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MOZALINK

Final report

Western Indian Ocean Marine Science Association (WIOMSA)
Grant N° : MASMA/OP/2013/02



Full project title : « MOZALINK - Linking marine science, traditional knowledge and cultural perceptions of the sea in the Mozambique Channel to build tomorrow's marine management using spatial simulation tools and educational game »

This final report was jointly developed by the Research Institute for Development (IRD, France) with the contributions from CORDIO (Kenya), University Eduardo Mondlane (Mozambique), University of Dar es Salam (Tanzania) and Institut Halieutique et des Sciences Marines (Madagascar) in February 2018.

Published by: IRD, La Réunion, France

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Citation: Lagabriele E., C. Sabinot, D. Obura, R. N. Mwaipopo, P. Chabanet, S. Bandeira, E. Rodary, B. Surugue, F. Cautain, E. Crochelet, J. Ferraris, J. A. Mahafina, E. Mariano, J. Majambo, J. Mbugua, B. Surugue (2018). MOZALINK final report. WIOMSA/MASMA/OP/2013/02. IRD, Saint-Denis, France. 39 p.

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Cover image: Ibo, Mozambique © Catherine Sabinot, IRD

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ABSTRACT

The MOZALINK 2014-2017 project aimed to develop analysis and solutions to support transparent, sustainable and science-based marine spatial planning (MSP) practices in the Western Indian Ocean. The Mozambique Channel area includes 90 million of inhabitants distributed in five countries: Mozambique, Madagascar, Comoros, Mayotte and Tanzania. Geopolitical fragmentation and socio-economic heterogeneity across the region are the main challenges for regional marine spatial planning. The project explored the links existing between 1) scientific products and models describing ecosystems species and ecological connectivity and 2) anthropological surveys of traditional knowledge, social perceptions and management. MOZALINK involved eighteen senior researchers, two post-docs, two research assistants and a dozen of MSc students, thus contributing to build regional capacities. Bringing decision-makers, stakeholders and scientists to work together in teams is a challenge. We made teamwork happening in MOZALINK through the development of boundary products that required interdisciplinary collaboration. The main output of the project are 1) an on-line spatial data infrastructure (MASPAWIO) and a participatory geodesign tool (Seasketch), 2) an educational toolkit designed to play around the co-management of marine resources, personalized to the Mozambique Channel countries languages (MARECO), 3) a roadmap toward MSP in the region taking into account geopolitical issues and 4) a 52 mn documentary to share the project results with the public. MOZALINK was funded by the Western Indian Ocean Marine Science Association through its Marine and Coastal Science for Management programme (2014-2017, US \$400.000). . Each country was represented in the project by a co-investigator.

1. THE MOZALINK PROJECT

1.1. General objective

The overall goal of the MOZALINK project was to describe the natural and cultural heritage related to the coast and the sea in the Mozambique Channel, to compare traditional and scientific knowledge, to help the people and countries bordering the channel to build a governance regime that reflects their values. Therefore, the MOZALINK project aimed to contribute to strengthen interactions between research institutions and management authorities. Throughout the development of the spatial planning simulation tool, MOZALINK also aimed to contribute to “establish a common regional platform by 2017 to advance and apply science for the sustainable development of marine and coastal environments, bringing together governments, institutions, the private sector and community stakeholders for joint actions”. More precisely, the MOZALINK aimed to address the following Priority Thematic Research Areas of WIOMSA.

Vulnerability, Resilience & Adaptation: We followed a trans-disciplinary approach to better understand the future state of social-ecological systems. This was achieved through the implementation of a spatial simulation model enabling to explore social-ecological resilience, and adaptive capacity to future change under different climate/impact mitigation scenarios.

Coastal Livelihoods: Through the study of interactions between local and regional management structure and socio-ecosystems, we highlighted the need for new management mechanisms, and the existence of key opportunities for the region. This contributed to develop strategies to improve local use of coastal and marine resources and to identify alternative livelihoods include the empowerment of local actors, especially women, who often have the least opportunities, enhancement of locally existing natural resource management systems, adoption of alternative/additional income generating activities, and increased environmental awareness.

Governance for the Future: A strong emphasis was made in the project on political sciences and anthropology to study the process of informed decision making that enables trade-offs between competing users of a given resource so as to balance protection with beneficial use in such a way as to mitigate conflict, enhance equity, ensure sustainability and hold officials accountable.

