, Education, Communication
IGA : Income Generating Activities
INSTAT : Institut National de la Statistique
IPCC : Intergovernmental Panel on Climate Change
KIIs : Key Informant Interviews
LMMAs : Locally Managed Marine Areas
MEDD : Ministère de l'Environnement et du Développement Durable
MIHARI : Mitantana Harena An-dRanomasina avy eny Ifotony (See LMMAs)
MNP : Madagascar National Parks
MPA : Marine Protected Areas
MPEB : Ministère de la Pêche et de l'Economie Bleue (Ministry of Fisheries and Blue Economy)
MSANP : Ministère de la Santé Publique (Ministry of Public Health)
MSC : Marine Stewardshi Council
NC-SWIOFC : Nairobi Convention Southwest Indian Ocean Fisheries Commission
NGO : Non-Governmental Organization
PCA : Principal Component Analysis
PNA : National Policy on Climate Change Adaptation
RCRMD: Regional Centre for Mapping of Resources for Development
SDG : Sustainable Development Goals
SES : Social-Ecological Systems
SIDA : Swedish International Development Cooperation Agency
SMS : Short Message Service
SST: Sea Surface Temperature
UNDP : United Nations Development Programme
UNEP: United Nations Environmental Programme
UNFCCC : United Nations Framework Convention on Climate Change
WCS : Wildlife Conservation Society
WFP : World Food Programme
WIO : Western Indian Ocean
WIOSAP : Western Indian Ocean from land-based sources and activities
WRI : World Resources Institute
WWF : World Wide Fund for Nature

Executive summary

Overview

This document discusses the concept of vulnerability as characterized in the climate change literature and how it is applied to coastal communities in Madagascar. It follows the steps suggested by the Climate Change Vulnerability Assessment (CCVA) framework for assessing sensitivity, adaptive capacity and vulnerability proposed by UNEP in 2021. The framework measures sensitivity of coastal communities through four domains: Livelihood and economic dependency, health, cultural and demographic. It is also based on an approache to build adaptive capacity across five domains: the assets that people can draw upon when required; the flexibility to adjust; the ability to organize and act as a community; the learning capability to recognize and respond to change; and the agency to determine whether to change or not. Data have been collected next to different communities living in the bay of Sahamalaza and the bay of Mahajamba. These bays have their own ecological characteristics (Coral reef, seagrass beds, mangroves in Sahamalaza and mangroves in Mahajamba) as well as management (Creation of Locally Managed Marine Areas are still in progress in Mahajamba whereas they are well established in Sahamalaza).

Key findings

Livelihood and economic dependency have been found as the main driving factors of sensitivity. Traditional culture could be barriers and strength at the same time. Climate change such as windspeed variability has negative impact on food security as wind is an important factor for fishers wether they are able to go out to see or not. Age and health concerns are causing many fishers to gradually leave fishing and focus on agricultural activities. Regards to adaptive capacity, results show the important roles played by governmental and non-governmental organizations. However, law enforcement should be led impartially avoiding being trapped in corruption and discrimination of fishers. Beside poor education and skills, open access to the resources pushes fishers to overexploit marine resources by using more and more non-selective gears. The use of mosquito nets has been observed across all communities. Fishers have also limited options of livelihoods due to the lack of skills, technologies and knowledge. They strongly rely on natural resources to adapt to climate change. However, natural resources too are under the threat of climate change, the reliance to nature are therefore very sensitive.

Agriculture could have been an alternative option to climate change for fishers, but this activity is also very sensitive to climate change. Plus, agricultural techniques are very archaic and non-sustainable (slash and burn agriculture), the lands are not irrigated, and land tenure rights in coastal communities constitute another issue. The most vulnerable category of people are mainly single mothers and older people. Migrants seem to be less vulnerable than non-migrants due probably to the fact that originally they are geographically mobile. Most of vulnerable households are not involved in management of marine resources meaning that either they are marginalized either they do not understand the importance of marine resource management yet. Finally, it has been found that the mean value of vulnerability indices across the two bays are significantly different. The difference could be explained by the amount of resources and the presence of a long time management of marine resources in Sahamalaza.

The analysis of the impact of the Covid-19 pandemic (an extra stressors apart from climate change) has shown that the most sensitive domain is livelihood and economic dependency. Covid-19 has also impacted the family budget and food security. During the pandemic, there has been an escalation of insecurity.

Principal recommendations

Under the SDG goals and the National Policy on Climate Change Adaptation in Madagascar, the following recommendations have been suggested to increase the index of each domain of adaptive capacity:

- **Trust in organizations:** (i) Support law enforcement by establishing fishing judicial police officer. (ii) Reinforce the surveillance especially during closure. (iii) Develop laws governing activities that may harm sea cucumbers and seagrass meadows. (iv) Validate and implement the "Dina" (Local community agreement) in the management of natural resources

- **Level of education/Access to credit:** (i) Support fishers and stakeholders on climate change adaptation. (ii) Conduct financial education sessions for local communities. (iii) Train fishers on conventional fishing techniques. Ensure the availability of fish products all year round: train fishers on how to preserve and store products (smoking, salting, etc.)

- **Livelihood multiplicity:** (i) Increase the area of cultivable land through irrigation and contour cropping. (ii) Support the policy of land tenure rights of fishers. This should be taken into account in a national policy. (iii) Financially and technically train fishers on animal husbandry (animal feed, hygiene, care, etc.)

- **Community infrastructure:** Improve community infrastructure (roads, hospitals, schools) and reduce the level of insecurity (armed robbery in rural areas targeting zebus).

- **Access to information**: (i) Develop innovative early warning systems on wind speed, cyclones and rainfall. (ii) Governments should work with mobile telephone companies to improve mobile coverage and access to such services. (iii) Conduct inventories of the resources.

- **Knowledge of rules** : Sensitise fishers mainly on the topics of fishing closures and laws (gears to be used, fishing ground and protected areas).

- **Linking social capital/Gear diversity:** (i) Enforce laws prohibiting the use of any gear mounted with a mosquito net. Reduce the use of destructive fishing gear. (ii) Check the mesh size of nets during certain periods of the year. (iii) Support fishers on how to make fishing nets, build and repair canoes. (iv) Support fisher's associations to obtain an eco-certified label for their products under the "Marine stewardship council". (v) Establish a fishing closure adapted to the life cycle of targeted species. (vi) Register canoes and pirogues in a database.

- **Recognition of causality**: (i) Conduct and map seagrass meadows ecosystems nationwide. (ii) Identify the causes of coral bleaching and conduct research to restore degraded corals

- **Level of participation** : (i) Provide communities with materials for the monitoring and control of resources (speedboat, nets meeting standards, vests, fins, mask, weather forecasting device). (ii) Support exchange visits between coastal communities.

- **Perceived capacity to change**: Develop a booklet of mangrove reforestation and restoration of other ecosystems.

- **Community cohesion**: (i) Set up a fishing cooperative. (ii) Distribute professional fishermen's cards. (iii) Migrant fishers must register within fisher's associations before being able to access the fishing areas.

Key words: adaptive capacity, sensitivity, coastal community, resource dependency, Madagascar, Climate change, Mangrove, Seagrass beds, coral reef.

1 Introduction

To address the impacts of climate change, scientists, governments, development agencies and civil society around the world are conducting global research to effectively produce strong and evidence based policies. Outcomes of research in climate change vulnerability assessments for example help develop adaptation and conservation policy and support the integration of socioeconomic and ecological factors into decision making. Particularly, adaptation to climate change is cited in Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) and requires the signatory countries to define and implement national and regional measures to facilitate adequate adaptation to climate change (Drouet, 2009). However, investments in improving people's capacity to adapt to change have tended to focus on a very narrow understanding of adaptive capacity (Cinner et al., 2018). Three linked fields have traditionally characterised the research on vulnerability: risk and hazard, political ecology and resilience. Firstly, risk and hazard involves the anticipation of how environmental hazards, usually climated-related, are presumably impact human societies. Secondly, political ecology explores the social causes of differential susceptibility. Finally, resilience research identifies the underlying processes that determine the ability to cope and adapt to change (Thiault et al., 2021).

Coastal zone impact assessment work has been driven to a large extent by the Intergovernmental Panel on Climate Change (IPCC) through Technical guidelines for Assessing Climate Change Impacts and Adaptation and the United Nations Environmental Programme (UNEP) Handbook on Methods for Climate Change Assessment and Adaptation Strategies (Dolan & Walker, 2006). IPCC AR4 (2007) and AR5 (2014) guidances are the current concepts used in climate change vulnerability assessments. Based on these, most recently, the Nairobi Convention within the UNEP has recently developed a Climate Change Vulnerability Assessments (CCVA) toolkit necessary to assess climate change socio-ecological vulnerability. This study is part of pilot testing for standardized application in the Western Indian Ocean (WIO) countries including Mozambique, the United Republic of Tanzania, Kenya and Madagascar. This research has been prepared to provide an overview of the methodology and how it is applied in coastal communities in Madagascar. Apart of being an island (the fifth biggest one in the world), the great particularity of Madagascar compared to the other countries is that Within the Western Indian Ocean region, the most extensive stands of mangroves are found in Madagascar.

This research is part of a project entitled "Implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities" (WIOSAP) implemented by the Secretariat for the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean region, within the Ecosystems Division of UNEP with funding from the Global Environment Facility (GEF) and the Partnership project between the Nairobi Convention and the South West Indian Ocean Fisheries Commission (NC-SWIOFC PP) for marine and coastal governance and fisheries management for sustainable blue growth with funding from the Swedish International Development Cooperation Agency (SIDA). The NC-SWIOFC partnership project seeks (i) to enhance the resilience of livelihoods based on WIO marine and coastal ecosystem and habitats, (ii) to promote sustainable management of coastal fisheries using the ecosystem approach to fisheries, and (iii) to enhance coordination between fisheries and environmental management institutions. Vulnerability to climate change of coastal communities in Madagascar will be first reviewed and assessed and recommendations for managers/policy makers for adaptation options and/or mitigation aligned with Sustainable Development Goals will be suggested.

2 Climate Change Vulnerability

2.1 What is climate change vulnerability?

According to the fourth assessment report (AR4) of IPCC (2007) vulnerability to climate change is "the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity". The definition of the IPCC specifically highlights three components of vulnerability in the climate change context: exposure, sensitivity and adaptive capacity. In the climate change context, exposure relates to "the nature and degree to which a system is exposed to significant climatic variations". Social exposure is defined from the main climate risk factors to which households are exposed: increased storm intensity, altered rainfall patterns and sea level rise. Sensitivity is defined "to the degree to which a system is influenced, positively or negatively, by climate variability or climate change" (Adger, 2003). In other words, sensitivity gathers the adverse effects and the magnitude that the risks from exposure have on local populations, their economic activities and natural resources. The words adaptive capacity depend on the relative level of economic resources, access to technologies, access to information on climate variability and change, the skills to use it, the means institutional and equitable distribution of resources (Smit et al., 2001).

2.2 Social-ecological vulnerability

A social-ecological system consists of a biogeophysical unit and its associated social stakeholders and institutions. Social-ecological systems are complex and adaptive, and delimited by spatial or functional borders surrounding particular ecosystems. Connections with the ocean, including cultural, livelihoods from fishing and aquaculture/mariculture, transport, tourism, and recreation have been developed by coastal communities. These connections, some of which are crucial for the subsistance and wellbeing of coastal communities, are under pressure from climate change (Maina, 2019). The CCVA framework aims at defining these threats or pressures that are faced by ecological and social system. It has the challenge to determine if these threats are different across marine ecosystems of local communities. Through a development of indicators, one of the purposes of this framework is to define the degree of sensitivity and the capacity for the system to adapt. Therefore, the overall social-ecological vulnerability is conceived as a result of the sensitivity of socio-economic systems to ecological vulnerability, and the capacity of the society to adapt to such impacts (Cinner et al., 2013).

2.3 General approaches to conducting CCVA and concepts

Approaches to vulnerability assessments are centered on two prominent vulnerability concepts in the context of climate change : outcome and contextual vulnerability. Outcome vulnerability (also known as the "end-point" interpretation) is a concept that considers vulnerability as the (potential) net impacts of climate change on a specific exposure unit after feasible adaptations are taken into account. Contextual vulnerability (also known as the "starting point" interpretation) is a concept that considers vulnerability as the present inability of a system to cope with changing climate conditions, whereby vulnerability is seen to be influenced by changing biophysical conditions as well as dynamic social, economic, political, institutional and technological structures and processes (Fellmann, 2012). The CCVA approach used in this study incorporates elements of top down and bottom up and therefore represents a hybrid approach (both contextual and outcome vulnerability). For example, the construction of the exposure dimension utilizes global scale data and indicators, while estimating the social adaptive capacity applies at village level demographic information (Maina, 2019).

Thiault et al. (2021) have suggested that practitionners who assess vulnerability of SES should apply 12 steps dividing across four phases: scoping, design, operationalization, and implementation .The 12-step framework) synthesizes the different approaches that have been used to evaluate vulnerability in SES (Social-Ecological Systems) and highlights current best practices. These 12 steps are : Objectives (*cf.* 2.4), System exploration (*cf.* 3. Components of vulnerability), Review (*cf.*3.4), Structure (*cf.* 4.1.1), Indicators (*cf.* 4.1.2), Data collection (*cf.* 4.2), Standardization (*cf.* 4.3.2), Integration (*cf.* 4.3.3), Uncertainty (*cf.* 4.4), Interpretation (*cf.* 6; 7), communication and learning (*cf.* 9). The interpretation follows both approaches of contextual and outcome vulnerability. The framework has strong similarities with the vulnerability approach designed by GIZ (Fritzsche et al., 2014) updated in 2017. It contains guidelines on using the Vulnerability Reference Guide approach by incorporating the IPCC AR5 concept of climate risk.

2.4 Objectives

The general purpose of this study is to use the CCVA framework on selected coastal communities in Madagascar. These communities are dependent on major coastal ecosystems i.e. mangroves, coral reefs and seagrass beds, and other marine resources. They can be traditional, artisanal, migrant or non-migrant fishers. The specific objectives of this study are:

- To propose effective adaptation strategies in response to climate stresses and risks which will be translated into concrete and operational actions in order to anticipate the possible impacts of climate change.
- To identify specific adaptation technology needs, and national plans and with a focus on the needs of coastal communities
- To develop knowledge of risks and possible responses to extreme climatic events.
- To identify potential networks for the sharing of information on successful adaptation, and contribute to management and policy option on climate change necessary for decision making.

3 Components of vulnerability

3.1 Indicators of climate exposure

Climate change exposure indicators are a set of geophysical parameters that represent aspects of climate change and provide information on the most relevant domains of climate change impacting on a system. Below are some commonly used indicators that describe climate exposure in Madagascar coastal areas.

- **Sea Surface Temperature**: The western Indian Ocean has warmed steadily since 1982 until present by 0.65°C (at 0.1°C/decade). The warmest years over the WIO were 1998, 2010 and 2016. From 2011 to 2016, SSTs have been increasing steadily resulting in longest bleaching thermal stress (Maina, 2019).
- **Rainfall** : Overall, rainfall in the East African region including Madagascar has decreased over the decades by around -1.5 mm/ per decade between 1960-2017, which implies that the climate is drier. For Madagascar, the length of rainy season and seasonal distribution of rainfall has changed compared to data before 2010. If the rainy season started in November and ended in May, local observation reported by WWF (2013) highlighted that the range has reduced from January to March.
- **Sea level rise** : While the IPCC estimates an overall sea level rise of between 0.28m to 0.98m based on mitigation efforts from around the world by 2100, GIZ's analysis (2021) found a projection of 11cm, 22 cm and 43 cm in the coastal areas of Madagascar around 2030, 2050 and 2080 respectively. Intense cyclones bring heavy rains and cause coastal erosion (Asconit-Pareto, 2011)

- **Exposure to wind**: The wind is an important climatic parameter in fishing as it influences the fishing effort (eg: when to fish, the distance travelled, fishing time, etc.). According to WWF (2013), the period of the wind (called “Varatraza” in the North) has increased sharply based on local perception. This type of wind is however known for its high intensity which considerably influences the fishing periods offshore and at the reefs.

