Report of the GLORIA Workshop, Antananarivo, Madagascar

14 – 16 June 2016

by

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Contents

Executive Summary

i) Overall conclusions and recommendations

The government of Madagascar and other stakeholders are well aware of the threats arising from climate change for coastal communities in the country and of the need to prepare for and adapt to those threats as well as to any opportunities that may arise from climate change. To this end, a National Adaptation Plan of Madagascar has been developed and the country has legislation and other texts in place on climate change and adaptation in the country. WWF Madagascar and Blue Ventures have developed an effective methodology for undertaking vulnerability assessments of coastal communities and have used the methodology in a number of vulnerability assessments of communities in the country. The participants in the GLORIA workshop, who came from 17 different institutions in Madagascar and seven international institutions, worked from this foundation and considered whether, using some of the latest approaches and technologies, they could add to the existing knowledge on and methods being applied to investigate the major challenges caused by climate change facing coastal communities and help to identify options for adaptation to the climate challenges.

A comprehensive list of conclusions and recommendations were developed at the workshop. These were grouped under the headings of: Methods for vulnerability assessment; Priorities for further research on climate change, coastal communities and fisheries; The major climate-related challenges facing communities; and Key issues to be included in an action plan to strengthen adaptation capacity and resilience to climate change in the communities. The most important overall messages from the workshop can be summarised as the following:

- It was clear from the workshop that the major challenges confronting coastal communities are already well understood in Madagascar, at least by scientists and the management agencies, but the details and local specifics are often less well understood. Similarly, the potential adaptation options for coastal communities in Madagascar have already been discussed and considered by the different stakeholders in the country, but this needs to be taken further at the local level.

- The overall message from the workshop on challenges and adaptation options was that the challenges and options should not be considered separately and in isolation but that it is necessary to look at them as a whole, considering their combined and cumulative impacts. A key recommendation is therefore that it is essential in planning for adaptation to look at the whole picture and to take an integrated approach to the characteristics and dynamics of each community and the ecosystem of which they are a part, together with consideration of the wider human and natural environment and processes that influence them. It is also essential to consider not only the present impacts and vulnerabilities, but those that are likely to develop in the coming decades.

- Generic adaptation options based on experiences elsewhere are of limited value and can be counter-productive when applied to specific cases. The particular vulnerabilities, needs and opportunities for each community and fishery or fisheries must be considered and solutions designed in a participatory manner for that particular case, also taking into account likely future changes.

- Some of the scientific tools and approaches presented and applied at the workshop could be of value in future work in Madagascar on these topics. These include: use of high resolution global climate and oceanographic models for forecasting likely future trends; application of traits-based methods for assessing species and ecosystem vulnerability to change; greater use of conceptual and other models for strengthening knowledge of how the whole system interacts and behaves; and the use of GIS (geographic information systems) in participatory discussions and assessment of vulnerability of communities and options for adaptation.

- It is important to create awareness of the importance of the oceans and climate amongst children and other stakeholders. Different tools and techniques are available to facilitate such learning and could be applied in local schools and in other settings where learning takes place.

A more detailed summary, including the elements of an action plan are provided immediately below and full details are provided in the rest of the report.

ii) Introduction to the workshop

The design and organization of the workshop was a collaborative effort between the GLORIA international team, WWF Madagascar and the Western Indian Ocean and IH.SM, with some input from Blue Ventures. It was held at the Carlton Hotel, Antananarivo from 14-16 June 2016. A total of 49 people representing 17 institutions in Madagascar and seven international institutions participated in the workshop.

The workshop addressed the geographical areas of the north and south of the western side on Madagascar with the following objectives:

- To identify major challenges caused by climate change facing coastal communities that depend on the sea by bringing together a multi-disciplinary group of international experts, local scientists, community representatives and other stakeholders;
- To help to identify options for adaptation to the climate challenges by using best approaches to combine and integrate global and regional scientific information with local knowledge;
- To develop effective communication strategies to ensure that suggested adaptation options are valid and acceptable to stakeholders;
- To develop recommendations for an action plan for effective use of limited public resources to facilitate adaptation; and
- Collectively to make recommendations for priorities for future research on marine hotspots.

iii) *Opening and structure of the workshop*

After the opening of the workshop, there were introductory presentations on the National Adaptation Plan of Madagascar, Texts and Legislations on Climate Change and Adaptation in Madagascar and Projections of the impact of climate change on the marine environment around Madagascar. Thereafter, discussions and actions were divided into the following activities:

Activity 2: Climate change projections - recent advances in climate change modelling, most recent projections of key ocean characteristics.

Activity 3: Ecological sensitivity assessment - highlight species and fisheries that may be most vulnerable to climate change.

Activity 4: Key ecological assets - current ecosystem modelling, development of conceptual and other simple models of the system.

Activity 5 & 6: Vulnerability assessment, poverty and vulnerability, coping strategies and adaptation options - determine perceptions of risks to livelihoods, identify current and potential coping strategies, and identification of adaptation options and opportunities.

Activity 7 & 8: Assessing perceptions of change and participatory mapping - working together using GIS and other technical tools to capture and map spatial information on communities and resources, and analyse the dynamics and characteristics of poverty.

Activity 9: Education and outreach – provide tools that can strengthen awareness and knowledge of the oceans through effective teaching.

iv) Outcomes and recommendations from Activities 2 – 8.

For activities 2 to 8, each activity reported back to plenary on the outcomes from the activity, the major challenges within the scope of the activity that faced communities and recommendations on the priorities for future research, options for adaptation to climate challenges and elements for an action plan.

Vulnerability Assessments

Activities 2 to 8 also considered the approaches being applied in Madagascar and internationally to assess vulnerabilities of communities. The primary recommendations and conclusions on vulnerability assessments were that:

1) Generic adaptation options are of limited value and can be counter-productive in specific settings. It is therefore essential to take an integrated approach and to consider the specific vulnerabilities, needs and opportunities pertaining to each particular fishery system in developing options that are feasible, acceptable and likely to fulfil their goals.
2) High resolution global climate models can provide accessible and cost-effective information on future trends in the main climate drivers of the coastal and marine ecosystems and habitats of Madagascar;
3) Inclusion of the traits-based ecological risk assessment presented at the workshop would considerably strengthen the current set of indicators used to estimate ecological sensitivity of Malagasy coastal communities and ecosystems;
4) Greater use of conceptual, qualitative and quantitative models could help in strengthening integrated understanding of the structure and dynamics of communities and fisheries and in identifying important gaps and needs;
5) Simple models coupled with forecasts from global climate models could be used to assess vulnerability in the future;
6) It is important to include consideration of supply chains (of reef based and pelagic fisheries) when assessing vulnerability and considering adaptation options;
7) Understanding the local management measures, including historical and traditional measures, and the institutional governance systems in place is important for vulnerability assessment and identifying adaptation options.

Research Priorities

A number of recommendations for future research were formulated in each activity. It is recognized that it would not be feasible to implement all of those recommendations but it was advised that they should all be evaluated and prioritised according to, amongst other considerations, knowledge gaps, the urgency of problems, and the available capacity for doing the research. The research recommendations from the workshop can be summarised as:

1) Forecasts of climate change and its impacts on the oceans are important in vulnerability assessment and adaptation planning. Using the high resolution global models already available may be more effective use of resources for Madagascar than the development of new regional models.

2) It would be useful to undertake a review of the different methods available for assessing the sensitivity of marine ecosystems and marine species to climate change and to develop an optimal, integrated methodology for use throughout Madagascar.
3) Madagascar should consider developing a toolbox of modelling approaches (including conceptual, qualitative and quantitative models) for provision of information and advice for managers and decision-makers at all scales.
4) Research on communities should be undertaken with understanding of the overall context of the community and all its interactions with other human and environmental drivers. Supply chains, management institutions and rules are an important part of this wider context.
5) There are many tools and approaches for working with communities on vulnerability and adaptation. The value of these approaches can be enhanced through integration with information from other scientific sources. The development of standard protocols for undertaking such integration would assist stakeholders in following holistic approaches to vulnerability assessment.

<u>Major challenges confronting communities</u>

The major challenges that are confronting coastal communities are already well understood in Madagascar by local scientists and the management agencies, but the details and specific issues for different communities and fisheries are often less well understood. The workshop noted that these challenges can interact with and reinforce each other and can also have knock-on and indirect impacts that go beyond the direct impacts. It was concluded that it is important not to address these challenges separately and in isolation but to consider the integrated and cumulative impacts.

With reference to adaptation options, GLORIA was designed to discuss and evaluate methods and approaches for adaptation but not to develop detailed and concrete recommendations. The adaptation options that could be applicable to marine-dependent coastal communities in Madagascar were, in general terms, already well-understood by the different stakeholders in Madagascar and have been presented in other publications and reports. The overall message from the workshop on adaptation options was that all these options need to evaluated and planned with full knowledge and awareness of the local specifics and context and in an integrated way, making use of the best available information, including scientific, traditional and other stakeholder knowledge.

<u>Recommendations for an action plan</u>

The primary recommendations for an action plan generated at the workshop can be summarised as follows:

1) Extend coral bleaching alerts and monitoring of their impacts across the different coral areas of Madagascar, and possibly extend these alerts to give warning on key fishery species that are known to be intolerant to changes in temperature;
2) Build national capacity in the use of global models for regional projections;
3) Develop an integrated methodology for undertaking analyses of the sensitivity of species and ecosystems to climate change to determine the sensitivity of high priority fisheries species and sensitive ecosystems throughout Madagascar;
4) Establish new or utilise existing systems to collect and analyse fisheries data (e.g. catch and effort) for as many fishery resources as possible to facilitate effective management and maintaining resilience of populations;
5) Develop guidelines to assist in building models (conceptual, qualitative and quantitative) as a tool for synthesizing information and exploring and discussing adaptation options. Use conceptual and other models as a standard approach to assist in undertaking vulnerability assessments and to help identify important data gaps and needs;

6) Increase the knowledge and understanding for more of the species that are caught in fisheries in Madagascar and their supply chains;
7) Build or strengthen capacity in sustainable fishing principles, practices and techniques, particularly amongst non-traditional fishers who will not have the benefit of traditional knowledge ;
8) Develop effective legal tools at local government level to allow for secure sea tenure and access to fishery resources;
9) In areas where they do not exist or have been eroded, build or reinvigorate local governance systems and institutions as well as management rules and measures.

v) Activity 9 – the Education Workshop

Activity 9 consisted of the Education workshop – Communicating Ocean Science and Climate Change. It took place as a separate workshop, held in Toliara. It was designed to be relevant for diverse audiences and addressed topics such as ocean and climate literacy needs, consideration of how learning happens and fundamental ideas about learning, the learning cycle, designing a learning experience and discussion of effective learning and teaching. Twenty five participants from diverse sectors participated in the full day workshop. They included staff representatives from the University of Toliara, students, teachers, NGOs, and city council administrators. Participants engaged in several hands-on activities and received a demonstration of materials that could be used for effective teaching and learning, and hands-on activity kits. The workshop was very successful and the feedback comments from participants were positive. They reported that they were inspired to include more ocean and climate related effective teaching and to use the materials provided.

List of Figures

List of Tables

List of Acronyms

BNCCC	Bureau National de Coordination des Changements Climatiques (National Climate Change Coordination Office)
CORDIO	Coastal Oceans Research and Development – Indian Ocean
COSAP	Comité de Soutien des Aires Protégées (Support Committee for Protected Areas)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DGM	Direction Générale de la Météorologie (General Directorate of Meteorology)
DRRHP	Les Directions Régionales des Ressources Halieutiques et de la Pêche (The Regional Department of Marine Resources and Fisheries)
IH.SM	Institut Halieutique et des Sciences Marines (Fisheries and Marine Sciences Institute)
IMAS UTAS	Institute for Marine and Antarctic Studies, University of Tasmania
MEEF	Ministère de l'Environnement, de l'Écologie et des Forêts (Ministry of environment, ecology, and forests)
MIHARI	MIHARI Madagascar Locally Managed Marine Area Network
MNP	Madagascar National Parks
NOC	National Oceanography Centre
RU	Rhodes University
SAGE	Service d'Appui à la Gestion de l'Environnement (Support Service for Environmental Management)
SEMer	Secrétariat d'Etat chargé de la Mer
UCSC	University of California, Santa Cruz
USP	University of Sao Paulo
WWF	World Wide Fund for Nature

1. Introduction

The oceans are not warming evenly and some areas are warming faster than others. The 24 fastest warming marine areas have been identified from historical observations of sea surface temperature (SST) and include the Mozambique Channel and waters off Madagascar and Mozambique (Hobday and Pecl, 2014). The current and future impacts of climate change on the inshore areas of Madagascar and coastal communities are one more challenge that must be faced on top of a number of other drivers that are already threatening fishery resources and inshore ecosystems, including over-exploitation, coastal degradation, weaknesses in governance and management of resource utilization and others.

Madagascar was identified as the target of the GLORIA project because of the rapid rate of ocean warming, the high level of poverty in the country, the presence of communities that are highly dependent on marine resources and the already degraded state of many of those resources. Nationally poverty in that country tends to be most severe in the rural areas and its prevalence in the coastal areas is typically worse than the national average. Traditional fishing communities in Madagascar are characterised by large households with a high proportion of children, low standards of education at all ages, poor access to potable water and health service, and physical isolation from many basic services including schools and markets. The communities are highly dependent on already degraded marine and coastal resources that are exploited in open access systems. Poor coastal communities in low-income countries are those where the impacts of climate change are likely to be felt most acutely, and where impacts of climate change are most likely to reinforce existing inequalities and social tension.

Recognizing these threats and the challenges of addressing them, the GLORIA project was developed to contribute to existing efforts by Malagasy governmental and non-governmental agencies to develop options for adaptation to climate change that promote governance for sustainable utilization of ecosystem services as a contribution to the long-term alleviation of poverty for marine dependent communities. It was intended to complement the important strides that have already been made in the country in evaluating the risks of climate change and assessing the vulnerabilities of some communities. Harding (2013) provides a comprehensive report on progress in assessing the small-scale fisheries in Madagascar, while Gough (2012) describes the methodology that is being used for assessment of the vulnerability of fisheries in the country.

With this background, the project was designed to develop innovative and rapid approaches to combine and integrate global scientific and local information and knowledge for application in existing and future initiatives to facilitate adaptation and resilience building in Malagasy coastal communities. The core of the project was the expert workshop described in this report, which brought together a multi-disciplinary team of international researchers experienced in marine climate change and fisheries from a number of different countries, local experts and specialists with detailed knowledge of the hotspot area, and community representatives with rich local understanding and knowledge. The intention of the workshop was that collectively this diverse and experienced group would identify key areas of environmental change and their likely consequences for local populations. It would explore adaptive solutions and develop recommendations for future action to minimize societal impacts on low-income communities in the hotspot region. With the limited time and resources available for the project it was not possible to test current theories through implementing them but the workshop provided a valuable opportunity for intensive discussion and exchange on adaptive solutions between experts in the theory and coastal stakeholders who are intimately familiar with their own circumstances and needs. It was also planned that the experiences, information and lessons learned from this participatory process would help to develop and test current theories for developing climate change adaptation strategies.

2. Workshop Arrangements and Approach

The design and organization of the workshop was a collaborative effort between the GLORIA international team, which included members from six countries and eight institutions, WWF Madagascar Country Office (hereafter referred to as WWF MDCO) and IH.SM, and some input from Blue Ventures. It was held at the Carlton Hotel, Antananarivo from 14-16 June 2016. A total of 49 people representing 17 institutions in Madagascar and seven international institutions participated in the workshop (Appendix A).

The initial GLORIA proposal had planned to focus on local communities in south western Madagascar but, in discussions with WWF Madagascar and Blue Ventures, it was agreed that the workshop would address communities from both the north and south of Madagascar. Communities from these different areas are confronted by different challenges and it was agreed that broader geographical coverage would make the workshop more widely relevant and useful.

The workshop agenda is provided in Appendix B. The workshop was divided into the following activities:

Activity 2: Climate change projections - recent advances in climate change modelling, most recent projections of key ocean characteristics.

Activity 3: Ecological sensitivity assessment - highlight species and fisheries that may be most vulnerable to climate change.

Activity 4: Key ecological assets - current ecosystem modelling, development of conceptual and other simple models of the system.

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Activities 7 & 8: Assessing perceptions of change and participatory mapping - working together using GIS and other technical tools to capture and map spatial information on communities and resources, and analyse the dynamics and characteristics of poverty.

Activity 9: Education and outreach – provide tools that can strengthen awareness and knowledge of the oceans through effective teaching.

With the exception of Activity 9, which was implemented in a dedicated workshop in Toliara, the activities were addressed in parallel sessions, with no more than two activities simultaneously taking place at any time. Participants chose the activity in which they wanted to participate during each session. The activities reported back to plenary at intervals during the workshop and an attempt was made to integrate results and conclusions from the different activities in the closing plenary session. The agenda and copies of many of the presentations made at the workshop can be found at http://gullsweb.noc.ac.uk/activities.php.

3. Opening and Introductions

The workshop was opened by Dr Hery Rakotondravony, Directeur du Bureau National de Coordination des Changements Climatiques (BNCCC) of Madagascar and Dr Kevern Cochrane, Rhodes University, on behalf of the GLORIA project. Dr Man Wai Rabenevanana also welcomed participants on behalf of the Secretary of State in Charge of the Sea (SEMer).

Thereafter, Kevern Cochrane presented an overview of the GLORIA project and the objectives for the workshop. He explained that the goal of the GLORIA project was:

> "to bring together scientific and traditional understanding and knowledge of the changes taking place in marine and coastal ecosystems in Madagascar and the benefits that are obtained from them, as well as experiences from changes happening in other marine regions of the world also undergoing rapid change. By combining this knowledge and experience from different sources, the project should add to the existing knowledge and capacity in Madagascar to understand and adapt to change, as well providing examples and approaches for other comparable countries and regions around the world."

The objectives for the workshop itself were:

- To identify major challenges caused by climate change facing coastal communities that depend on the sea by bringing together a multi-disciplinary group of international experts, local scientists, community representatives and other stakeholders;
- To help to identify options for adaptation to the climate challenges by using best approaches to combine and integrate global and regional scientific information with local knowledge;
- To develop effective communication strategies to ensure that suggested adaptation options are valid and acceptable to stakeholders;
- To develop recommendations for an action plan for effective use of limited public resources to facilitate adaptation; and
- Collectively to make recommendations for priorities for future research on marine hotspots.

The slides he presented are available on the GLORIA website at http://gullsweb.noc.ac.uk/activities.php.

This was followed by presentations on:

1) The National Adaptation Plan of Madagascar / Plan National d'Adaptation by Harisoa Rondo Herinirina, of BNCCC, Madagascar;
2) Texts and Legislations on Climate Change and Adaptation in Madagascar by Nivohary Ramaroson of BNCCC, Madagascar; and
3) Projections of the impact of climate change on the marine environment around Madagascar by Katya Popova of the National Oceanography Centre, United Kingdom.

Their presentations can be found on the GLORIA website at http://gullsweb.noc.ac.uk/activities.php.

The opening session was followed by a lunch-break, after which the workshop moved into the activity sessions, with regular reports-back to plenary.

4. Activity Reports

4.1. Activity 2 – Climate change projections

Convenors: Katya Popova (UK); Climate projections team: Simon van Gennip (UK), Val Byfield (UK).

4.1.1. Summary

Climate change is a global phenomenon but its impact on living marine resources and dependent communities is local and often unique to the area. Information from global ocean models is very complex and the long term trends for the different variables, or climate and ocean characteristics, need to be translated into a form that matches the specific, local needs. This can only be achieved using a participatory approach that combines climate science with local data and knowledge to identify impacts on species critical to the livelihoods and wellbeing of the communities involved. This approach to climate modelling was applied at the GLORIA workshop.

Some challenges related to the climate that were identified during Activity 2 were:

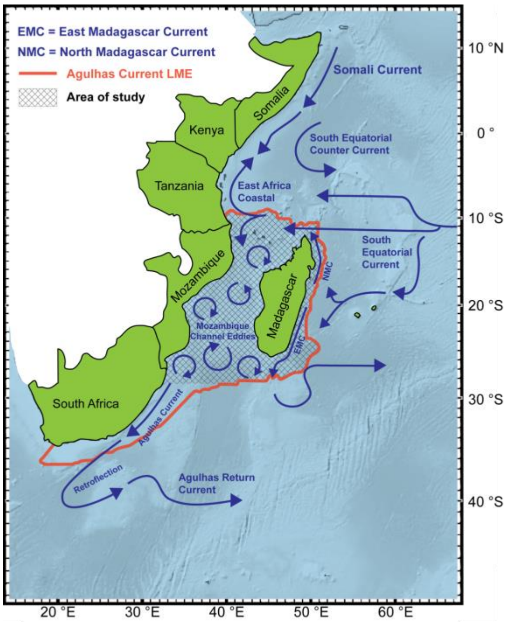
- Rising ocean temperatures are increasing the incidence and extent of coral reef bleaching in Madagascar;
- Rising ocean temperatures are affecting the movement of fish species important to small scale fisheries as the fish move away to escape heatwaves;
- Rising ocean temperatures can increase the incidence of harmful algal blooms (HABs), which can lead to risks from, for example, eating shark liver and sardine heads when HABs occur;
- Concerns about a potential shift in upwelling, which supports valuable fisheries and ecosystem communities in Madagascar, and changes in ocean circulation could result in the spread of diseases affecting marine species;
- Sea level rise is increasing the extent of coastal erosion, while intensification of cyclones, precipitation and wave activity could create problems such as sedimentation at the coral reefs from higher rainfall and land run-off, increased wave activity and changes in ocean currents;
- Changing climate is affecting local weather patterns making local knowledge less reliable and reducing the number of fishing days.

The participants agreed on recommendations for future research. These included determining the tolerance of the main fishery species to higher temperatures and collecting data on sea temperatures. It was agreed that the available information on the Western Indian Ocean from global models should be analysed, including comparisons of the output from different models and comparing model outputs with information from satellites on key oceanographic features. Participants were of the opinion that it would be better use of human and financial resources to use the already available high resolution global models for forecasting climate change, rather than developing new regional models.

A number of follow-up actions were identified. One such action was to extend coral bleaching alerts to ensure they were covering all coral areas in the country and to monitor the impacts of coral bleaching. The value of MPAs was noted but when MPAs are being planned or evaluated it is important to consider the impacts of ocean currents and how the MPA is connected to other areas upstream and downstream. MPAs should be seen as a network rather than an as isolated areas. It is also important to choose locations for MPAs that are most resilient to future change. Capacity building in the analysis of available models, interpretation of the results and assessment of the value and reliability of results for application in Madagascar was also recommended.

4.1.2. Background information on activity content

For the workshop, the climate modelling team carried out an in-depth analysis of the climate change projections for the area and produced a Report Card (Popova et al., 2016) containing information on the most generic climate change indicators relevant for marine ecosystems. Selection of the climate change indicators was informed by the GULLS global modelling work (Popova et al., 2016) and region-specific reports of Harding (2013) and Obura et al. (2012). These indicators were presented, discussed, revised and developed further during the workshop in collaboration with national and international experts with knowledge of Madagascar's living marine resources and the communities that depend on them.



The indicators were obtained on the basis of high resolution ocean projections produced by the National Oceanography Centre, UK. Where possible, they were compared with CMIP5 projections. However, it should be noted that CMIP5 models are of much lower resolution and generally not applicable to regional scales. The projections were obtained using the RCP8.5 (business as usual) emission scenario. Geographically we follow the Large Marine Ecosystems (LMEs). All area-averaged characteristics are presented for the northern Agulhas Current LME region (north of 28.25°S) as shown in Figure 4.1. This separates the productive southern region from the oligotrophic northern region, which shows a different response to climate change.

Figure 4.1. Ocean circulation around Madagascar and area of the climate projection analysis.

4.1.3. Outline of the way the activity was presented

Information from the climate models is very complex and notoriously difficult to convey to a wide multi-cultural audience that includes participants from a variety of experiences, disciplines and occupations. To ensure that climate model outputs are understood by all the GLORIA workshop participants, the climate change indicators were presented in three different forms:

Online model visualisations (http://gullsweb.noc.ac.uk/ocean_projections.php).

The model visualisation webpage includes animations of ocean currents around Madagascar and future projections of the three main climatically-driven stressors of marine ecosystems: Sea Surface Temperature (SST), ocean acidification (pH) and primary production, which underlines dynamics of marine food webs. Changes to the total amount of production can have profound impacts up the entire food chain and affect the success of fisheries and aquaculture. The web page includes a simple description of these stressors and their importance for a wider audience. All visualisations are available to download and can be used to facilitate any educational or policy and industry relevant activities related to climate change.

Climate Change Report card:

The Climate Change Report Card (Popova et al., 2016) provided a detailed description of the main climate change indicators, their forward projections and associated uncertainty. The Report Card included a variety of the model outputs and is aimed at local and international scientists and higher-level policy makers with a good understanding of environmental issues related to the climate change impacts. The climate change indicators discussed in the Report Card included: SST, marine heatwaves, coral bleaching index, ocean circulation, connectivity and dispersal footprints, upwelling zones, ocean productivity, acidification, deoxygenation, sea level rise and changes in precipitation.

Plenary presentation:

The Plenary Talk describing Climate Projections for the key environmental stressors of the marine environment around Madagascar and importance of participatory approaches in identifying the key climate change indicators was presented by Katya Popova. This presentation was aimed at all participants and facilitated subsequent discussions and local input into selection and modification of the region-specific climate-change indicators.

<u>Participatory approach to identification of the relevant climate change indicators (open discussion)</u>:

During the discussion the generic climate change indicators were assessed and revised and recommendations for the new more region-specific indicators were developed (see "Outcomes of the activity"). The main goal of the discussion was to work with local experts to develop more regionally applicable indicators of climate change than those routinely extracted from the climate models. The approach can be illustrated by the following example of ocean warming: Generic indicator: long term SST trend; Region specific indicator: coral bleaching index.