1.2. Specific objectives

More specifically, the project aimed:

- 1) To develop a spatially explicit understanding of marine connectivity patterns, ecosystem state, and their vulnerability to drivers of change in the Mozambique Channel.
- 2) To study the natural and cultural marine heritage in the Mozambique Channel, i.e. marine and coastal resources, peoples' movements, governance regimes and perceptions by different groups of actors, at local and regional levels.
- 3) To share knowledge and perceptions of natural and cultural marine heritage between different groups of actors, and identify harmony/discordance among these.
- 4) To build capacity for improved marine management through interdisciplinary collaboration, training and exchanges around spatial simulation tools and pedagogical games related to the management of the sea.
- 5) To foster the incorporation of perceptions of natural and cultural heritage into marine governance regimes in the Mozambique Channel at local and regional levels.

1.3. Context and rationale

The Mozambique Channel

Mozambique Channel lies between Madagascar and the eastern coast of Africa. It is 400 miles wide and 1,050 long. Marine ecosystems (e.g. coral reefs, mangroves, seagrasses) in the Mozambique Channel contribute to the food security and economic development of millions of coastline inhabitants in Comoros, Tanzania, Mozambique, Madagascar and Mayotte/Iles

Eparses (France).

The Mozambique Channel stands out as globally unique in the Western Indian Ocean – together with the Mascarene Plateau. It is a distinct element of the geological history of the Indian Ocean basin, going back >150 million years. It fundamentally affects the currents that drive all marine ecosystems and species, on evolutionary and ecological scales. Due to the location of Madagascar in the path of the South Equatorial Current, and of the Asian monsoon system with its opposing trade winds, the Western Indian Ocean experiences a highly energetic and seasonally variable western boundary current system found nowhere else on the planet. Because of the geographic size of both these areas, it could be considered as serial trans-boundary sites containing multiple smaller-scale sites that are essential components of the whole.

More precisely, the Mozambique Channel experiences a highly energetic and variable regime of meso-scale circular currents (eddies, approx. 100-300 km across) that cause water to flow in all directions – north, south, east and west – and fundamentally affect the diversity and productivity of marine ecosystems within the channel. The coral reefs in the northern channel are the most diverse in the Indian Ocean (save for those parts bordering Indonesia), and represent a second hotspot of tropical marine biodiversity globally. The open-water food webs in the channel are highly productive and dynamic, resulting in concentrations of fish, turtles, marine mammals and seabirds that are critical for the species themselves and are spectacular natural phenomena. They also support the coastal and national economic activities of the bordering countries, through sectors such as fisheries and tourism. The Mozambique Channel and East African coast are the prime habitat of the coelacanth, a ‘living fossil’ that illustrates the long-term stability of this region.

Sites within the Mozambique Channel are presented in Obura et al. (2012) report as examples that express some aspect of the geological and/or oceanographic features that make the channel unique globally, combined with biological features best represented at the individual sites. States Parties with jurisdiction over these sites (Mozambique, Madagascar, Comoros, Tanzania and France) may follow a traditional approach of single-state nominations to the World Heritage List, or develop an innovative inter-governmental approach that could establish a multi-country serial site in the Mozambique Channel.

Building an interdisciplinary understanding of the Mozambique Channel

Building tomorrow's marine and coastal management in the Mozambique Channel requires an interdisciplinary approach, involving specialists in both natural and human sciences. It also necessitates expressing this knowledge in language that is accessible to the general public, including children (the actors of tomorrow) and policy-makers. This project brought together local and regional partners in the Mozambique Channel under a common goal: to describe natural and cultural marine heritage in the Channel and its social representations, and by doing this, to help ensuring the implementation of sustainable management of the ecosystems and resources in the region.

Several programs and research projects studied oceanography, marine ecosystems, species and connectivity in the Mozambique Channel (ASCLME, WIO 'Coral Triangle', etc.). There was a need to share this scientific knowledge and to balance it with a local understanding of social, political and economical issues related to marine management. Our objective was to show the diversity and differences of culture and social perceptions of the sea across the region while contextualising it with scientific data on ecosystems. The objective here was to build adaptive management solutions taking into account, on a similar level, the ecological, social, political, and economical dimensions of marine resources management.