3.2 Ecological component of vulnerability

3.2.1 Coral reef

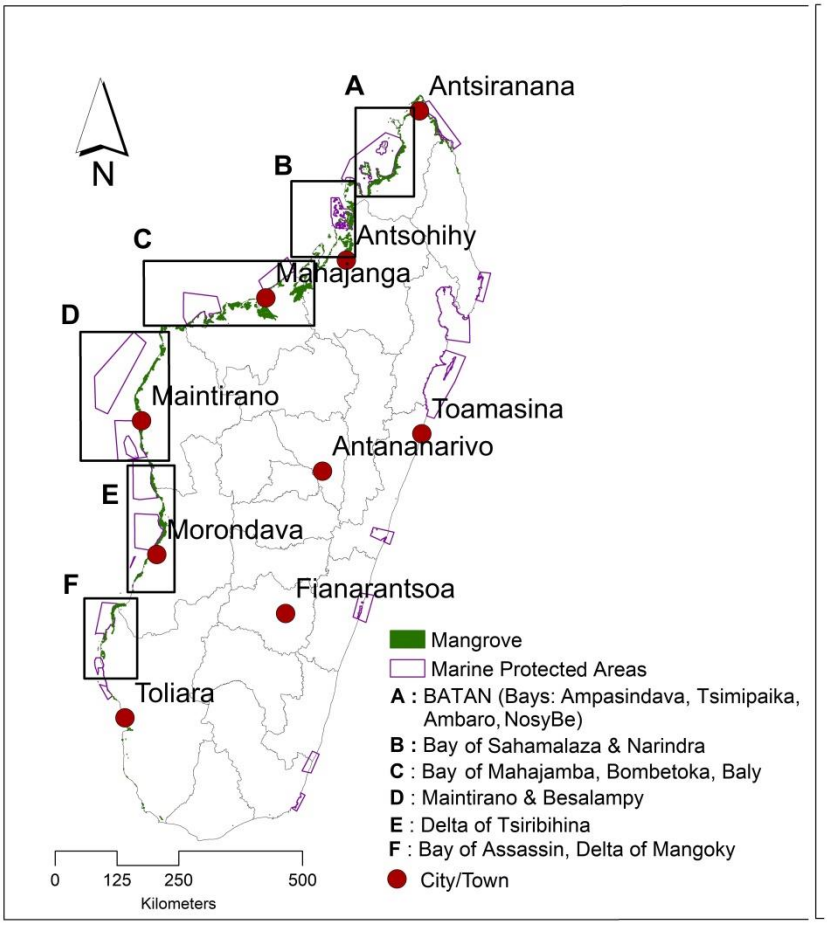
Coral reef ecosystems in Madagascar cover an area of 2,000 km2 (Gabrié, Vasseur, Randriamiarana, Maharavo, & Mara, 2000) and extend along more than 3,450 km of coastline (Cooke, Lutjeharms, & Vasseur, 2003), including the entire west coast and parts of the north and central east coast. However, one major threat toward these ecosystems is their loss to bleaching as a result of warmer sea surface temperatures across the region. According to the World Bank (2011), in 2005, 80% of the corals in the north-eastern part of Madagascar experienced bleaching due to the rise in ocean temperature. Coral reefs play a vital role for human livelihoods by supporting reef fisheries and tourism and provide protection for coastal communities. The corals in the Far South of Madagascar are less sensitive among many others thanks to this phenomenon of "upwelling". This phenomenon corresponds in particular to the rise to the surface of colder water from the deep parts of the ocean (Mahatante, 2016).

3.2.2 Mangrove

Within the Western Indian Ocean region, the most extensive stands of mangroves are found in Madagascar, which in total supports approximately 327,000 ha of mangroves. Mangroves are widespread along the entire west coast of the country facing the Mozambique Channel, with the largest stands located in the northern and central parts of the west coast where the climate is more humid. Mangroves provide many important services to local communities by protecting the coast and enabling the renewal of fish stocks. It is a spawning area for many fishery resources including shrimp and crab. The mangrove forest is also one of the main sources of timber wood and firewood. Mangroves are amongst the most vulnerable ecosystems to the threats of future climate change with estimates of loss of mangroves due to climate change by 2100 in the order of 10 – 15% (Alongi, 2008) . Sea level rise is expected to be the most significant threat to mangrove ecosystems resulting from climate change. They are also under threat of siltation.

3.2.3 Seagrass meadows

Seagrasses are aquatic flowering plants found mainly in shallow nearshore salt water. They thrive in sheltered areas where currents are slow and there is little wave action, mostly in tropical regions and usually between mangroves and coral reefs (Short et al., 2011). Seagrass meadows provide critical ecological services. Seagrass leaves attenuate wave energy, reducing coastal erosion, while their dense network of roots stabilises the sea - bed, reducing sedimentation and water turbidity (Hemminga & Duarte, 2000). They also have an important role in stabilizing reef sediments against reef bleaching phenomena. Seagrasses act as a nursery and as feeding grounds and refuge areas for many commercially valuable fish species, including snappers and parrotfish (Heck & Thoman, 1984). They are also breeding grounds for sea cucumbers. Fewer seagrass meadows in Madagascar have been mapped.



Map 1: Marine ecological sites in Madagascar

3.3 Social component of vulnerability

3.3.1 Coastal fisheries

Coastal communities are people living on the thin strip of land or on the water along the fluctuating line where the sea meets the land. Coastal communities have multiple sources of income but there are often serious threats to food security. With over 5,500 km of coastline, Madagascar has a diversity of marine and coastal ecosystems that is unequalled in the Indian Ocean. These habitats provide valuable services to coastal communities; they are critically important source of food security and revenue for the country's population, over half of which lives within a buffer zone of 100 km of the coast (WRI, 2003). About one million of Malagasy people live from fishing. Eighty three percent (83%) live in coastal areas and practice small-scale fishing. The largest component of total domestic fisheries catches is taken by small-scale artisanal and subsistence fishers, which account for 75% of total catches that include traditional fishing, artisanal fishing and industrial fishing. Malagasy coastal populations are among the most vulnerable. In most of the cases, they do not have arable land and are entirely depend on marine resources to insure their food security (MIHARI, 2017).

3.3.2 Migrant fishers

The Malagasy fishing sector is affected by temporary and seasonal human migration. Migrant fishers move to distant fishing grounds for periods ranging from weeks to months. They operate within the socio-economic and ecological setting and are influenced by external factors and processes that result in changes at both the individual and community level. Population growth and migration caused by free access to these resources result in even more pressure on marine ecosystems (Kasprzyk *et al.*, 2018). For example, the Menabe region (Western of Madagascar) hosts the Vezo (a nomadic ethnic

group) from the South who move from their area to a new region by following schools of fish (Ranaivoson et al., 2018). Migrant fishers from the southwest of Madagascar target shark and sea cucumbers due to declining resource availability in their areas of origin and continued availability of lucrative resources for export to China (Cripps & Gardner, 2016). In the North of the country, the vast majority of migrant fishers come from agricultural regions. The comparison of calendars of agricultural and fishing activities, shows an alternation of the rhythms of weak and strong activities according to the seasons. This alternation depends on climate parameters: wind for fishing and rainfall for agriculture. Most particularly, between December and February, the need for agricultural labor is important as it is the rainy season and the rhythm of fishing is slower than usual. During this period, shrimp fishing is prohibited (legal closure) and the humidity makes it difficult to stock fish. Late February, migrants leave their agricultural land to come to fish in the bays. In June, strong wind prevents fishers to go out to sea. Fishmongers are becoming rarer and fishing no longer provides migrants with sufficient income. They then return to their home village where the harvest has begun. From mid-September, the winds are once again favorable for fishing (Goedefroit & Tazarasoa, 2002).

3.3.3 Governance

Two main ministries share the responsibilities for marine environment and related activities. The Ministry of Environment and Sustainable Development (MEDD) is in charge of the protection of habitats and species, as well as the establishment of marine protected areas, while the Ministry of Fisheries and Blue Economy (MPEB) is in control of the development, management and marketing aspects of fisheries. The national policies of these two ministries promote sustainability, the preservation of natural resources and the involvement of all stakeholders in the decision-making processes relating to their use. On one hand, the Fisheries Monitoring Center at the MPEB monitors fishing effort in the traditional, artisanal and industrial fisheries. On the other hand, the National Commission for Integrated Management of Mangroves (CNGIM) of the MEDD is responsible for coordinating the integrated management of mangrove areas. The National Committee for Integrated Management of Coastal Zones (CNGIZC) coordinates the integrated management of coastal and marine zones. In connection with climate change, the BNCCC-REDD+ is responsible for the GHG inventory and for transmitting the national monitoring report to the UNFCCC. Its most recent project is to improve the national reference emissions level for forests with the integration of forestry inventory data from mangrove forest (MEDD & BNCCC-REDD+, 2017).

Madagascar has also developed specific policies for delegating management rights for natural resources to local user associations. This kind of community - based natural resource management is meant to foster local people's responsibility and raise their awareness of the value of conservation (Fritz-Vietta, Röttger, & Stoll-Kleemann, 2009). In 1996, the first law on the co-management of natural resources was developed, the Gestion Locale Sécurisée (GELOSE). It is applicable to all natural resources and aims at better environmental stewardship through the establishment of local management entities, formal institutions, and empowerment. For coastal and marine resources, Locally Managed Marine Areas (LMMAs) have been put in place since 2004. These LMMAs are interconnected in the MIHARI network, which brings together more than 200 associations of small-scale fishers and around 20 partner NGOs. Associations are based on internal and specific regulations (Dina). The Dina constitutes contracts binding the members to the association. It is a collective agreement between members of a community. Its content provides for criminal or civil measures. The presence of customary authorities within the association reinforces both the Dina and the obligations of the members.

3.4 Research on climate change vulnerability in Malagasy coastal communities

Madagascar is ranked 29th among countries that are most vulnerable to climate change in the world (Eckstein, Hutfils, & Winges, 2017). The island is exposed to cyclones, droughts and floods. Marine and terrestrial protected areas constitute only 2% of the territory . One of the first climate change vulnerability analysis carried out in marine ecosystems was led by WWF in 2010 (Clausen, Rakotondrazafy, Ralison, & Andriamanalina, 2010). The study was conducted at a commune[1] and village level. The main driving factors of vulnerability were the distance from essential services and infrastructure, the presence of a primary school, the presence of running water, the duration of the lean period (food security) and the percentage of population in agriculture, fishing or husbandry activities. Results have shown that 2/3 of the communes are very vulnerable to climate change. Asconit-Pareto (2011) have found that the index of vulnerability is high in coastal areas. As their studies covers several areas and not just the fishing sector, the authors have not used specific indicators and the scoring method for exposure, sensitivity and adaptive capacity follows three ranges of values: low, medium and high. Both studies support that, despite the threats posed by climate change, the rate of deforestation and anthropogenic pressures on mangroves currently outweigh the risks from climate variability.

4 Methods for conducting CCVA

4.1 Study design

4.1.1 Model structure

The main objective is to describe the links between exposure, sensitivity and adaptive capacity. Vulnerability assessments incorporate three nested layers that vary in the specificity of their definition: dimensions (generic), domains (moving from generic to specific), and indicators (context-specific). Domains break down each dimension into the features that moderate, or contribute to vulnerability. Domains can include multiple elements that are deemed locally relevant. Various model structures linking exposure, sensitivity, and adaptive capacity have been proposed in the literature to reflect the way the system was conceptualized initially.

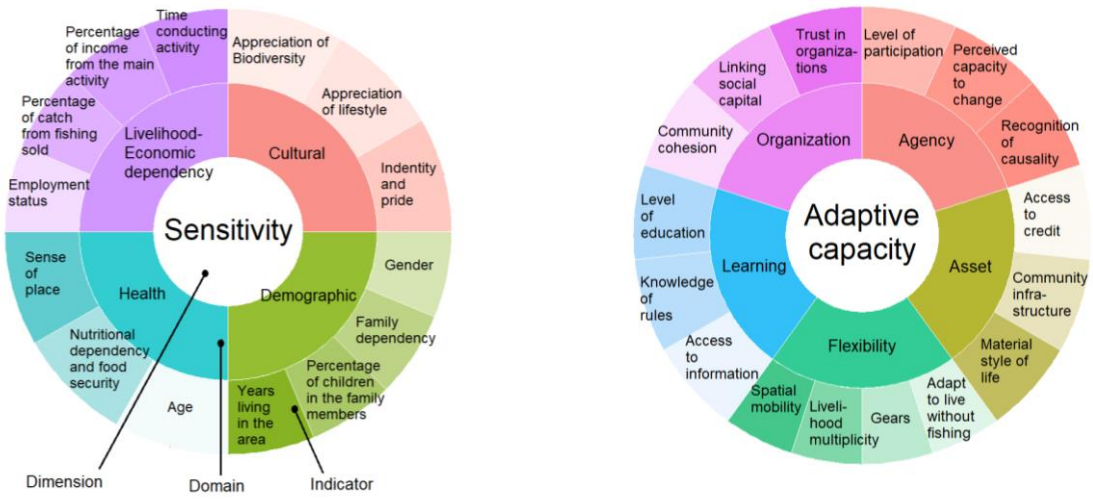


Figure 1: Conceptual diagram illustrating the three proposed nested layers for theoretically and contextually grounded vulnerability assessments: dimensions (inner circle), domains (middle circle), and indicators (outer circle). Examples of domains and indicators are modified from (Thiault et al., 2021)

[1] For administrative purposes, Madagascar is divided into a system of decentralized territorial collectivities: regions, districts and communes. The regions, the largest units, are further divided into districts, which are subdivided into communes.

4.1.2 Indicators

Indicators are characteristics or processes that can be measured or estimated to track the state or trend of a particular domain. The best indicators are those that follow the SMART model : specific, measurable, attainable, relevant, and time-bound.

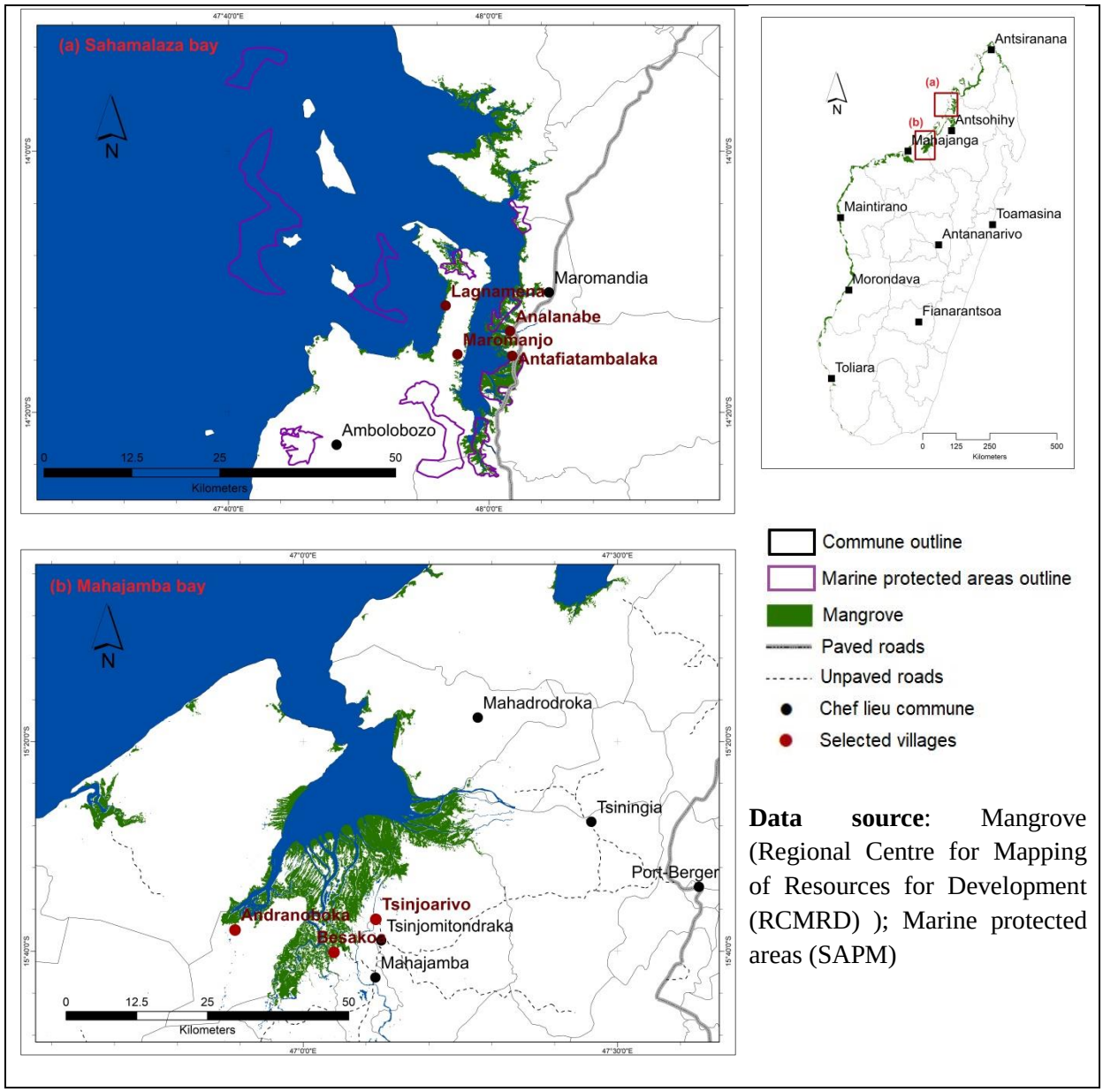
Table 1: Dimension, domain and indicators of the analysis