4.1.4. Outcomes of the activity

The following region-specific challenges related to the main climatic stressors were identified during the discussion with recommendations to the climate modelling community:

Generic climate change stressor	**Region-specific challenges imposed by the stressor (participatory input)**	**Recommendation for development of relevant climate change indicators**
Rising of the ocean temperature	Rising temperatures intensify coral reefs bleaching	Develop region-specific coral bleaching index and produce spatial maps to illustrate strong regional variability
Rising of the ocean temperature	Rising temperature affecting small scale fish movement (fish is escaping heatwaves)	Develop marine heatwave indicators and consider extreme events rather than averaged trend of SST
Rising of the ocean temperature	Rising temperatures (T) increase harmful algal blooms (HABs); need alerts with advise for e.g. not eating shark liver and sardines heads when T increases a threshold	Establish T thresholds and develop HAB index
Change in ocean and atmospheric circulation	Concern about potential shift in upwelling which supports valuable fisheries and ecosystem communities	Develop and routinely output upwelling characteristic from the climate models of sufficient

		resolution. Monitor the strength and spatial shifts of the main upwelling areas.
Sea level rise	Sea level rise exacerbating coastal erosion	Develop sea level rise indicator which takes into account coastal elevation and coastal ecosystems especially vulnerable to sea level rise (i.e. mangroves)
Intensification of cyclones, precipitation and wave activity	Sedimentation at the coral reefs potentially caused by intensification of cyclones, heavy precipitation and land run-off, increased wave activity, changes in ocean currents	Develop sedimentation index which takes into account intensification of cyclones, heavy precipitation and land run-off, increased wave activity, changes in ocean currents
Change in ocean circulation	Spread of diseases affecting marine species through changing connectivity or changing climate "upstream" (white spot affecting shrimps and arriving 6 months after being observed in Mozambique)	Focus on simple lagrangian characteristics which can alert to potential changes of connectivity with the continent and surrounding islands
Change of the local weather patterns	"Confused fishermen" – changing climate affecting local weather patterns making local knowledge less reliable and reducing number of fishing days	No quantitative index can be developed in the present-day global climate models (regional models are required) however concerns about "confused fishermen" phenomena needs to be acknowledged and properly communicated to the climate modelling community

As a main outcome of this activity, a peer-reviewed publication describing region-specific climate change indicators and motivation for their selection was proposed. This publication will be led by the UK team (Simon van Gennip and Katya Popova) in collaboration with some of the local Malagasy experts and international GLORIA scientists.

4.1.5. Recommendations

__Recommendations for future research__

- Establish thermal tolerance of the key species and ensure that climate change indicators reflect these ranges.
- Initiate Western Indian Ocean regional analysis of high resolution global models output.
- Initiate model intercomparison for the area (use the power of Madagascar as a developing nation and request international climate modelling collaborations to address the needs of this region).
- Establish key regional features (using satellite data) that the model must be able to reproduce to be treated as acceptable (e.g. upwelling areas, main currents).
- Consider that setting up regional models might not be a wise use of resources. Using high resolution global models at this stage promise faster and more reliable results.

Recommendations for an action plan

- Extend coral bleaching alerts and monitoring of their impacts (Obura, CORDIO) making sure that spatial diversity is covered (North vs South). Link this to thermal tolerance of the key species.
- When setting up or analysing MPA take into account how the MPA is connected to other areas through, for example, ocean currents and the 'footprints' (what is upstream, and downstream?). Consider MPAs as a network rather than an isolated entity. Chose locations that are most resilient for the future change including alien species coming with changing currents and changing conditions upstream. Consider "downstream seeding" impact of MPAs.
- Use the power of Madagascar as a developing nation and request international climate change modelling and satellite observation networks to address issues of this region.
- Capacity building: global models are becoming better with regional projections. Build capacity in analysis of available models, interpretation of their results, and assessment of value/reliability for the Madagascar region.
- Capacity building: linking local observations with global satellite data will help to extend coverage of localised observations for Madagascar-wide environmental monitoring in the real time to short term.

4.2. Activity 3 -Ecological sensitivity assessment

Convenors: Gretta Pecl (Australia), Harisoa Rakotondrazafy, (Madagascar), Warwick Sauer (South Africa), Nicola Downey-Breedt (South Africa).

4.2.1. Summary

Assessments of vulnerability to climate change can provide important information when developing adaptation policies and actions to reduce the risks to coastal communities from climate change. Generally, three components of vulnerability are assessed. Those are: exposure to climate-related impacts; sensitivity to those impacts; and the capacity of communities, fish species or ecosystems to adapt to the impacts. This topic is not new to Madagascar and Blue Ventures and WWF Madagascar have compiled a report on methods for assessing the vulnerability of traditional Western Indian Ocean fisheries to climate change (Gough, 2012). The activity at the workshop focused on ecological sensitivity and considered a rapid method for assessing the sensitivity of fisheries species that had been developed by Pecl et al. (2014). An assessment of the sensitivity of species can allow the identification of those regions with the greatest concentration of sensitive species, the most sensitive species within each region, and the priorities for monitoring, management action and further assessment. The activity considered whether this particular method would be a useful complement to the methods already employed by WWF in the Western Indian Ocean Region and useful for identifying priority fishery species for further study and attention.

The assessment of ecological sensitivity of species to climate change demonstrated and discussed at the workshop is based on those traits or attributes of each species that indicate the potential for changes in abundance (measures of potential for biological productivity), distribution (measures of the capacity of a species to shift) and phenology (measures of potential impact on timing of life cycle events). Each attribute is assigned a score, the scores are summed and the species ranked based on the total scores. This traits-based sensitivity is transparent, repeatable and rapid, and thus can quickly identify priority species that are likely most sensitive. It is particularly useful in data or resource limited situations. However, the precise sensitivity threshold of each trait is usually unknown, and all traits are weighted equally when the weighting or choice of traits may not be appropriate for all species.

A preliminary species assessment for Southwest Madagascar had been conducted on 40 species as part of GLORIA, however, additional input from local and regional experts is required to refine the species list and further the assessment. The workshop participants agreed that the assessment methods demonstrated by the GLORIA team would be useful for Madagascar, especially because of the general lack data on the species in the region. Workshop participants were asked to indicate if they would be interested in being involved in taking the preliminary species sensitivity assessment for southwest Madagascar further. Decisions now need to be made on which important fishery species to include in the assessment, followed by the expert scoring and expert review process.

It was agreed that, considering the number of different vulnerability assessment methodologies that have been applied in Madagascar, a formal review of the different approaches and methodologies for biological and ecological sensitivity is urgently needed to enable recommendations on an integrated, common methodology to use throughout Madagascar to be made.

4.2.2. Background information on activity content

The notion of vulnerability has emerged as a central organizing concept for research on climate change (see Polsky et al., 2007). Assessments of vulnerability to climate change are aimed at informing the development of policies to reduce risks associated with climate change (Fussel and Klein, 2006). As pointed out by Fussel and Klein (2006), information on WHAT to adapt to and HOW to adapt, and the resources to implement such adaptation measures are essential for effective adaptation. Vulnerability assessments are key to identifying these components, and are performed to (Fussel and Klein, 2006):

- increase the scientific understanding of climate-sensitive systems under changing climate conditions;
- inform the specification of targets for the mitigation of climate change;
- prioritize political and research efforts to particularly vulnerable sectors and regions; and
- develop adaptation strategies that reduce climate sensitive risks independent of their attribution.

Generally, three components of vulnerability are assessed: exposure, sensitivity and adaptive capacity. Together with Blue Ventures, WWF Madagascar has developed a report (Gough, 2012) on methods for assessing the vulnerability of traditional fisheries to climate change. Included in this methodology is an ecological assessment, a fisheries landings assessment and a socio-economic assessment in which susceptibilities are established using key indicators (allocated Low (1), Medium (2) or High (3), with respect to exposure, sensitivity and adaptive capacity variables). An assessment such as this allows scores to be compared between sites to determine which sites should be prioritized. Analysing each component and the levels of grading can help managers to determine ways in which to improve the adaptive capacity or sensitivities of these components through management activities. Currently, this assessment has been trialled in three locations along Madagascar's coastline.

This methodology, which was developed to conduct vulnerability assessments for traditional fisheries of Madagascar, was critically assessed in terms of its validity and specificity by Harding (2013). The current method is designed to assess the impact of climate change on fisheries particularly on reef fish populations but is not able to measure the impacts of other climate stressors, which could also be on other species or fish habitats. Other fisheries targets in the same ecosystem, such as invertebrates or non-reef finfish, are currently also not part of the vulnerability assessment. A number of suggestions were provided to improve the methodology for this specific combination of ecosystems, climate stressors and fisheries in Madagascar. One suggestion being to modify the methodology to assess a particular target species or assemblage (e.g. shrimp, lobster, sea cucumber, shark, octopus) rather than constructing a vulnerability assessment for the whole ecosystem in question (Harding, 2013). The current situation for small-scale fisheries in Madagascar is not promising and Madagascar has reached a critical point in the status of its marine fisheries (Harding, 2013). Although prioritization may be difficult when there are extensive information gaps, Harding (2013) recommends that it is essential to focus on the ecosystems most vulnerable to climate change, and the coastal populations with the greatest reliance on marine resources and the least adaptive capacity. He further recommends, in terms of fisheries management, efforts should focus on those fisheries that are the most important to fishing communities in terms of providing food and income (e.g. reef fish, sea cucumber and octopus for the southwest).

The rapid fisheries species sensitivity assessment, developed by Pecl et al. (2014), may not only be a useful complement to the methods already employed by WWF in the Western Indian Ocean Region, but may also be useful in identifying priority fishery species for further study and resource allocation. The value of this approach in identifying knowledge gaps and priority species for further ecological assessment was demonstrated on key Australian fishery species (Pecl et al., 2014). The rapid assessment method has also been adapted by the National Oceanic and Atmospheric Administration (NOAA) and applied to fish and shellfish fishery species (Morrison et al., 2015), and by Canadian researchers who performed the assessment on 43 West Coast Vancouver Island species (Hunter et al., 2014). The NOAA methodology included not only sensitivity, but also exposure.

4.2.3. Outline of the way the activity was presented

Presentations and discussions on existing approaches to climate change vulnerability assessments were undertaken. Workshop participants identified areas where more work may be required to resolve any uncertainties surrounding vulnerability to climate change and identify the key drivers and life cycle stages that determine high vulnerability.

Presentations:

The following presentations were made:

i) Methods for assessing species sensitivity or vulnerability to climate change

Presentation delivered by Harisoa Rakotondrazafy, WWF Madagascar.

ii) Methods applied by WWF Madagascar and Blue Ventures for biological and ecological factors Madagascar Early Warning System

This presentation by Manakasina Todisoa, BNCCC, summarised the methods described in Gough (2012) Methods for assessing the vulnerability of traditional fisheries to climate change: Part of the Capacity for adaptation to Climate Change, Madagascar.

iii) Methods for assessing species sensitivity or vulnerability to climate change

Presentation delivered by Gretta Pecl, University of Tasmania.

Previous vulnerability assessments have done an excellent job in examining the vulnerability of Malagasy habitats, regions and fisheries to climate change. A number of gaps/priorities were also identified, namely: effects of climate change on main target species, sustainable fishing levels for targeted resources and projected climate change impacts on important species. As many species are fished in Madagascar, it would be impractical to address gaps for all of these species. A useful complement to existing WWF/BV reports could be to identify those species most sensitive to climate change.

The purpose of the species sensitivity assessments is to identify any of: regions with the greatest concentration of sensitive species; the most sensitive species within a particular region; and priorities for monitoring, management action and further assessment. Assessments can be correlative, projecting future distributions based on niche models; mechanistic, using laboratory and field observations together with detailed and data intensive models; or trait based, using biological characters as a predictor of risk.

A trait-based approach for assessing relative species sensitivity within regions has been developed and applied in South East Australia, and repeated in northern Australia and West Australia (total of approximately 120 species). The assessment is built on Ecological Risk Assessment for fisheries approach (Hobday et al., 2011), and in addition to Australia has been adapted and applied by NOAA and Canada, and currently also Brazil, India and South Africa. Climate change driven alterations in the distribution and abundance of marine species, and the timing of their life history events (phenology), are being reported around the globe. The assessment of ecological sensitivity of species to climate change is based on attributes that estimate potential for changes in abundance (measures of potential for biological productivity), distribution (measures of capacity to shift) and phenology (measures of potential impact on timing of life cycle events) attributes. Each attribute is assigned a score (e.g. Figure 4.2), the totals are summed and the species ranked (Figure 4.3).

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change): High sensitivity (3), low capacity to respond (higher risk)	Medium (2)	Low sensitivity (1), high capacity to respond (lower risk)
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	<2 weeks or no larval stage	2–8 weeks	>2 months ★
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	<10 km ★	10–1000 km	>1000 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	<10° latitude ★	10–20° latitude	>20° latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	No unoccupied habitat; 0 – 2° latitude or longitude ★	Limited unoccupied habitat; 2–6° latitude or longitude	Substantial unoccupied habitat; >6° latitude or longitude

Figure 4.2: Scores for South East Australia Rock lobster distribution attributes.

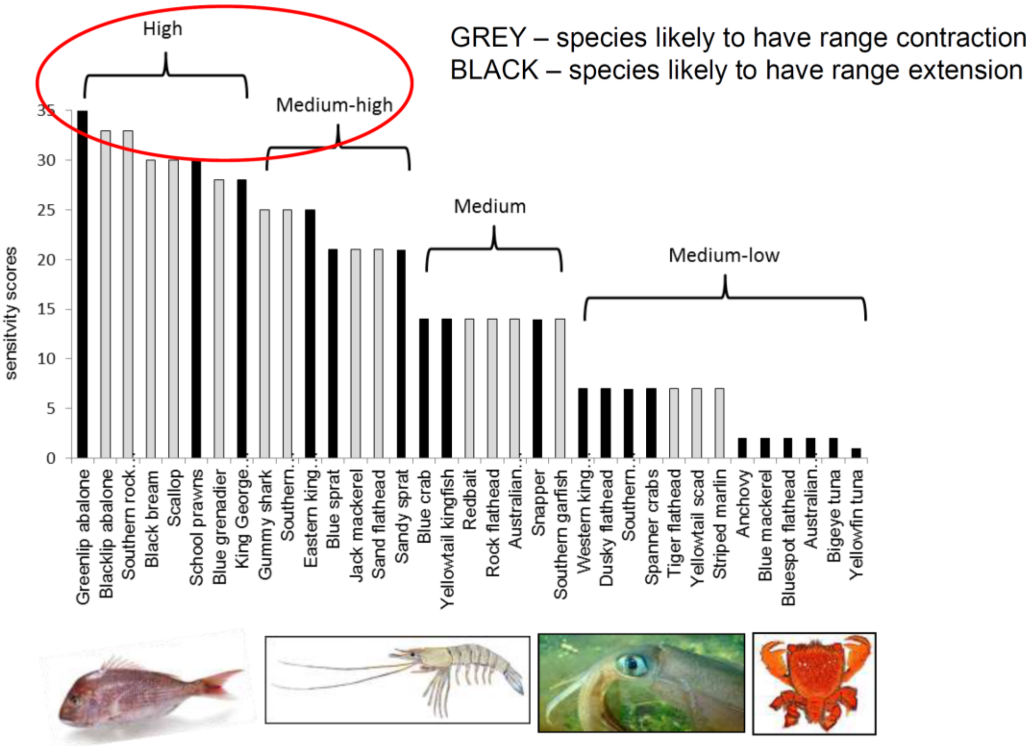
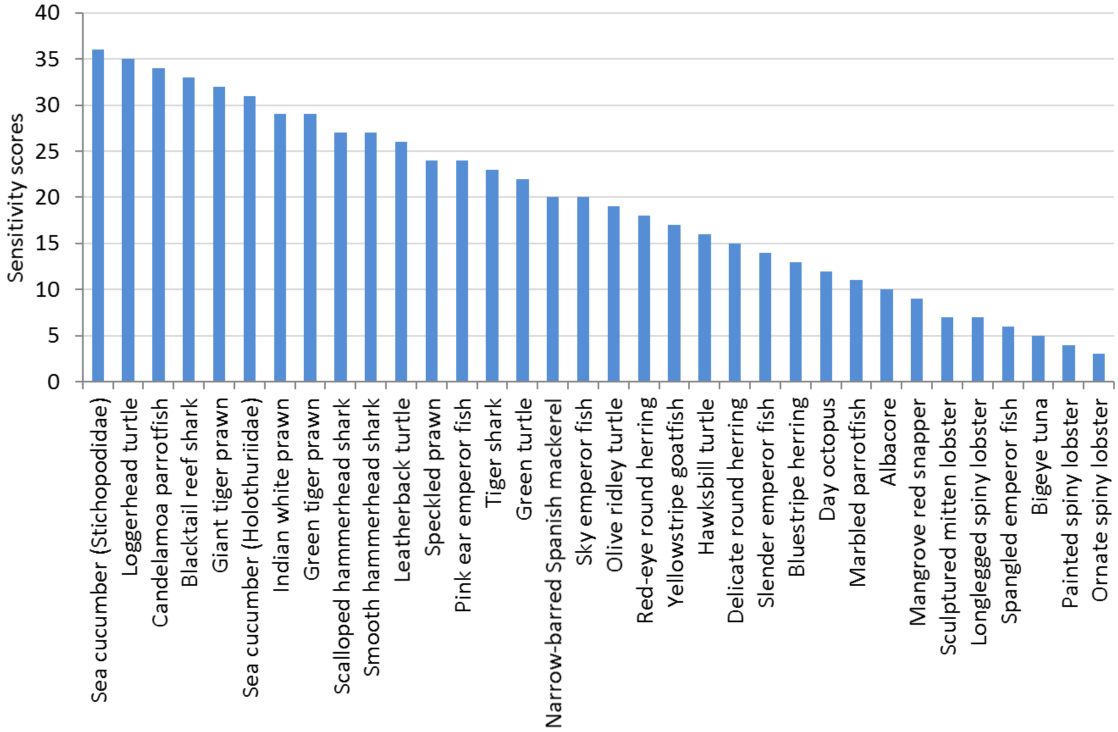


Figure 4.3: Relative species sensitivity rankings for South East Australia.

As with all methods and approaches, the trait-based approach has several weaknesses and strengths. The trait-based sensitivity assessment is transparent, repeatable and rapid, and thus can quickly identify priorities. It is particularly useful in data or resource limited situations. However, the precise sensitivity threshold of each trait is unknown; all traits are weighted equally when the weighting or choice of traits may not be appropriate for all species, and it is not designed for all species (e.g. it may not be suitable for species like turtles). Additionally, the assessments need to be reviewed by those with local expertise.

A preliminary species assessment for Southwest Madagascar has been conducted on 40 species (Figure 4.4) as part of GLORIA; however, additional input from local and regional experts is required to refine the species list and further the assessment. The preliminary assessment highlighted the need to adapt certain attributes to make it relevant to the Madagascar region and species (Table 1). It was also noted that an assessment that dealt specifically with potential of species to change distribution within Madagascar could be useful to identify species at risk of moving out of Madagascan waters and new species that may become more common in regions from which they were previously absent.



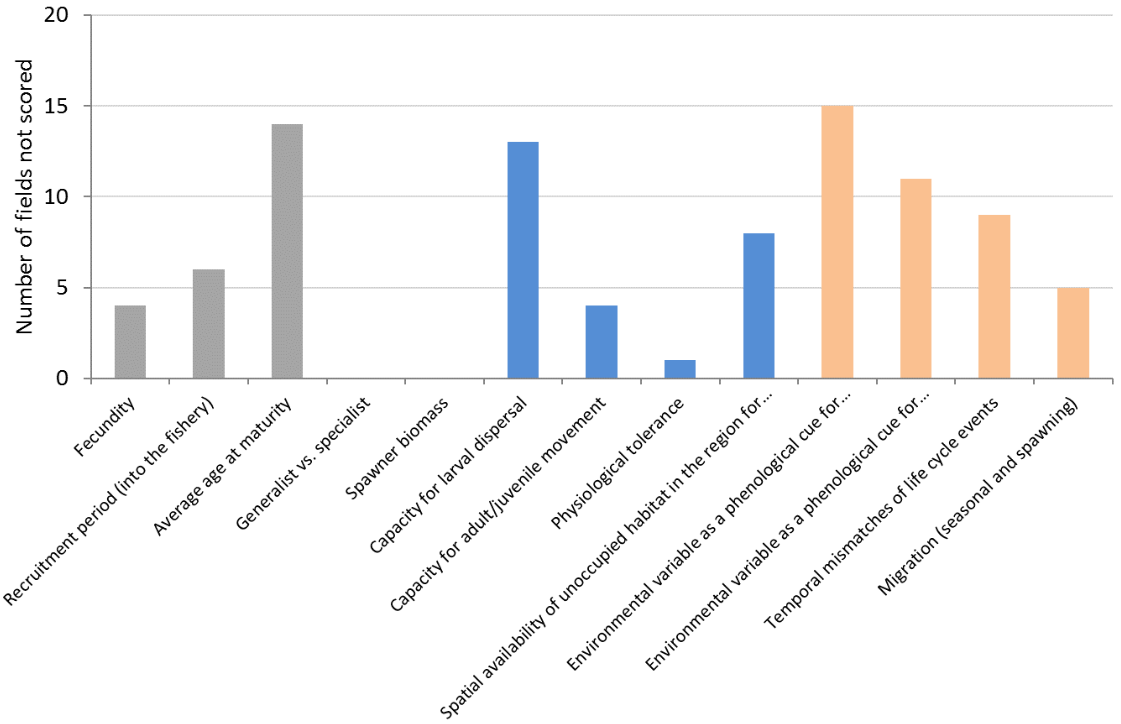


Figure 4.4: DRAFT results of the preliminary Malagasy species sensitivity assessment (top). Although over 100 literature resources were examined for the assessment, there were still significant data gaps (bottom), thus review by local experts is particularly important.

Table 1: Attributes used in the trait-based sensitivity assessment for Madagascar, modified from Pecl et al. (2014).

Attribute		**Category**		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium (2)**	**High sensitivity (3), low capacity to respond (higher risk)**
Abundance	Fecundity – egg production	>20,000 eggs per year	100–20,000 eggs per year	<100 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Consistent recruitment events every 1–2 years	Occasional and variable recruitment period	Highly episodic recruitment event
	Average age at maturity	≤2 years	2–10 years	>10 years
	Spawner biomass	robust	uncertain/vulnerable	threatened
	Generalist vs. specialist – food and habitat	Reliance on neither habitat or prey	Reliance on either habitat or prey	Reliance on both habitat and prey
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	>2 months	2–8 weeks	<2 weeks or no larval stage
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	>1000 km	10–1000 km	<10 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	>20º latitude	10–20º latitude	<10º latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	Substantial unoccupied habitat; >6º latitude or longitude	Limited unoccupied habitat; 2–6º latitude or longitude	No unoccupied habitat; 0 – 2º latitude or longitude
Phenology	Environmental variable as a phenological cue for spawning or breeding – cues include salinity, temperature, currents, & freshwater flows.	No apparent correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	Strong correlation of spawning to environmental variable
	Environmental variable as a phenological cue for settlement or metamorphosis	No apparent correlation to environmental variable	Weak correlation to environmental variable	Strong correlation to environmental variable
	Temporal mismatches of life-cycle events – duration of spawning, breeding or moulting season.	Continuous duration; >4 months	Wide duration; 2–4 months	Brief duration; <2 months
	Migration (seasonal and spawning)	No migration	Migration is common for some of the population	Migration is common for the whole population

Questions raised for group discussions included:

- Is a species sensitivity assessment a useful complement for Madagascar?
- If so, how would we adapt the approach to best fit?
- Can we revise the species list to make it more relevant to SW Madagascar?

4.2.4. Discussions and outcomes of the activity

The workshop participants agreed that assessment methods demonstrated by the GLORIA team would be useful for Madagascar because of the lack of regional species specific data. Indeed, one advantage of this method that was discussed was the theory underpinning the categories and that information for similar species or same species from different regions could be used. However, local expert opinion is also essential when data or information are not available or known. A suggested improvement to method would be to include ‘exposure’ (and not only ‘sensitivity’) in the assessment, although this may be outside the resourcing for the current project. Implementing this improvement would involve identifying the range for each exposure measures relevant to Madagascar (e.g. coral bleaching). It was also noted by workshop participants that assessing exposure would be complementary to the eco-system vulnerability assessment developed by Blue Ventures. A number of participants expressed interest in contributing to a species sensitivity assessment adapted to southwest Madagascar. A key next step for future work would be to investigate ways to integrate both the methodologies presented, and other methodologies that may exist but were not discussed at the workshop, into an integrated approach for Madagascar. A suitable approach that integrated exposure and sensitivity may be similar to that described in Hare et al. (2016), which can be found at http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0146756).

4.2.5. Recommendations for future research and activities

Expert opinion is an important component of the species sensitivity assessment methodology. Scores for sensitivity attributes are allocated by experts using scientific literature as well as expert knowledge. Although scores can be allocated by individual experts, to eliminate bias, scores should also be allocated by expert groups. To advance the preliminary species sensitivity assessment for southwest Madagascar, workshop participants interested in being involved were identified at the workshop.

Decisions then need to be made on which important fishery species to include in the assessment, followed by the expert scoring and expert review process.

Interested participants will also have the opportunity to co-author the publications resulting from the species sensitivity assessment.

Considering the number of different vulnerability assessment methodologies that have been applied in Madagascar, a formal review the different approaches/methodology for biological/ecological sensitivity is urgently needed to enable recommendations on an integrated/common methodology to use throughout Madagascar to be made. WWF reported that a dedicated workshop was to be organised in the near future on the VA assessment methodology developed by BV&WWF and the report on the vulnerability of Madagascar traditional fisheries to climate change.

4.3. Activity 4 - Conceptual models of key ecological assets, processes and drivers

Convenors: Éva Plagányi and Ingrid van Putten (Australia), Tom Chaigneau (United Kingdom). David Obura (Kenya) contributed to the development of this activity but was unable to attend the workshop.