Comparing traditional and science-based knowledge

Coastal inhabitants who depend on sea for food also have an important responsibility in maintaining their resources. The resource management role can be positive (sustainable use) or negative (destruction of habitats, overuse). This role is often deeply rooted in a common heritage, varying from one region to another according to the diversity, structure and history of human societies. An anthropological approach thus becomes necessary to gain a full

understanding of the stakeholders interacting within the marine ecosystems, of how knowledge is transmitted and of possible conflicts of perception, so as to facilitate the emergence of management regimes that are efficient in sustainable terms, consistent with local and meta-population dynamics of marine organisms, and respectful of the knowledge and perceptions of local populations. This also implies to recognize the existence and value of cultural coastal landscapes and seascapes.

To ensure a harmonious development of the relationships between humans and environments, it is essential for scientists and marine and coastal ecosystems users to share their knowledge, notably with the future generations, and for these exchanges to be studied. This information must be also accessible to managers and policy-makers. To this purpose, the concepts of meta-populations and marine ecological connectivity are well known among marine scientists but not widely appreciated in the broader community. Yet, connectivity revealed through marine species – reef fish, corals, marine mammals, turtles, etc. – is often mirrored in human dimensions, such as through shipping and trade connections, fishing migrations, historical migrations, and other features.

In this project we attempted to use the concept of connectivity – which in oceanographic terms looks at geographically distinct sites and how they are linked by oceanographic processes – at both natural and human levels (i.e. looking at people in geographically distinct sites and exploring how different natural, cultural, social and political processes link or separate them, physically or socially). Based on this knowledge, we also aimed to strengthen interactions between national research institutions and management authorities, and between stakeholders/interested parties in the Mozambique Channel.

From ecological connectivity to trans-national cooperation

Integrating ecological connectivity into spatial planning is crucial, moreover in a global context of growing degradation of ecosystems. This is particularly challenging in a context of cooperation among different countries sharing common and inter-dependant marine resources.

Numerical transport models have been developed to infer pattern of coral and reef fish larvae dispersal. They are increasingly being used worldwide for the design of MPA systems, fisheries management and disaster management. Larvae transport across the ocean is the main process underlying connectivity. It determines species evolution, genetic mixing and overall adaptation of reef fish, coral, seagrass (etc.) populations. If a population is replenished by its own recruits (i.e. self recruitment), the population should be managed locally to maintain the genetic pool. However if there is substantial exchange between geographically distinct populations, those species should be managed at a broader scale, for instance through larger single marine protected areas or spatial reserve networks.

Understanding connectivity patterns is a major challenge in ecology and management of living resources especially in a global context of severe fish stocks depletion. The knowledge stemming from those analyses is important to guide marine spatial planning. It is crucial to identify flows between marine populations but also the source sink relationships. If a reef is identified as a natal source of marine larvae, it is essential to protect marine populations with a pelagic stage. If a reef is identified as a sink of marine larvae, it is essential to focus on habitat conservation.

Developing a trans-boundary spatially explicit understanding of connectivity across scales in the Mozambique Channel is a vital basis for the sustainable management of the regional marine ecosystems. We aimed to contribute to build such trans-boundary strategies to prevent ecosystem loss or other negative socio-economic impacts on local communities in the Mozambique Channel. Thus, the project aimed to highlight the need for significant articulated local/large-scale cooperative marine management strategies, to avoid the most damaging effects of human-induced change on marine ecosystems.

Exploring futures of the Mozambique Channel using spatial simulation and pedagogical games

The Mozambique Channel ecosystems are unique, diverse and complex, but are also extremely threatened due to the combined impacts of human activities and climate change (overfishing,

exploitation of sea bottom, pollution, and other direct impacts). Responding to these pressures demands decisions at multiple levels, based on an interdisciplinary knowledge of the socio-ecological systems across scales, and on a strengthened awareness and preparedness among stakeholders to build adaptive management solutions at local and regional level. This is a contribution to the implementation of the Nairobi Convention.

Spatial management simulation is increasingly used to accompany the development of marine management policies. Spatial simulation aims to promote the emergence of innovative management solutions and to facilitate negotiation and experience-sharing among participants. Scenarios describe the possible co-evolution of social and ecological systems. Generally developed at regional level with decision-makers, managers and scientists, those scenarios combine plausible long-term evolution and short-term evolution (economic, social, technical, political, etc.) of the system.

Spatial management simulation models are generally implemented as Multi-Agent System, Geographic Information System (GIS) or cellular automata, or a combination of those tools. More recently, web-based decision support tools such as SeaSketch (i.e. MarineMap) in combination with Aquamap (species distribution data) and IPCC scenarios, offer promising perspectives for data integration, scenario simulation and interactive marine spatial zoning of activities.