Dimension	Domain	Most frequently used indicators (Maina, 2019; Thiault et al., 2021)
Sensitivity	Livelihood	• Employment – measures how people earn money or gather food. A special emphasis is on assessing people directly using marine resources, especially fishers. • Proportion of income from activity, time conducting the activity and percentage of fish sold.
	Demographic	• Age, gender • Percentage of children in the household, years during which the family has lived in the village and family dependency (percentage of active member in the family).
	Cultural	• Cultural / heritage impacts – measures what areas or reef resources are of special interest to communities for cultural or religious purposes. The indicator can be converted as “Identity and pride” explained by the feeling of ownership of the land and resources • Appreciation of lifestyle: feeling of willing to live in the village doing the same activities . This also includes the traditional uses and activities
	Health	• Age of the household leader • Nutritional dependency and food security, sense of place (sense of being home)
Adaptation capacity	Learning	• Education level, religion, literacy • Level of understanding and cooperation of MPA regulations – managers need this information to develop education programs to increase support for MPA management: Knowledge of rules/laws, access to information on climate change, early warning system
	Assets	• Community infrastructure : hospitals, schools and coastal protection infrastructures • Material style of life (accessories owned by the households). This can be translated as the index of wealth. • Access to credit
	Flexibility	• Livelihood multiplicity, usage of different gears,Spatial mobility and the ability to adapt to live without fishing.
	Agency	• Local perception of reef management and management success: perceived capacity to change, recognition of causality (management affecting availability and quality of marine resources) and level of participation (Involvement in natural resource management)
	Organization	• Social networks and interactions – this are important in determining who are the key decision makers and how decisions are made in the community. This domain contains the following indicators: trust in organization, community cohesion and linking Social capital (social relationships in which the knowledge processes take place (Kianto & Waajakoski, 2010))

4.2 Data collection

4.2.1 Sampled study sites

Located between latitudes 14°S and 15°S and longitudes 46°E and 48°W, the Mahajamba and Sahamalaza bays are home to three different ecosystems : mangroves (in both sites), seagrass beds and coral reefs (only in Sahamalaza bay). Mahajamba bay is located about 100 km Northeast of Majunga (its nearest biggest town and large port city). Administratively, it straddles the Boeny and Sofia regions. With an area of approximately 27,000 ha of mangrove, Mahajamba Bay has mangroves that are still relatively preserved compared to other mangrove forests in Madagascar. An industrial shrimp farm managed by AQUALMA is located in the bay. It has an area of 700 hectares of ponds. Sahamalaza bay is part of Sahamalaza National Park which is located in the North West of Madagascar, 75 km North of the city of Analalava and 100 km south of Nosy Be/Hellville by sea. It is part of the World Network of Biosphere Reserves. This protected area is among the remaining hotspot for the endangered dugong which they rely on seagrasses for food.



Map 2: Sample study site location

Both sites are traditionally home to the Sakalava ethnic group. A population of approximately 46,000 lives in Sahamalaza (Commune of Ambolobozo, Maromandia) and 35,000 in Mahajamba (Commune of Andranoboka, Mahajamba Usine, Tsinjomitondraka) (INSTAT, 2018). In recent years immigration to the area has become more pronounced and has resulted in overexploitation of fisheries. The literacy rate of the local population is low and access to markets, health and education services are very limited. The population relies on fishing, agriculture, notably rice production, and animal husbandry (Zebu, Goats). Mangrove resources are used for house and fencing construction, fuel wood and traditional medicines.

This study covers traditional and artisanal fishing communities. Traditional fishing is legally defined as a small-scale practice. It is carried out mainly on foot or with the help of non-motorized boats. Artisanal fishing is characterized by the use of motorized boats with engine power less than or equal to 50 hp. The main targeted fish are: demersal and pelagic fish, crabs and shrimps and sea cucumber.

- **Pelagic and demersal fish**

These are mainly pelagic fish (tuna, anchovies, sardines) but also benthic and demersal fish.

- **Crab and shrimp**

They are the main source of income for small Malagasy fishers. The mangrove crab *Scylla serrata* (drakaka/mud crab) is a common species present all along the East African coast. The species lives on muddy substrates and is particularly fond of mangrove ecosystems and muddy grass beds. Dried species such as chevaquines (*Caridina serratirostris*), varilava (*Stolephorus heterolobus*), and small shrimps are part of the product list.

- **Sea cucumber**

Sea cucumbers collected typically ranged between 6 cm and 20 cm wet length. Larger individuals are rare and smaller individuals are not purchased by village buyers. A local Chinese farm in Lagnamena buys the juveniles, which is however prohibited. The products are not dried (no gutting, boiling and drying) but are sold directly to collectors.

Fishers travel about 4 to 6 hours (sometimes more) to reach their fishing area (mangroves and estuaries). These fishers bring food and stay in these fishing grounds for one or two weeks. They have a small house that can accommodate three to four people (the crew). From this place to the fishing ground, fishers have to walk or canoe for at least half hour. A one day work can last between 5 to 8 hours.

4.2.2 Key informant interviews

As part of the government policy, national administrations in Madagascar encourage local communities to be involved in management of natural resources. In 2012, MIHARI network was created on the initiative of community associations involved in the local management of marine and coastal resources in Madagascar, in close collaboration with the organizations that support them. Prior to data collection, interviews have been conducted next to government bodies and NGOs that work with coastal communities in the sample study sites: Blue Ventures in Mahajamba bay and Madagascar National Parks in Sahamalaza bay. KIIs have allowed to better understand the context of small scale fishing and to identify villages that are good samples for surveys.

4.2.3 Focus group

Focus group is a group interview technique that collects information on targeted subjects. By comparing individual opinions, this technique makes it possible to build collective representations. The sample for a focus group has individuals with characteristics of the overall population and can contribute to helping the research gain a greater understanding of the topic. The group must be rather homogeneous or in any case representative of the population studied (Association of fishers, Migrant, Elders of the village…). The aim of this approach is to allow the protagonists to give their opinion without judgment while using the interaction of the group to advance the debate of ideas. It also leads to a stratified random sampling for household surveys. It is a method of sampling that involves the division of a population into smaller sub-groups known as strata. In stratified random sampling, or stratification, the strata are formed based on members' shared attributes or characteristics such as income, educational attainment or migrants. Within each stratum, households will be selected randomly based on the availability of households in the villages.

4.2.4 Households surveys

Maritime fishing villages are small and generally scattered all along the Malagasy coast, isolated for the most part and far from important market places. In total, 218 individuals (households) were interviewed during the study. Household surveys mainly consist of collecting information relating to household characteristics and socio-economic variables deemed to be decisive for the study using questionnaires. A household is defined as a set of individuals who share the same roof. One household consists of a head of household (male or female), his wife or wives (for male heads of household) and their children. In total 14.68% of the respondents were women.

Table 2: Number of survey responses per village

Bay	Village	Est. pop	Est. HHs	HHs	%	Rationale for chosing the village
Mahajamba bay	Andranoboka	500	100	51	50%	Biggest fishing village in the West of the bay, Chef lieu Commune, 3km from mangroves
	Besakoa - Antafiazamotry	95	21	20	95%	Migrant fishing village on the edge of the main village of Besakoa. Presence of an industrial shrimp farm (AQUALMA)
	Tsinjoarivo	542	108	67	62%	Biggest fishing village in the East of the bay
Sahamalaza bay	Analanabe	80	15	7	47%	Small fishing village located along mangrove channels, near the national road and the biggest marketplace.
	Antafiatambalaka	120	24	18	75%	Biggest fishing village located along mangrove channels.
	Lagnamena	180	40	37	93%	Seagrass beds (inshore) and coral reef (2km). Presence of a chinese sea cucumber farm.
	Maromanjo	102	20	18	90%	Located on the West side of the bay.
Total				218	74%	

4.3 Data analysis

4.3.1 Scoring procedures

In total, 14 sensitivity and 16 adaptive capacity indicators were used. Qualitative and quantitative indicators are scored based on the type of variables (categorical, ordinal and interval). The following methods describe how the indicators were scored.

- **Continuous values**: The indicator can have any numerical value along a gradient of possible values. (Example: the percentage of fish sold, Age)
- **Intervals**: Ranges of indicator value are established and all members within the same interval have the same score. (Example: assigning class 8 or less, Secondary school - level certificate, A-level certificate, Tertiary, and University and above different category values based on level of education).
- **Ordered categorical values**: This approach starts with non-numeric categories and assigning them in sequence of importance according to a stated criterion. (Example: assigning responses to how to increase sustainability different category values based on whether the responses follow the rules/laws or not)
- **Rank ordering**: The raw, continuous value of the indicator is used to arrange the entities from highest to lowest and give each a rank number. (Example: the level of participation in a community)
- **Binary values**: The indicator scoring has just two values, 1 or 0. This type of scoring reflects simple presence or absence.

4.3.2 Standardization

Data standardization is a data processing workflow that converts the structure of different datasets into one common format of data. In other words, standardized scores refer to raw data being converted to standard or normalized scores in order to maintain uniformity in interpretation of statistical data. Standarization rescale values by adjusting them to a notionally common scale between zero and one. Indicators that are already scaled in this manner and can be used as is (Thiault et al., 2021).

- **PCA mix (Principal component analysis of mixed data)**

It performs principal component analysis of a set of individuals (observations) described by a mixture of qualitative and quantitative variables. PCA considers a set of variables (x_1, x_2, ..., x_p) upon a group of objects or individuals and based on them a new set of variables y_1, y_{21}, ..., y_p is calculated, but these new variables are uncorrelated with each other and their variances should decrease gradually (Rencher, 2005). PCAmix process is done with the purpose of reducing the number of variables that describe the problem, therefore the components that explain 80% of the variance of the data is selected.

One of the outputs available in the PCAmix method are the squared loadings (sqload). Squared loadings for a qualitative variable are correlation ratios between the variable and the principal components. For a quantitative variable, squared loadings are the squared correlation between the variable and the principal components. Some others outputs are:

- Coordinates of groups are the sum of the absolute contributions of variables belonging to the groups.
- Partial individuals coordinates are factor coordinates of individuals according to a specific group. This will be used as the final score for each household.

In this study, data on the material style of life describing all the household items or facilities present in the household have been analysed following the PCAmix technique.

- **Min-Max normalization**

For every feature, the minimum value of that feature gets transformed into a 0, the maximum value gets transformed into a 1, and every other value gets transformed into a decimal between 0 and 1.

$$Normalized\ value\ = \frac{Actual\ value - Minimum\ value}{Maximum\ value - Minimum\ value}$$

4.3.3 Integration

Some indicators and domains have a greater relative importance than others. Weights of each indicator have been assigned by a pool of experts including academics, decision makers, and stakeholders using analytical hierarchy process (AHP). The AHP method is a method adapted to multi-criteria decision problems, i.e. comprising several solutions satisfying a set of criteria. This method was developed by Saaty (1980) to help decision makers find the option that best suits their goal and understanding of the 'problem', while taking into consideration factors that cannot be quantified. The AHP method assigns a value representing the preference degree for a given alternative to each additional alternative (Chai, Liu, & Ngai, 2013). AHP is a form of multi-criteria analysis that undertakes pairwise comparisons using expert judgements to derive priority scales. The method helps to consider tangible and intangible elements together, allowing these to be traded off against each other in a decision making process. The method is applied by making comparisons using a scale of absolute judgements that represents how much one element dominates another for a given attribute. The derived priority scales are then synthesised and the various weighted scores are aggregated.

The participant is asked to express a graded comparative judgment about the pair in terms of the relative importance of two criteria C_j over C_k with respect to the goal. For example, in the dimension of sensitivity, domain of cultural, there are three (3) criteria: appreciation of biodiversity, appreciation of lifestyle and Identity and pride. The participant is asked to perform a pairwise comparison of the criteria. The comparative judgement is captured on a semantic scale (equally important, moderately more important, strongly important, very strongly important) and is converted into a numerical integer value a_{jk} (values from 1 to 9). The relative importance of C_k over C_j is defined as its reciprocal, i.e., $a_{kj} = 1/a_{jk}$. A reciprocal pairwise comparison matrix A is then formed using a_{jk}, for all j and k. ($a_{jj} = 1$). The weights of criteria can be estimated by finding the principal eigenvector w of the matrix A:

$$AW = \lambda_{max} w$$

When the vector w is normalized, it becomes the vector of priorities of the criteria with respect to the goal; λ_{max} is the largest eigenvalue of the matrix A and the corresponding eigenvector w contains only positive entries. The methodology also incorporates established procedures for checking the consistency of the judgments provided by the participant. Using similar procedures, the weights of alternatives with respect to each criterion are computed. Then, the overall weights of alternatives are computed using the weighted summation (Ramanathan, 2004).

$$\begin{pmatrix} Overall\ weight \\ for\ alternative\ i \end{pmatrix} = \sum_j \begin{pmatrix} Weight\ for\ alternative\ i \\ with\ respect\ to\ C_j * weight\ of\ C_j \\ with\ respect\ to\ the\ goal \end{pmatrix}$$

The AHP approach has high relevance for the analysis of climate adaptation related decisions, given it is useful where a range of stakeholders are dealing with issues that have a high degree of complexity, that involve uncertainty and risk, and include subjectivity, i.e. human perceptions and judgments. In the context of climate adaptation, the method can be used by comparing a set of adaptation options against a set of defined criteria using participants' experience and judgment about the issues of concern. AHP also provides a consensus indicator to quantify the consensus of the group. The consensus value (from 0 to 100%) estimates of the agreement on the outcoming priorities between participants. It is a measure of homogeneity of priorities between the participants. In general, consensus values were assigned as "Moderate" (from 65% to 75%).

Table 3: Determination of vulnerability index

Indictor (i)							Domain (d)				Dimension			
(i) 1.1.1	Scoring	1.1.1 scored	Standardization	1.1.1 standardized	Weighting[1]	1.1.1 weighted	Sum	(d) 1.1	Weghting [2]	1.1 weighted	Sum	1. Sensitivity index	Subtraction	Social climate change vulnerability index
(i) 1.1.2		1.1.2 scored		1.1.2 standardized		1.1.2 weighted								
(i) 1.1.3		1.1.3 scored		1.1.3 standardized		1.1.3 weighted								
(i) 1.2.1		1.2.1 scored		1.2.1 standardized		1.2.1 weighted		(d) 1.2		1.2 weighted				
(i) 1.2.2		1.2.2 scored		1.2.2 standardized		1.2.2 weighted								
(i) 1.2.3		1.2.3 scored		1.2.3 standardized		1.2.3 weighted								
(i) 2.1.1		2.1.1 scored		2.1.1 standardized		2.1.1 weighted		(d) 2.1		2.1 weighted		2. Adaptive capacity index		
(i) 2.1.2		2.1.2 scored		2.1.2 standardized		2.1.2 weighted								
(i) 2.1.3		2.1.3 scored		2.1.3 standardized		2.1.3 weighted								
(i) 2.2.1		2.2.1 scored		2.2.1 standardized		2.2.1 weighted		(d) 2.2		2.2 weighted				
(i) 2.2.2		2.2.2 scored		2.2.2 standardized		2.2.2 weighted								
(i) 2.2.3		2.2.3 scored		2.2.3 standardized		2.2.3 weighted								

- The table should be read from left to right.
- Cells with the same colour scheme belong to the same domain and dimension.
- Weighting[1] : First weighting using AHP result at indicator level.
- Weighting[2] : Second weighting using AHP result at domain level.