4.3.1. Summary

The participants in this activity agreed that there would be high value in the development of models of the Madagascar coastal biophysical systems as a means to improve understanding of system functioning and to allow for simulation of the benefits and other impacts of alternative management strategies. This would help in assembling an integrated overview of Madagascar's coastal resources, and the dependencies and vulnerabilities of those resources. Conceptual models assist in the synthesis and communication of current understanding and knowledge of key ecological assets, processes and drivers. Such models are also a valuable tool to predict how a system will respond to disturbance or perturbation, in order to guide management interventions (Dambacher et al., 2009).

During the workshop, two qualitative, mathematical conceptual models were developed with the participants, using as examples the octopus fishery and crab fisheries. The development of the conceptual models helped to provide a holistic, integrated understanding of the fisheries. With such models, simulations could be run to evaluate and compare the effectiveness of alternative management strategies. The participants in the activity noted that it would be advantageous to develop spatial models to explore the potential benefits of alternative spatial and temporal closure regimes for the octopus fishery. Participants agreed that the octopus fishery provides a useful example of a climate change winner (i.e. not all climate change impacts are bad) and hence that careful management at all levels is necessary to ensure that communities continue to benefit from optimal utilization of this resource without negatively impacting the future sustainability of the octopus fishery. The model of the crab fishery demonstrated the complex interactions that take place between different climate drivers and the crab fishery, as well as the interactions between the crab and the shrimp fishery. Participants highlighted the need to include differences in crab habitat between front and back mangroves in the model and that these are affected differently by climate drivers.

The participants agreed that a project on the development of models of fisheries in Madagascar would be useful. Production of qualitative models of the marine and coastal ecosystems of Madagascar will facilitate cross-comparisons with other similar southern hemisphere ecosystems, and particularly other hotspot regions. Conceptual and qualitative models can also facilitate the future development of more complex marine system models to support natural resource management in the region. The development of a toolbox of modelling approaches (conceptual, qualitative, and quantitative) as a tool for supporting integrated decision making was encouraged. A key requirement is to collect data on key resources harvested and especially to establish total amounts removed.

4.3.2. Background information on activity content

The GLORIA and related GULLS projects acknowledge that climate change will increasingly impact human populations worldwide, both directly, for example, by inundation of infrastructure as a result of rising sea levels, or indirectly, for example, by impacts on individual physiology and life history or warming ocean temperatures that lead to shifts in the distribution and abundance of marine species (Doney et al., 2012; Hobday et al., 2016). Extreme events such as cyclones are also projected to become more intense under climate change (Walsh et al., 2004). In parallel increasing coastal development and population growth coupled with the need for sourcing food and income sources from the ocean will likely add further pressure to the marine environment (Plagányi and Hobday, 2015). With these changes looming ahead, there is an urgent need to start developing climate-smart adaptation strategies (Stein et al., 2014; Plagányi and Hobday, 2015) to support future ocean management. Ecological simulation models are useful tools to road-test climate-smart management responses, strategies or to inform the design of adaptation options (Plagányi and Hobday, 2015).

This session commenced with an overview of different model types and their uses, based on Plagányi (2007). In general, models are representations of a system that can be used to synthesize understanding and make predictions. An advantage of models is that they can simulate alternative scenarios (cf flight simulator) and predict the impact of management actions that would be difficult to achieve in the real world. Different models have different objectives as summarised below (FAO, 2008):

Conceptual/Conceptuel: of the structure, functioning and interactions of the ecosystem. May not be used explicitly in decision-making or scientific advice. Forms underlying context for any detailed management planning and decision-making

Strategic/Strategique decisions: linked to policy goals and are generally long-range, broadly-based and inherently adaptable

Tactical/Tactique decisions: aimed at the short-term (e.g. next 3-5 years); operational objective in the form of a rigid set of instructions e.g. tactical decisions regarding setting a catch quota.

There are a range of model types used in marine fisheries and ecosystem management, ranging from simple to complex, qualitative (descriptive, conceptual drawing), through to semi-quantitative and quantitative (involving numbers, statistics), as well as differences in terms of whether models focus on mechanistic understanding or are dynamics process models fitted to data using statistical theory. Different models can be mapped along axes describing the level of detail in representation of physical, biological and human complexity (Plagányi et al., 2011). An example was provided of the toolbox of modelling approaches being used in Australia, covering the full range from simple to complex, qualitative through semi-quantitative to fully quantitative. Multiple models of the same system are considered ideal where feasible (Fulton and Smith, 2004; Plagányi, 2007; Plagányi et al., 2011).

It was also noted that in countries such as Australia, Ecosystem Approaches to Fisheries management (EAF) has also broadened to Ecosystem-Based Fisheries Management (EBFM) with a much broader focus that considers multiple sectors, industry, mining and so forth. Moreover, there is increasing incorporation of economic and social factors in models, and models increasingly need to come to grips with merging fisheries and conservation science. Lastly, it was noted that although the goals of EAF can be accomplished in some cases without the need for models, use of appropriate models and Management Strategy Evaluation (MSE) (Smith et al., 2007) is widely accepted as a key tool for advancing an EAF approach (Levin et al., 2009; Link, 2010). This is also considered best practice by the FAO (FAO, 2008). MSE is an ideal tool because of its ability to account for uncertainty as well as make explicit the trade-offs between diverse societal objectives (for example Fulton et al., 2011; Plagányi et al., 2013).

An overview was provided of "Models of Intermediate Complexity for Ecosystem assessments" (MICE) (Plagányi et al., 2014). MICE have a tactical focus, including use as ecosystem assessment tools. MICE are constructed to be context- and question-driven and they restrict the focus to those components of the ecosystem needed to address the main effects of the management question under consideration (Figure 4.5). A key to the success of MICE, and indeed any modelling approach, is that it involves stakeholder participation and dialogue. MICE estimate parameters through fitting to data, use statistical diagnostic tools to evaluate model performance and account for a broad range of uncertainties. These models are thus able to address concerns that have been raised as to greater use of ecosystem models in strategic and particularly tactical decision-making for marine resource management and conservation.

Whereas much effort has been invested in identifying ecological indicators and developing whole-of-ecosystem models that support strategic planning, much less attention has been given to developing tractable (smaller or intermediate scale) models where uncertainties in simulations are encapsulated in risk assessments. The MICE approach has advantages in terms of being able to construct a tool reasonably rapidly to assist with scientific decision making. In the context of Madagascar, MICE models could be used to construct quantitative models answering specific questions regarding part of the ecosystem (e.g. pelagic or coral reef systems, or single target species and their interactions), based on the information generated by the qualitative modelling. Tactical adaptive management will benefit greatly from such models as a result of the ability to assess complex interactions and uncertainties and as a tool to facilitate sustainable management of natural resources, particularly in the coastal and marine realm.

An example was presented showing the use of a range of models to understand and inform management of Crown of Thorns Starfish (COTS) outbreaks on Australia's Great Barrier Reef. The first step entails constructing one or more conceptual models to synthesize understanding of the system drivers and interactions, as shown in the example in Figure 4.6. Examples were then presented of qualitative models developed for the system (Babcock et al. 2016), with a range of alternatives being used to explore alternative hypotheses, and finally a fully quantitative MICE model that was fitted to available data (Morello et al., 2014).

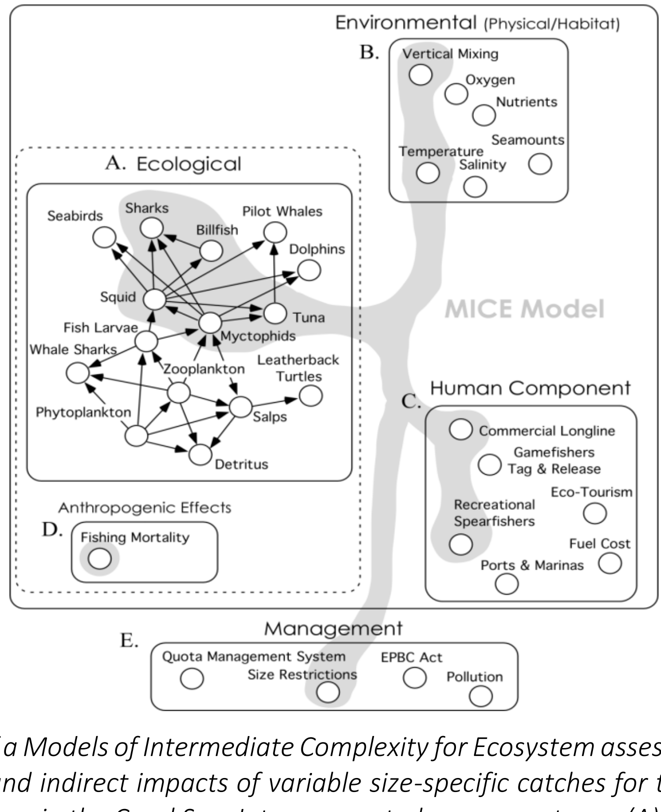


Figure 4.5: Overview of a Models of Intermediate Complexity for Ecosystem assessments (MICE) example illustrating the direct and indirect impacts of variable size-specific catches for tuna, sharks and billfish by commercial long-liners in the Coral Sea. Inter-connected components are (A) Ecological information, including multispecies trophic or competitive network and spatial habitat processes; (B) Environmental information, including physical and habitat drivers of ecological processes; (C) Human components of the system, including different fishing sectors and their behaviors, other stake-holders and economic

drivers; (D) Anthropogenic effects, including fishing mortality; and (E) Management, including input and output controls as well as other environmental policies (from Plagányi et al., 2014).

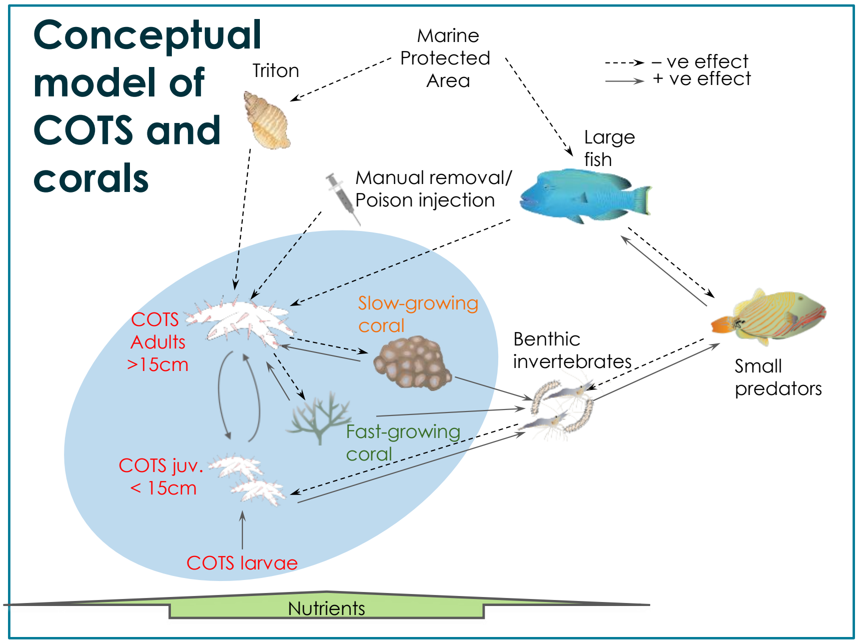


Figure 4.6: Example conceptual model showing the main factors involved in Australia's Great Barrier Reef (GBR) Crown of Thorns Starfish (COTS) outbreaks (from Morello et al., 2014). The shaded ellipse represents the interactions included in the base-case model (COTS larvae, COTS juveniles, COTS adults, fast-growing coral and slow-growing coral); the empty ellipse includes additional drivers of COTS numbers tested in the projections. Symbols are courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

4.3.3. Outline of the way the activity was presented

The workshop focused on identifying key species, climate drivers, linkages and dependencies for selected Madagascan marine ecosystems, as a basis for identifying key focus areas to develop models to support decision making. Given limited time, the workshop focused on collaborative development of two conceptual and qualitative models as a first step in this process.

Workshop participants were first asked to identify key species, climate drivers, linkages and dependencies for Madagascan systems of interest. The discussion took into account earlier presentations describing projected climate change variables (Activity 2) as well as ecological sensitivity assessments (Activity 3), which identified some of the most vulnerable species. Participants also discussed which species are economically and socially important, taking into account considerations such as gender and food security. A number of key resources were discussed, including octopus, sea cucumbers, lobsters, seaweed, crab fisheries and reef fish. It was decided collaboratively to focus in the first instance on the octopus fishery and crab fisheries and to link these examples to discussion around supply chains and vulnerability as for Activities 5 & 6.

For each example, key processes and components were identified, considering not only the focus species but also any other related species, important physical drivers and processes influencing these species, and the use and users of the resource. These nodes were drawn on a whiteboard and participants asked to comment on the direction and strength of connections between components in order to develop a conceptual model of the system. It was noted that connections between model components could be weak or strong, and also negative or positive, and it was important to distinguish between these. Drawing a conceptual model in this way provides a framework for a more formal qualitative model as described below. An example was also provided as to how the conceptual model could be developed further into a quantitative model – in the first instance based only on available information/knowledge with the possibility of refining as more data and information become available.

Qualitative mathematical models (Levins, 1998) formally describe the relationships that connect ecosystem variables (Dambacher et al., 2009). These models contain only the sign (+,-,0) of interactions between components and do not account for the strength or precise magnitude of the interaction. The models are useful for understanding how the structure of a system affects its dynamics, and hence can be used, for example, to explore how a system responds to a perturbation (disturbance). Following established mathematical protocol, a matrix of interactions can be used to calculate the predicted direction of a response to a perturbation. The predicted signs are calculated as the net feedback cycles between a perturbed variable and the variable of interest. Qualitative models (sometimes in combination with quantitative models) allow the assessment of current and future ecological and socio-economic risks and can provide information on alternative adaptations, which will be useful for Madagascar climate change adaptation planning.

4.3.4. Outcomes of the activity

<u>Octopus Example</u>

For the octopus example, participants expressed a need to first summarize important life history information for this species, and this was captured on a whiteboard summary and a conceptual model developed as shown in Figure 4.7.

Participants collectively mapped key interactions, drivers and uses of octopus as shown in Figure 4.8. This information was used to construct a conceptual model of the system (Figure 4.9) as well as a qualitative model (Figure 4.10) that could be analyzed.

Octopus cyanea

- Reef associated, 0-60m
- Most octopus hunt at night but this species forages during day
- Juveniles rapidly form homes and defend these against conspecifics
- Life-span appears to be between 12 and 15 months from settlement
- Males may mate many times with several different females but do not appear to outlive females
- Grows at up to 6% per day
- Hatchlings 2-3mm and feed straight away on small crustaceans
- Females deposit from 100-1000 to several hundred thousand (eg up to 700,000) eggs (Van Heukelem 1983)
- 21 days for embryo development at mean temperature of 27.1°C (Van Heukelem 1973)
- Larval duration also at least 21 days, but others suggest significantly longer needed (up to months, as has been recorded for the similar *O. vulgaris* paralarvae) to explain the gene flow necessary between the widely spaced coral-reef habitats in the tropical Indian and Pacific Oceans (Villanueva and Norman 2008).

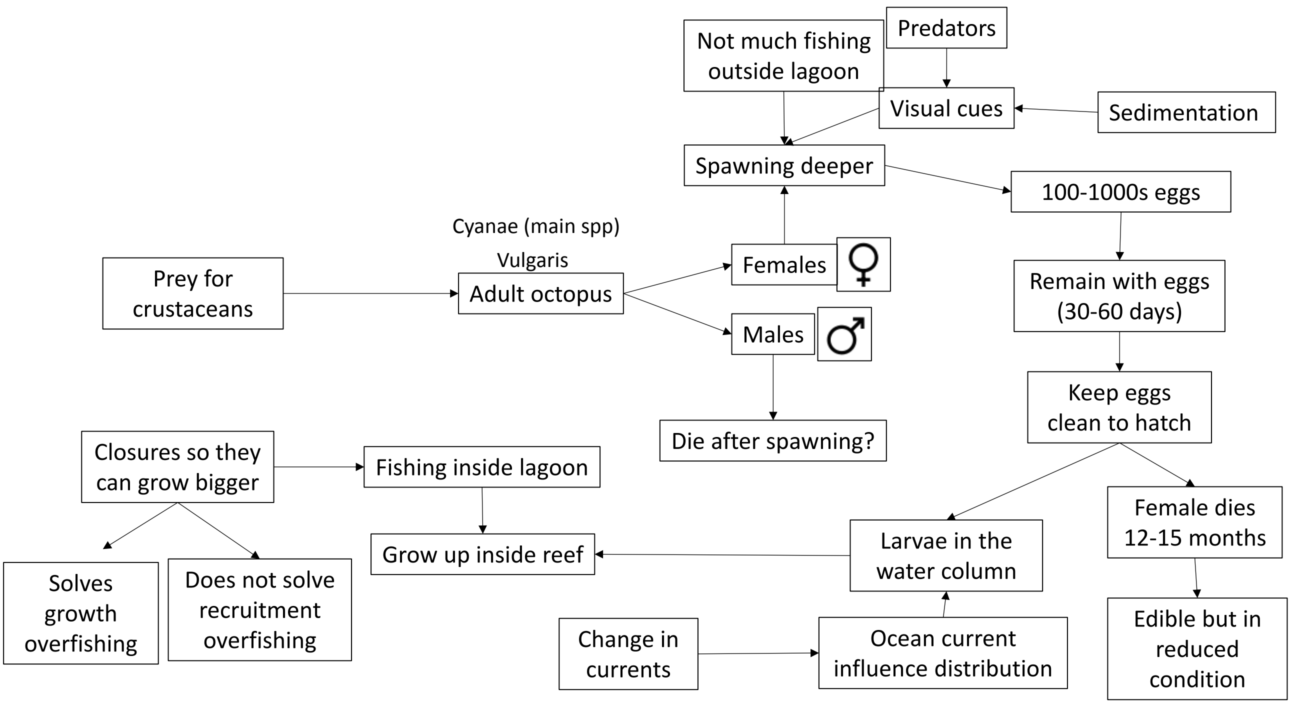


Figure 4.7: Summary of life history and fishery information for octopus example.

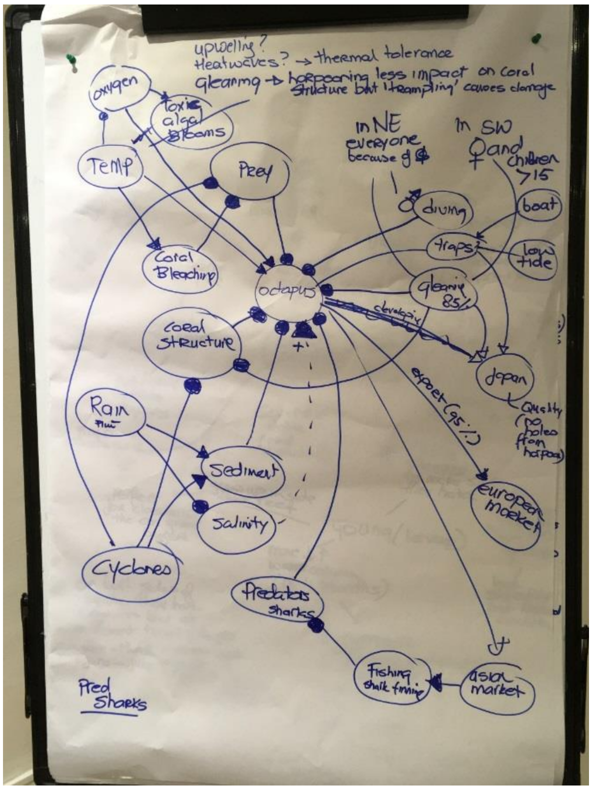


Figure 4.8: The conceptual model for octopus developed collaboratively with workshop participants.

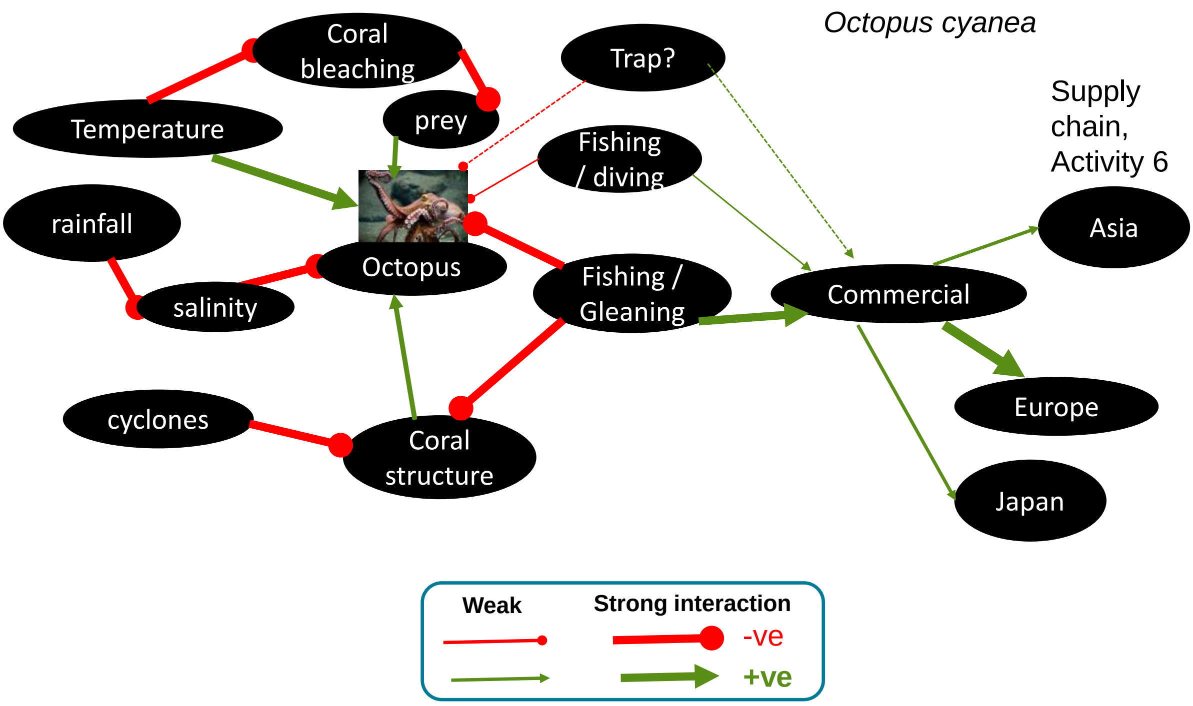


Figure 4.9: Schematic showing octopus conceptual model.

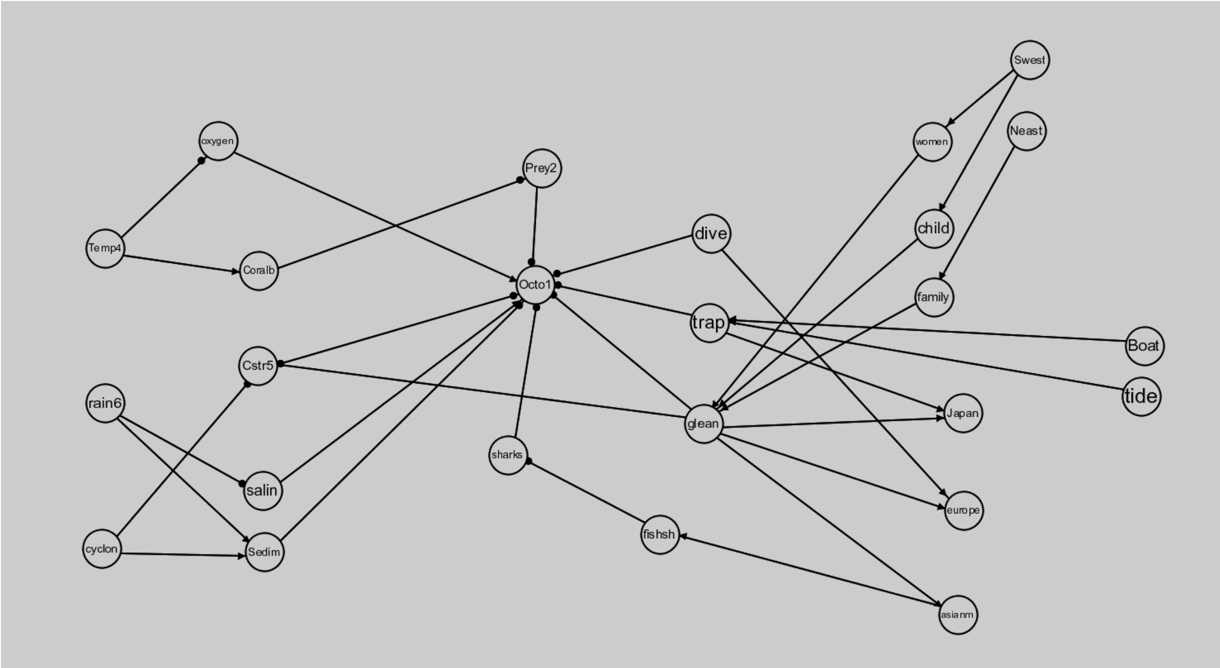


Figure 4.10: Schematic showing preliminary octopus qualitative model (note that the feedback system is incomplete and a stability analysis has not been carried out).

The octopus model highlighted the complexity of interactions and drivers in the coupled climate-fishery-human users system (Figure 4.10). A number of physical climate variables were identified that potentially impact on the octopus, with many of these impacts indirect: for example, rainfall influences salinity, which negatively affects octopus, which may then take refuge in deeper water and be less accessible to fishers. If rainfall increases and hence runoff increases, poor land management practices can exacerbate problems in the marine environment, for example, because of increased sediments, which could also cause problems for visual predators such as octopus. In addition to a direct positive effect of temperature on octopus (via the growth rate for temperatures within the thermal tolerance range for octopus), there is also an indirect negative effect if the elevated temperatures result in coral bleaching and hence negatively impact the prey of octopus. Similarly, cyclones indirectly negatively impact octopus through damage to coral structures that they rely on. An important relationship between the health of coral structures and the method of fishing was also identified, in that gleaning activities where fishers walk over the reef causes destruction to the coral structures and hence adversely affects octopus too. This was seen as a critical link for adaptation options that would not only enhance the current status of the octopus resource, but also build resilience to future climate change impacts. In some regions progress has already been made in implementing fishing methods (e.g. traps) that reduce negative impacts on coral structures when harvesting resources. Discussion also focused on the design of traps, highlighting, for example, that if lighter traps could be developed that do not require using a boat to set, then this would ensure that women who may not have access to a boat are not excluded from this activity and could set traps in shallow regions.