Following a similar trend in mixing environmental science, management and participation, pedagogical games are increasingly used to improve environmental awareness and cooperation among participants. Those participants are typically local community members (adults or kids). The design of such games is a scientific and social challenge by itself. The second challenge is to measure the “real” impact of the gaming activity before/after, with prior and naïve subjects. Generally those pedagogical games take the form of board games combined with card games.

The scenario building and the gaming activities can be conceptualised as a learning process leading the participants (decision-makers, stakeholders and researchers) to explain and share opinions regarding the complex socioecosystem and its management options. This approach promotes the social acceptability of marine ecosystems management policies and their integration along with sectoral management policies.

1.4. Institutions involved and coordination with regional efforts

The IRD Institute for Research and Development coordinated the MOZALINK project. The partners were CORDIO (Kenya), the University Edouardo Mondlane (Mozambique), the Institut Halieutique et des Sciences Marines (Madagascar) and the University of Dar es Salaam (Tanzania). Each partner was responsible for the management of its fundings. Partners were plainly involved in the project through participation to workshops and meetings, co-training of students and co-publications.

Founded in 1944, the IRD is a public science and technology research institute under the joint authority of the French ministry in charge of research and of the French ministry in charge of Foreign affairs. Emphasizing interdisciplinarity, the IRD has focused its research for over 65 years on the relationship between man and its environment, in Africa, Mediterranean, Latin America, Asia, Oceania and the French tropical overseas territories. Working throughout the tropical countries and territories, the IRD has three main missions: research, training-capacity building, and consultancy work. Its research, training and innovation activities are intended to contribute to the social, economic and cultural development of southern countries.

The IRD is implicated in the incubation and implementation of interdisciplinary projects between Northern and Southern countries, or even between several Southern countries, such as the Regional Pilot Programs (PPR), relying on the scientific excellence of its Units to do so.

PPR Parego-Herego - The conception of the MOZALINK project was carried out under the IRD programme Heritage Resources Governance (HEREGO), which promotes consideration of the inter-linkages between natural and cultural domains in determining how to sustainably manage human-environment interactions in development and poverty context. The purpose of this grant was to bring together a group of researchers from different disciplines to explore ideas of marine Heritage in the Western Indian Ocean, the importance of connectivity in the marine domain and to identify linkages across natural and cultural domains. The planned outcome was to chart a course of action to push this agenda forward through multi-disciplinary collaboration in the region between French and African, and islands and mainland scientists. Researchers from IRD, Université de la Réunion (France), CORDIO (Kenya), University Eduardo Mondlane (Mozambique), and Institut Halieutique et des Sciences Marines (Madagascar) have worked together during a week in December 2013 to propose the concept note "MOZALINK".

Three major domains, each investigated by a specific scientific department (health, society, environment and natural resources), constitute priority issues for the IRD and will be tackled by the IRD on its quest to contribute to the achievement of the Millennium Development Goals. Therefore most of the research programmes contribute to the sustainable development of the countries from the South with an emphasis upon the relationship between humans and their environment. Relative to researches on development and governance, IRD follows two objectives (and the MOZALINK project responded exactly to these objectives):

- The primary objective is to analyse the policies and complex support structures, which are central to the development. At the level of the States, issues on the novel tools required in order to implement the "poverty-fighting policies" raise the fundamental question on the role and methods of intervention of the public authorities and of the governance.
- The secondary objective is to study the environmental issues and the management of natural resources, of water, of soil and of land in general, by analysing the links between public policies and local practices.

All IRD's activities are carried out in collaboration with universities, other leading higher education institutions and private or public research institutes, from France and from the developing countries together. The IRD conducts its research in close co-operation with its numerous partner countries. It operates in some 40 countries and has 35 research centres and representatives' offices in France and all over the tropical world. 600 of its technical staff are from the countries of the South, and foreign researchers are directly involved in its research programmes. Key figure for IRD in 2011: € 232.9 million budget, € 31.2 million revenue from contracts and value-added products, 2176 staff including 837 researchers, 997 engineers and technicians and 342 locally employed staff, 37% of staff working outside metropolitan France, of whom roughly 51% work in Africa or the Mediterranean / 60 research units, over 1556 scientific articles published, 45% signed jointly with Southern partners. More over IRD supported in 2011 44 new teams in the South

IRD is present in La Réunion since 1987 with research programmes in sea sciences and remote sensing for sea environment monitoring. In the Indian Ocean IRD operates in cooperation with other IRD research units located around the Western Indian Ocean countries and territories. Together with the University of La Réunion, IRD is involved in the implementation of a Regional Marine Pole of Excellence that has been supported by a FP7 EU grants "Run Sea Science" project. Three IRD research units will collaborate for this project: the IRD/SPACE-DEV unit, the IRD/CoRéUs unit and the IRD/GRED unit.