4.4 Study limitations and constraints

The data was collected from coastal communities in Northern Madagascar. These coastal communities live near ecosystems of mangroves, coral reefs and seagrass meadows. Individuals coming from a wide range of ethnic groups, different religions, different origins (migrants and locals) have responded to the questionnaires. However, the vast majority of traditional fishers live on the west coast of the country of which the South and the Middle-West up to Mahajanga are inhabited by the Vezo. The Vezo, this emblematic fishing people, live between Toliara and Mahajanga (Le Manach et al., 2012). Given the latitudinal distribution of mangrove ecosystems (from 12°S to 24°S), a better representative sampling would be to investigate coastal communities in the South and West of the country, although this is time consomming. This study is a test of CCVA and surveys of these other coastal communities can be conducted in the future.

Data have been collected directly from the fishers during individual surveys and focus group. No catch measurements were made and responses were subjective. Even with the help of local guides to introduce the interviewer to the household, information shared by fishers are based on their knowledge and experiences often limited by their intellectual abilities. Moreover, despite the insurance that the the survey will be anonymous and confidential, responders were sometimes afraid to share the whole truth on their finance, diversity and number of gears, trusts towards government representative. The main reason of this fear is that there is substantial gap between government and villagers.

Regards to data analysis, the main idea behind normalization/standardization is always the same. Variables that are measured at different scales do not contribute equally to the model fitting. Thus, to deal with this potential problem, Min-max normalization is one of the most common ways to normalize data.The downside of this technique is that it does not handle outliers very well. For example, the majority of respondents were aged between 20 and 50. However, the maximum age was 69.

5 Principal driving factors of vulnerability from AHP and literature review

In order, the following indicators for each domain have the most overwhelming importance based on experts review (AHP):

- Sensitivity
  - Nutritional dependency and food security (Health)
  - Percentage of income from the main activity (Livelihood and economic dependency)
  - Family dependency (Demographic)
  - Appreciation of biodiversity, appreciation of lifestyle and Identity and pride (Cultural)
- Adaptive capacity
  - Level of education (Learning)
  - Community infrastructure (Assets)
  - Access to information (Learning)
  - Livelihood multiplicity (Flexibility)
  - Community cohesion, linking social capital and trust in organizations (Organizations)

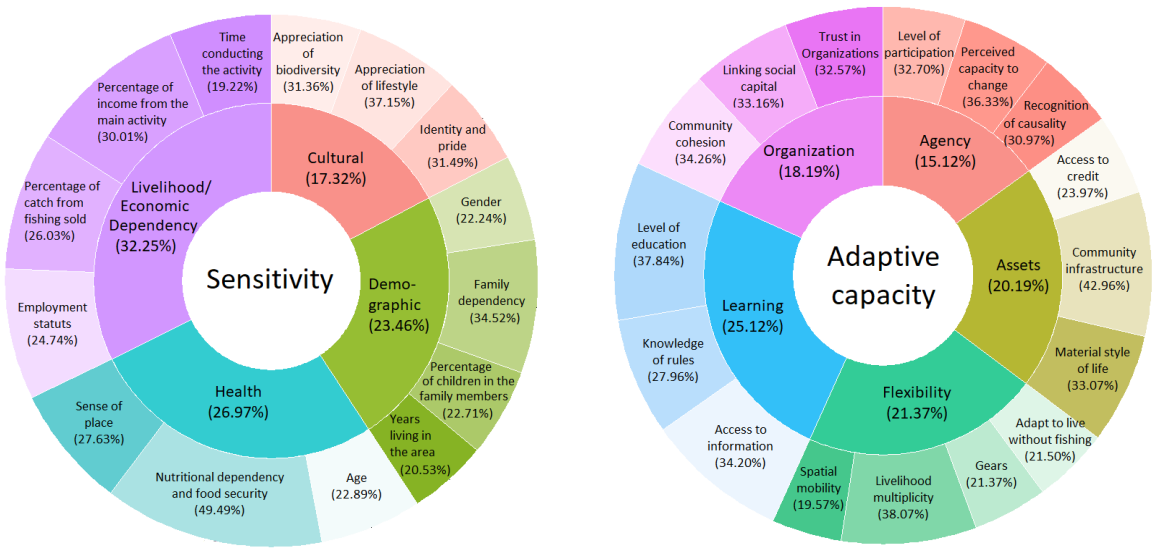


Figure 2: Weights of each domain and indicator from experts review

a) Principal indicators of sensitivity in statistical references

- **Nutritional dependency and food security:** in general, Malagasy poor rural households devote some 66% of their expenditures to food with the lion's share of this food bill spent on rice (32%). Nationwide, 53 % of rural households have unacceptable food consumption, i.e., they consume limited or insufficient nutritious foods. Of these, 12 % have poor food consumption, mainly surviving on tubers (cassava and sweet potato) with proteins essentially absent from their diet (WFP et al., 2010).
- **Percentage of income from the main activity:** the largest component of total domestic fisheries catches in Madagascar is taken by small-scale artisanal and subsistence fishers (72% of total catches), which illustrates the massive importance of the small-scale fishery sector for domestic markets and food security, artisanal and traditional fisheries are still marginalized and poorly monitored (Fritz-Vietta et al., 2009). Generally, 90% of seafood that is caught is self-consumed. One family eats fish and seafood products more than once a week. This proportion also shows that the market is not well-developed. The major problems of small-scale fishery are related to product outlets and the supply of fishing gear and other equipment.
- **Family dependency:** A Malagasy household is made up, on average, of 4.6 people and this mean size varies slightly from 4.7 in rural areas. Nearly one household in four (21%) is headed by a woman (INSTAT, 2005).
- **Appreciation of biodiversity, appreciation of lifestyle and Identity and pride (Cultural):** In some Malagasy communities, important marine species such as dolphin hunting is important culturally as well as for subsistence, which poses a particular challenge. In contrast, for some cultures, such as the Sakalava people, it is a "fady" or taboo to kill dolphins (MEFT et al., 2010).

b) Principal indicators of adaptive capacity in statistical references

- **Level of education:** Low education levels is believed to be among possible causes of low adaptive capacity (Clausen et al., 2010). At the national level, one in five men and about a quarter of women (24%) have no education. School life expectancy in rural areas is 7.2 years (INSTAT, 2018).

- **Community infrastructure:** Traditional fishing villages are small and generally scattered along the Malagasy coast. Road networks are inadequate which makes technical supervision, equipment supply and the collection of fish difficult especially during rainy season. Madagascar's electrification rate is one of the lowest in Africa: only 15% of inhabitants are connected to an electricity grid. Only a proportion of 28.3% in rural areas, which nevertheless concentrates 70% of the country's population, has grid electricity. Nationwide, the percentage of households that have access to clean water is 27.7% wehereas in rural areas, it is 18.6%. More than 40.1% of household do not have latrines (INSTAT, 2018). Finally, the availability of health care facilities in rural areas is very limited. Shortage of physicians is noticed and minimum basic services are offered (MSANP, 2016)
- **Material style of life:** Construction materials of houses in rural areas are poor. 77,8% of HHs have poor flooring, 80.4% have poor wall and 66.5% live under precarious roof (INSTAT, 2018).
- **Access to information:** Access to information is an ineluctable mean to identify, assess and monitor the various disaster risks and strengthen early warning systems (UNDP et al., 2012). For Malagasy people, the main means to get access to information are radio broadcasts (INSTAT, 2005).
- **Livelihood multiplicity:** Malagasy households use different coping strategies to deal with reduced agricultural production, food insecurity and income loss by diversifying their source of income (Harvey et al., 2014).

6 Climate change vulnerability across domains and indicators

There was a general perception among fishers that climatic conditions have changed over the last 20 years. Commonly observed climatic trends included warmer conditions (reported by 42% of fishers) and drought (32%), late rainy season (15%). Normally, the rainy season extends from November to May, but recently it extends from December to March. The winds become stronger and prevent fishers to go out to sea. Three main cyclones have caused considerable losses and damages in this part of Madagascar: Gafilo (2004), Bondo (2006), Indlala (2007). Villagers living in Tsinjoarivo have stated that after the cyclone Indlala, the Mahajamba River was blocked due to siltation in the river mouth and important sedimentary deposits. When tidal current is flowing inland (flood tide), salt water rises and penetrates the soil of agricultural land.

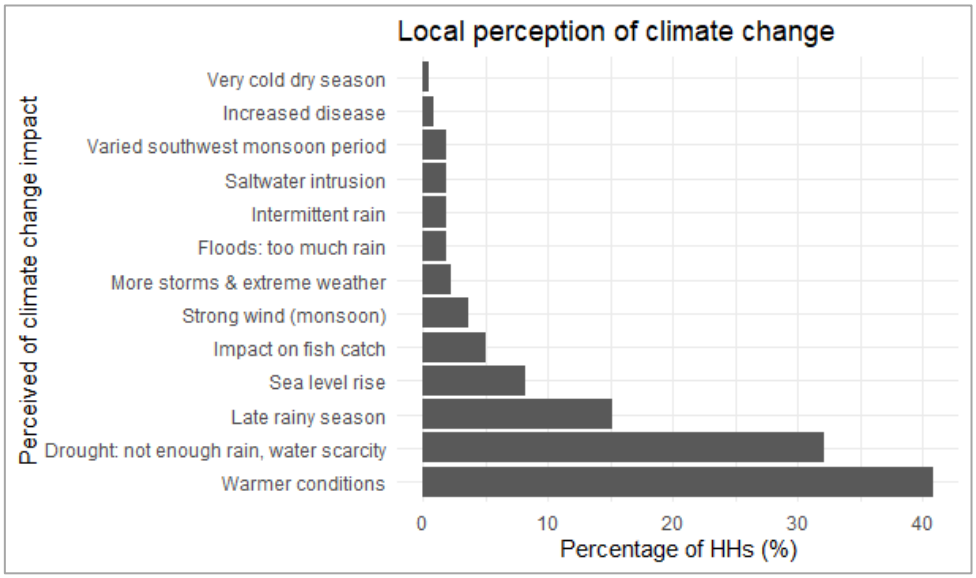


Figure 3 :Local perception of climate change

6.1 Sensitivity

The following chart shows the proportion of weighted values of indicators and domains of sensitivity. The pie donut chart indicates that livelihood/economic dependency is the most sensitive domain.

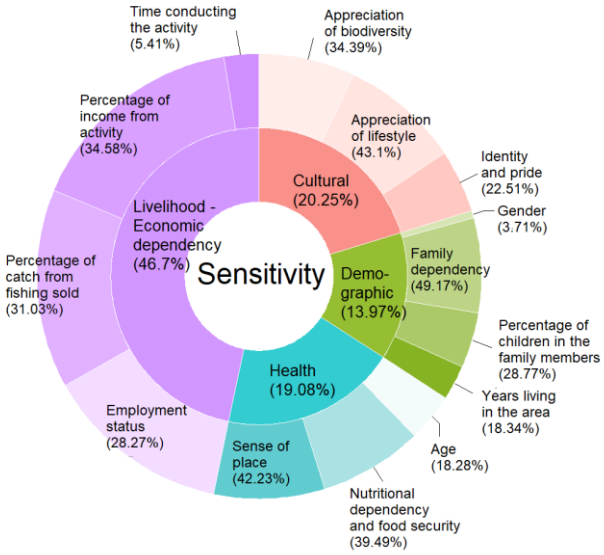


Figure 4 : Proportion of weighted values of indicators and domains of sensitivity

6.1.1 Livelihood and economic dependency as main driving factors of sensitivity

Livelihoods account for almost half of the areas sensitive to climate change. Being sensible means that the majority of the income comes from fishing and a major part of the catches are sold. The difficulties experienced by households during fishing closures illustrate this problem of total dependence on fishing. Fishers also have extrem reliance on nature. This mentality means that cultivation for subsistence and the collection of natural resources provide the basis for rural livelihoods. According to some fishers "harvesting agricultural products at best occurs three months after sowing while for fishing, the catch can be carried out in due time".

6.1.2 Traditional culture: barriers and strength at the same time

The three cultural indicators including the appreciation of biodiversity, the appreciation of lifestyle and Identity and pride are also sensitive but most importantly they are not mutually inclusive. To illustrate, the royalty is important to the Sakalava as Kings represent the ancestors through the tromba[2] cults. In Sahamalaza, the prince of Maromandia was very supportive when the Wildlife Conservation Society (WCS) and Association Européenne pour l'Etude et la Conservation des Lémuriens (AEECL) started the initiative to establish the protected area. However, when he realized that the envisioned protection zone would include part of the mangroves that he personally used for exploitation, he started to oppose the activities. The local population has followed his opposition to the project (Fritz-Vietta et al., 2009). The mandate of the king is unlimited, but it depends on his health condition. He can also be deposed as a result of his behaviour towards the population. The king also has to follow the rules.

[2] Madagascar's cultural particularity basically lies on the fact that the country is a place where the Bantu people from Eastern Africa and South-East-Asia once met. The Tromba cults, linked to the masters of the soil, would have been recovered and established by the dynastic groups in the same way as the latter did for the rites dedicated to the relics (Kent, 1968).

According to the Malagasy thinking, nothing happens by chance. Social norms are built on a strong mesh of specific taboos and traditional patterns of behaviour (Fritz-Vietta et al., 2009). Fady is the Malagasy word for taboo. The Fady is based on anecdotes and stories, and their roots are hidden in traditional legends and myths. For example, some fishing grounds in Mahajamba and Sahamalaza are considered taboo and are prohibited from operating. It is also taboo to work at sea on Thursdays. This gives spaces and time for recovery of the marine resources.

There is a symbiotic relationship between ecosystems and cultural identity. Dolphins (*Feso*) are animals of particular importance in Northern Madagascar. According to a legendary story, they would have saved the Sakalava communities, gone to sea during the ethnic war which confronted them with the *Merina* (Ethnic group in the Hihghlands). It is forbidden to slaughter or even eat these marine mammals because they are considered ancestors or family members from the good they have done. Sea turtles (Fano or *Chelonia mydas*) and Tandraly are also among those marine animals of great value to the Sakalava, as they are considered protectors. The law prohibiting the fishing of these species of biodiversity is highly respected. Finally, ecological values of mangroves are well known by local communities (medicinal plants, crabs spawning sites and recreational areas).

6.1.3 Negative impacts on food security and livelihoods

A fluctuating income have influence on food security. At the slighest variation of windspeed for example, fishers are not able to go out to fish, there is less catch and the quantity of fish sold is increased at the expense of the quantity of fish consumed by the household. As a consequence, there will be less protein on the menu. As an alternative, proteins are obtained from a horse radish trees leaves (*Moringa oleifera*). Moringa proteins offer a promising solution to the demand for plant-based proteins. The horse radish tree is a fast-growing, drought-resistant tree of the family Moringaceae. It is widely cultivated for its young seed pods and leaves, used as vegetables and for traditional herbal medicine. The lean season in coastal areas begins in January and generally ends in April. However, it can arrive earlier depending on the nutrition security and the rainfall. Fishing is essential for the food security of coastal regions, with fish representing 20% of the animal protein in the Malagasy diet.

6.1.4 Age and health: limitations factor on fishing

In this survey, fisher mean age is 34.6 years which is not far from (McClanahan, Cinner, & Abunge, 2013) who has found that Eastern African fishers average age is 37.0 years. Fishers were generally young, with very few senior fishers putting to sea. The average fishing experience of respondents was 13 years. Age and health concerns are causing many fishers to gradually leave fishing and focus on agricultural activities. Crab fishing is no longer practiced beyond the age of 40.

Villages located next to mangroves are damp, muddy and infested with mosquitoes. Through government programs, the local population has access to the use of long lasting insecticidal mosquito nets. Young children (2 to 3 in a household) are highly vulnerable to malaria and are a primary target group for bed net distribution programs. Despite increased distribution by the government of treated mosquito nets, malaria remains a major problem. Poverty drives people to turn mosquito nets into fishing nets. Since the nets are being used for fishing rather than warding off mosquitos, critics suggest the practice leaves people vulnerable to disease.