The development of even a conceptual model as in Figure 4.10 was helpful in synthesizing an integrated understanding of the octopus fishery, and in future model simulations could be run to evaluate and compare the effectiveness of alternative management strategies. It was noted that it would be advantageous to develop spatial models to explore the potential benefits of alternative spatial and temporal closure regimes. Workshop participants agreed that the octopus fishery provides a useful example of a climate change winner (i.e. not all climate change impacts are bad) and hence that careful management at all levels is necessary to ensure that communities continue to benefit from optimal utilization of this resource without negatively impacting the future sustainability of the octopus fishery.

A new paper published was of interest to workshop participants in terms of highlighting some of the characteristics necessary to sustain healthy ecosystems in the face of changing environmental conditions and socioeconomic drivers, with so-called "bright spots" identified as places where ecosystems are substantially better than expected (Cinner et al., 2016). Amongst other variables, bright spots are characterised by:

- Strong sociocultural institutions
- Taboo/Tenure
- Engagement
- Dependence
- Favourable environmental conditions
- Deep water refuge

These characteristics were considered encouraging in the case of the octopus fishery where there are some well-established tenure systems, engagement, strong dependence and the octopus has a deep water refuge because it moves to deeper water to spawn.

<u>Crab Example</u>

The crab conceptual model developed collaboratively is shown in Figure 4.11. The model highlights the complexity of interactions between different climate drivers and the crab fishery, as well as linked interactions with the shrimp fishery. Stakeholders also highlighted in the model differences in crab habitat between front and back mangroves, with these affected differently by climate drivers.

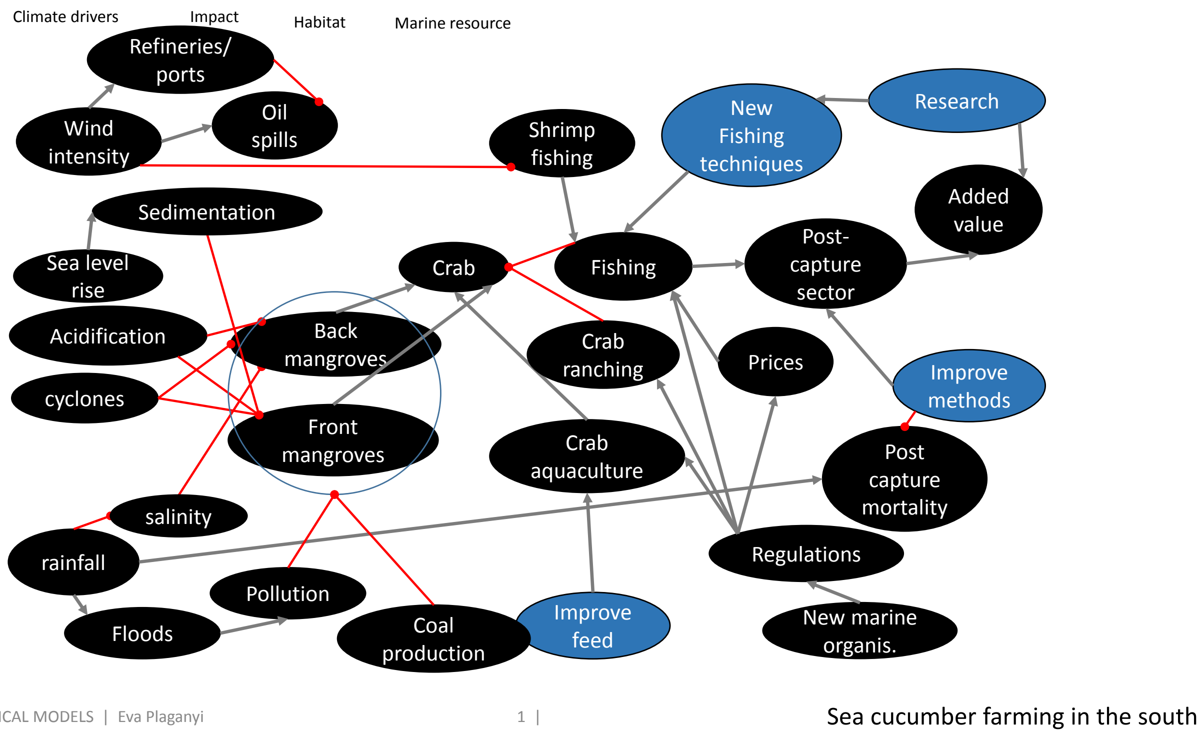


Figure 4.11: Conceptual crab fishery model developed by participants.

The proposed qualitative modelling project will enhance local capacity building by training local scientists in the art of conceptual and qualitative model development, as well as the potential applications and utility of these approaches.

4.3.5. Recommendations

Greater use of simple conceptual, qualitative and quantitative models could help in understanding the structure and dynamics of communities and fisheries holistically and in identifying important gaps and needs.

Models can be used to:

- Identify major challenges caused by climate change
- Help identify options for adaptation to the climate challenges
- Facilitate communication
- Develop recommendations for an action plan
- Make recommendations for priorities for future research

Identify major challenges caused by climate change (CC) facing coastal communities

- Ensure management is successful in maximising potential increases in octopus production and building resilience, e.g. by protecting reefs
- Climate change -related impacts, e.g. bleaching, damage to coral structure as a result of cyclones makes it even more important to minimise any human-related damage (e.g. via fishing methods) to protect ecosystems, leading to benefits for fisheries
- Changes in rainfall can affect the distribution, availability and possibly productivity of some species
- Changes in the start of dry/wet season can influence catch rates (availability) and prices paid for product
- Changes in trade winds make some fishing activities more difficult (e.g. prawn fishing) and hence a switch to other resources (e.g. crabs), which can lead to overexploitation and conflicts
- If rainfall increases and hence runoff increases, poor land management practices can exacerbate problems in the marine environment, e.g. because of increased sediments, which could also cause problems for visual predators
- Increased runoff can also lead to increased pollution, which negatively affects marine systems, and especially sensitive mangrove systems
- Major challenge is the cumulative impact of different stressors and hence with the knowledge that CC will increasingly negatively impact some systems, it is urgent to implement improved legislation and protection measures for marine ecosystems

Identify options for adaptation to the climate challenges (that are valid and acceptable)

- Explore alternative fishing methods that reduce negative impacts on coral structure when harvesting resources e.g. traps for octopus
- Explore types of traps, e.g. lighter design, that do not need a boat to set (and thus do not exclude women who could use them in shallower regions)
- Explore sustainable aquaculture solutions as well as improved feeds with low environmental footprint

Recommendations for an action plan

- Collect and analyse data (e.g. catch and effort) for as many resources as possible

- Use conceptual and other models to help identify important data gaps and needs
- Develop some general guidelines for building conceptual models as a tool to synthesize information and use as a framework for discussing adaptation options
- Review opportunities for value adding, also as a mechanism for compensating for reduced catches

Recommendations for priorities for future research.

- Further develop toolbox of modelling approaches (conceptual, qualitative, quantitative) as a tool for supporting integrated decision making
- Monitor changes in the marine ecosystem and dependent communities to severe and extreme environmental events to inform on expected responses under climate change
- Use conceptual or other models to holistically consider all linkages in a system from the physical variables through the ecosystem and along the supply chain to facilitate exploring the full range of potential management levers and adaptive solutions
- Collect data on key resources harvested and especially to establish total amounts removed

4.4. Activity 5 - Supply chains

Convenors/ *Présidente*: Ingrid van Putten and Éva Plagányi, CSIRO (Australia)

Tom Chaigneau, Exeter University (United Kingdom)

4.4.1. Summary

An integrated overview of Madagascar's coastal resources, dependencies and vulnerabilities would be incomplete without consideration of the fisheries (and aquaculture) supply chains. In particular, the interactions between those climate impacts that are already evident and future potential impacts starting at the ocean and ending at the markets and consumers need to be understood. Activity 5 was aimed at explaining quantitative measures or metrics that could be developed for fishery supply chains in Madagascar. The vulnerability of these chains to climate change impacts can then be identified and compared. The set of quantitative metrics discussed in this activity could be applied to any fishery in Madagascar, which would make it possible to identify the different vulnerabilities in the future. The method for presenting and evaluating a supply chain that was applied in the activity also allowed the participants to think about the importance of considering supply chains in vulnerability assessments. Formal approaches to conceptual assessment of supply chains also assists in understanding connections and identifying vulnerabilities alongside the more traditional supply chain evaluation aimed at creating or adding product value.

In Activity 5, a supply chain model was developed for the crab fishery in consultation with stakeholders. The conceptual, qualitative model of the crab fishery developed in Activity 4 was used as a basis for the supply chain model. The development of the model helped to highlight that the supply chain pathway is not the same for all fisheries and also not the same within each fishery. For example, in some cases fishers' wives may play a role in collecting fish from their husbands and re-selling it to others who then send it to sub-collectors, who in turn sell it to collectors who take it to Toliara and beyond. There are many intermediaries in the fishery chain: in summary they are fishers, fish sellers, buyers, collectors and exporters. The crab supply chain is impacted by the effect of climate change, for example through strong winds that prevent fishing from taking place and through causing delays in the timing for selling crab, which may impact markets. In addition, prices may change as a consequence of a shift in the dry season, with rains now starting earlier in the year than they used to.

The participants in the activity identified a number of priorities for research that are listed under 4.4.6 Recommendations, and also recommended an action plan that should include: the development of conceptual models of supply chains and the linkages between them for different resources (e.g. crab and shrimp) fisheries; that the supply chains should be analysed using the currently available and new quantitative methods; and that it is important to link and integrate research on the ecological and fishery systems with analyses of supply chains and studies on socio-economic wellbeing.

4.4.2. Background information on activity content

Supply chains for most fisheries start at the ocean and end at the markets and consumers. A supply chain is made up of "retailers, distributors, transporters, storage facilities and suppliers that participate in the production, delivery and sale of a product to the consumer" (Harland, 1996 quoted in De Silva, 2011). The difference between a supply chain and a value chain is that a value chain focuses on the components of the supply chain where value is created or added to the product. The supply chain's focus is on the interconnection of all the activities and not on the value.

Supply chains of species of different economic importance, such as tuna, crab, octopus and shrimp, are likely to be composed of a different number of nodes and different length chains before they end up with the consumer (De Silva, 2011). Species of different (or 'lesser') economic importance may be of high social or cultural importance and may have much shorter supply chains. The length, diversity and complexity of the supply chain may impact the resilience of the chain to changes and shocks and it is therefore important to understand the shape of fisheries supply chains.

Fishers face many risks in the context of climate change and assessment of their vulnerabilities is essential – but persons involved in the next step in the fisheries supply chain may be equally vulnerable. The actors involved in the supply chain are typically inter-dependent and need to manage a multitude of risks, such as supply variability, prices, demand etc. Determining vulnerabilities to climate and other changes in the supply chains of fisheries (and aquaculture) is key to underpinning adaptation to climate change. Disruptions to supply chain, transportation of supplies and products, and price structures of inputs such as fuel, can make fishing operations unprofitable or impossible. Increased awareness of the individuals, institutions and companies that make up a supply chain, and the markets and opportunities along the supply chain will benefit adaptation to climate change in the future (Hobday et al., 2014; van Putten et al., 2015).

Traditional supply or value chain analysis provides opportunities to identify strategic opportunities for structure change while facilitating and balancing resource use and sustainability (De Silva, 2011). There are numerous methodologies available for supply chain analysis, but traditionally these analyses have focused on identifying economic efficiencies and to a lesser extent vulnerabilities. In various industries supply chain processes have been driven by the marketing concepts developed (De Silva, 2011) such as the 4Ps of marketing or marketing mix: Product, Price, Place and Promotion.

Supply chains can be conceptually shown in a wide variety of ways (Figure 4.12 and Figure 4.13).

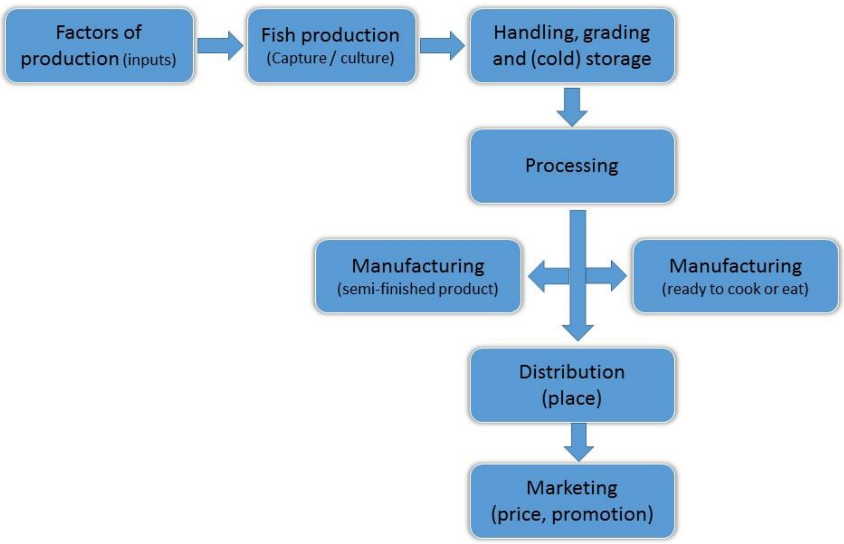


Figure 4.12: Conceptual model of key links in fish and fishery product supply chain (adapted from De Silva, 2011).

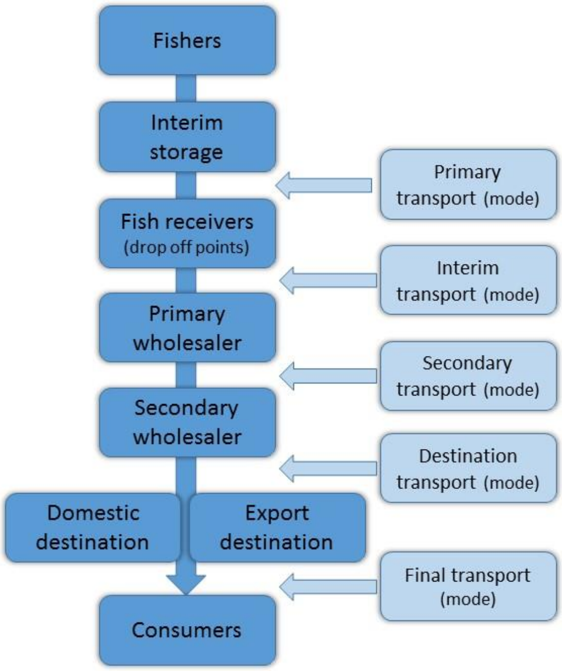


Figure 4.13: Conceptual model of fishery supply chain (adapted from Hobday et al., 2014).

Another way that the relationships between nodes of a supply chain can be shown is by focusing on the supply chain shape (linear or not), the number of nodes, and number of connections. Plagányi et al., (2014) developed a theoretical basis for comparing key features and critical elements in wild fisheries and aquaculture supply chains under a changing climate. The quantitative Supply Chain Index (SCI) metric (analogous to indices used to analyse food-webs) identifies critical elements as those elements with large throughput rates, as well as greater connectivity (example shown in Figure 4.14).

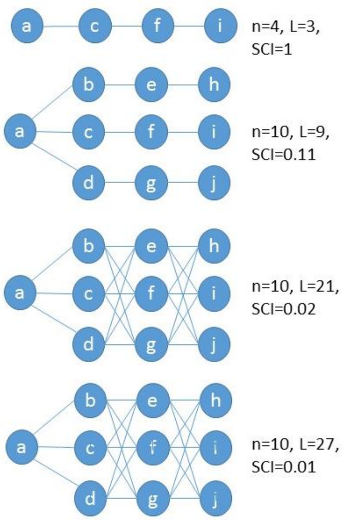


Figure 4.14: Schematic showing alternative hypothetical supply chain networks connecting producer / fisher (on the left) to final consumers (on the right). Each chain has n nodes, L links and the Supply Chain Index (SCI) is also shown, with lower values suggesting greater resilience to climate shocks (see Plagányi et al., 2014 for details).

The framework shows that the supply chain may be useful in identifying and understanding crucial vulnerability aspects in addition to the more traditional supply chain research that focusses on competitive strengths and core competencies in the marketplace (De Silva, 2011).

A number of supply chains have been developed for Madagascar fisheries, for instance, the Indian Ocean Commission (2015) for shark fin, Yvergniaux and Signa (undated) for crab, and Rasolofonirina et al., (1998; 2004; 2007) and Lavitra et al., (2008) for sea cucumber. As part of the Marine Stewardship Council (MSC) certification process supply chain information would have been gathered for the octopus fishery of southwest Madagascar, which has undergone a pre-assessment for MSC certification (Blue Ventures, 2015).

4.4.3. Outline of the way the activity was presented

Activity 5 was aimed at explaining quantitative metrics that could be developed for fisheries supply chains in Madagascar on which vulnerability to climate change impacts could be identified and compared. The quantitative metric can be applied to any fishery in Madagascar and different vulnerabilities can thus be identified in the future. This method for presenting and discussing a supply chain also allowed the participants to think about the importance of considering supply chains in vulnerability assessments.

In the first part of the activity, a presentation was given by the convenors of the activity entitled "Vulnerability assessment of fisheries supply chains" (chaîne d'approvisionnement pêcherie). The overall aim of the presentation was to outline the impacts of climate change on the fisheries supply chain and how this might affect Malagasy people. Examples of conceptual models of supply chains with different levels of complexity in terms of product flow were outlined (Figure 4.15).

Figure 4.15: Conceptual model of a supply chain with a certain level of complexity in terms of product flow (as presented at the workshop).

After the presentation of the theoretical framework for supply chain analysis an interactive session was held. The session made use of interpreters who translated from English to French. This made the 'interactions' somewhat tricky because of the delay and occasional subtleties that were lost in translation. This session (Activity 5) built on information gathered in the previous session (Activity 4) where a qualitative model was developed for the crab fishery (in addition to the octopus fishery).

The interactive session loosely followed a logical sequence as presented in a survey by the Indian Ocean Commission (2015). Supply chains structures were examined based on where the product is caught (a list of the villages), what happens to the products once landed, how often the product is landed, who buys the product directly from the fishers, and do the fishers sell to one buyer? Are there any sub-collectors, what are the transport routes, where does the product go then (in Madagascar), how is the product transported (4 x4, aeroplane), who on-sells the product, and what is the final destination of the product? The participants in the workshop contributed their views on available fishery catches and available supply chain details loosely following the above questions.

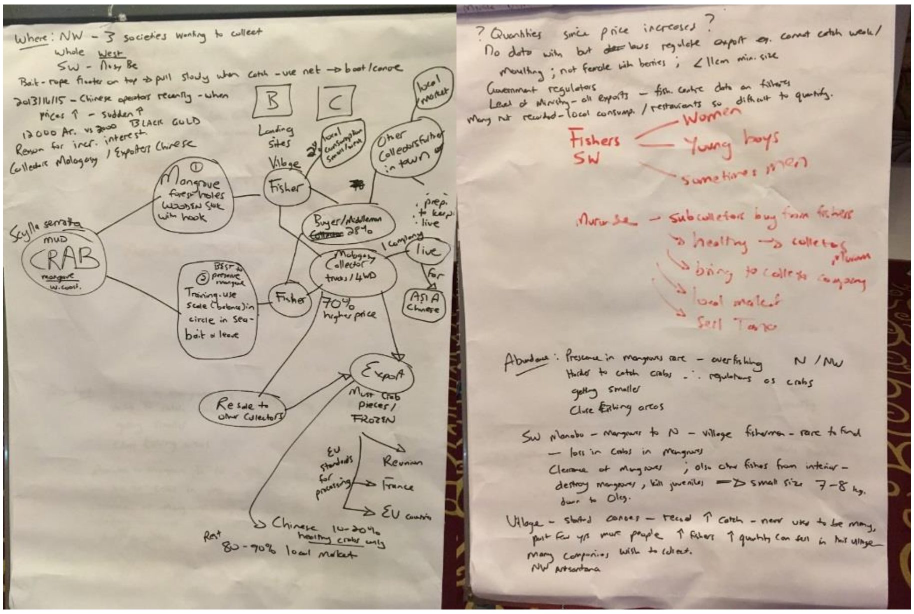
4.4.4. Crab Example

This aim of the activity was to identify vulnerabilities and strengths in fisheries supply chains, with the first step in this process being to conceptually map an example of a supply chain in a structured manner. This was then used as a basis for developing adaptation options, and some quantitative methods were described that could strengthen the analysis of potential strengths and weaknesses along the supply chain. Workshop participants collaboratively developed the supply chains and some adaptation options were discussed. Local capacity was built by training local scientists in the art of conceptual and qualitative model development, as well as the potential applications and utility of these approaches.

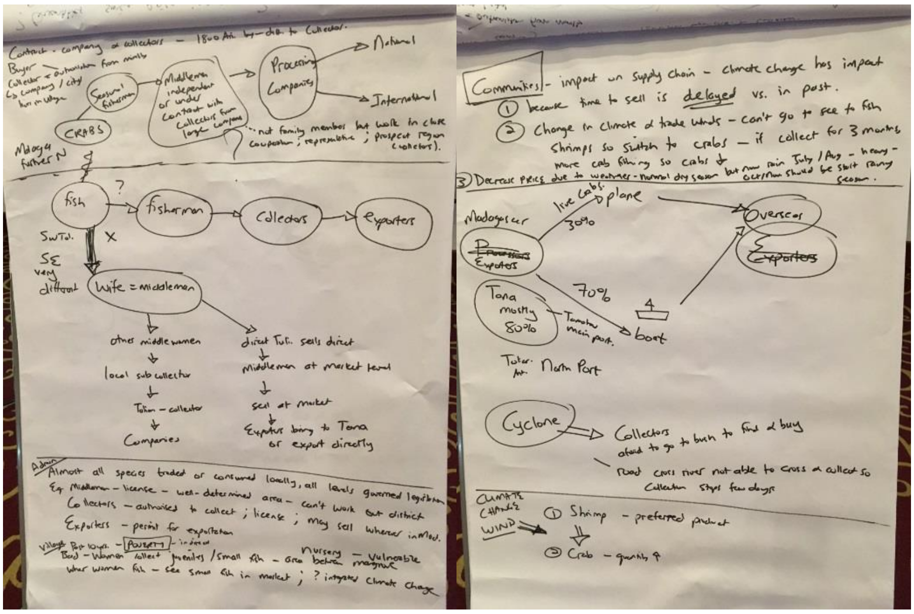
The crab model developed collaboratively in the modelling in Activity 4 (Figure 4.11) formed the basis of the development of a crab fishery supply chain model. Workshop participants indicated that after octopus, crab is the next largest export so it was an important example. There are multiple steps in the supply chain for crab between the fisher and the final consumer. The most important is the role of the fish collectors – these are middle men or women (often the wives of the fishers who collect and trade the fish). The middle men who buy the fish are generally not from the villages themselves but represent the companies in Antananarivo and who transport the perishable live product straight from the village to the capital city. Transport of perishable products from remote regions is complex and the main aim is to deliver the product as efficiently as possible.

It would seem that in Madagascar the supply chains of most reef species caught and landed in the smaller villages are similar to those developed at the workshop – especially where the involvement of the fish collectors and middle men/women is concerned.

The interactive session produced four schematic diagrams in which the details of the supply chain information for this species were noted. The pathway by which the product gets from the fishers to the final destination is shown in panels a) and c) (Figure 4.16).



a) b)



c) d)

Figure 4.16: notes taken at the workshop in Madagascar where participants developed a conceptual model of a crab fishery supply chain.

The model created for the crab supply chain identified vulnerability to climate change mainly in terms of the potential impact of extreme events impacting the transport of the product.

4.4.5. Outcomes of the activity

A vulnerability assessment is a search for potential weaknesses in the supply chain. In the context of climate change in the marine environment, these vulnerabilities may start in relation to changes in the resource (for example, in distribution, abundance and phenology – see Activity 3) but also as they occur in the supply chain (e.g. disrupted transport system). Categories of major risks have been identified for agricultural supply chains and they can be categorized as weather related risks and natural disasters (including extreme weather events).

Consumers are placing growing concerns on sustainability, and one way forward is to attain MSC certification. When fisheries attempt to get MSC certification, supply chain information is also required. For example this has been provided for the octopus fishery of southwest Madagascar, which has undergone a pre-assessment for MSC certification (Blue Ventures, 2015).

The specific project outcomes were (i) to identify inefficiencies and potential points for enhancing profitability (ii) the identification of strengths and weaknesses in the value chain, and together with the LCA, the development of adaptation options, and (iii) development of realistic adaptation management and policy options to enhance cost-effectiveness along the supply chain.

There are two main ways in which crab is caught in Madagascar. One is to go into the mangrove forests and to find the crab's burrows and use a pole with a hook to capture the crabs. The other way is to use a pot/trap with bait, which is set in the channels in the mangrove swamps. Mud crabs are found where there are mangroves, so all mangrove sites will have some crab catch.

Crab collection is of interest to people living in the North West and South West of Madagascar. In the South West it is mainly women and boys who go fishing for crabs. The abundance of crab is declining and they are getting increasingly rare in the North West as a result of the intensive fishing of crabs. The workshop participants expressed the need for management of this fishery and offered closures as a way to better manage crabs. For one village (in NW) that was monitored and used traps with bait there was evidently an increase in the number of crabs.

While the fishers are out collecting crabs, the collectors wait for the fishers to return and land the crab. Some but not all collectors will buy the crabs directly from the fishers. The collectors often have 4-wheel drive vehicles or lorries in which crab is transported. There are also sub-collectors who buy the crabs from the fishers and then sort the good quality crabs from the poor quality crabs. The high quality crabs are sold to the larger collectors who will choose the best for exporting. A small proportion of the catch (around 2%) tends to be small and low quality, and this will be sold on the local markets.