The MOZALINK initially brought together national institutions from the Mozambique Channel: Eduardo Mondlane University (Mozambique), IHSM (Madagascar), University of Dar es Salaam (Tanzania), IRD (France) and CORDIO (Kenya). Interactions among partners were developed through regular annual meeting, co-authoring and co-supervision of students. Despite encouraging initial contacts, our partner from Comores couldn't fulfil its commitment.

Throughout the project implementation process, collaborations were further developed with external partners including the International Union for Conservation of Nature (MASPAWIO

project), the Indian Ocean Commission (IOC) and the McClintock Lab (University of Santa Barbara, California, US). Other interactions with on-going projects, included contacts with the Fonds français pour l'environnement mondial (FFEM), the UNDP Global Environmental Finance/ASCLME project, the SPACES Ecosystem Services from Poverty Alleviation programme and the IOC/ISLANDS project. A collaboration was developed with the Natural Marine Park of Mayotte.

The MOZALINK project also served as a spin-off platform for at least three projects: EU/EASME/EMFF Ocean Metiss Maritime Spatial Planning In the South-Western Indian Ocean Basin (1.2 M euros 2018-2020), EU/EC MOVE Mapping and assessing the state of ecosystems and their services in the outermost regions and overseas countries (1.2 M euros 2018-2020) and the IOC/UE/FED G2IO Great Observatory of the Indian Ocean (on-going funding application). CORDIO and partners are involved in the Northern Mozambique Channel Initiative (NMCI).

2. THEORETICAL FRAMEWORKS

The theoretical frameworks of reference are inter-disciplinary by nature with the following disciplines being involved: ecology, geography, anthropology, political sciences and informatics. More specifically, the theoretical frameworks entails the following concepts:

2.1. Marine ecosystems and ecological studies

Marine ecosystems, and more particularly coral reefs are important ecosystems, supporting food and large economic sectors from artisanal fisheries to tourism. However, they are seriously threatened by increasing human pressure on coastal areas and habitat that make them much more susceptible to climate change. The manner in which communities respond to these perturbations and how increase their resilience are among the most fundamental aims of ecological studies to settle management actions on coral reefs. The maintenance of biodiversity is highly conditioned by deterministic factors (such as habitat structure, currents) as well as stochastic processes (such as the success of recruitment related to currents and habitat).

2.2. Drivers of ecosystem changes

Ecosystems are increasingly threatened, not only at local scales, but also at regional and global scales (Folke et al., 2007). This is a synergetic effect of the growth of the human population, of the globalisation of trade and exchanges supported by technical innovations and a lack of management of negative externalities (Turner et al. 1990). Those systems are now so interwoven that many individual actions occurring locally are regional and global in their cumulative and combined effects (Halpern et al., 2009). In reverse, global drivers of change, such as climate-related drivers, affect socio-ecological systems at all scale.

2.3. Ecological connectivity

Ecological connectivity is considered as the flux of items between different locations (Sale et al., 2010). The effective transfer of individuals (especially pelagic larvae) between local populations is very important for coastal management but also notoriously difficult to study empirically and quantify. Connectivity between distant populations is a result of hydrodynamic transport and biological traits of larvae. Marine larvae dispersal is notoriously difficult to study empirically due to the small size of larvae and long dispersal distances (up to hundreds of kilometers from their initial release site, Leis, 1984; Victor, 1987; Clarke, 1995). Moreover, the details of dispersal patterns vary among species. Understanding connectivity patterns is a critical component in the design of marine protected areas (MPA). Indeed if a fish population is replenished by its own recruits (i.e. self recruitment), the population should be managed locally to maintain the genetic pool. However if there is substantial exchange between geographically distinct populations, those species should be managed at a broader scale (Botsford et al., 2003), for instance through larger single marine protected areas (Claudet et al., 2008) or MPA networks (Lockwood, 2002). Numerical transport models have then been developed to infer pattern of larval dispersal (Schultz & Cowen, 1994; Roberts, 1997; Cowen et al., 2000; Trembl et al., 2008; Mora et al.,

2012) and are increasingly being used worldwide for the design of MPAs (Planes et al., 2009) and fisheries management (Gaines et al., 2010).