6.1.5 Importance of gender and active members in the family

Fishing villages are made up of roughly the same proportion of men as of women (52.3% against 47.7%). However, fishing appears to be an activity that is dominated by men. About 88.8% of men in the households surveyed go fishing compared to 39.3% among women (see Figure 5). Women go to fish where it is feasible such as around the village, close to the mangroves. Women use easy-to-handle fishing equipment such as mosquito nets. They are much more involved in other activities that do not require physical strength such as gleaning or work as medium scale fish trade. For example, single mothers rather use non-selective gears that are easy to manoeuvre such as mosquito nets, coastal dams (*valankira*) and crab-catching gears. These women work inshore and use their gears alone or in teams with other women.

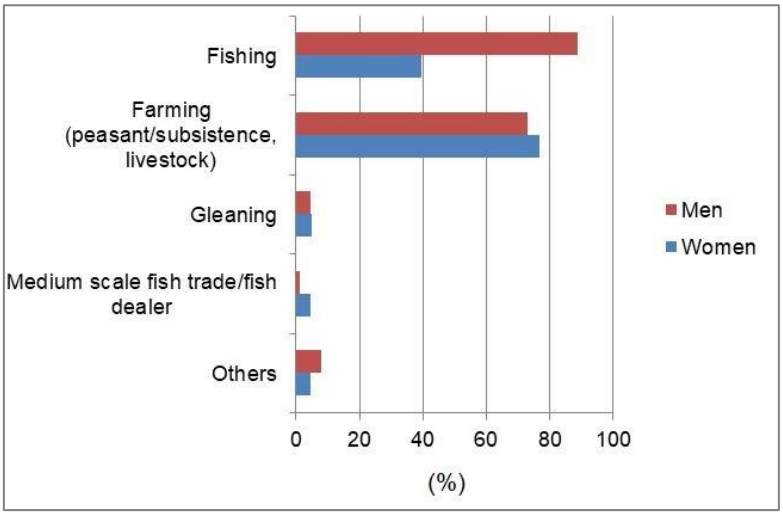


Figure 5 : Percentage of women and men in every activity

In terms of active members in the family, apart from the couple, 32.11% of households have a third working adult. In most cases, it is either an out-of-school child who does not yet have sufficient strength to take care of adult activities, or it is an active adult who is not yet married or married but is unable to afford a new home. Regardless of age, most household members participate in the various fishing activities. The father, who is generally the head of the household, coordinates the operations. The young people are in charge of activities that require energy (canoe, net). Women take care of the catches, fish cleaning and sorting. In fatherless households, the monthly income produced by the mother is very low. Women and children are most often responsible for water retrieval and cooking.

Photo 1: Children removing fish scale

6.2 Adaptive capacity

The chart below shows the proportion of weighted values of domains and indicators of adaptive capacity. Organization and learning are until now the most advanced domains but still more actions are required to get better results.

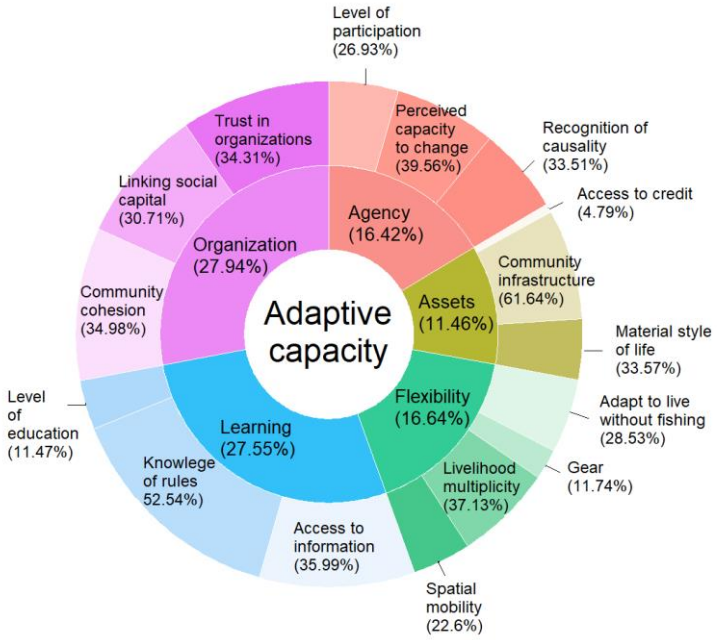


Figure 6 : Proportion of weighted values of indicators and domains of adaptive capacity

6.2.1 Strength and weaknesses of organizations

Figure 6 shows that organizations have been playing important roles in increasing adaptive capacity of fishers. The roles of state services are limited to technical supervision and monitoring-evaluation of the application of laws including natural resource management plans (mangroves, coral reefs, seagrass meadows). The Fisheries Monitoring Centre has a mission to protect and conserve fisheries and aquaculture resources. However, based on the surveys, fishers have little trust toward representatives of fisheries monitoring centre who, according to them, "are corrupt and unjust on how they apply laws". They mainly complain about the seizure of mosquito nets. These nets are seized and then sold to other households.

Malagasy laws[3] recognize the role of community governance in the management of fisheries resources and the aquatic ecosystem. Under forestry laws, mangroves are within the public domain of the state, meaning that extraction, transportation, stocking and sale of timber in mangrove ecosystems is banned, but local communities can be granted user rights for their domestic use of related resources, including timber. However, commercial timber extraction is forbidden. Local management rights can be established through either Protected Areas (with Madagascar National Park in Sahamalaza) or Natural Resource Management Transfer regulations (process in progess in Andranoboka with Blue Ventures). Transfering the management of natural resources is a complex, expensive and time consuming process (Jones et al., 2016). In Sahamalaza National Park, MNP work closely with the local mayor's office, communities in the park and other stakeholders. These laws have helped reduce human threats on the resources.

[3] Law No. 2015-053 on February 3, 2016 on the Fisheries and Aquaculture Code lays the foundations for the development and management of fisheries and aquaculture.

In order not to overexploit mangroves and marine resources, organizations are promoting alternatives and stable income generating activities (IGAs). These include sustainable agriculture, establishment and improvement of livestock, poultry farming, beekeeping and handicrafts. Madagascar National Park in Sahamalaza has in its program a variety of training courses on IGAs. The problem with IGAs is that the people who have benefited from these trainings do not sensitize other rural fishers/farmers and often do not apply them. On the one hand, the insufficiency of their production does not allow them to make the savings necessary for the investment (example for poultry farming, beekeeping). On the other hand, fishers are not totally convinced of the idea and do not have real initiatives.

6.2.2 Non-compliance with management rules

The use of non-selective gears such as Mesh gillnets below 40mm and mosquito nets are prohibited by law (Order No. 290/2018) but some fishers still use these gears. Some fishers also do not respect the fishing closure: Crab (October-December); Shrimp (December-February). Chaboud (2006) stated that fishers become poorer because of the free access to the resource. Villages are located in isolated areas, with few alternative employment opportunities. It is the poverty of the economic environment of fishing and the low cost of access to this activity which would explain the inexorable tendency to the degradation of fisheries.

6.2.3 Poor education and skills

Overfishing practices seem to be fairly common, including non-selective fishing gears and overexploitation. Reasons often mentioned include poor education and skills on the side of the fishing communities, and lack of local institutional arrangements regulating freshwater fisheries. Most of fishers (55.9%) have not attended beyond primary school. More than 90% of the individuals surveyed have a level of education that does not exceed secondary school.

In Sahamalaza, the best means of transportation are canoes or pirogues. Often, fishing villages have a public primary school, rarely a secondary one. The problem of education in these areas is mainly linked to their isolation. This leads to a deficiency of teachers and infrastructure and subsequently to overcrowded classes.

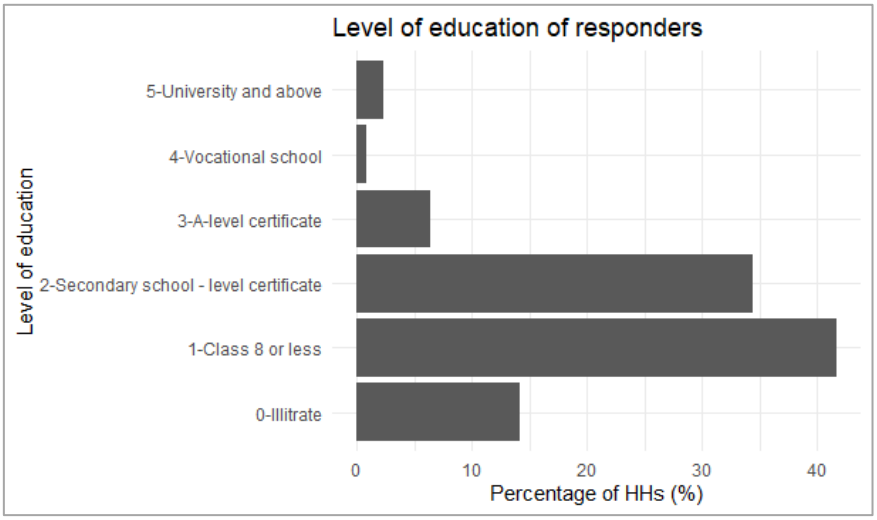


Figure 7: Level of education of responders

6.2.4 More use of non-selective gears

Different fishing gear types have different impacts on bycatch[4], habitat and the rate at which overfishing occurs.

- **Longline**

This is not an expensive gear. It is widely used. Longline fishing is a traditional method practiced by one or a maximum of two fishermen aboard a small boat of 4 to 5 m. The end is extended by twisted steel cable 1.5 to 3mm in diameter (snoods). It measures between 1.8 and 2.5m. The steel cable is connected to the line by a swivel. Hooks are special for shark and big fish fishing. They must have an opening of 5 to 10cm. For fishing in shallow waters targeting Sciaenidae, Pomadasydae, etc. the opening of the hooks varies from 1 to 2cm.

- **Hand line**

The line (which can be of various thicknesses) is weighted with a lead / metal blocks, and usually has a single hook, which receives bait. The hooks are of different sizes, and are chosen according to the conditions and the target species.

- **Coastal dam fishing (*Valakira, Vonosaha)***

They are made up of an assembly of partitions made of wooden laths, split bamboo or raffia ribs, held together by piles of mangrove wood.

(i) The ***valakira*** is a coastal dam in the shape of a "V" whose point is oriented towards the open sea. They are barriers set-up in the intertidal area which is covered during high tide. They have the form of a funnel in which the angle zone is accumulated for the catch. The main catches are juvenile shrimps with a dominance of the species *Fenerropenaeus indicus* and fish whose market values are low.

(ii) The ***vonosaha*** have the same principle as the valakira but block an entire channel with wooden lathing. This fishing gear consists of catching shrimps in the diverticula of estuaries using a dam made of raffia lath with a spacing of 1 to 2 mm depending on the rope used.

- **Mesh gillnet, above 5cm (2inches**)

(i) Gillnets of large mesh in braided wire called “GTZ” or “ZZ” [5]. The "ZZ" net with meshes between 8 and 10 cm is designed to target large pelagic fish species and sharks. Its fall length is about 8.6 m.

(ii) Large-mesh gillnets (**Jarifa**) used on all the coasts of West Africa (Lagoin, 1961) to retain sharks and large fish. The Jarifa is generally approximately 100-200m long with a drop length of around 5m, and a mesh size between 12 and 25cm. It is often used when targeting large pelagic fish and sharks (Akio).

- **Mesh gillnet, below 5cm (2inches)**

Small-mesh gillnets are used mainly for shrimp and small pelagic fishing. They are made of monofilament nylon.

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[4] Unwanted fish and other marine creatures trapped by fishing nets during fishing for a different species.

[5] Named after the German development group GTZ in 1992 to reduce the effects of fishing on nearshore reefs through the development of offshore fisheries Fishermen called them ZZ because they can't pronounce the name of the GTZ organization correctly (Gough et al., 2009)

(i) Periky: gillnets measuring between 100 and 300 m with a mesh size of 20 to 25 mm and a drop height varying between 3 and 4 m. Those with a mesh size of 20 mm are generally used to catch shrimp while those with a mesh size of 25 mm for fish.

(ii) Poto[6] : These gears follow the same principle as the valakira. These are passive gears, a kind of shelf trawls, which work at the ebb tide of spring tides and are dismantled during neap tide or after each day of use depending on their type. The mesh is 10 or 12 mm, more rarely 14 or 15 mm.

- **Purse seine net (*Kaokobe*)**

The gear is characterized by a mesh side length of 12 to 15 mm with a headline length ranging from 50 to 100 m. The drop height is between 6 and 10 m. At this depth, the gear ends up touching the bottom and catching demersal species. It is operated by three to four people (Domalain & Rasoanandrasana, 2000)

Photo 2: Kaokobe (Purse seine net)

- **Small/beach seine net (*Malira*)**

The mesh size is 12mm. Their length is around 200m.

- **Mosquito nets (*Sihitry*)**

Those are fishing gear with a very fine mesh being used for fish fry, fingerlings, and small shrimps. They require two persons generally women and children (or a couple). This gear is used in bays or estuaries in shallow waters from 0.5 to 1 metre. It has a length of 3 to 5 m, for a width of 2 to 2.5 m. The "Sihitry" net is used along the shore in shallow areas and is particularly intended for catching Chevaquine, a mixture of small brackish water shrimp (Family of Sergestidae) and juvenile shrimp (Family of Peneidae). The price of a mosquito net is 5000 ariary. One family has up to 20 pieces.

[6] From the French word « Poteau »

- **Crab fishing : Treko, Garigary, Fingovitra**

The gears have bait traps for crabs:

(i) Treko: It is a conical trap made of women palm/vines (100 × 40 cm, with 10 cm opening and 6 cm mesh). They are deployed and collected at low tide, secured by a stick.

(ii) Garigary: It is a baited, circular lift net (diameter ~60 cm, mesh size ~3 cm). They are deployed beneath a marker (empty bottle) and left for 10 min to 2 h. Fishers operate 1–20 traps spaced 5–20 m apart.

(iii) Fingovitra (Poto): Long wooden stick (~1–1.5 m) with carved hook end. Used at low tide to remove crabs from exposed burrows

The majority of fishers make their own *Treko*, however the *Garigary* requires funds. However, the use of the treko is prohibited because it captures crabs smaller than 11 cm.

- **Sea cucumber : Gleaning and freediving pickup**

Sea cucumber fishing was encountered in the Sahamalaza bay in the village of Lagnamena. It is basically a collection on foot at low water or freediving pickup using only a mask, snorkel and flippers. Near the shore, people glean sea cucumbers in a plastic bucket with torches as it is conducted mainly at night. For freediving pickup techniques, some fishers, especially migrants, are equipped with diving bottles for deep water exploration. The use of diving bottles is however prohibited.

Table 4: Inshore and offshore gears

	Selective gears	**Non-selective gears**
Inshore	• Garigary • Fingovitra (Poto) • Hand line • Longline	• Treko • Moquito nets : • Small/beach seine net: Malira • Coastal dams :Valakira, Vonosaha • Mesh gillnet, below 5cm (2inches): Periky, Poto
Offshore	• Mesh gillnet, above 5cm (2inches): ZZ, Jarifa • Longline • Hand line	• Mesh gillnet, below 5cm (2inches): Periky • Mosquito nets • Purse seine net : Kaokobe

Fishers have used larger mesh gillnets during times when there were plenty of marine resources, but as the catch was decreasing, they have started to use nets with smaller mesh size. Small-mesh gillnets are used mainly in the dry season. Using insecticide-soaked nets to fish may contaminate waterways. Due to the fact that the mesh on mosquito nets is so small, the nets risk capturing juvenile fish and eggs. Fishers are aware that mosquito nets hurt the ecosystem, are detrimental to the fishery resources and are not legal to use. Assuming that there will be less catch in the future, most of the households have answered that they would choose to change fishing gears (including the purchase of new gears) or fishing grounds, and then to fish more often. These new gears are usually mosquito nets as they are relatively cheap and easy to handle. Few households opted for a change of activities. It is expected that a more intensive traditional fishing will occur.