The price increase from catch to export is very large. Collectors either re-sell the produce to others who export the crabs or they may export the produce themselves. Collectors are Malagasy and are recognized by the national government and the ministry. However buyers are not recognised. The exporters often transform the produce and freeze it before exporting. Approximately 70% of the catch goes from the collectors to the buyers or processors. Ten to twenty percent of catch is healthy and suitable for live export to the Asian market. Most of the export goes to China. Information about the export is kept by the ministry and the government. Most live product is exported from Antananarivo by airfreight. The remainder is exported from the main ports by vessel.

The supply chain pathway is not the same for all fisheries and also not within each fishery. For example, fishers' wives may play a role in collecting fish from their husbands and re-selling it to others who then send it to sub collectors, who in turn sell it to collectors who bring it to Toliara and beyond. There are many intermediaries in the fishery chain. In summary there are fishers, fish sellers, buyers, collectors, exporters. All these types of exploitation have their own laws that are relevant to them. They each work in their own zones and at their own scales.

The crab supply chain is impacted by the effect of climate change. One of the effects is indirect and is a consequence of bad weather, particularly strong winds, preventing shrimp fishing from taking place. Shrimp is the preferred catch but crab is an alternative product for the community, captured only when shrimp fishing is not possible. So increasing crab fishing can be explained by the decrease in prawn fishing. It is a second string product.

A direct climate impact is that the timing for selling crab is being delayed and this may impact markets. In addition, prices may change as a consequence of a shift in the dry season. Rains are now starting in July/August whereas they should be starting in October/November.

The logistical disruptions from climate impacts are mainly that collectors will not travel to the more remote areas when there is rough weather. In addition there are several river crossings that are impassable at times of high rainfall. Obviously the fishers are not able to go out fishing in rough weather and during extreme events.

4.4.6. Recommendations

Recommendations for future research

The vulnerability assessment methodology as applied by past and current research in Madagascar is very comprehensive and only minor extensions are recommended. The main extension may be through inclusion of more detailed market and supply chain analysis, or more specifically, a supply chain vulnerability assessment. A supply chain vulnerability assessment can be undertaken at a business, industry, and sectoral level. In the case of reef fisheries in Madagascar the vulnerability assessment may be most useful at the sectoral level (because the path by which fish reaches the market seems to be similar for most reef fish species). However, for the offshore fisheries it may be more useful to undertake these supply chain analyses at the business or industry level. Another useful addition to the supply chain vulnerability assessment would include a spatial representation of the product pathways (i.e. showing the route to market and the quantities involved).

A supply chain vulnerability analysis will make any flow-on effects of impacts on the primary resource apparent. In particular, it will show the flow-on effect on processors and middle men/women who on-sell product. A formal supply chain vulnerability assessment will elucidate if it is robust to short and long term shocks. For instance, a middle man/woman may be able to sustain a temporary reduction in supply of fish because they are able to source other fish species or have alternative livelihoods. In contrast, a long term shock to the system may mean that processors move to other towns to source their fish, which means that the chain is broken and may be difficult to mend. Mapping the supply chains for not only reef fish but also the offshore fisheries this may be a useful addition to the vulnerability assessment already carried out.

From the literature around supply chain assessment in developing countries, it is apparent that strengthening of weak financial structures, focus on formal financial systems, reducing power imbalances in the governance structures, and resolving socio-cultural and environmental concerns are major priorities (De Silva, 2011). In addition, to improve welfare of fishing communities, good governance systems, protection of remaining stocks, stopping of illegal and unregulated fishing practices, and mitigation measures to climate change need to remain at the forefront (De Silva, 2011).

Identify major challenges caused by climate change (CC) facing coastal communities

- The major challenge for coastal communities in Madagascar in the context of climate change is that the effects will be felt not only by the resource itself but it will propagate all the way up the supply chain
- There is a need to understand the full supply chain and impacts
- Increase understanding of the links between inshore and offshore fishing and the interactions between large and small scale fisheries – over the whole fishery supply chain
- Precisely identify the key and critical links in the supply chain to ensure future resilience

Identify options for adaptation to the climate challenges (that are valid and acceptable)

- Assure the supply chain is flexible in terms of dealing with fluctuating quantities and that logistics can be adjusted accordingly.
- Alternative ways of processing fish locally (i.e. smoking fish) - capturing the value-added component and increasing durability.
- Find synergies between larger and smaller scale fishing operations to identify supply chain opportunities.

Recommendations for an action plan

- Develop conceptual models of supply chains and the linkages between them for different resources (e.g. crab and shrimp) for as many fisheries as possible
- Formally analyse these chains using existing methods, and where possible, new quantitative approaches such as the Supply Chain Index (SCI) described above.
- Link and integrate research on the ecological and fishery systems, with supply chain analyses and studies on socio-economic wellbeing.

4.5. Activity 6 - Modelling interactions between climate change adaptation, indigenous cultures and participation in fishing.

Convenors: Tomas Chaigneau (United Kingdom), Ingrid van Putten and Éva Plagányi (Australia)

4.5.1. Summary

In order to understand how ecosystem services can contribute to the sustainable alleviation of poverty it is necessary to understand and appreciate how changes to ecosystem services will affect communities in the future. At present a lot of the work on these topics focuses on current interactions between the environment and the services they provide to communities that depend on them, but little is done to examine how communities and their members will be affected by future changes to the environment. Activity 6 aimed to understand the vulnerability of individuals to the future environmental changes that had been identified in the other activities. It built on recent work carried out in East Africa through the project Sustainable Poverty Alleviation from Ecosystem Services (SPACES) and discussed with the participants how these environmental changes could affect the wellbeing of Malagasy communities and how they might cope or respond to such changes. The activity made use of presentations on social and economic activity and wellbeing, which were followed by group discussions on specific topics. In this way both conveners and stakeholders could learn from each other on the ways in which people and the coastal environment interact in Madagascar and about vulnerability of communities in the face of future environmental change.

Three specific sets of outcomes were obtained from this activity. The first was that discussions of the impacts of future environmental change on wellbeing, and which groups were potential winners and which potential losers for each scenario, led to the identification of indicators associated with vulnerability. A second outcome was that potential adaptation responses, and the repercussions for the environment of those responses were identified for each scenario. This was done through discussing peoples' responses to change and the likely impacts this will have on people and the environment. Finally, different ways to improve or facilitate appropriate responses and to increase adaptive capacity were recognized through discussions on how to help people respond to future environmental changes.

The activity agreed that there was a need for greater understanding of the wellbeing of people at the present time and how this is related to the environment and ecosystem services. This is necessary in order to assess which groups and individuals will be most vulnerable to future changes. With this improved understanding, it will become easier to plan and prepare more effectively for future environmental change impacts on those who are in most in need and most vulnerable. A number of research priorities to achieve this were identified and are provided in section 4.5.5. The following priority actions were also identified: to put mechanisms in place to train non-traditional fishers in sustainable fishing practices and techniques; and to encourage discussion and positive relationships between farmers and fishers to provide efficient transfer of mutually-relevant information between them. Such transfer would increase the likelihood that they would work together on future collective action.

4.5.2. Background information on activity content

The concept of vulnerability is a critical term to help us understand the susceptibility of individuals to future environmental change. It will help to prepare for climate change impacts and ensure "the effective and successful management of coral reefs as we move into the Anthropocene" (McLeod et al., 2008). One can consider the vulnerability of an ecosystem to future environmental changes (such as coral reefs) or vulnerability of the services that ecosystems provide (such as fisheries). However this activity considers social rather than ecological vulnerability and focuses on the vulnerability of associated communities and individuals.

Most research frameworks investigating vulnerability, consider three aspects (Gough, 2012; see Figure 4.17):

- Exposure: the degree to which a system is stressed by climatic events and environmental conditions
- Sensitivity: the intrinsic degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses
- Adaptive Capacity: the preconditions that enable adaptation to change

In this case, this activity considers the vulnerability of people to future environmental changes. However recent work investigating the links between environment and wellbeing in coastal Kenya and Mozambique (Daw et al., 2016) highlights that people derive wellbeing from coastal ecosystems and the services they provide in myriad ways, not solely from monetary benefits. Different people will be vulnerable to different stressors and environmental changes to varying extents. It is important therefore to be more holistic and understand how future changes will influence wellbeing before it becomes possible to understand vulnerability in the future.

There are now many frameworks, with varying lists of different domains, which shape how wellbeing might be captured, measured, and ultimately understood (Scott, 2012). Doyal and Gough's (1991) Theory of Human Need, however, is a particularly useful starting point when considering vulnerability in the context of future environmental change. Not only are the list of needs universal in that they can be applied to all humans but they also provide life essentials, without which the person would incur serious harm of an objective kind. This enables discussions as to which needs will be affected by future changes and to compare this between different groups of people. Furthermore, it allows us to explore who will be most susceptible to harm and hence most vulnerable to predicted future changes.

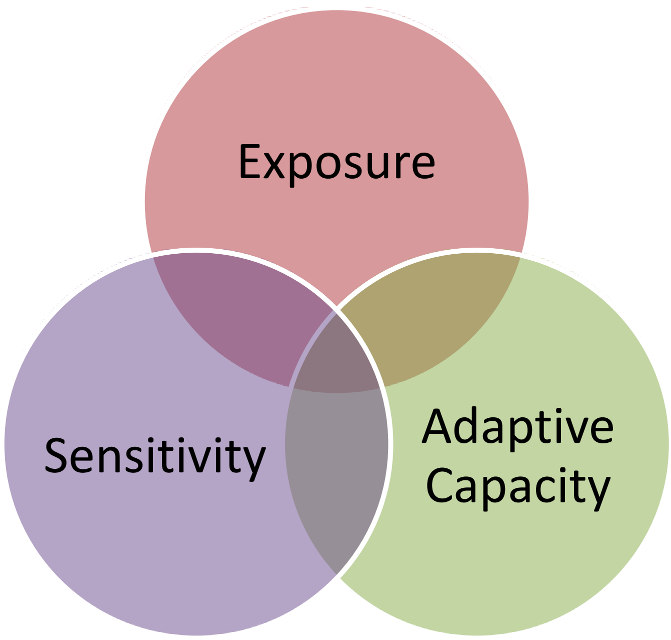


Figure 4.17: Vulnerability is comprised of three components; Exposure, Sensitivity and Adaptive Capacity (from Gough 2012)

Recent work carried out by the SPACES project in Mozambique and Kenya (Daw et al 2016) highlights the different ways through which benefits obtained from the environment can contribute to human needs to different extents (see Figure 4.18). Eight focus groups at 4 different sites in northern coastal Mozambique asking respondents to rate the importance of different ecosystem service contributions (such as fisheries) to human needs were carried out. Whilst fisheries are perceived to be important for economic security and food, which is generally accepted, they are also believed to be highly important for fostering community ties and relationships within the sites as well as playing a critical role for ones' autonomy and sense of respect. It is outside the scope of this report to discuss the links between different human needs and ecosystem services in Mozambique but these findings emphasise that individuals are vulnerable to future environmental changes in many different ways.

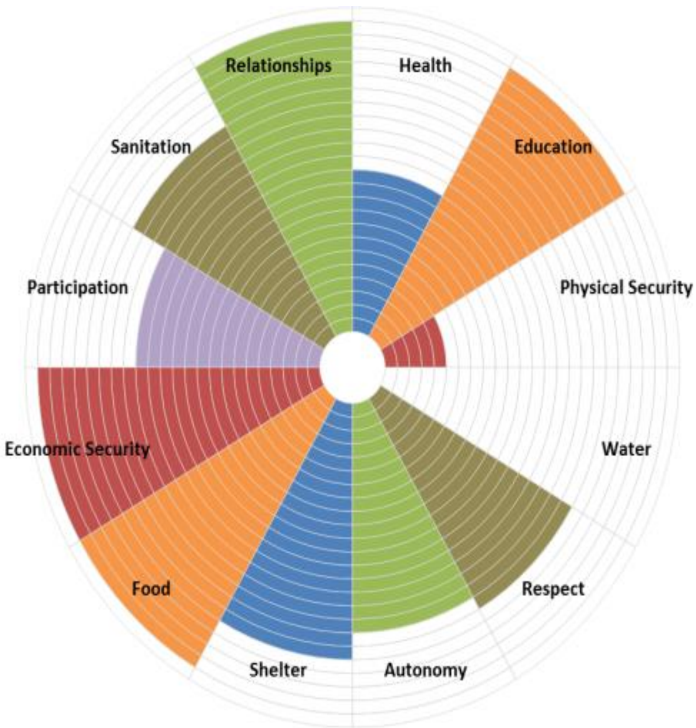


Figure 4.18: Perceived importance by four coastal Mozambican communities of the contribution of fisheries to different human needs.

4.5.3. Outline of the way the activity was presented

The aim of this activity was to think holistically about the different future costs and benefits of environmental change, to consider the potential winners and losers that would arise out of the situation and to determine those most likely to be vulnerable.

In the first part of the activity, a presentation was given by the conveners of the activity with the title: "Vulnerability Assessment of Fishing Communities - What are the impacts of climate change on the Madagascar communities dependent on fisheries? What can be done about it?" Here, the concept of vulnerability was re-introduced with a specific focus on social and economic vulnerability of Malagasy communities. Different definitions of vulnerability and how it can be measured were explored, concluding with the approaches described above by Gough (2012, see Figure 4.17).

Before the second part of the activity, the notion of wellbeing and the theory of human need were introduced. Recent work carried out by the SPACES project (see Figure 4.18) in eastern Africa was touched on and some results from communities in coastal Mozambique were presented. The objective was to get stakeholders to think more holistically about how individuals derive wellbeing from the environment and, therefore, how future environmental changes may lead to vulnerability for individuals and communities through different pathways and mechanisms.

The second half of the activity involved an exercise with the stakeholders. Following on from convener presentations of previous activities (notably climate range projections and ecological modelling activities) and discussions amongst stakeholders that arose consequently within sessions and after and during coffee breaks, three plausible future scenarios were constructed by the conveners of this activity. Firstly, a scenario with warming sea surface temperature where coral bleaching incidences may increase and could have negative repercussions for reef associated fisheries. Secondly, a scenario was envisaged where Madagascar would be under increasing threat of droughts. Under this scenario, less rain is thought to result in farmers turning to fishing and increasing fishing pressure on an already dwindling resource. And finally, a scenario where there is increasing wind intensity and frequency, which would prevent fishers from being able to go to sea regularly.

We split the stakeholders into three relatively even groups of 6-9 people. Each group had a bilingual English-French moderator to ensure that all information and discussion points were communicated to each stakeholder effectively. Each group was assigned a specific scenario, which was explained fully and the following sets of questions were asked in an informal setting to all participants. Approximately an hour was given to each group to answer the questions. Notes were taken as discussion amongst the participants ensued. The questions asked are included below.

1. How will climate impacts in the marine environment affect wellbeing?
    a. Will these impacts for wellbeing be similar everywhere?
    b. How will the impacts for wellbeing differ within sites?
    c. Probe for different aspects of wellbeing (health, education, economic security, food etc.)
2. Who will win and who will lose? And why?
    a. Think of regional differences in Madagascar
    b. Think of differences within sites/communities
        i. Probe for Occupation
        ii. Probe for Wealth
        iii. Probe for Gender
        iv. Probe for Access
    c. Think of the whole value chain
3. How might they respond?
    a. Think of scale
        i. At a community level
        ii. At an individual level
    b. What do people need to have to respond
        i. Material
        ii. Relationships
        iii. Personality
4. What can be done to help people respond appropriately?
    a. Think of scale, national, regional and local
        i. Is this feasible?
    b. What are the difficulties/problems that not to be overcome
        i. At a national level

ii. At a local level

4.5.4. Outcomes of the activity

The co-learning aspect of this activity whereby presentations were carried out on social and economic activity and wellbeing followed by group discussions on specific topics meant that both conveners and stakeholders could learn from each other on the ways in which people and the coastal environment interact in Madagascar and about vulnerability of communities in the face of future environmental change.

Three specific sets of outcomes were obtained from this activity. Firstly, indicators associated with vulnerability for different plausible future scenarios were identified through discussions of impacts of future environmental change on wellbeing and potential winners and losers for each scenario. Secondly, potential adaptation responses and repercussions for the environment were identified for each scenario through discussions of peoples' responses to change and the likely impacts this will have on people and the environment. Finally, different ways to improve or facilitate appropriate responses and to increase adaptive capacity were recognized through discussions on how to help people respond to future environmental changes.

The notes from the discussions are included below. It is important to note that due to time constraints and preferences of participants certain questions were answers in more detail at the expense of others.

Warming Sea Surface Temperatures

Impacts on Wellbeing

- The locally available fish species will change in number and composition. There will be more of a focus on octopus in this scenario.
- There will be migration of fishers to other locations that are less affected in Madagascar.
- This will lead to changes in management and the Madagascar people will have to fend for themselves.
- In the South, currently, there is famine. All those in the south will be seriously impacted by such changes.
- Those from the South will move North in response to famine and reducing numbers of reef fish.
- An increase in temperature may also lead to changes in salinity. This will affect the mangroves and will lead to an increase in *Avicennia* mangrove species. These species are not used for building houses and are less useful than other species.
- It will lead to an increase in the price of fish.

Winners and Losers

- The Vesu in the extreme north are very destructive and whilst others complain, they will increasingly learn these destructive fishing practices as migration to new areas increases. All will initially benefit and catch more fish but at the expense of the environment and negative consequences in the longer term.
- As the quantity of fish decreases, the poor will benefit as they will be able to sell the fish for more money.
- Temporary migrants are very dangerous because they do not care about the environment. No long term management. This increase in levels of migration may lead to less consideration of the environment.

- Some people in the value chain will lose their jobs.
- Apart from fishers, the rest of the community will lose as they will not be able to buy the expensive food from the coastal environment.
- Collectors will make the most money compared with fishers.
- Those fishers ready to move to more fertile oceans will leave their wives (they do this already) and have a negative effect on families.

Increasing wind intensity and frequency

Impacts on Wellbeing

- Fishers depend on the weather for their livelihoods. If the winds come from the south, this prevents many from being able to fish. Currently there are a number of days (approximately 3 days a month) when fishers cannot go fishing, in particular in June, July and August when the south winds are dominant. Fishers have adapted to this and their current local ecological knowledge of these events means that they adapt their calendar to the prevailing winds and factor these days off accordingly.
- If southern winds increase in intensity or frequency it would be a catastrophe.
- An important consideration would be about being able to predict these winds? How would one do this?
- There is also an infrastructure aspect. These winds could have an important impact on homes and would lead to increasing amounts of savings being put in to protecting or repairing homes and buildings. More money obtained from fishing would be pumped into these aspects.
- Those in the South West, East and North are most likely to be most affected by these winds.

Who wins, who loses?

- Those who will win are those involved in agriculture as they can up the price of their produce in times of intense and frequent winds.
- Butchers, for example, currently put the price of meat up from 4000 to 6000 Ariary per kilogram. This is a big issue along the coast where seafood is the number one source of food/protein.
- It might actually reduce conflict as farmers and fishers will have to work together to sort through these issues. It will strengthen links and cooperation.
- The elderly are likely to lose out as their old ways of fishing and local ecological knowledge are no longer applicable. They will lose their authority.
- *There was also a big debate relating to migration, which had very little to do with the winds but is obviously a big issue.* This involves non-traditional fishers coming to the coast and involving themselves in fisheries. They use non-sustainable forms of fishing and tarnish the Vezo name and way of doing things. They are an economic group, not an ethnic group (cultural group). They think in the short term and not the long term.
- Fewer fish as a result of increasing fishing pressure would lead to increasing pressure on other ecosystems.

Adaptation Strategies

- Micro finance strategies are flourishing and will continue to flourish. Many are wary of lending money to others, but these programmes allow this to occur.
- Illegal mining is a possible and likely alternative livelihood.
- Smoking fish and infrastructure/technology for this to be able to occur is likely to happen and is already happening at some sites. It means that fish can be kept for longer in times of bad

weather (where no fishing can happen). This is then sold for a higher price when fishing is not an option in times of high wind.

- Building of cellars to be able to keep fish and produce is also an option. For an element of food security in times of bad weather.
- There will need to be a diversification of food sources. This needs to be approached carefully. For example, simply giving chickens is not necessarily a good option, as the chickens will need to be fed, which can be an issue in itself as chicken feed is expensive.
- Goats are an option as they are every cheap and can eat anything.
- Investing in technology and seeds that are resistant to drought will be very important in this scenario.

Increasing Drought

Impacts on Wellbeing

- Those without any experience of the sea will not be able to fish in the deep sea and so pressure on the reef fisheries closer to shore will be very high. Little boats are cheap, and the lagoon and reef are relatively safe for fishing, which will attract non-traditional fishers.
- Fishers can also be farmers and farmers will come closer to the fishing community and start to observe and learn about fishing. They will start to experiment and learn fishing without full knowledge of the proper techniques. They will use non-sustainable techniques such as beach seining. While they are learning it is likely that they will destroy a lot of the habitat.

Winners and losers

- The winners will be predominantly the collectors and sellers whilst the losers will be the fishers (including women gleaners), farmers, the marine environment as well as the terrestrial ecosystems.

Adaptation strategies

- The middle men will take the opportunity to collect the maximum profit from the victims (in terms of price) and will exchange the products.
- Women will look for alternative jobs and get into debt and beg for money.

What to do?

- Government plans to help people to adapt to changes
- A need to fix the lack of knowledge of local authorities on environmental change
- Train non-fishers on sustainable and safe fishery techniques.
- Develop fishing techniques that are adapted to specific contexts
- Find alternative activities that fit with local needs
- Encourage relationships and cooperation between farmers and fishers
- Empower local communities to manage resources and make decisions

4.5.5. Recommendations

Recommendations for future research

A clearer look at current wellbeing of people and links with the environment and consequent ecosystem services will be required to see who will be most vulnerable to future changes. By further understanding the myriad ways in which wellbeing is derived from the environment, it will become easier to better plan and prepare for future environmental change impacts on those most in need and most vulnerable.

Furthermore, there is scope for more participatory scenario approaches to understanding vulnerability to future environmental change. Scenarios are plausible descriptions of how the future will evolve based on a set of assumptions about key elements and drivers of change (Alcamo, 2008). In contrast to predictions and models, they explore uncertainty of future events and hence are more resilient to surprises (Palomo et al., 2011). Given the multitude of environmental and non-environmental factors that will interact to moderate the future vulnerability of coastal communities to environmental change, such an approach will be vital in developing future management plans and promoting appropriate adaptation strategies.

Identify major challenges causes by climate change facing coastal communities

- Changing fish species composition and in number:
  - Through coral bleaching, changes in temperature etc.
  - This has an effect on elders and their traditional knowledge on where and how to fish
  - Can lead to less sustainable/traditional fishing approaches/techniques
- Migration of fishers to other areas
  - Reduction in number of fish in many areas will lead to fishers to migrate to more fertile areas
  - Will have a negative repercussion on family life as in many cases, women and children will be left behind.
- Move from farming to fishing
  - Increasing fishing pressure
  - Increasing conflict
  - Increasing use of destructive fishing practices by non-traditional fishers

Identify options for adaptation to the climate challenges (that are valid and acceptable)

- Food storage (if extreme weather events increase in future)
  - Cellars
  - Smoking fish
- Improving agriculture (if drought or decreasing fish)
  - Drought resistant species
  - Goats rather than chickens (less expensive to keep)

Recommendations for an action plan

- Put in place mechanisms to train non-traditional fishers in sustainable fishing practices and techniques
- Encourage discussion and positive relationships between farmers and fishers for efficient transfer of information and increase likelihood of future collective action.

4.6. Activities 7 & 8 - Perception of change, participatory mapping

Convenors: Lucy Scott, Shankar Aswani, Anne Lemahieu (South Africa), Val Byfield United Kingdom), John Bemiasa, Jose Randrianarimanana (Madagascar), Mary Gasalla (Brazil), Willem Malherbe (South Africa)

4.6.1. Summary

The ongoing climate and human-driven environmental changes are increasing the vulnerability of coastal communities in developing countries. In order to address adaptation strategies, the vulnerability of coastal communities in Madagascar was assessed through perception and participatory mapping surveys. Prior to the workshop, a 12 day fieldtrip was conducted in two fishing communities in the vicinity of Toliara, South-West Madagascar (Ambola and Ambotsibotsike), where a total of 48 interviews were administered. A focus group method was used for participatory mapping, semi-direct interviews for evaluating peoples' perceptions of climate change and questionnaires for the socioeconomic vulnerability assessment. Despite differences in environmental and economic configuration, the most quoted change in both villages was a decrease in marine resources (fish) and mangrove resources (fish and shrimps). The participatory mapping exercise showed that there had been a shift in the distribution of some target species (from the reef lagoon to the fore reef area) in Ambola, and that the decline of shrimp biomass was evident in the mangrove channel in Ambotsibotsike. As an adaptation strategy, both villages' respondents said they were adapting their fishing techniques and strategies (e.g. fishing further from the shore) as well as gears. The comparison exercise between the two villages showed insights as to how communities respond to external drivers such as NGOs' presence. In the case of Ambola, knowledge of how to preserve catches was evident, as a tool to mitigate local vulnerability and enhance resilience to changes.

The perception exercise provided useful insight into how environmental changes are perceived and whether consensus exists, and it documents ongoing adaptation processes. The comparison between the two villages also showed how communities interpret changes differently according to their natural and social environment.

Such surveys could contribute, in future, to the identification of targeted and valuable species and bring insight into historical dynamics and evolution of important stocks. In addition, geo-referencing the information from the households that were interviewed could give a spatial dimension to perceptions, and highlight spatial dynamics and the extent of consistency in responses across social groups as defined by several parameters (tribe, wealth, occupation, distance to the sea, etc.)

4.6.2. Background information on activity content

During the workshop planning phase, activities 7 and 8 (Participatory GIS and Capacity Development, Engagement with local communities) were consolidated to allow for joint field activities as well as to make the best use of time in the workshop.