2.4. Marine Protected Areas networks

In the context of degradation and overexploitation of these ecosystems, the establishment of marine protected areas (MPAs) is one way to foster the resilience of coral reefs in protecting habitat from human pressure and manage halieutic resources to overcome their overexploitation. Marine reserve networks are an effective tool for conserving marine biodiversity. However, the translation of marine reserve network theory into practice remains a social, methodological and technical challenge (Agardy et al., 2011, Banks and Skilleter, 2007). Among the barriers to identify and implement future marine reserves, a common issue is the difficulty to deal with multiple scales (Cash et al, 2006).

2.5. Marine spatial planning

Marine spatial planning is aimed at allocating human uses of the sea, by balancing socio-economic interests with the ability of marine ecosystems to support the synergetic changes induced by those activities. Despite conceptual and technical advances, Marine Spatial Planning still poorly reflects the multi-scalar and multi-level nature of the world. Yet, the integration of multi-scale interactions within MSP remains a practical challenge. This is paradoxical as the need to address cross-scale dimensions in conservation planning is acknowledged and multi-resolution data describing social-ecological systems and processes through space and time are increasingly available. So far, marine spatial planning has been implemented at a single scalar level: at local level (Banks and Skilleter, 2010), national level (Douvere et al, 2007) and at regional or global level (Gilliland and Laffoley, 2008). MSP focuses on a single scalar level and rarely examines the interactions of phenomena, either social or ecological, across scales (Cash et al., 2006).

2.6. Environmental anthropology

Anthropology, and especially ethnoecology and environmental anthropology facilitate the study of relationships between humans and the environment (Bahuchet 1985; Berkes 1993; Haudricourt and Dibia 1987). It takes into account the ways in which populations use their environments, and also how they perceive, conceive and experience them. Furthermore, it provides an interesting and holistic view regarding the transmission of knowledge, know-how and perceptions of the environment (Brunois 2005; Friedberg 1997; Gibson 1986; Ingold 2000; Ingold 2004; Pálsson 1998; Sabinot 2005; Sabinot 2007). Due to the fact that ethnoecology was constructed at the boundary of various fields of science, and is today at their interface, it also facilitates dialogue with the latter.

2.7. Political ecology

The political ecology approach we chose to adopt will lead to the analysis of contexts, actors and stakes involved in the local and regional concept of heritage. We propose to conduct our research in relying on this assertion “Where there is contrasting knowledge, there is also potential for dialogue and convergence”(Hviding 2006): we will mobilize the authors that have built their reflection on the definition (and the use) of the concepts of local ecological knowledge and nature regimes, including (Agrawal 2004; Agrawal and Gupta 2005; Berkes and Folk 1998; Biersack and Greenberg 2006; Bohensky and Maru 2011; Escobar 1999; Pálsson 1994). This theoretical framework could permit to respond to those fundamental questions: how various actors conceive the ocean?; how the concept of local, regional or world heritage is built? ; and when new discourses relative to environment are proposed by transnational or national organisations and institutions, how each actor appropriate, interpret and transform them? It is through this local negotiation that a process of heritage can take place, confronting various environmental experiences, perspectives and futures key to the understanding of changing power relationships.

2.8. Environmental modeling

Environmental modelling often implies defining elements that relate and interact with each other, in a system that evolves with time. Within the framework of the project we initially planned to use the Ocelet domain specific environmental modelling language that is designed around a limited set of key concepts chosen to help modellers focus on their model, while leaving the implementation to an automatic code generation phase (Degenne et al. 2009). In particular, Ocelet allows building behavioral graphs that describe how interact the entities of the model in simulation scenarios that describe the possible temporal evolutions (Degenne et al. 2010). To better reflect local, real-world processes, the Ocelet language allows describing spatial and social dynamics that are described as interacting processes. Through the establishment of direct links between model entities and GIS data, Ocelet focuses on the fact that interactions between landscape elements are essential in environmental modelling. In order to facilitate landscape visualization (Sheppard and Cizek 2009), Ocelet models results can be exported as kml or shp files with temporal attributes, which makes possible to display and compare simulations scenarios over time with popular software like Google Earth. Beyond the usual monitoring of selected indicators, this interactivity adds value to models that aim at providing support to discussion, knowledge integration, and land-use foresight as in current participatory modeling projects in Reunion Island (Lestrellin et al. 2013, David et al. 2012).