Table 5: Percentage of households using selective and non-selective gears

	Gears	Offshore	Inshore
Non-selective gears	Coastal dams	0.00	4.64
	Mesh gillnet, below 5cm (2inches)	**61.11**	23.18
	Mosquito nets	18.52	**61.59**
	Small/beach seine net	18.52	2.65
	Treko (Crabs)	0.00	8.61
Selective gears	Garigary (Crabs)	0.00	21.09
	Gleaning (torche, bucket)	1.92	7.03
	Hand line	26.92	39.06
	Hand spear	3.85	5.47
	Longline	11.54	5.47
	Mask, snorkel, fins	25.00	3.13
	Mesh gillnet, above 5cm (2inches)	9.62	13.28
	Multiple hooks (more than 20)	1.92	0.00
	Poto	0.00	7.03
	Others	9.62	2.34

6.2.5 Low access to credit

The development of a good micro-credit system is necessary to support activities such as agriculture and other IGAs. Access to credit is an important factor that contributes to securing the income of beneficiaries. In Mahajamba Bay, the closest microfinance institution is located in the major city of Mahajanga at 100km West of the bay. In the bay of Sahamalaza, some can be found in the chief town of Maromandia (4hours on a canoe from the village of Lagnamena) but barely few households (5%) have registered with them. The main blockage to microfinance is the fishers fear that their properties could be seized.

6.2.6 Low access to information

Fishers have no or limited access to strategic information sources. Only a proportion of 36.7% of households have a radio station, 64.2% have a mobile phone, 6.9% have a television set, and 1.4% has a computer. The news is broadcasted through the national and regional radios. In case of climatic hazard such as cyclones, families receive calls from relatives that live in the city. The chief of village takes the responsibility to alert villagers of possible bad weather conditions. Most of the time, information is exchanged during the market day (Thursday).

6.2.7 Limited options of livelihoods due to the lack of skills, technologies and knowledge

Livelihood diversification is a common trend in fishing communities either as a coping (short-term) strategy, or as an adapting strategy (long-term). It involves activities such as farming both farming and livestock herding. For instance, fishing communities (78%) in the two bays commonly switch between rice farming, fishing or seasonal migration as a response to the variability of catch and fishing closure. However, diversification is seen to be one of the coping strategies to deal with vulnerability for self-consumption purposes only as fishing remains the only activity that generates income. For them, stopping fishing and making living on land is not a livelihood option.

In Malagasy rural areas including coastal communities, most households generally do not possess more than a small cottage, a small piece of agricultural land for cultivation, and a small amount of livestock. Livestock are not commercially exploited but serve as security in times of scarcity.

Moreover, Agriculture is rendered difficult by a chronic lack of water, the absence of a well - established and well - functioning irrigation infrastructure. More specifically, in Sahamalaza, dearth of irrigated flatlands does not help households to practice a more developed agriculture. Slash-and-burn agriculture, called tavy, is the prevailing method employed.

6.2.8 Strong reliance on natural resources for material style of life

Fisher's houses are generally small. Their frame is made of mangrove wood and their walls and roof are made of ***satrana*** (Borassus) leaves. Sometimes the roof widens on the long sides forming a veranda supported by a mangrove poles. Traditional houses of the regions do not have a chimney. Most of roof, wall and floor materials are made of biomaterials.

Table 6: House building materials

Roof material	HHs (%)
Metal	11.9
Other: Falafa (Ravinala Madagascariensis), Satrana (Hyphaene coriacea)	88.1
Wall material	
Bricks	0.5
Cement	4.6
Dirt	41.3
Mangrove wood	2.3
Metal	1.4
Other: Falafa, Satrana, Baobao (*Raphia farinifera)*	50.0
Floor material	
Lino	0.9
Concrete	19.7
Dirt/Soil	14.7
Mangrove wood	1.8
Tiles	0.5
Other: Borassus, Baobao, Bamboo	62.4
Electricity	
None	43.1
Solar	56.9

Photo 3: Frame of a fisherman's house

7 Climate change vulnerability across different groups of households

The mean of vulnerability index is -0.112 ± 0.138. A Shapiro-Wilk normality test shows that the data is normally distributed (p-value = 0.2042; p-value is not equal or less to 0.05; W = 0.991). Therefore, 95% of observations fall within -0.112 ± 0.276 (+/- 2 times the standard deviation around the mean) . Overall 72% of households are vulnerable to climate change (Vulnerability index values < 0).

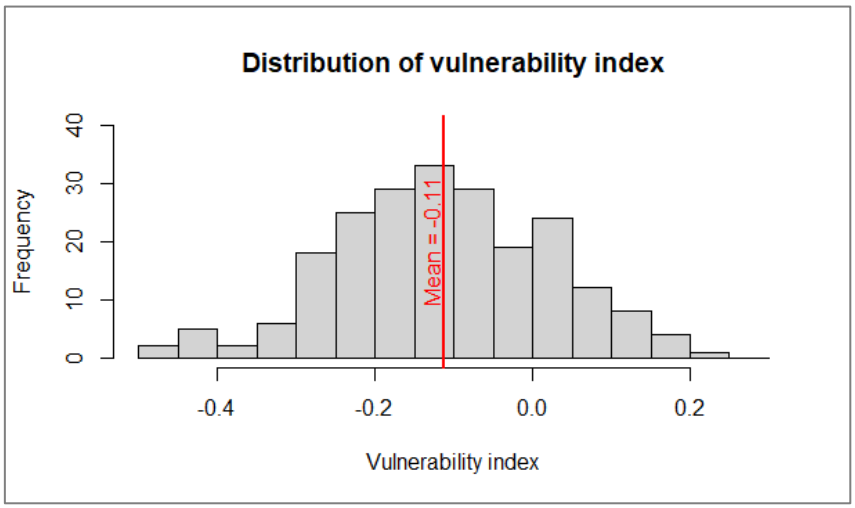

Figure 8: Normal distribution of vulnerability index

Four (4) categories of households can be distinguished based on sensitivity and adaptive capacity scores:

- Low sensitivity and low adaptive capacity (13.36% ~ N = 29) : First quadrat
- High sensitivity and low adaptive capacity (63.3% ~ N = 135) : Second quadrat
- High sensitivity and high adaptive capacity (14.68% ~ N = 32) : Third quadrat
- Low sensitivity and high adaptive capacity (9.6% ~ N = 21) : Fourth quadrat

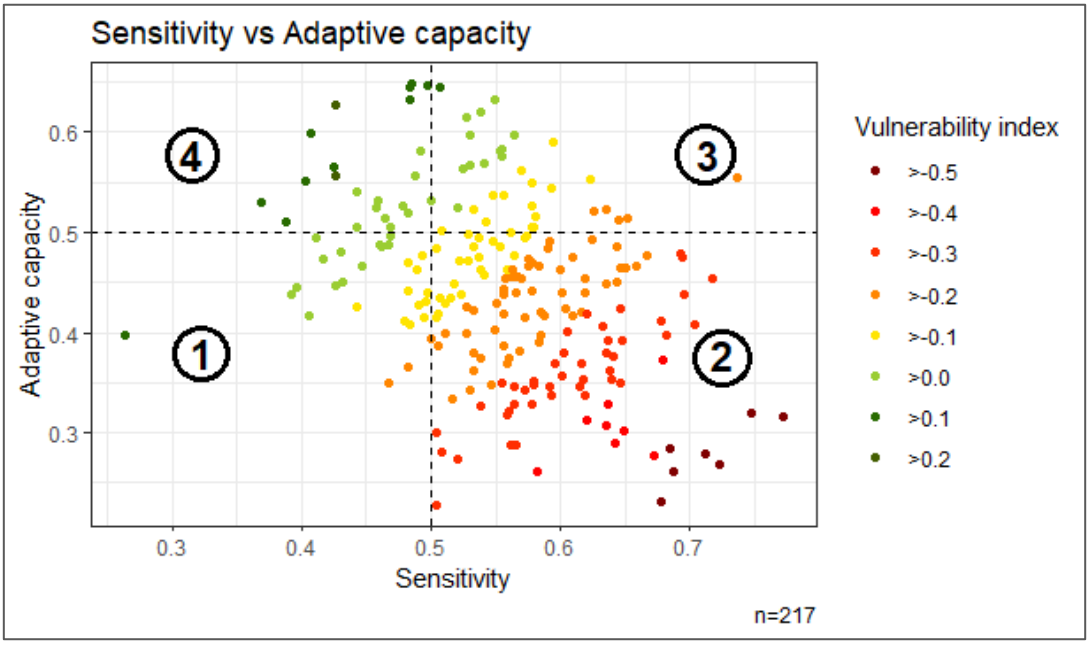

Figure 9: Household vulnerability indices

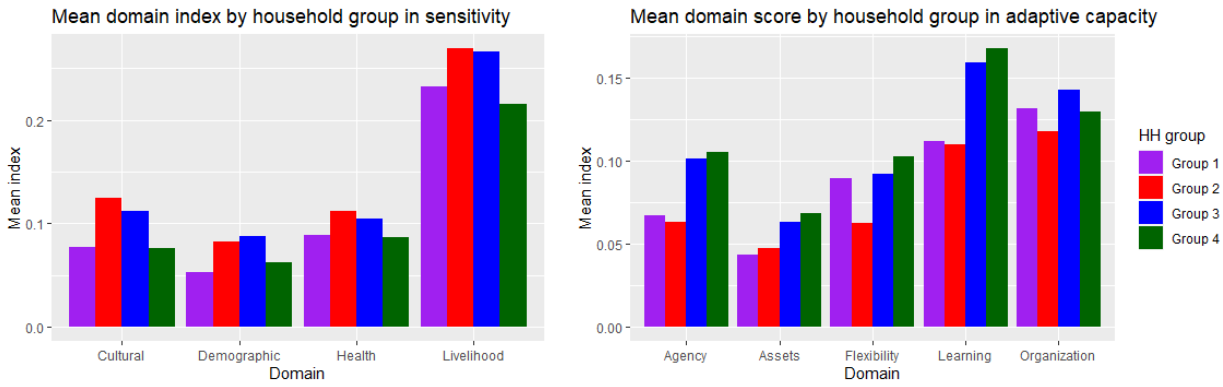

Figure 10 : Mean index of sensitivity and adaptive capacity per domain and household groups

In general, all households are most sensitive in terms of livelihood and economic dependency. Indicators linked with learning and organization such as the level of education, knowledge of rules and access to information; community cohesion, trust in organizations and linking social capital contributes most to the adaptive capacity of HHs.

a) Principal characteristics of HHs

- **HH Group 1** (13.36% ~ N = 29) : Households in this group got their income only from fishing. More than 55% of the head of household have attended primary school only. 69% of HHs in this group use non-selective gears such as mosquito nets, fishnet with mesh size below 50mm, "*Treko*", coastal dam. If there is 50% less catch, these HHs would change fishing grounds (62%) and fishing gears (24%). 16% of migrant HHs are in this group.

- **HH Group 2** (63.3% ~ N = 135): This group contains the most sensitive HHs. Almost all domains have the highest mean indices compared to other groups. HHs in group 2 got their income only on fishing. 19% have not received any education. 48% went to primary school only. 58% of HHs with single mothers are in this group. 16% practice fishing only. 77% practice both fishing and some agriculture. 72% use non-selective gears. If there is 50% less catch, 20% would change fishing gears; 45% would move to another fishing ground. 88% of HHs in this group do not participate in local decision-making (77% of HHs in the whole sample) . 48 % of migrant fishers are in this group.

- **HH Group 3** (14.68% ~ N = 32): The monthly income in this group is slightly higher. 44% of HHs have not received any education or their level of education is not beyond primary school. 9% practice fishing only. 84% practice both fishing and agriculture. 84% use non-selective gears. If there is 50% less catch, 44% would change fishing gears; 39% would change fishing grounds. 19% of migrant HHs are in this group.

- **HH group 4** (9.6% ~ N = 21): The monthly income in this group is the highest. 90% of HH have attended more than primary school. 33% practice fishing only. 48% work also, apart from fishing and agriculture, in an area other than the two. 71% use non-selective gears. If there is 50% less catch, 29% would stop fishing entirely. 17% of migrant HHs are in this group.

b) Key findings and discussions

- There is no significant difference between HHs in the groups that practice fishing only or fishing and agriculture. Fishers and farmers have the same level of exposure of climate change. An extra activity helps HHs to cope with climate change and reduce their vulnerability. Fishing and agriculture are all both activities that are vulnerable to climate change. Smallholder farmers faced frequent risks to their agriculture, including disease outbreaks, pest damage, crop loss during storage and occurrence of extreme weather events (Harvey et al., 2014).

- The rate of use of non-selective gears is the same across all the groups. Traditional and artisanal fisheries provide the typical example of the tragedy of the commons, which occurs when access to a resource is open (Hardin, 1968). The result is often overexploitation of the resource. Chaboud (2006) stated that fishers become poorer because of the free access to the resource.

- Fishers who are better educated have more diversified systems and are less vulnerable to climate change. This category of fishers would not find difficult to adopt new strategies. Among the consequences of low education is that the adoption of new, improved agricultural or fishing techniques is very low (Clausen et al., 2010). Therefore, NGOs and local governments appeal for the services of fishers who have received a better education to lead people in biodiversity conservation activities.

- The most vulnerable category of people are mainly single mothers and older people. The sudden death of the fishermen might leave behind poor single mothers. This illustrates that women mainly depend on their husbands for a living. However, in most traditional fishing communities, women not only fish, but make and fix nets, and process and trade catches. Women are not able to go far, paddle canoes for a long distance and get more valuable catches as men.

- Migrants seem to have lesser vulnerability compared to the global HHs. The reason could be that they are likely to have greater willingness to be geographically mobile, which may contribute to their adaptive capacity.

- People with least participation in local decision-making do not share the vision of the importance of marine resource management. However, most of vulnerable households are not involved in management of marine resources. An improved understanding of communities of their rights and responsibilities with regard to natural resource ownership, access, and use rights should be conducted.

- Two sample t-test between the two sites (see Appendix 2) show that there is a significant difference of vulnerability means between communities living in Mahajamba bay and Sahamalaza bay. This could be explained by the fact that marine resources are more diverse in Sahamalaza (presence of mangroves, coral reef and seagrass beds) meaning that people use more gears. However, terrains in this area also steep and are not suitable for agriculture (constraints in livelihood multiplicity). Another reason is that Sahamalaza is a National Park and is part of the MIHARI network which is a network of Locally Managed Marine Areas. In

other words, there is a strong connection between local communities and biodiversity conservation managers. MNP (Madagascar National Parks) in Sahamalaza has been leading projects to increase the adaptation capacity of the local population by introducing income generating activities.

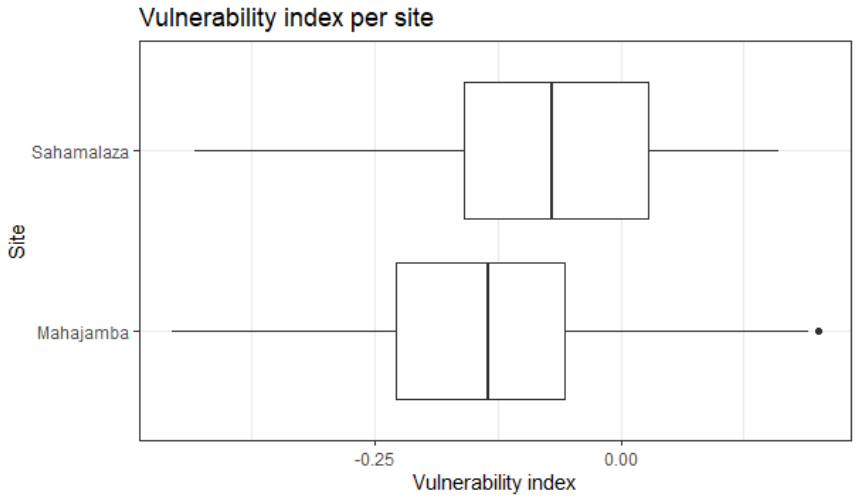

Figure 11 : Box plot of vulnerability index per site

- Vulnerability indices for each village follow the order of values for each bay. The village of Tsinjoarivo is the most vulnerable. The main reason could probably the lack of organization and governance. This village is not part of the MIHARI network. The village of Besakoa has more opportunities economically thanks to the AQUALMA that increases the livelihood multiplicity. The village of Andranoboko is currently supported by Blue Ventures to be part of the MIHARI Network. Villages in the bay of Sahamalaza are less vulnerable than the previous villages. Here, the main factor of vulnerability the access to information and market places (Antafiatambalaka) and the diversity of resources (Lagnamena). The village of Maromanjo does not have these assets, thus its vulnerability index is the lowest.