In the context of the two activities, and in association with the Institute of Marine Sciences (IH.SM), Madagascar and WWF Madagascar, communities in the area of interest (South West Madagascar) were chosen in which to undertake a field activity prior to the workshop. Selection criteria were that:

- the communities were easily accessible given the time available;
- were of sufficient size to allow 100 interviews (although fewer than 100 were actually done in the field);
- were users of the marine and coastal area; and
- were not considered fatigued by other research projects also conducting interviews.

It was ensured that there was no overlap with Blue Ventures (BV) and WWF Madagascar community study sites. These considerations led to the selection of two final sites, namely Ambola and Ambotsibotsiky (Figure 4.19).

Figure 4.19: Location of selected sites: Ambola and Ambotsibotsiky.

1. Desktop data collection of GIS data at relevant spatial scale took place, in association with IH.SM.
2. The field activity took place from 3 June to 15 June, after which the field team convened with the GLORIA workshop team in Antananarivo. The participatory GIS involved several members of each of the local communities as well as the community leader/representative. Spatial information was collected on environmental characteristics (ecological units and local names) as well as patterns of use and perceptions of change over time. Other components of the field study, outlined in Activity 7, included analysis of local perceptions of change (survey method) and analysis of local vulnerability (survey method).
3. Results from the field activity were presented at the GLORIA workshop, and additional information as well as feedback was provided.

4.6.3. How it fits in with vulnerability assessment

A vulnerability assessment survey was performed to identify the vulnerability of social, economic, and ecological components in communities to the effects of climate change. Through the survey it was possible to identify components of high vulnerability where adaptation planning will be most effective. Conversely, identified areas of low vulnerability require preservation as means of providing resilience to climate change effects.

A total of 48 surveys were administered over 8 days of sampling (Ambola n=26, Ambotsibotsiky n=23). The unit of analysis was at the household level and a systematic sampling technique was employed as village organization did not possess knowledge of the number of households in both communities. Transects were drawn through a map of the village, after which every second house on each transect was sampled. Questionnaires were aimed at the head of the household, as identified by the household members themselves, and if unavailable any household member with knowledge of the household. If no such persons were available the household was skipped and returned to at a later stage.

The participatory mapping exercise also identified ecological use areas, some of which may be identified as vulnerable from other studies.

The assessment of perceptions of change provided useful insight into local vulnerability. The local communities of both villages were asked through a questionnaire to identify changes, their implications and their causalities. By doing so, the communities could reveal their comprehensive understanding and approach to ecological systems and the way they comprehend environmental positive or negative feedback loops. Respondents were asked to provide estimates of the period over which changes occurred and thereby provided a temporal dimension that generally goes beyond the available scientific knowledge. Adaptation processes were also addressed by asking the respondent the way they were adapting to environmental perturbations, bringing a dimension that contributes to diagnosis of vulnerability and resilience.

4.6.4. Outline of the way the activity was presented

Results from the participatory mapping exercise were presented to the GLORIA workshop session, and an interactive discussion followed. Translation was provided between English and Malagasy throughout.

Environmental change perception questionnaire results were presented.

The two villages were sampled according to the same method i.e. systematic sampling (interviewing each 4 houses along a transect through the village). Each interview consisted of 12 questions about the respondent's characteristics (see supplementary materials), a free-listing exercise to identify the various dimensions recognized by the villagers, and open questions about the changes observed in their environment over a lifetime.

Data were reported in a database and codified in order to harmonize between both villages (Table 2). Results were shown using charts and tables.

Table 2: Example of classification of variables

Variable	Modality	Code
Change	Change observed	1
	No change observed	2
Change description	Less fish, sea product (pelagos)	1
	Damaged corals, less algae, less sea cucumber (benthos)	2
	Improvements	3
	Fish size decrease	4
	Geomorphological changes	5
Cause	Human-driven (demography, fishing effort, pollution)	1
	New gears/Damaging fishing techniques	2

	Climate-driven, God willing	3
	NGO/Tourism effects	4
	Don't know	5

Results from the field activity were presented

A. Results from the Ambola field site

A.1. Environmental change perception exercise

Overall, we interviewed 20 males and 6 females resulting in 90 answers about the changes noticed in the different environmental dimensions quoted by the respondents. Half of the respondents were mature males (+50). The first step consisted of reconciling all the dimensions cited by the respondent (Figure 4.20). Overall, 20 names were given to qualify 7 different dimensions (Figure 4.20). "Anaovany" (lagoon/shallow reef environment) was the most cited environment, hence indicating the importance of the lagoon in the villagers' life.

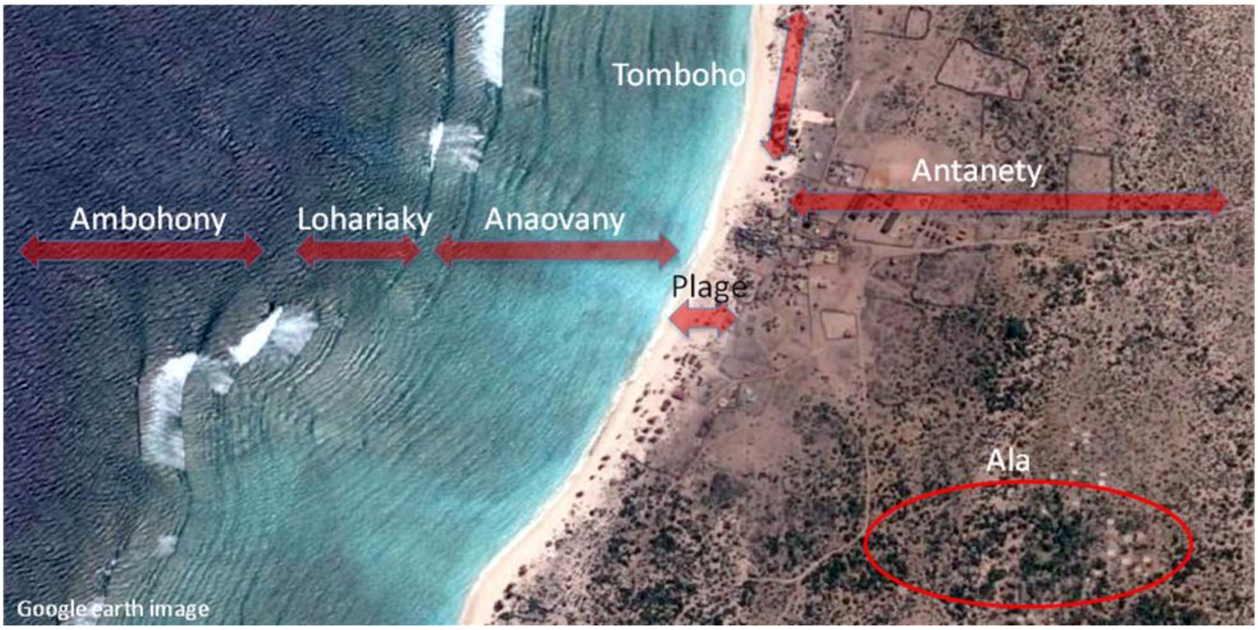


Figure 4.20: The 7 main dimensions identified in Ambola and vernacular names.

The most recurrent change reported by the villagers was a decrease in fish. Most of respondents identified a human origin to this change (46% of the answers), followed by fish technology origin (modern and efficient gears, 10 % of the answers) (Figure 4.21). A deterioration in benthos i.e. dead corals, sea cucumber decrease and algae cover decrease, was also a change often cited by the respondents. Some improvements were reported, mainly induced by NGO interventions in the village and positive effects of tourism.

Respondents reported that most of changes started 21 to 40 years ago. They identified the same period when describing NGO intervention, although WWF has been involved in the region for a shorter period (Figure 4.22).

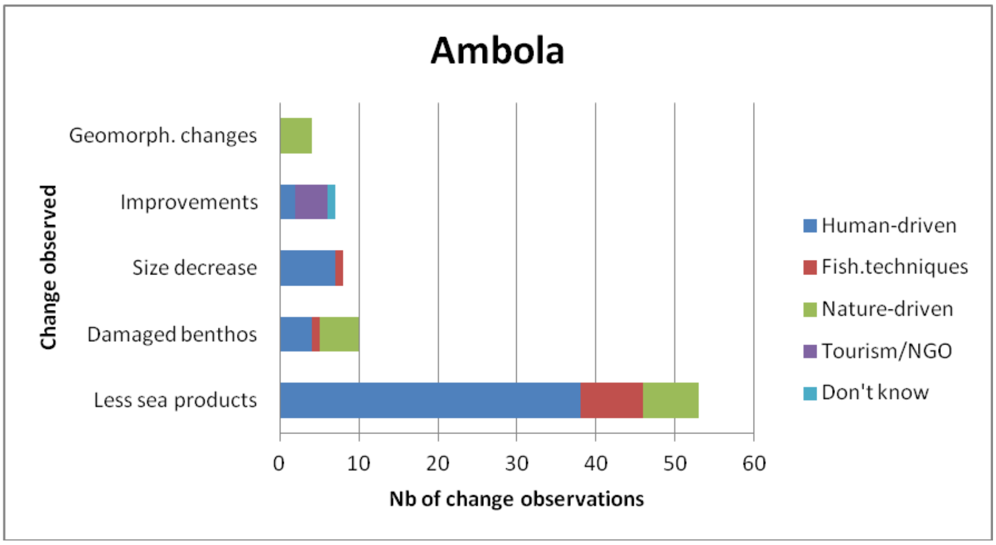


Figure 4.21: Types of changes against the origin of changes in Ambola in sea environment (n=90)

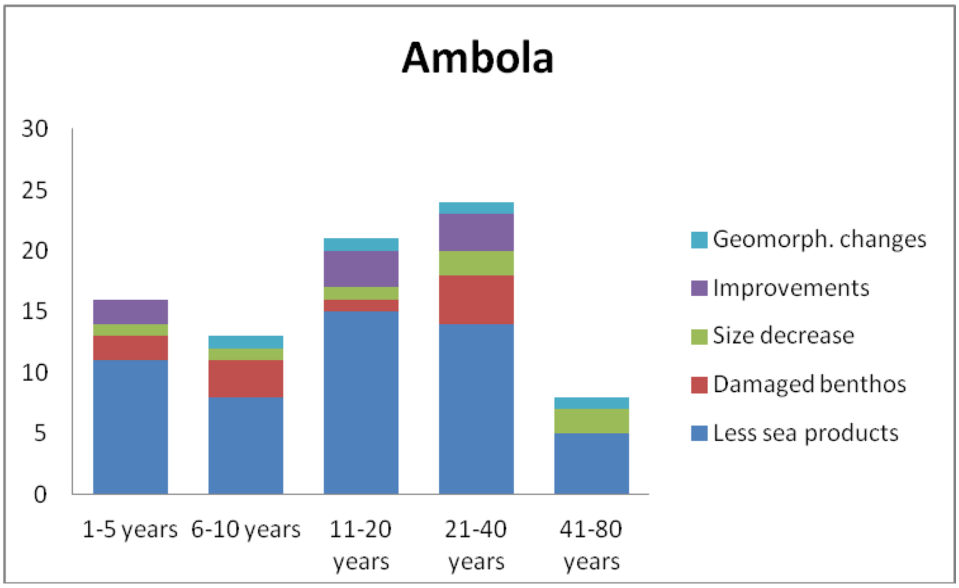


Figure 4.22: Type of change and period of beginning in Ambola (n=90)

Responses to sea environment changes in Ambola (n=81) are quite diversified (Figure 4.23) with most of the respondents claiming "no adaptation" (28%) and 26% saying they were adapting fishing techniques to maintain a certain level of catch. As a third answer, Ambola villagers said they were making reserves to compensate for the lack of resources.

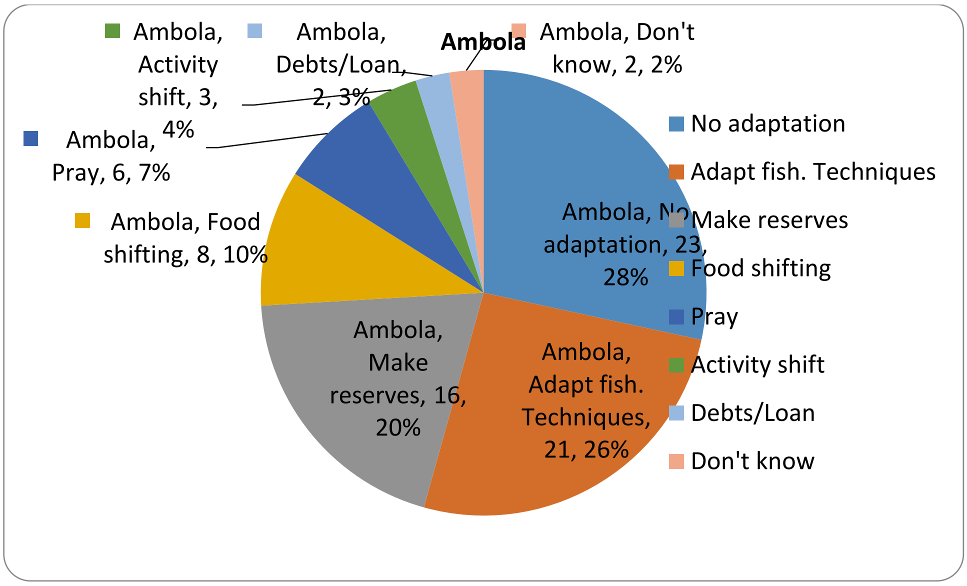


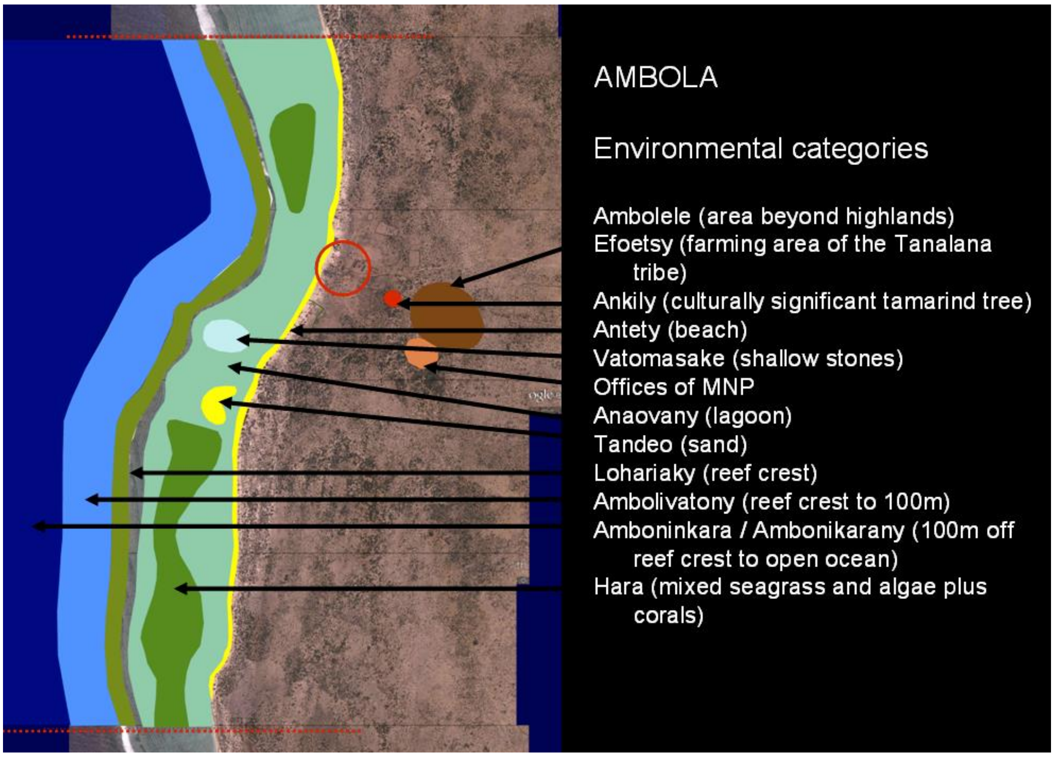
Figure 4.23: Adaptation responses to sea environmental changes (n=81)

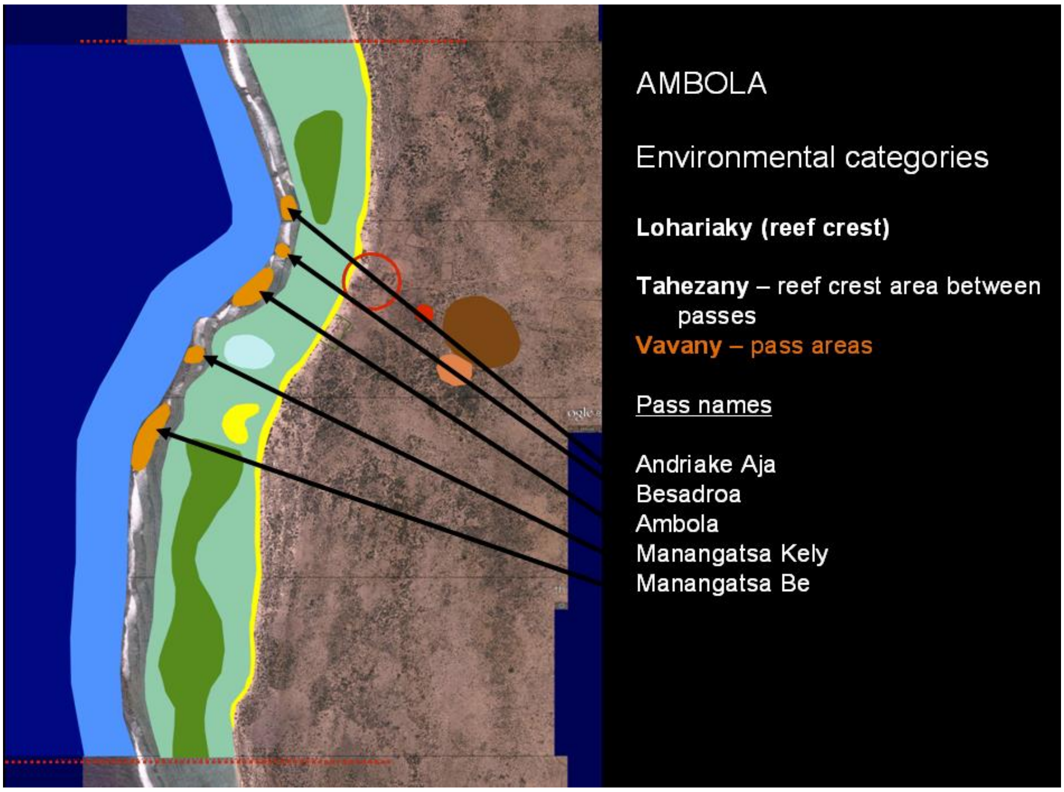
<u>A.2. Participatory mapping exercise</u>

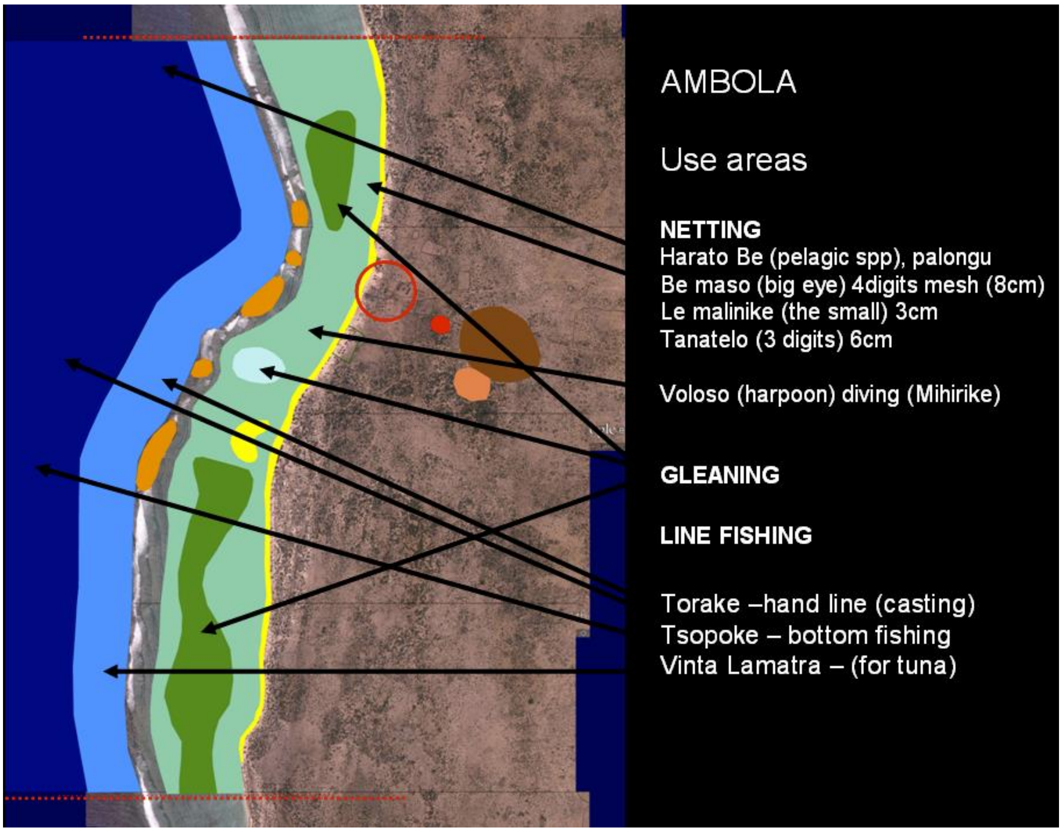
The participatory GIS results were presented in the following categories:

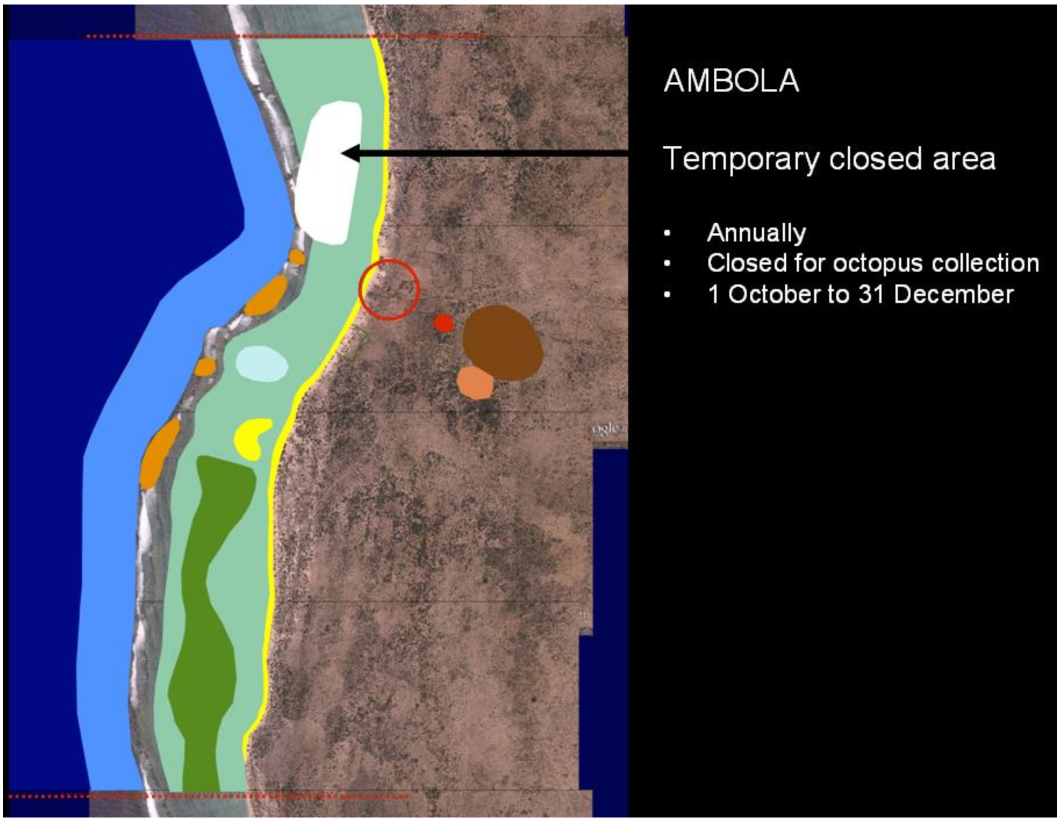
- The present and historic governance of marine resources in the area
- Mapping of local resource classification: distribution of habitats and their local names
    - size of habitats
    - allocation if any (tenure)
    - important areas for any species (spawning, feeding)
    - any temporary or permanent areas closed to fishing / gleaning

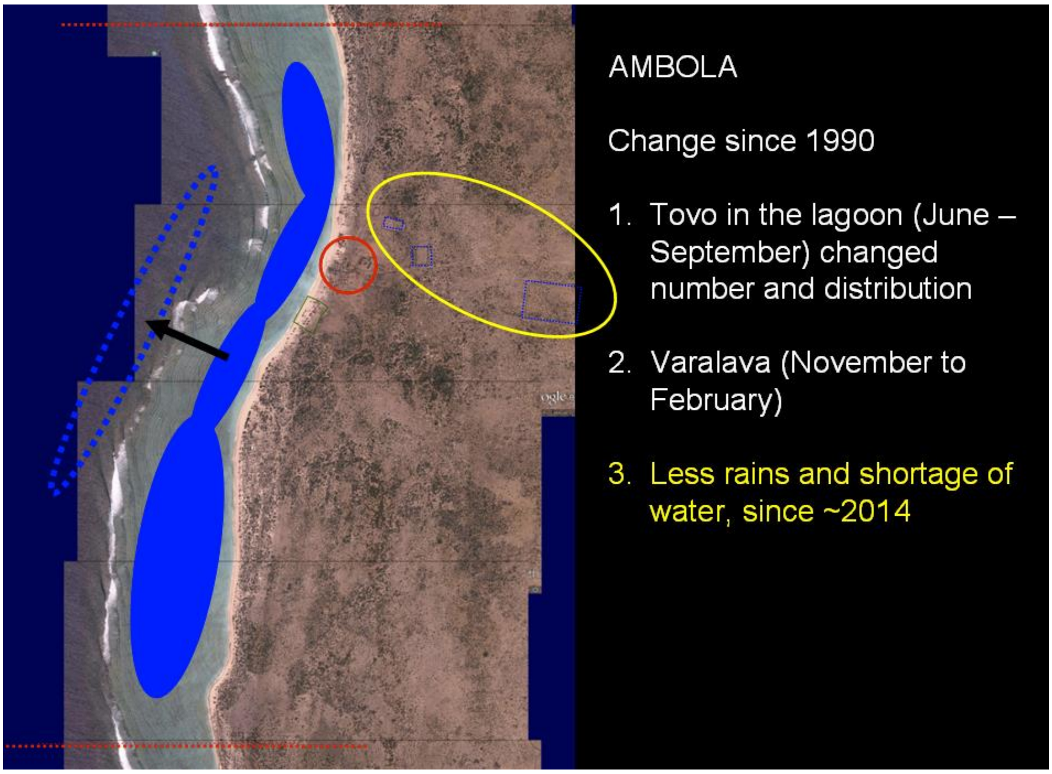
- Areas for fishing (each method)
    - Lining, trapping, diving (octopus), gleaning, spearing, netting
- Seasonal changes
- Changes that have been observed in the last 25 years.