3. PROJECT IMPLEMENTATION

3.1. Project structure

To achieve its objectives, the project was organized in six Modules (i.e., work packages) described in the conceptual framework below (Figure 1):

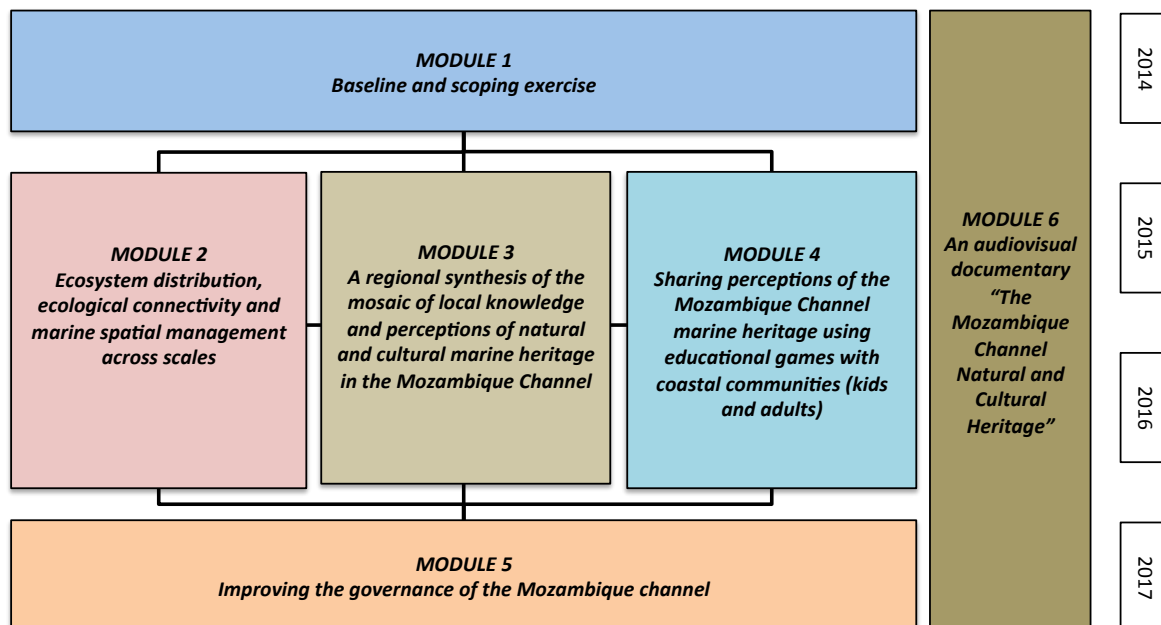


Figure 1. Structure of MOZALINK modules.

3.2. Detailed project structure

Each module entailed the following detailed activities (Figure 2).

MODULE 1 <i>Baseline and scoping exercise</i>	<i>Activity 1.1 – Understanding the regional context</i> <i>Activity 1.2 – Understanding the national and local context</i> <i>Activity 1.3 – Understanding marine and coastal governance across scales</i>
MODULE 2 <i>Ecosystem distribution, ecological connectivity and marine spatial management across scales</i>	<i>Activity 2.1 – Modelling regional-scale connectivity for oceanic dispersive species</i> <i>Activity 2.2 – Compiling regional-scale data on the movement of species</i> <i>Activity 2.3 – Assessing ecosystem state using field data and satellite images</i> <i>Activity 2.4 – Simulating future scenarios using a spatial simulation model</i>
MODULE 3 <i>A regional synthesis of the mosaic of local knowledge and perceptions of natural and cultural marine heritage in the Mozambique Channel</i>	<i>Activity 3.1 – The marine natural heritage as perceived by local actors</i> <i>Activity 3.2 – Regional-scale analysis of the perception of the marine heritage</i>
MODULE 4 <i>Sharing perceptions of the Mozambique Channel marine heritage using educational games with coastal communities (kids and adults)</i>	<i>Activity 4.1 – Adapting the MARECO toolbox to the Mozambique Channel context</i> <i>Activity 4.2 – Playing the MARECO toolbox game with local communities</i>
MODULE 5 <i>Contributing to the future governance of the Mozambique Channel marine heritage</i>	<i>Activity 5.1 – Identifying local marine resources management and governance issues</i> <i>Activity 5.2 – A roadmap toward the Marine Spatial Planning in the WIO</i> <i>Activity 5.3 – Identifying and sharing emerging challenges</i>
MODULE 6 <i>An audiovisual documentary “The Mozambique Channel Natural and Cultural Heritage”</i>	<i>Activity 6 – Audiovisual documentary</i>

Figure 2. Detailed content of MOZALINK modules.