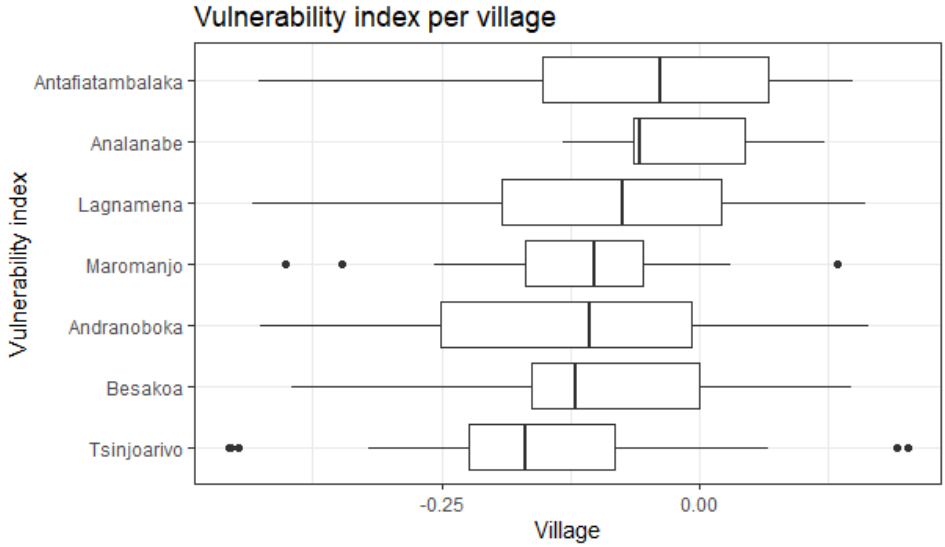

Figure 12 : Box plot of vulnerability index per village

8 Impacts of the Covid-19 pandemic on fishing activities

a) Decrease in fishing frequency

Going out to sea was less frequent than during the period pre-covid as 81% of households have mentioned. It was difficult to sell catches as few wholesalers have come to buy them. The duration of fishing activities has also decreased. Before the pandemic, the weekly fishing frequency was 4 to 5 days, it is now 3 to 4 days a week.

b) Decrease in household income

A significant number of households have indicated that their income has dropped since the health crisis. Main markets were not accessible and wholesalers can't come to the villages as regional trips were limited. Fish products could not be transported to consumption the cities. Some fishers have admitted they went to smaller marketplaces other than those in the big cities, because police checks are less strict there. The downside is that there are no buyers.

- Decrease in the quantity of fish sold
- Reduction of selling prices (Law of supply and demand). Prices have between 25% and 50%. In Tsinjoarivo, the price per kg of Karapaka (*Macrura kanagurta*) went from 1500 Ariary to 500 Ariary. The price of a 20 litre container of chevaquine (*Caridina serratirostris*) was 35,000 Ariary and has dropped to 20,000 Ariary.
- Lack of alternatives as a source of income

c) Decrease in the number of wholesalers

Due to the lockdown, roads have been closed and public administrations work on a minimum basis. The issuance of collection permits and fishmongers cards has been delayed. Due to travel restrictions, wholesalers have struggled to ship their products to other areas. Urban households, main consumers of fish products, have reduced the demand as their income too has decreased. Demands of fish products have dropped drastically and so the frequency of collection by wholesalers.

d) Change on the family budget and food insecurity

Basic goods (Sugar, cooking oil, rice) were not available on the market. Many households have had difficulty accessing them because they were expensive and most of the time not available. Families had to change their recipes. Despite being as a staple food, rice has been replaced by cassava, sweet potatoes and even mango. Emotionally, rural and coastal populations have felt alone, abandoned and were on their own.

e) Other impacts

- Resurgence of social insecurity: the number of thefts of fishing gear such as longlines and nets has increased. In the village of Tsinjoarivo, an average of 4 burglaries per month has been recorded.
- The use of barter (basic goods against fish or crabs) became familiar
- Increase in the number of migrants. Migrants have fled from the pressures of the city where they can't make any income.
- Some villages are totally isolated like the village of Lagnamena which is only accessible with a small boat or a canoe.

9 Recommendations for managers/policy makers as adaptation options and/or mitigation.

To decrease vulnerability, we can increase adaptive capacity. Therefore, greater actions should be conducted in all domains: flexibility, learning, organizations, agency and assets by increasing the number income generating activities, train fishers using more sustainable gears and improve or create better infrastructure within local communities for example. These ideas are recorded in the National Climate Change Adaptation Plan (PNA: Plan National d'Adaptation au Changement Climatique) established in 2019 (MEDD, 2019) and that contains measures to mitigate the impacts of climate change. Further recommendations interlinked both with this plan and the Sustainable Development Goals (SDGs) are suggested in the table below.

- **SDG Goal 13**: Climate action
  - **Target 13.1**: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
  - **Target 13.3**: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

PNA strategic action plan	**Activities**	**Indicator of Adaptive capacity/Recommendations**
Develop weather early warning systems for fishers	Improve the Early Warning System (EWS) and the monitoring of local population mobility dynamics in coastal communities	**Access to information** • Develop innovative early warning systems on wind speed, cyclones and rainfall • Data can be acquired on Windguru website and transfered via SMS. • Governments should work with the mobile telephone companies to improve mobile coverage and access to such services.
	Strengthen policies on Information, Education and Communication (IEC) activities of traditional fishers on the general life cycle of the species.	**Knowledge of rules** • Sensitise fishers mainly on the topics of fishing closures and laws (gears to be used, fishing ground and protected areas).

- **SDG Goal 14**: Life below water
  - **Target 14.2:** By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.

PNA strategic action plan	**Activities**	**Indicator of Adaptive capacity/Recommendations**
Set up marine reserves and protect corals and mangroves	Carry out an inventory of coral reefs and their level of management	**Recognition of causality** • Conduct and map seagrass meadows ecosystems nationwide. • Identify the causes of coral bleaching and conduct research to restore degraded corals.

PNA strategic action plan	Activities	Indicator of Adaptive capacity/Recommendations
	Support the process of creating Marine Protected Areas including coral systems and mangroves with high conservation value	**Level of participation** • Provide communities with materials for the monitoring and control of resources (speedboat, nets meeting standards, vests, fins, mask, weather forecasting device) • Support exchange visits between coastal communities.
	Restore mangroves in coastal areas	**Perceived capacity to change** • Develop a booklet of mangrove reforestation and restoration of other ecosystems
	Protect coral reefs, mangroves and seagrass meadows.	**Trust in organizations** • Support law enforcement by establishing fishing judicial police officer • Reinforce the surveillance especially during closure • Develop laws governing activities that may harm sea cucumbers and seagrass meadows. • Validate and implement the "Dina" (Local community agreement) in the management of natural resources

- **SDG Goal 1**: No poverty
  - **Target 1.5:** By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.

PNA strategic action plan	Activities	Indicator of Adaptive capacity/Recommendations
Develop and disseminate new fishing technique	Establish an updated database of stock fish	**Access to information** • Conduct inventories of the resources • Establish a fishing closure adapted to the life cycle of targeted species
	Restructure and regulate small-scale fishing	**Linking social capital/Gear diversity** • Enforce laws prohibiting the use of any gear mounted with a mosquito net. • Check the mesh size of nets during certain periods of the year. Limit fishing effort, especially from nets with small mesh size • Support fishers on how to make fishing nets, build and repair canoes. • Support fisher's associations to obtain an eco-certified label for their products under the "Marine stewardship council" (MSC)

PNA strategic action plan	Activities	Indicator of Adaptive capacity/Recommendations
	Develop and promote fish farming, aquaculture (oysters, sea cucumbers, seaweed, etc.)	**Livelihood multiplicity**
Explore and develop entrepreneurial characteristics of small-scale fishfarmers	Integrate fishers into a cooperative that is managed by its members	**Community cohesion** • Set up a fishing cooperative • Distribute professional fishermen's cards. • Register canoes and pirogues in a database. • Migrant fishers must register within fishermen's associations before being able to access the fishing areas
	Develop a capacity building program for fishers associations	**Level of education/Access to credit** • Support fishers and stakeholders on climate change adaptation • Conduct financial education sessions for local communities • Train fishers on conventional fishing techniques • Ensure the availability of fish products all year round: train fishers on how to preserve and store products (smoking, salting, etc.)

- **SDG Goal 12:** Sustainable consumption and production
  - **Target 12.a**: Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
  - **Target 12.b**: Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
- SDG Goal 5: Gender equality
  - **Target 5.a**: Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws.

PNA strategic action plan	Activities	Indicator of Adaptive capacity/Recommendations
Create income-generating activities less dependent on natural resources	Support the development and implementation of IGA development programs	**Livelihood multiplicity** • Increase the area of cultivable land through irrigation and contour cropping.
	Conduct a detailed assessment of the constraints of the tourism industry that limit the potential for its development	**Community infrastructure** • Improve community infrastructure (roads, hospitals, schools) and reduce the level of insecurity (armed robbery in rural areas targeting zebus).
Secure land tenure rights for all	Give men and women the same right to access to land	**Livelihood multiplicity** • Support the policy of land tenure rights of fishers. This should be taken into account in a national policy.

PNA strategic action plan	Activities	Indicator of Adaptive capacity/Recommendations
Promote agriculture practices that are resilient to climate change	Develop pilot studies and agriculture incorporating the resilience of integrated agricultural systems (IAS) to climate change	
	Use environmentally friendly and climate-resilient agriculture inputs	
Develop an income diversification through animal husbandry	Prioritise local cattle breeds	**Livelihood multiplicity/ Access to credit** • Financially and technically train fishers on animal husbandry (animal feed, hygiene, care, etc.)
	Improve the resilience of cattles (disease-resilient livestock)	

10 Conclusion

Coastal populations heavily rely on traditional fishing for income and subsistence. However, overfishing and climate change threaten their livelihood. Combined with limited access to information, poor infrastructure, poor education and skills, livelihood is not resilient as it cannot cope with and recover from shocks and stress (climate change has been broadly explained in this study plus Covid-19). A flagrant use of destructive gears such as "Periky", "Valakira", "Kaokobe" and mosquito nets has been observed. Fishers with coastal dam gears are mostly elderly women and men. These are people who can no longer go offshore and handle gear like the “periky” or the “kaokobe”. Culturally, given the important place that these categories of fishers hold in coastal communities, suggesting them to replace their gears with other more selective ones is a challenge. The open access to the resources does not make this task easy because in addition there is a growing competition with industrial fishing vessels in nearshore waters. The government has to make sure that fishing activities are inclusive, not putting aside small-scale fishers while ensuring that rules are followed. Besides climate change, declining fish stocks and overexploitation of resources, there is also the problem of migration. Migrant fishers come to the bays because they no longer have fish in their area. These migrants use non-selective gears which create fears and growing competition between and among local fishers.

Education is a real hope to adapt to climate change. However, schools in coastal and all rural villages of Madagascar lack of infrastructures. They are in poor condition, the materials used are very archaic and do not follow the national standards. If in primary school, education is precarious, training fishers and adults is another challenge. Understanding the laws is quite superficial: fihsers know the rules but do not apply them. This creates a total disconnection between fishers and governmental representative responsible for fisheries surveillance. Although, there is a willingness of fishermen to participate in the sustainable management of resources, interventions of the public authorities such as sustainable agriculture by improved irrigation techniques, road construction and promotion of income generating activities are required. Finally, one factor that is considered to be the cause of fishers poverty is limited access to credit and the non-existence of opportunities that allow them to be financially educated. Different recommendations linked with the SDG goals and the National Policy on Climate Change adaptation in Madgascar have been proposed. The CCVA approach used in this study help which domain/indicator can be prioritised. With this approach, index values can be monitored and progress in terms of vulnerability assessment can be analysed by comparing future results by a baseline data.

To conclude, the ministry of environment and sustainable development has launched a policy on Integrated Coastal Areas Management integrating economic, social and environmental adaptive capacities to climate change. Madagascar has benefited from the Southwest Indian Ocean Fisheries Governance and Shared Growth Programme (known as the SWIOFish programme2) of the World Bank/Global Environmental Facility, which aims to enhance regional collaboration in fisheries research and management, improve governance of priority fisheries including developing fisheries resilience to climate change, and increasing economic benefits from priority fisheries. In 2021, Madagascar has announced that it has officially requested to enter the Fisheries Transparency Initiative (FiTI), joining the recent commitments of other coastal states including Senegal, Seychelles and Mauritania. The FiTI promotes informed public debates on fisheries policies by making fisheries management more transparent and inclusive. Madagascar commits in a participatory and multi-stakeholder approach, with representation and participation by small-scale, artisanal and industrial fishers, civil society, and government authorities. These initiatives constitute additional fundamental basis of recommendations suggested in this document.

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12 Appendices

Appendix 1: List of species and gears

Common name	Family	Scientific name	Gear
Alovo (Merou-Cabot)	Epinephelidae	*Epinephelis sp*	Longline, Hand line, Mesh gillnet above 5cm (2inches)
Ambamba	Engraulidae	*Thryssa vitrirostris*	
Ambariake	Gerreidae	*Gerres spp*	Hand line, Mesh gillnet above 5cm (2inches), Mesh gillnet below 5cm
Ango	Chanidae	*Chanos chanos*	Mesh gillnet
Ankiho (Shark)	Carcharinidae	*Carcharinus leucas*	Longline
Antseradava	Belonidae	*Tylosurus acus melanotus*	Longline, Mesh gillnet above 5cm (2inches)
Besisika	Clupeidae	*Herklosichthys quadrimaculatus*	Longline, Mesh gillnet above 5cm (2inches)
Bika	Mugilidae	*Mugil sp*	Longline, Mesh gillnet above 5cm (2inches), Mesh gillnet below 5cm
Capitaine	Lethrinidae	*Lethrinus sp*	Longline, Mesh gillnet above 5cm
Crevettes	Penaeidae	*Fenerropenaeus indicus; M. monoceros*	Mesh gillnet above 5cm (2inches), Mosquito nets
Drakaka	Scyllaridae	*Scylla serrata*	Garigary, Treko, Poto
Drihy	Teraponidae	*Terapon theraps*	Mesh gillnet below 5cm (2inches)
Gogo	Ariidae	*Arius madagascariensis*	Longline, Mesh gillnet above 5cm (2inches),
Karapapaka (Sardine plate)	Clupeidae	*Macrura kanagurta*	Hand line, Mesh gillnet above 5cm (2inches)
Kikao	Carangidae	*Decapturus sp*	Mesh gillnet below 5cm (2inches)
Madame tombée	Lutjanidae	*Lutjanus sebae*	Longline
Mahaloky	Caesionidae	*Caesio caerulaurea*	Longline, Hand line
Maheriloha, Ambitsy, Miandravola	Carangidae	*Trachinotus blochii*	Longline, Mesh gillnet above 5cm (2inches)
Makoba (Raie)	Dasyatidae	*Dasyatis varnak*	Longline, Mesh gillnet above 5cm (2inches)
Menahelika	Lethrinidae	*Lethrinus reticulatus*	Longline, Mesh gillnet above 5cm (2inches)
Patsa	Atyidae	*Cardina nilotica*	Mosquito nets, Coastal dam
Salelo	Leiognathidae	*Leiognatus equilus*	
Sea cucumber	Holothuriidae	*Holothuria spp*	Gleaning, Diving
Tretreky, Dongiry, Bemaso	Monodactylidae	*Monodactylus argenteus*	Mesh gillnet below 5cm (2inches)
Tsivakia (Chevaquine)	Atyidae	*Caridina serratirostris*	Mosquito nets
Tsivaravaraha	Lutjanidae	*Lutjanus bohar*	Mesh gillnet below 5cm (2inches)
Varilava	Engraulidae	*Stolephorus*	Mosquito nets, Coastal dam

		heterolobus	

Appendix 2: Two-sample t-test of vulnerability index between the bays of Mahajamba and Sahamalaza

t = -2.9025, df = 169.01, p-value = 0.004196

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval: -0.0924346 , -0.0175979

sample estimates:

- mean in group Mahajamba = -0.13240000 ;
- mean in group Sahamalaza = -0.07738375

Appendix 3: Two-sample t-test of vulnerability index between two ecological sites: Mangrove only, and mangrove plus coral reef plus seagrass beds

t = 1.2247, df = 100.48, p-value = 0.2236

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval = -0.01567525, 0.06624834

sample estimates:

- mean in group Coral reef, Seagrass bed, Mangrove = -0.0932400
- mean in group Mangrove = -0.1185265

Appendix 4: Households survey

Study site: _____ County/District: _____
Village:_____ Date: _____
Survey no.:_____ Name of interviewer: _____
Latitude/longitude:_____

PART 1: SENSITY DIMENSION

Demographic Characteristics *(Please tick one)*

1) Age (in years): ……
2) Sex:
   [1] Female [2] Male [3] Other
3) Formal education:
   [1] Class 8 or less [2] Secondary school - level certificate [3] A-level certificate
   [4] Tertiary [5] University and above
4) What is your religion?
   [1] Muslim [2] Christian [3] Hindu
   [4] Traditional [5] Other (specify) ……
5) Marital status: [1] Single [2] Married [3] Married before [4] Other
6) Where are you originally from? (*Tick only one option below)*
   [1] This village [2] Another village in this county [3] Coastal area other than this location [4] This country (not coastal area) [5] Another country
7) How many years have you lived in this village? .....
8) How many people are currently in your household, including yourself? *(Please write down the number of people below each category)*

Adult male	Adult female	Male children	Female children

9) What is your employment status? [1] Unemployed [2] Employed
10) If employed, what form of employment are you engaged in?
11) If unemployed, is anyone from your household engaged in formal employment?
[1] No [2] Yes
12) Please give details of employment for any members of your household who are employed (specify type of occupation)
    _____
13) If unemployed, how do you earn income or obtain food and other necessities?
    _____
14) How much income do you earn per week/month/year? KShs.
    _____
15) If fisher, what marine resources do you depend on? KShs.
    _____

PART 2: SOCIAL ADAPTIVE CAPACITY DIMENSION

FLEXIBILITY

Livelihood multiplicity

16) Traditional uses of marine resources
   i. What goods did you obtain from the marine resources in the past?
   ii. Have these goods changed over time? [1] No [2] Yes
   iii. If yes, how?
   iv. How else did you benefit from the marine resources in the past? *(probe for ecological services)*
   v. Has the benefits changed over time? [1] No [2] Yes
   vi. If yes, how?
      a) How do you use marine resources now?
         i. What goods do you obtain from the marine resources now?
         ii. How else do you benefit from the marine resources now? *(probe for ecological services)*

17) What economic activities do you engage in to obtain food or income to your house? What do other people in your house do that brings in food or money to your house?

Livelihood activity	**Tick livelihoods of the respondent**	**Number of people in the household involved in activity**		**Rank the economic activities in order of importance**
		Women	**Men**	
Fishing				
Gleaning				
Medium scale fish trade/fish dealer				
Fish mongers (*mama karanga*)				
Mangrove cutting or trade				
Agent (middleman)				
Aquaculture/Mariculture				
Hunting				
Farming (cash crops)				
Farming (peasant/subsistence, livestock)				
Salaried employment (e.g. teacher, nurse)				
Tourism and handicrafts				
Small business(not marine related)				
Other:				
Other:				

18) Is fishing your primary livelihood? [1] No [2] Yes

19) If yes, how much do you agree with this statement? *(Please circle **one** option):*
"I could easily stop fishing, and make my living on land"

Strongly disagree	Somewhat disagree	Neither	Somewhat agree	Strongly agree

20) Cultural/heritage impacts

a) What areas of the marine environment/resources are of special interest to communities for cultural or religious purposes?

b) Has this changed over time? [1] No [2] Yes

c) If yes, how? _____

Fishing and Marine Resources Management/Gear diversity

21) Do you own a boat? (Tick as appropriate)

[1] No boat

[2] Boat without a motor (e.g., canoe)

[3] Boat with a motorized engine (engine has__hp)

[4] Other(specify)__

22) Which fishing gears does your household use? *(Tick appropriately)*

Gear	Tick gear used	Gear	Tick gear used
Hand line (inshore/reef)		Purse seine net	
Hand line (offshore/blue water)		Hand spear	
Multiple hooks (more than 20)		Spear-gun	
Trolling line		Fish trap	
Mesh gillnet, above5cm(2inches)		Explosives/Poison	
Mesh gillnet, below5cm(2inches)		Gleaning	
Mosquito nets		Other(specify):	
Small/beach seine net (nets dragged along substrate)		Other(specify):	

23) Which fishing gear is the most important to your household?_____

24) Where is your fishing ground_____

25) Catch, fishing effort and catch value:

Parameter	Details
Quantity of fish & other seafood landed (Kgs/ Bundles/pieces)	
Number of fishing crew	
Number of hours (fishing and travelling)	
Total value of catch (local currency)	

26) Typically, what percentage of your catch from fishing or gleaning do you sell, retain for own consumption or give away?

Retain for own consumption ___% sell ___%give away___% don't know ____%

27) If you were to get 50% less catch all year what would you do? (*Tick **multiple boxes** if necessary*)

Keep fishing at same amount	Fish more often	Change fishing grounds	Change fishing gears	Fish less & switch to other livelihood	Stop fishing entirely
Other(specify):					

28) In general, how often do you and your household eat locally caught fish or other sea food that was caught by you or someone in your community? (*Please circle **one** option*)

More than once per day	Once per day	More than once per week	Once per week	More than once per month

29) Over the past 5 years, has the number of fish caught around your area changed? If so, how has it changed?*(Tick **one** option)*

[1] Significant decrease [2] Decrease [3] No change

[4] Increase [5] Significant increase

30) What can be done to increase availability of fish in the sea around here?_____

_____

ORGANIZATION

31) In general, how much do you trust the following people? (*Tick **one** option for each group).*

	Not at all	Distrust more people than trust	About half-half	Trust more people than distrust	Trust all
People in your village					
Village leaders					
Marine resource management group					
NGOs					
Government					

32) I am interested in learning about some of the rules and traditions about fishing here. **(A)** Are there places where people are not supposed to fish, nor use certain gears, etc.?
(B) Who created the rules? (**C**) Do people still fish there? If so, how many people? *(Interviewer: please **fill out first row** before moving to next row, i.e. ask A-C for places where people are not supposed to fish followed by A-C for fishing gears that people are not supposed to use).*

Rule	**Description of rules, e.g. what gears are not used etc.**	**Who created the rules?** *(tick multiple boxes if necessary)*	**Do people still fish there? If so, how many?** *(tick one box)*
Places where people are not supposed to fish		☐ Fishers/local users ☐ NGO ☐ Government ☐ Other:_____ ☐ Don't know	☐ No one ☐ A few ☐ About half ☐ Most ☐ Everyone ☐ Don't know
Certain **fishing gears** that people are not supposed to use		☐ Fishers/local users ☐ NGO ☐ Government ☐ Other:_____ ☐ Don't know	☐ No one ☐ A few ☐ About half ☐ Most ☐ Everyone ☐ Don't know
Certain **times** that people are not supposed to fish		☐ Fishers/local users ☐ NGO ☐ Government ☐ Other:_____ ☐ Don't know	☐ No one ☐ A few ☐ About half ☐ Most ☐ Everyone ☐ Don't know
Certain **species or types of fish** that people are not supposed to catch		☐ Fishers/local users ☐ NGO ☐ Government ☐ Other:_____ ☐ Don't know	☐ No one ☐ A few ☐ About half ☐ Most ☐ Everyone ☐ Don't know
Other, please describe:		☐ Fishers/local users ☐ NGO ☐ Government ☐ Other:_____ ☐ Don't know	☐ No one ☐ A few ☐ About half ☐ Most ☐ Everyone ☐ Don't know

Social Capital

33) Social networks

a) Are there times when you go to someone else for help? [1] No [2] Yes

b) If the answer to question a) is yes, who do you run to for help in times of need?

_____

c) Why do you run to this person(s) and not any other person(s)?

_____

d) Who are the key decision makers in the community?

_____

e) How are decisions made in the community?

_____

Learning

34) Local perception of marine resources management and management success

a. In your opinion, are the marine resources managed well?

_____

b. What aspects of management do you consider successful in your area?

_____

f) Is there effective enforcement of rules and regulations governing marine resources? [1] No [2] Yes
If yes, explain:

_____

c. Are the local communities involved in marine resources management?
[1] No [2] Yes
If yes, how?

_____

d. What is your opinion regarding marine resources conservation?

_____

35) Level of understanding of human impacts on marine resources

a. Are there any activities that damage marine resources in the area?

_____

b. Are you concerned about sustainability of the marine resources?

_____

36) Distance from village to the sea; importance of markets; slope

_____

37) Distance from village to nearest market

_____

38) How is cultural knowledge passed down by the community from one generation to another? _____

39) Is there any cultural memory, traditions, and assets that relate to coastal and marine resources that have been handed over to you? _____

_____

Food Security and Wellbeing

40) Were there any moments in the last month when your home did not have enough to eat?
[1] No [2] Yes [3] I don't know

41) Was this unusual?
[1] No [2] Yes [3] I don't know

42) In the past year, have there been times when you feared that your food would not last until you were able to get more?
[1] No [2] Yes [3] I don't know

43) In general, how many times do you eat in the day?
[1] Once [2] 2 times [3] 3 times [4] Over 3 times

44) Since yesterday, can you tell me about the meals you have prepared for your family?

ASSETS AND ACCESS TO CREDIT

Material Style of Life

45) Material style of life and owned assets. *Please **tick all the household items or facilities p**resent in the household. Also **record the number of each asset** owned by the household.*

Cooking pots [1] No [2] Yes How many:	**Radios/cassette/CD** [1] No [2] Yes How many:	**DVD/VCD players** [1] No [2] Yes How many:	
Mattresses [1] No [2] Yes How many:	**Mobile phone** (not smart phone) [1] No [2] Yes How many:	**Smart phone sortables** [1] No [2] Yes How many:	
Flushing toilet [1] No [2] Yes How many:		**Indoor piped water (tap)** [1] No [2] Yes How many:	
Washing machine [1] No [2] Yes How many:	**Computers** [1] No [2] Yes How many:	**Electric refrigerators or freezers** [1] No [2] Yes How many:	
Cattle/Goats/Pigs /Sheep(livestock) [1] No [2] Yes How many:	**Televisions** [1] No [2] Yes How many:	**Satellite dishes** [1] No [2] Yes How many:	
Private toilet [1] No [2] Yes How many:	**Other1** [1] No [2] Yes How many:	**Other2** [1] No [2] Yes How many:	
Roof Material □ Bamboo/Thatch □ Wood □ Metal □ Tile □ Other:_____	**Wall Material** □ Bamboo/Thatch □ Wood □ Metal □ Cement □ Other:__	**Floor Material** □ Dirt/Soil □ Wood □ Concrete □ Tile □ Other:____	**Electricity** □ Solar □ Generator □ Grid □ None □ Other:_____

46) Community infrastructure
    a) How are the communities governed?
    b) How do the communities relate with higher levels of government?
47) It would be great to know more about how you feel about your life here. All things considered, has your satisfaction with your life as a whole changed over the last three years? [1] No [2] Yes.
    If so, how has it changed? *(Please tick **one** option)*

Much worse	Worse	No change	Better	Much better

48) *If there was a change,* what are the three main causes of this change?
    1._____
    2._____
    3._____

49) Supposing that for some reason you were moving away from your current village, how would you feel about leaving?

Very sad	Sad	Neither happy nor sad	Happy	Very happy

50) Do you have access to savings to respond to extreme climatic events?
    [1] No [2] Yes
51) Do you have access to credit facilities? [1] No [2] Yes; Explain _____
52) For people dependent on marine resources, do you have access to markets?
    [1] No [2] Yes
53) Do both men and women have equal access to resources? [1] No [2] Yes
54) Are there any barriers restricting access to the coastal and marine resources? Explain
55) Is government investing in longer term adaptation options? [1] No [2] Yes,
    If yes, how? _____

AGENCY

Recognition of causality

56) Does fisheries and mangrove management affect this community? [1] No [2] Yes
57) Does fisheries and mangrove management affect you? [1] No [2] Yes
58) If yes, what are the positive impacts of fisheries and mangrove management for you?
    _____
59) What are the negative impacts of fisheries management on you? _____
    _____
60) In general, do you think management has affected fish stocks? If yes, how has the fish stock been affected? *(Please tick **one** option)*

Much worse	Worse	No change	Better	Much better

61) In general, do you think management has affected the quality (e.g., size) of fish and other sea food landed?

*(Please tick **one** option)*

A lot less	Somewhat less	No change	Somewhat more	A lot more

62) In general, do you think management has made it easier or harder to catch fish and other sea food (in terms of time, effort, or travel distance)? (*Please tick **one** option*)

Much harder	Hard	Neither	Easier	Much easier

63) In general, do you think management has affected the reliability of what you can catch?

If yes, how has it changed the reliability? (*Please tick **one** option*)

A lot less reliable	Less reliable	No change	More reliable	A lot more reliable

Level of participation

64) Currently, are you involved in the following aspects of marine resources management?

a) decisions about marine resource use (attending meetings about marine resources)

Not at all	Seldom	Never	Often	Very often

b) management of marine resources

Not involved	Involved a little	Never	Involved	Highly involved (in leadership)

65) How much do you agree or disagree with this statement: *(Please tick **one** option)*

"People like me have influence on the management of marine resources."

Strongly disagree	Disagree	Neither	Agree	Strongly agree

66) In general, do you think the way that decisions are made about marine resource use and management are fair? *(Please circle **one** option)*

Very unfair	Unfair	Neither	Fair	Very fair	Don't know

Why? _____

67) Is there any conflict over marine resources here? If yes, how often does this conflict occur? *(Please circle **one** option)*

No conflict	Daily	Weekly	Monthly	More than once per year	Less than once per year	Don't know

CLIMATE CHANGE

68) Have you heard of climate change or global warming?
[1] No [2] Yes

69) Can you tell me what it is? *Please check all the answers the respondent provides. Do not prompt the respondent*

☐ Drought – not enough rain ☐More storms & extreme weather
☐ Floods – too enough rain ☐Increased disease
☐ Sea level rise ☐Impact on fish catch
☐ Warmer conditions
☐Other

70) Are you worried about this affecting your family?
[1] Not worried [2] A little worried [3] Not sure [4] Worried [5] Very worried

71) What traditional knowledge or practices relevant to addressing climate are available in the communities?
_____

72) What adaptation options are available to you and the local communities? _____
_____

73) Do you and other members of the community have access to relevant information, such as forecasts or early warming?
_____

SUPLLEMENTARY QUESTIONS - Adaptation to Covid-19

74) How has COVID-19 impacted how you and your family obtain food and income compared to how you normally would at this time of year?

75) Have you and your family made any changes to cope with these impacts? [1] No [2] Yes

76) If the answer to question 74 is yes, please explain
_____

77) Has COVID-19 changed the quantity of fish or other sea food that much you have been catching compared to how you would normally catch at this time of year?
[1] No [2] Yes
If yes, how?

Much worse	Worse	No change	Better	Much better

78) Has COVID-19 impacted the fish market? [1] No [2] Yes
Please explain
_____

79) Are people in the community able to access markets? [1] No [2] Yes
Please explain _____

80) Have you and your family made any changes to cope with these impacts? Please tell me about them.

81) Has COVID-19 changed the price of fish now compared to this time of year normally? How?
Has COVID-19 affected the types and variety of food you and your family are eating now, compared to normally at this time of year? [1] No [2] Yes
If yes, how? _____

82) Are there foods you normally eat at this time of year that you are not able to eat at the moment? [1] No [2] Yes
If yes, why?

83) Have you and your family made any changes to cope with these impacts? Please tell me about them.

84) What impacts has COVID-19 had on livelihoods in the community?
_____

85) Has the number of people who are engaged in fishing changed? [1] No [2] Yes
If yes, how? _____

86) Has the intensity of fishing changed? [1] No [2] Yes
If yes, how? _____

87) How has the community responded to COVID-19? _____