AMBOLA
Environmental categories
Lohariaky (reef crest)
Tahezany – reef crest area between passes
Vavany – pass areas
Pass names
Andriake Aja
Besadroa
Ambola
Manangatsa Kely
Manangatsa Be


AMBOLA
Use areas
NETTING
Harato Be (pelagic spp), palongu
Be maso (big eye) 4digits mesh (8cm)
Le malinike (the small) 3cm
Tanatelo (3 digits) 6cm
Voloso (harpoon) diving (Mihirike)
GLEANING
LINE FISHING
Torake –hand line (casting)
Tsopoke – bottom fishing
Vinta Lamatra – (for tuna)





B. Results from the Ambotsibotsiky field site

B.1. <u>Environmental perception exercise</u>

Overall, we interviewed 14 males and 9 females resulting in 86 observations. The biggest sample was the mature male category (34%). The first step consisted of reconciling all the dimensions cited by the respondents. Overall, almost 50 names were given to qualify 5 main dimensions, showing a lower consensus than in Ambola. "Saha", a word meaning "garden" in Malagasy, was used to describe the mangrove ecosystem in this village. The latter was the most cited environment, hence indicating the importance of the mangrove ecosystem in the villagers' livelihoods.

In Ambotsibotsiky, the change most cited by the respondents was a decrease of sea products (Figure 4.24). In contrast to Ambola, villagers identified human-driven and nature-driven causes as being equally at the origin of these decreases. Because of its particular configuration i.e. settled along a mangrove ecosystem, a moving sand arrow and a lagoon, Ambotsibotsiky villagers reported more changes of geomorphological nature (17 % of reported changes, against 5% for Ambola), namely ongoing mangrove and lagoon sedimentation processes. This environmental change appeared to be obvious to most villagers, hence explaining why so many of them mentioned nature-driven origins to changes occurring in Ambotsibotsiky.

In Ambotsibotsiky, we found a consensus about the period when the catches sizes decreased i.e. 11 to 20 years ago (Figure 4.25). Changes observed on the benthos (i.e. coral reef deterioration, sea cucumber decrease) were said to start occurring 11 to 40 years ago. Finally, most geomorphologic changes (i.e. sand arrow migration, mangrove and lagoon sedimentation) were said to have started 11 to 20 years ago.

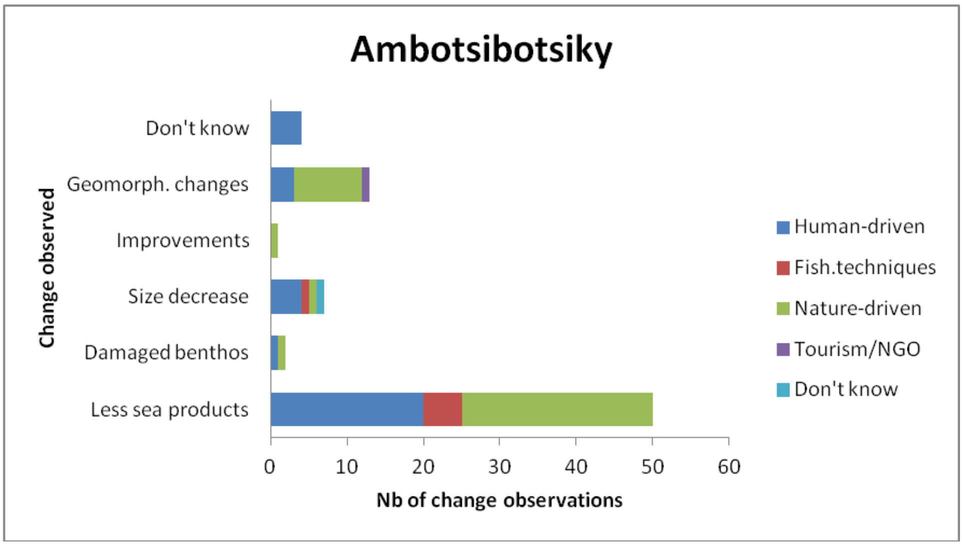


Figure 4.24: Types of changes against the origin of changes in Ambotsibotsiky in sea environment (n=86)

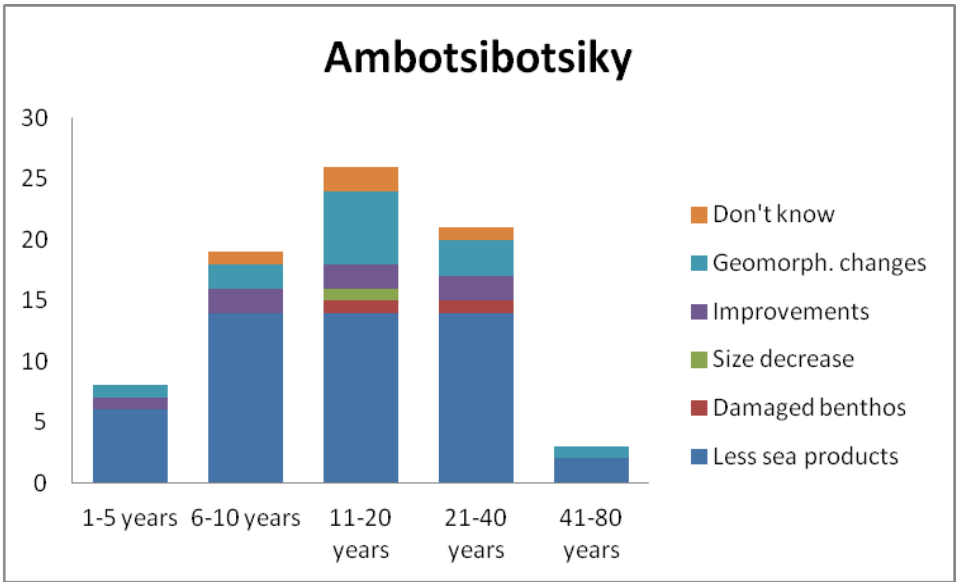


Figure 4.25: Type of change and period of beginning in Ambotsibotsiky in the sea environment (n=86)

Compared with Ambola, Ambotsibotsiky villagers (30%) claimed that they adapted their fishing techniques as a first adaptation response to the changes observed (Figure 4.26). Nevertheless, a large number (as for Ambola) said they had no adaptation response (25 %). Far fewer respondents said they were making reserves, showing the influence of NGO interventions in Ambola where WWF had trained villagers to adopt fish preservation techniques. Conversely to Ambola, an important place was given to "activity shifting" in Ambotsibotsiky as a response to changes, showing better diversification skills compared with Ambola where villagers said they were rather shifting their diet (to more land products), implying trading exchanges between different tribes/villages.

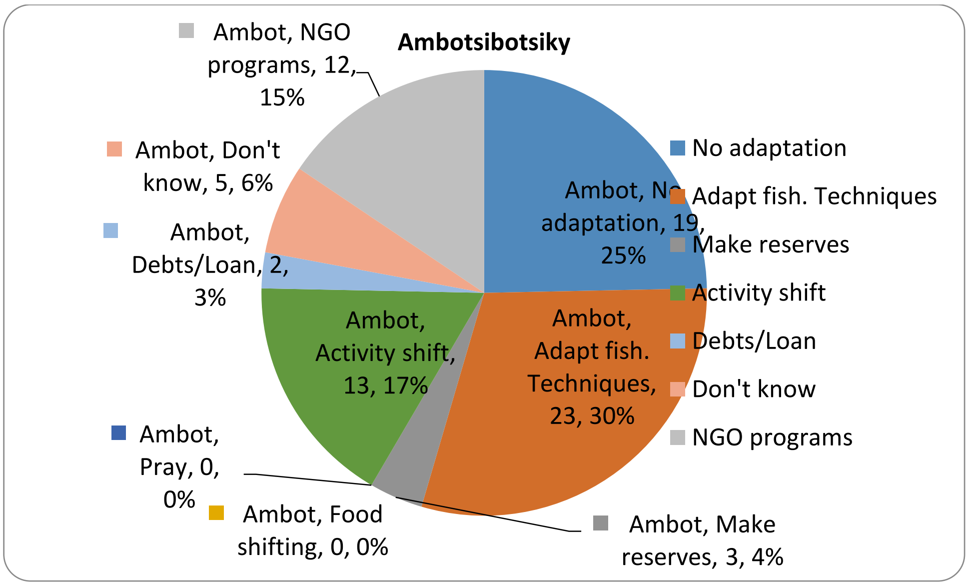
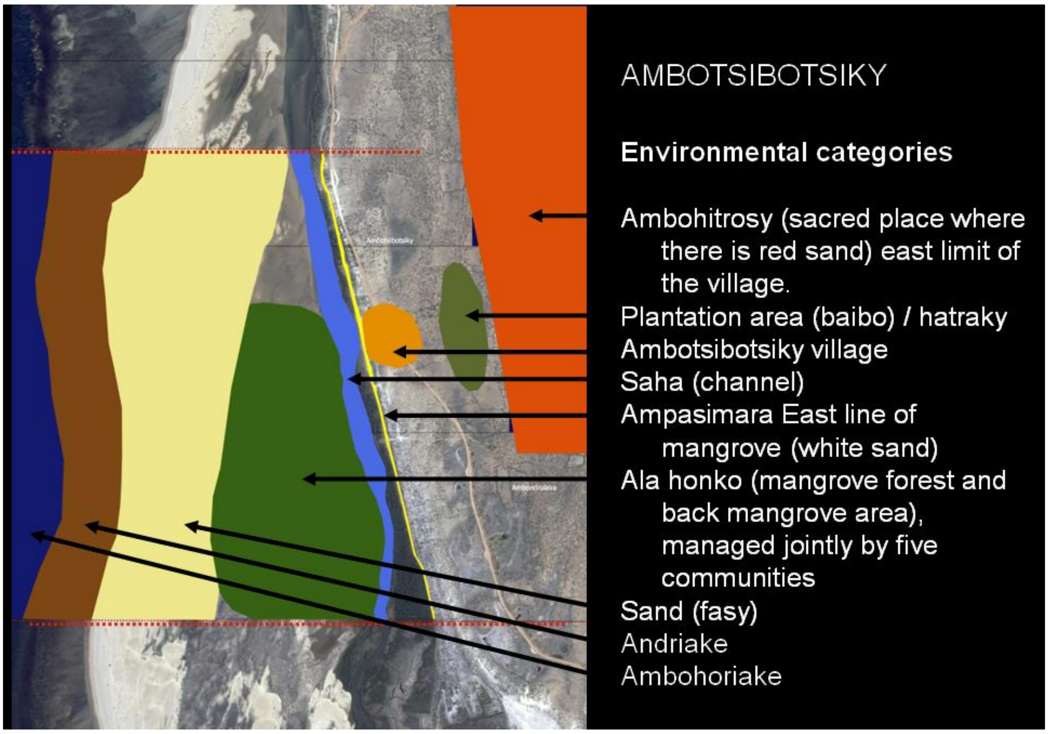
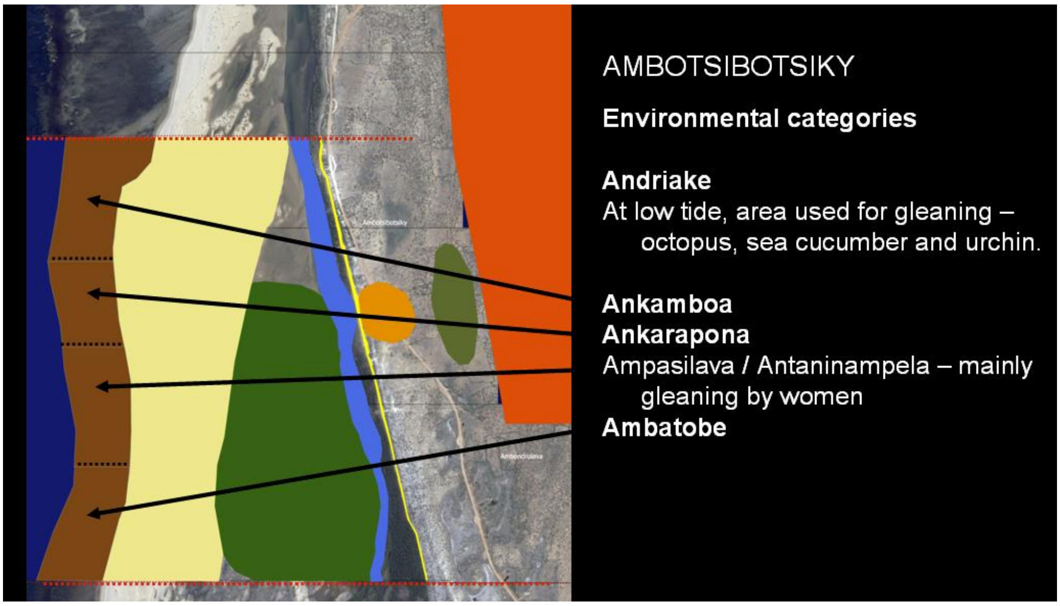
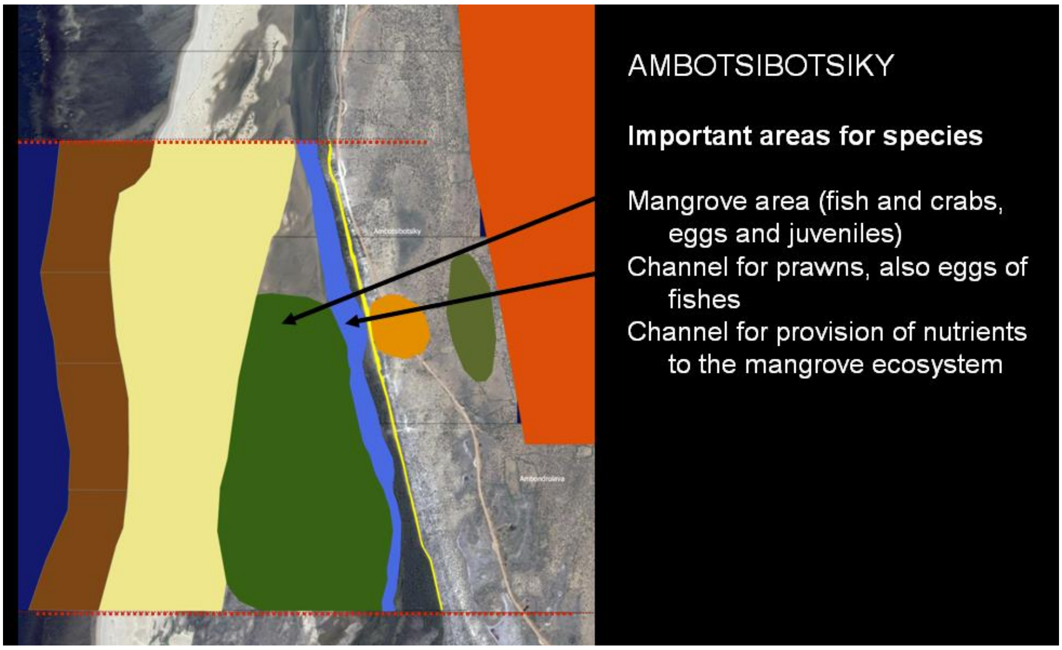


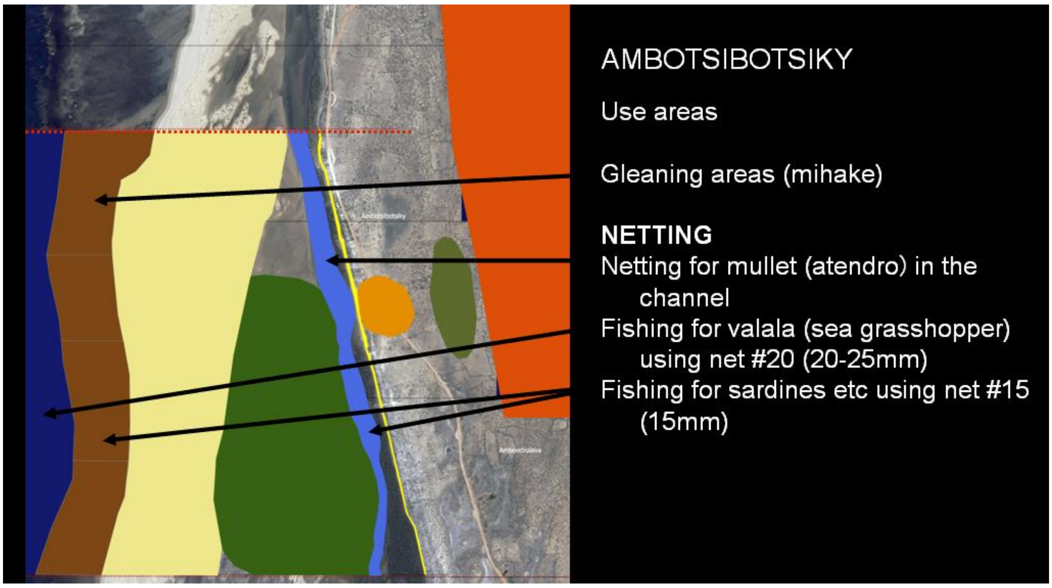
Figure 4.26: Adaptation responses for sea environmental changes in Ambotsibotsiky (n=77)

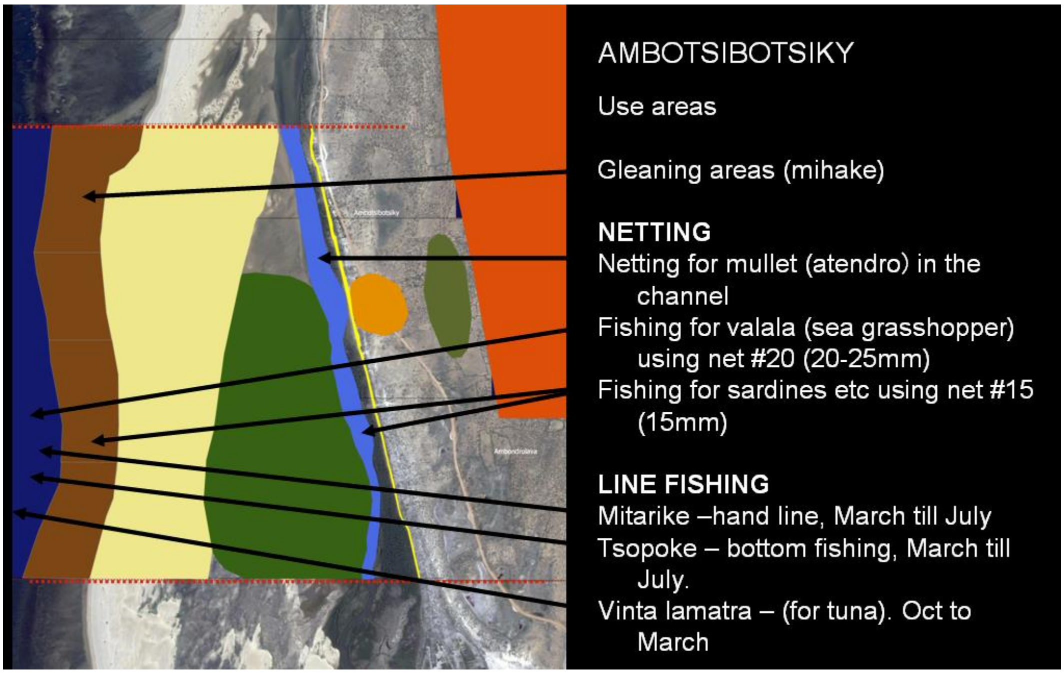
B.2. <u>Participatory mapping exercise</u>

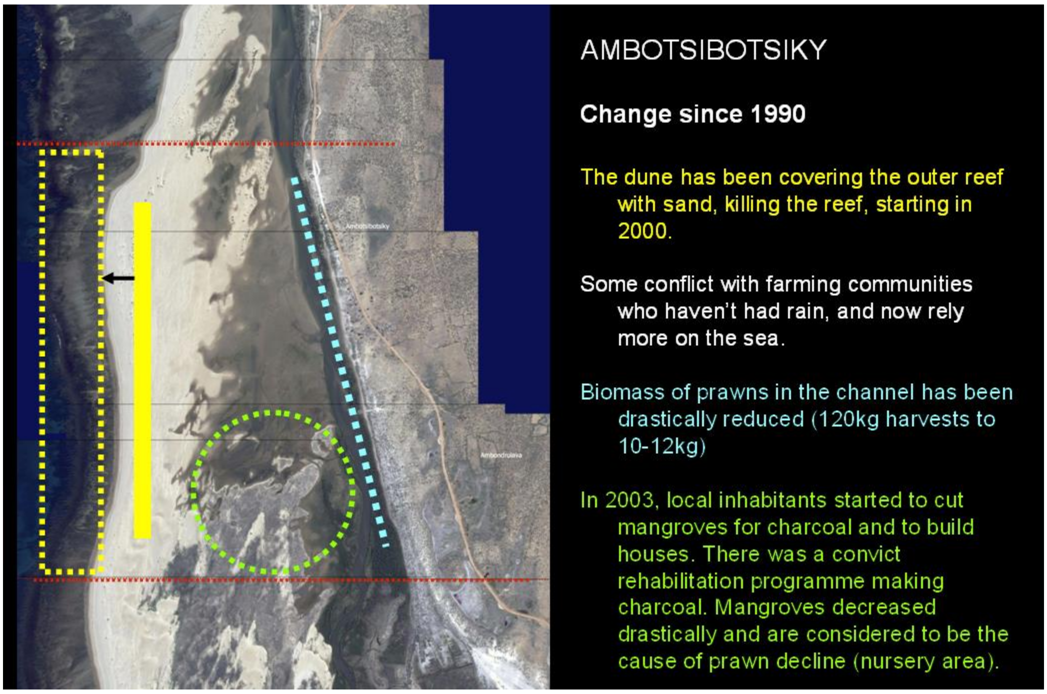


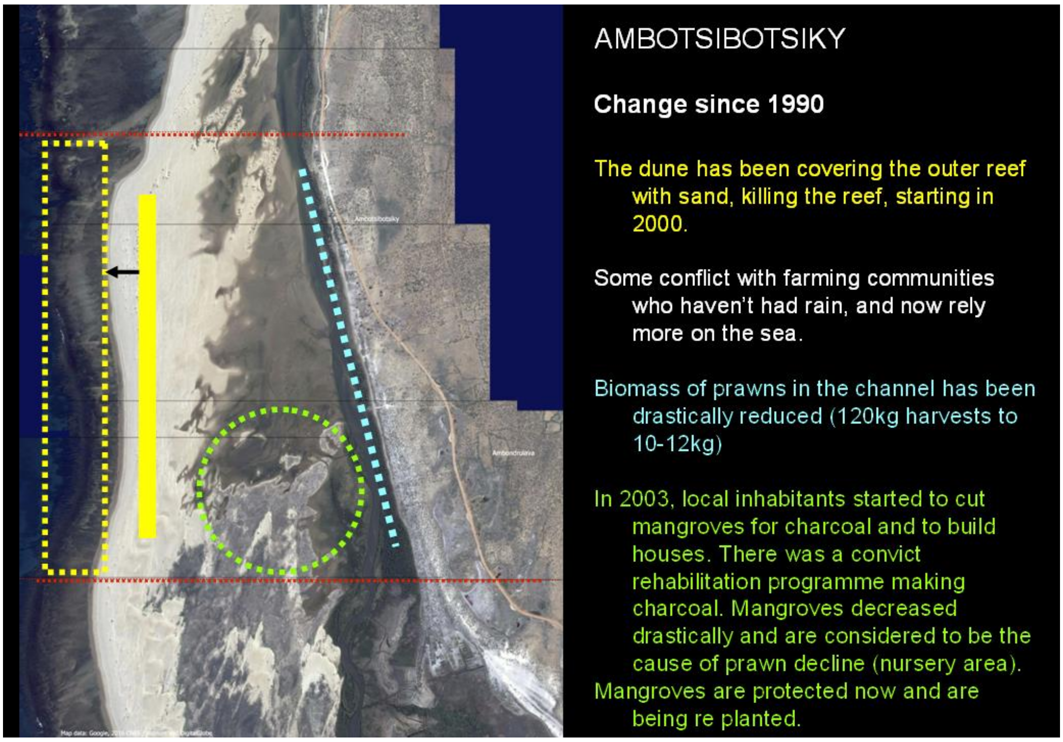



AMBOTSIBOTSIKY
Important areas for species
Mangrove area (fish and crabs, eggs and juveniles)
Channel for prawns, also eggs of fishes
Channel for provision of nutrients to the mangrove ecosystem


AMBOTSIBOTSIKY
Use areas
Gleaning areas (mihake)
NETTING
Netting for mullet (atendro) in the channel
Fishing for valala (sea grasshopper) using net #20 (20-25mm)
Fishing for sardines etc using net #15 (15mm)


AMBOTSIBOTSIKY
Use areas
Gleaning areas (mihake)
NETTING
Netting for mullet (atendro) in the channel
Fishing for valala (sea grasshopper) using net #20 (20-25mm)
Fishing for sardines etc using net #15 (15mm)
LINE FISHING
Mitarike –hand line, March till July
Tsopoke – bottom fishing, March till July.
Vinta lamatra – (for tuna). Oct to March


AMBOTSIBOTSIKY
Change since 1990
The dune has been covering the outer reef with sand, killing the reef, starting in 2000.
Some conflict with farming communities who haven't had rain, and now rely more on the sea.
Biomass of prawns in the channel has been drastically reduced (120kg harvests to 10-12kg)
In 2003, local inhabitants started to cut mangroves for charcoal and to build houses. There was a convict rehabilitation programme making charcoal. Mangroves decreased drastically and are considered to be the cause of prawn decline (nursery area).



4.6.5. Interactive session

Discussion was enthusiastic; further information was provided by Vezo representatives at the meeting on ecological use areas and long term patterns of change. Confirmation was given that this region of the south west of Madagascar was especially vulnerable to environmental change (as well as anthropogenic pressures) and that it is indeed an important area for study.

4.6.6. Outcomes of the activity

Maps provide context for the Perceptions of Change and the vulnerability exercise.

Participatory mapping provides additional useful information to local groups (NGOs, government and University) working with these changes/challenges on an ongoing basis in Madagascar.

The perception exercise provided an early insight into how environmental changes are perceived, whether a consensus exists, and it documents ongoing adaptation processes. The comparison between the two villages also showed how communities answer differently according to their natural and social environment.

Such a survey can also contribute to the identification of targeted and valued species and bring insight into historical dynamics and evolution of important stocks (not shown here). In addition, geo-referencing the information from the households that were interviewed can give a spatial dimension to perception outcomes, and highlight spatial dynamics and the extent of consistency in responses across social groups as defined by several parameters (tribe, wealth, occupation, distance to the sea, etc. - not shown here).

4.6.7. Issues addressed

1. The analysis of people's perceptions of environmental and climate-related transformations in two communities in SW Madagascar using various ethnographic and geospatial methods.

2. The analysis of people's observed changes over the past 2 decades across locally identified environmental domains and, for each recorded change, responses regarding the causes, timing, and people's adaptive responses to the change.

3. The team also worked on participatory mapping of environmental related changes across various environmental domains to produce broad-scale base maps of local perceptions of environmental change.

4. These activities contributed an environmental change survey schedule and participatory mapping research tools to be used/modified by BV/WWF

5. Overall these methods bring local peoples' experiences and knowledge into the management planning process.

4.6.8. Recommendations

- Delivery of data sets to IH.SM, along with the outputs from all other components.
- Development of adaptation strategies to address vulnerability scores for each component of the vulnerability assessment survey.
- In order to ensure data interoperability, coding methods should be standardised among the different users. According to the village sampled and the local environment and issues, the coding keys can vary. In this instance, we first sampled Ambola in order to have a list of suitable environmental categories recognized locally (the emic (i.e. local and internal) perception of habitats distribution) as well as the changes recognized within each domain. This coding frame was provided as a reference. A minimum amount of time, estimated at a week (if many interviewers), is required for a standard village size of 500 people.

4.7. Activity 9: Education workshop – Communicating Ocean Science and Climate Change

4.7.1. Summary

GLORIA included a public outreach and education program to provide information and help to enrich the knowledge of the general public on oceans and climate. This was done through a climate change education workshop designed to contribute to professional development and that could be used by participants to inform the local population about the ocean and the environmental impacts of climate change on marine resources. Twenty five people took part in this one-day event that was held in Toliara.

The workshop was very successful and the overall feedback was positive. Participants reported that after the workshop they were inspired to include more ocean and climate related effective teaching and use the materials provided. Dissemination of the workshop's content to a wider audience depends on adaptation of the teaching strategies and the utilization of the material to expand ocean and climate literacy. It is hoped that the GLORIA education workshop has inspired and motivated educators to rise to the challenge and that the programme will be implemented to increase ocean and climate literacy and increase the acceptance of any adaptation strategies by the local stakeholders and general public in Madagascar. In the future we will follow up to determine if and how often the materials are being used locally.

4.7.2. Introduction

The GLORIA project aims to obtain and provide the information and knowledge necessary to underpin the development of policy and management pathways that will support future coastal livelihoods and local food security in Madagascar. Achieving this goal requires that the communities and stakeholders understand the causes and consequences of climate and environmental change and are engaged and aware of the outcomes and ready to support the recommendations. Accordingly, a public outreach and education program that will provide information and educate the general public in order to build trust and cooperation was designed and delivered. Specifically, a climate change education workshop was designed to provide professional development that could be used by participants to inform the local population about the ocean and the environmental impacts of climate change on marine resources.

Activity 9 took place as a separate workshop and was held in Toliara. There were 25 participants at the workshop. It was designed to be relevant for diverse audiences and included the following:

a) Introduction of the workshop goals: to provide experiences with research-based teaching and learning strategies and hands-on activities that scientists and educators can use when communicating ocean and climate science to diverse audiences (public, K–12 students, university students, other scientists).
b) Discuss ocean and climate literacy needs
c) Consider how learning happens and fundamental ideas about learning
d) Focus on the learning cycle
e) Designing a learning experience
f) Discussion of effective learning and teaching

The logistics for the workshop and recruitment of participants was coordinated by Dr. Jose Victor Randraianarimanana and Dr. Paubert T. Mahatante from the University or Toliara. Twenty five participants from diverse sectors registered for the full day workshop (including staff representatives from the University, students, teachers, NGOs, and city council administrators). Participants engaged in a several hands-on activities and demonstration of materials that could be used for effective teaching and learning and a set of grades 3-5 and grades 7-9 curricula including hands-on activity kits were provided. In addition links to an extensive set of lesson plans and on-line resources was provided. This includes the MARE curriculum (http://mare.lawrencehallofscience.org/curriculum) and a complete Ocean Science curriculum for grades 3-5 and 6-8 including activity kits (http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence).

The workshops and kits were very well received as evidenced by the participant's reflections on their experiences (see workshop evaluation sections below).

4.7.3. Workshop

Agenda (in French)

8:30	**Accueil des participants**	
9:00	**Introductions**	
	Buts de l'atelier	
	Nature et pratiques de la science et de l'océanographie • Think Pair Share: travailler et partager en groupe.	
9:30-10:15	**Les étapes d'apprentissage – Sand on Stage** • Sand on stage (activité interactive) • Réflection sur les pratiques de la science et les bases de l'apprentissage employées pendant cette activité • Le cycle de l'apprentissage	
10:15-10:30	**Pause**	
10:30-12:00	**Concepts pédagogiques d'apprentissage actif : activités sur le climat** • Activité interactive (3 stations): le cycle du carbone • Démonstrations: les températures de l'air et de l'eau (1.2) • Démonstration: l'effet de serre dans une bouteille • Démonstration: l'élévation du niveau de la mer (glace and énergie thermique) (3.5) • Démonstration: l'acidification des océans • Démonstration: le mystère des ballons flottants (1.5) • Démonstration: comment générer des courants (1.7, 3.7) http://mare.lawrencehallofscience.org/curriculum/ocean-science-sequence/oss68-overview/oss68-resources	

12:00-13:00	**Pause Déjeuner**	
13:00-13:45	**It Takes All Kinds** • Anatomie et fonction des poissons (activité) • Cherchez les signes du cycle de l'apprentissage • Les cinq bases de l'apprentissage	
13:45 -14:00	**Questions, réflections et conclusions**	

4.7.4. Evaluation/Reflection Questions asked of participants

1. What do you want to take back and try out in your own?

2. What questions do you still have?

3. What else would you want to tell us?

4.7.5. Examples for Responses:

1. What do you want to take back and try out in your own?

- I really liked the different hands-on activities
- I liked to learn about the learning cycle and hope to use it
- The interactive way of teaching
- Very nice approach with the practical examples
- All the different activities were fun and interesting
- I liked all aspects of this training and want to practice this type of demonstration
- I like the dynamic formation with hands-on practices
- I learned about good new ways to teach about climate change
- All the activities were great
- The workshop was very clear and I really enjoyed the activities

2. What questions do you still have or suggestions for improvement?

- I would like to learn more about ocean acidification
- Have people work on how to use this locally
- I would like to improve my own knowledge
- I would like to know if teaching about climate will be useful in my school
- I want a workshop on biodiversity
- Can we all have a copy of the lesson books?
- I need more time to learn about these topics
- I want to practice the activities and lessons with children
- We need more such workshops!

3. What else would you want to tell us?

- Thank you for a wonderful and fun day!
- I just like what you're doing
- Would love to get pdf versions of all of the materials
- Thank you for a very nice and informative day

- The workshop was very short we need more
- I want this training to continue after today
- I hope to be a good teacher like Mrs. Adina Paytan
- Thank you, I enjoyed and can now share this knowledge
- I learned a lot

5. Overall Conclusions and Recommendations

The conclusions and recommendations from each of the activities undertaken at the workshop are included in Chapter 4 Activity Reports. Each sub-section of Chapter 4 reports on particular activities, under the headings of Outcomes of the activity, Recommendations for future research, Identify major challenges caused by climate change facing coastal communities, Identify options for adaptation and Recommendations for an action plan. This chapter, Chapter 5, addresses overall conclusions and recommendations that synthesise and integrate them across the different activities.

5.1. Vulnerability assessment methodology

It is clear from the different activities that it is insufficient to consider individual stressors and drivers on marine-dependent communities in isolation and that their cumulative impacts must be addressed, including the additive impact of climate change in combination with other stressors. It is also important to recognize that generic adaptation options are of limited value and can be counter-productive in specific settings. It is therefore essential to consider from an integrated perspective the specific vulnerabilities, needs and opportunities pertaining to each particular fishery system in order to develop options that are feasible, acceptable and likely to fulfil their goals. Some important methodological considerations when seeking integrated and tailored vulnerability assessments are summarised in Box 5.1 and discussed in more detail below.

Box 5.1 Considerations for integrated and case-specific vulnerability assessments

1) Generic adaptation options are of limited value and can be counter-productive in specific settings. It is essential to consider, from an integrated perspective, the specific vulnerabilities, needs and opportunities pertaining to each specific fishery system in order to develop options that are feasible, acceptable and likely to fulfil their goals.

2) High resolution global climate models can provide accessible and cost-effective information on future trends in the main climate drivers of the coastal and marine ecosystems and habitats of Madagascar.

3) Inclusion of the traits-based ecological risk assessment presented at the workshop would considerably strengthen the current set of indicators used to estimate ecological sensitivity of Malagasy coastal communities and ecosystems.

4) Greater use of simple conceptual, qualitative and quantitative models could help in understanding the structure and dynamics of communities and fisheries holistically and in identifying important gaps and needs.

5) Simple models coupled with forecasts from global climate models could be used to assess vulnerability in the future.

6) It is important to include consideration of supply chains when assessing vulnerability and considering adaptation options.

7) Understanding the local management measures, including historical and traditional measures, and the institutional governance systems in place is important for vulnerability assessment and identifying adaptation options.

Developing structured and integrated models (see Activity 4) provides a powerful tool for identifying cumulative impacts and exploring the range of likely vulnerabilities, which in turn contribute to identification of appropriate management actions and adaptive solutions to address individual and cumulative impacts and vulnerabilities. These can be conceptual, qualitative or quantitative models depending on the information available and the capacity of those involved in developing a model. Cumulative impacts can be multiplicative rather than simply additive and qualitative or quantitative models, where feasible, provide measured information on cumulative impacts in comparison to those of the individual components and enable ranking and prioritization of the contributions from the different individual stressors. This can assist in setting priorities for mitigating and adaptive actions. Using models that incorporate forecasts of future climate impacts (e.g. Activity 2) allows for forecasting the likely future vulnerability of social systems, ecological systems and the two in combination so that precautionary adaptation measures can be put in place well in advance.

Global models (Activity 2) provide a powerful tool for forecasting future climates and their impacts. They are being strengthened rapidly leading to improvements in the quality and resolution of forecasts at a regional scale. Developing new regional models, for example for Madagascar and the western Indian Ocean, would be expensive and take considerable time. The use of high resolution global models should be more accessible and able to generate reliable results. Knowledge of likely future changes in ocean climates is important in assessing ecological sensitivity and that of individual species to future changes and can be combined with the methods reviewed in Activity 3 for assessing the sensitivity of particular ecosystems, communities and species to future climate-driven change. This in turn could provide opportunities for management actions targeted at increasing the resilience of vulnerable species and ecosystems as well as for advance planning in communities to adapt to future negative ecological changes or take advantage of climate-driven opportunities, for example arising from distributional shifts in harvestable species.

When assessing vulnerability and adaptation, it is important consider the social-ecological system as a whole, from physical drivers through to the resources and their use – from fish to plate. Supply chains are a key component of any natural resource use, such as fisheries, and need to be included as part of the overall system. The catch and distribution channels in Madagascar range from direct use by harvesters and their families to complex and sophisticated channels to supply demanding and valuable export markets. It is essential to have a good understanding of the nature and vulnerabilities in these channels when planning and implementing adaptation measures.

An additional component of a fishery, and other systems of natural resource use, is the management or governance environment made up of the institutions, rules and processes involved in regulating resource use, including historical and traditional measures (see Activity 7 & 8). It is important to understand and consider this component when assessing vulnerability and identifying adaptation options.

5.2. Recommendations for future research

Recommendations for future research on each activity theme can be found in those sections earlier in the report (Chapter 4). These must be considered in their entirety, across all activities, when planning national and regional research activities and programmes for vulnerability assessment and adaptation of marine-dependent communities if the results are to be robust and effective. Failure to consider the overall context of any research can lead to incomplete and misleading results. This does not mean that all of the research recommendations made in this report must be simultaneously implemented. That is likely to be prohibitively costly and not feasible. However, it is important that all of the research issues and recommendations made here should be considered and prioritised on the basis of knowledge gaps, urgency of problems, the capacity of those undertaking the research and other such considerations so that the research that can be undertaken is likely to yield the greatest benefits or positive impacts with the human and financial resources available. It is important to attempt to harmonise and integrate new research activities with all relevant research already being undertaken by different stakeholders in order to maximise the benefits and impacts.

Research priorities identified at the workshop are closely related to the points raised in the previous section on methodologies for vulnerability assessment and can be summarised as:

1) Forecasts of climate change and its impacts on the oceans are important in vulnerability assessment and adaptation planning. Using the high resolution global models already available may be more effective use of resources than for Madagascar to develop new regional models.
2) It is essential to attempt to understand and anticipate the impacts of climate change on marine ecosystems and key species. There is a range of different methods available, each of which has positives and negatives for application in Madagascar. There would be considerable value in undertaking a review of the different methods for determining biological and ecological sensitivity and, based on that review, to develop an optimal, integrated methodology for use throughout Madagascar.
3) Models are valuable tools for increasing understanding, synthesising and integrating available knowledge and providing forecasts of future conditions and cumulative impacts. There would be considerable value for Madagascar in developing a toolbox of modelling approaches, covering conceptual, qualitative and quantitative models, to provide input and advice for managers and decision-makers at all scales from local to national and regional.
4) Research on communities should be undertaken with understanding of the overall context of the community and the actions and processes in which it engages and that impact on it. As discussed in the previous section, supply chains and management institutions and rules are part of and are important to communities.
5) There are many different tools and approaches for working with communities in undertaking research on vulnerability and adaptation. These include techniques such as mapping in different ways, participatory approaches to develop timelines of key events, biological inventories, listing concerns and opportunities related to climate change and other stressors and others (e.g. WWF – South Pacific Programme, 2009). These can and should be integrated with results and information from other scientific sources such as model forecasts of climate change, results from scientific stock assessments and sensitivity assessments, and results of participatory modelling. The development of standard protocols for undertaking such integration would encourage and facilitate holistic approaches to vulnerability assessment.

5.3. Major challenges caused by climate change facing coastal communities

The major challenges that are confronting coastal communities were discussed extensively in the different activities (Chapter 4) and are described there in the different activity reports. In general these challenges were already well understood in Madagascar by local scientists and the management agencies and have been recorded in earlier and ongoing work by government, NGOs and academic institutions in Madagascar. The details of how these challenges impact specific communities and fisheries are often less well understood, however. A primary focus of the workshop was to explore and discuss methods that would help to Identify and understand these details. An over-arching recommendation from the workshop is that, in order to maximise the likelihood of effective and costefficient action to address the challenges, it is important not to treat them in isolation but to consider the integrated and cumulative impacts.

Some examples of the importance of consideration of integrated impacts that were discussed at the workshop include:

- The impacts of climate changes on coral, such as bleaching and cyclone damage, can be intensified as a result of other human-induced threats such as physical damage from fishing and high water-turbidity as a result of river flows and poor land management (which can also have direct impact on fish predators that rely on vision).
- There are typically strong relationships between price (and hence benefit to fishers) and availability, which in turn can be affected by factors including total fishing effort, gear regulations and fishing seasons, supply chain disruptions and efficiency, and impact of non-fishery human activities on resources and ecosystems.
- The pattern of seawards migration of inland and traditional agrarian communities who engage in fishing and are disrupting established fisheries management systems. Addressing these population dynamics requires a broad landscape approach in tackling climate change impacts and in the development of adaptation measures.
- The impacts of climate change can lead to complex chains of events that can magnify (or in some cases may mitigate) the overall negative impacts. For example, changes in fish composition, abundance and availability as a result of climate change can lead to breakdown in the use of traditional knowledge leading to less sustainable fishing practices, and migration of fishers to other areas leading to increased fishing effort and possibly conflicts in the new areas and negative repercussions on the wellbeing of the families left behind in the old areas.

These are just three examples and knock-on effects of negative impacts on the complex networks that constitute fishery social-ecological systems can be expected to be the norm rather than the exception. Research, planning for meeting challenges and the implementation of adaptive actions need to have taken the knock-on effects and interactions of impacts into account in order to identify integrated and robust solutions.

5.4. Options for adaptation

Activities 2 and 3 did not explicitly consider adaptation options but addressed tools and methods for generation of critical information for informing consideration of adaptation options. The remaining activities did discuss adaptation and the conclusions are provided in the individual activity reports in Chapter 4. GLORIA was not designed to develop detailed and concrete recommendations for adaptation options but to discuss and evaluate methods and approaches to be used by authorities, communities and other stakeholders in Madagascar in the development of adaptation options. It is important to keep this in mind when interpreting the sections on adaptation options in this report.

As with the challenges facing communities, the broad and generic adaptation options that could be applicable to marine-dependent coastal communities in Madagascar were already well-understood by the different organizations and institutions working in the country. Some of these options include, for example, use of alternative fishing methods to reduce negative impacts on coral or that do not exclude use by women in shallow areas; development of aquaculture (with improved feeds) as an alternative or supplement to fishing; ensuring robust supply chains that ensure high quality and thereby good prices; improved methods for high-quality preservation of fish; diversification of food sources to improve food security (e.g. goats, arid environmental-friendly cultures) and diversification into other small scale enterprises (manufacturing, tourism, trade).

All of these options hold promise and some are being applied in some cases. The overall message from the workshop is to ensure that options have been evaluated and planned in a manner that has considered the local specifics and context thoroughly and has assessed the challenges and constraints, opportunities and adaptive capacity of the communities in an integrated way, making use of the best available information, including scientific and traditional and other stakeholder knowledge.

5.5. Recommendations for an action plan

Once again, recommended actions specific to the different activities are listed in the report on each activity given in Chapter 4. In summary, these included the following themes.

1) Extend coral bleaching alerts and monitoring of their impacts across the different coral areas of Madagascar. These alerts could also be extended to address key fishery species that have been identified to be intolerant to changes in temperature.
2) Build national capacity in the use of global models for regional projections, including capacity in the analysis of available models to assess their value and reliability for Madagascar, and in the interpretation and application of results from the models.
3) Develop an integrated methodology for undertaking analyses of the sensitivity of species and ecosystems to climate change that is suitable for use throughout Madagascar and apply it to determine the sensitivity of high priority fisheries species (to be identified) and sensitive ecosystems.
4) Establish new or utilise existing systems to collect and analyse fisheries data (e.g. catch and effort) for as many fishery resources as possible to facilitate effective management and maintaining resilience of populations.
5) Develop guidelines to assist in building models (conceptual, qualitative and quantitative) as a tool for synthesizing information and exploring and discussing adaptation options. Use conceptual and other models as a standard approach to assist in undertaking vulnerability assessments and to help identify important data gaps and needs.
6) Increase the knowledge and understanding for more species taken in fisheries catches in Madagascar and the distribution channels for their utilisation to assist in identifying options for improving livelihoods and to support building resilience and adaptation to climate change.
7) Build or strengthen capacity of non-traditional fishers in sustainable fishing principles, practices and techniques.
8) Develop effective legal tools at local government level to allow for secure sea tenure and access to fishery resources.
9) In areas where they do not exist or have been eroded, build or reinvigorate local governance systems and institutions as well as management rules and measures.

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7. Appendices

Appendix A: List of Participants

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Global Learning Opportunities for Regional Indian Ocean Adaptation (GLORIA)

Programme

A dedicated workshop for *Activity 9: Education and outreach* will be taking place in Toliara on 14th June, convened by Adina Paytan, University of California, Santa Cruz, United States of America and Paubert T. Mahatante and Jose Victor Randrianarimanana, IH.SM.

DAY 1, Tuesday 14 June[1]

O8h30 – 09h00 Registration

O9h00 – 09h30 Opening and welcomes

1. Dr Kevern Cochrane, Rhodes University, South Africa and Lead Project Investigator for GLORIA
2. Dr. Ylenia Randrianarisoa, Secretary of State in Charge of the Sea, Madagascar **(to be confirmed)**
3. Dr Hery Rakotondravony, Directeur du Bureau National de Coordination des Changements Climatiques (BNCCC), Madagascar

O9h30 – 09h45 Overview of GLORIA and the workshop objectives: Kevern Cochrane, GLORIA

09h45 – 10h30 Introduction of participants, including brief overview of activities and programmes on climate change, coastal communities and fisheries in Madagascar

10h30 – 11h00 Coffee break

11h00 -11h45 Projections of the impact of climate change on marine environment around Madagascar: Drs Katya Popova and Simon van Gennip, National Oceanography Centre, United Kingdom

12h00 – 12h30 The National Adaptation Plan of Madagascar: Jane Razanamiharisoa, BNCCC

12h30 – 12h15 Texts and Legislations on Climate Change and Adaptation in Madagascar: Nivohary Ramaroson, BNCCC

12h45 – 14h00 Lunch

14h00 – 14h45 Report on 'An Assessment of the Vulnerability of Small-scale Fisheries in Madagascar to Climate Change': WWF Madagascar and Blue Ventures

14h45 – 17h00	*Activity 3*: **Ecological sensitivity assessment**. **Convenors**: G. Pecl, University of Tasmania, Australia, H. Rakotondrazafy, WWF Madagascar	*Activity 7 & 8:* **Perceptions and mapping** **Convenors**: S. Aswani and L. Scott, Rhodes University, South Africa, T. Chaigneau, University of Exeter, United Kingdom

[1] Coffee breaks will be held from 10h30-10h50 and 15h30-15h50 each day

	and W. Sauer, Rhodes University, South Africa Presentations on different methods and projects, including: - Methods applied by WWF Madagascar for biological and ecological factors; - Madagascar Early Warning System by Manakasina Todisoa. BNCCC • Discussions and Conclusions	Assessing perceptions of change and participatory mapping.

17h30 – 19h30 **Reception, Carlton Hotel**

DAY 2, Wednesday 15 June

O8h30 – 09h00 Registration

09h00 – 09h30 Report to plenary on discussions the previous day on Activities 3 and 7+8

09h30 – 13h00 (with 30 min coffee break)	*Activity 4:* **Key ecological assets** **Convenor:** É. Plagányi, CSIRO Oceans & Atmosphere, Australia • Presentation on conceptual models of key ecological assets and processes • Collaborative development of conceptual models	*Activity 7 & 8:* Continued

13h00 – 14h00 **Lunch**

14h00 – 17h00	*Activity 2*: **Climate change projections** Convenor Katya Popova, National Oceanography Centre, United Kingdom (continued from Day 1) Interactive group discussions on climate change projections.	*Activity 5 & 6*: **Vulnerability assessment** **Convenors:** É. Plagányi and I. van Putten, CSIRO Oceans & Atmosphere, Australia, H. Rakotondrazafy, WWF Madagascar and T. Chaigneau, Exeter University, United Kingdom Presentations on: • Adapting coastal zone management to climate change considering ecosystem and livelihoods, Michaël Manesimana, PAZC, Madagascar • Methods applied by WWF Madagascar for social and other human aspects.

		• Recent field survey conducted by Rhodes University and IH.SM as a part of GLORIA project Discussions on: • Interactions between climate change and vulnerability • Poverty and vulnerability analysis • Vulnerability in fisheries supply chains

DAY 3, Thursday 16 June

O8h30 – 09h00 Registration

09h00 – 09h30 Report to plenary on discussions the previous day on Activities 2, 4, 5+6 and 7+8

09h30 – 13h00	Continued discussions on *Activities 2, 3 and 4* as required.	*Activity 5 & 6*: Continued • Synthesis and use of existing data • Discussion of adaptation options. Synthesis and discussion of vulnerabilities and adaptation options, including recommendations on WWF methodology and options for streamlining with particular reference to report on 'An Assessment of the Vulnerability of Small-scale Fisheries in Madagascar to Climate Change'.

13h00 – 14h00 Lunch

14h00 – 15h30

- Brief Reports Back by each activity
- Plenary discussion on bringing the learning from all sessions together and integrating the climate change projections with biological and ecological changes and the climate change observations and vulnerabilities.

15h30 – 15h50 Coffee break

15h50 – 16h50 Plenary discussion on overall conclusions and recommendations, what next?

16h50 – 17h00 Closure of workshop