3.3. Module leaders

Table 1. List of Module leaders

MOZALINK Module	Leader
Module 1	S. Bandeira (UEM, Mozambique) & E. Lagabrielle (IRD, France)
Module 2	D. Obura (CORDIO, Kenya)
Module 3	C. Sabinot (IRD, France) & R. Mwaipopo (UDES, Tanzania)
Module 4	P. Chabanet (IRD, France)
Module 5	E. Rodary (IRD, France) & E. Lagabrielle (IRD, UR, France)
Module 6	B. Surugue (IRD)

3.4. Regional study area delineation and selection of local study sites

MOZALINK addressed regional and local scale issues related to marine ecology, social representation of ecosystems and spatial planning in the Mozambique Channel. A regional MOZALINK Area Of Interest for the project has been delineated (Figure 3).

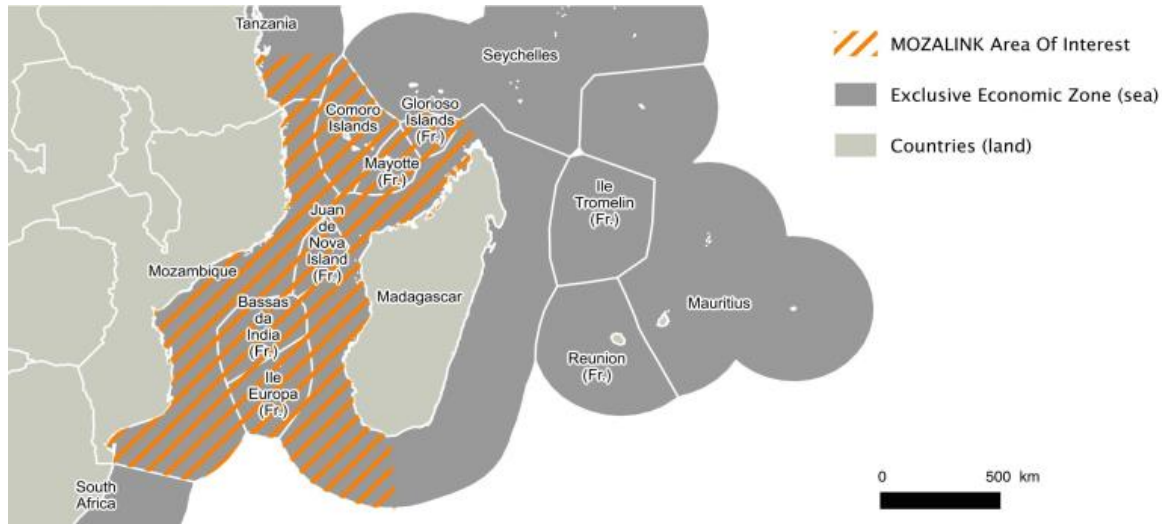


Figure 3. Area of interest of the MOZALINK project.

A set of local sites has been selected for focused local studies. Local study sites met several criteria, including geographic coverage of the Mozambique channel, mix of habitats and resources, inclusion in prior prioritizations and ‘control’ sites to these, presence of appropriate-sized villages (500-3,000 inhabitants), presence/absence of migrants, national prioritizations, and presence of local partners to facilitate in fieldwork and achieving impacts as a result of the project. After internal discussion among team members, we identified the following set of focal sites for local studies (Figure 4).



Figure 4. List of MOZALINK focal study sites. Mozambique (Quirimbas/Ibo, Inhaca/Maputo Bay), Tanzania (Mnazi Bay Marine Park, Mtwara), Madagascar (Ankatafa, Andavadoaka), Mayotte (Parc Naturel Marin) and Comores.

4. KEY ACTIVITIES AND RESULTS

4.1. Module 1 - Baseline and scoping exercise

Aims

Each country has specific institutions and histories that strongly influence possibilities, opportunities and constraints for management on the ground. Picturing regional, national and local contexts, including inter-governmental cooperation across the Mozambique Channel was important to ensure that the project understands its social, economic, political, cultural and biophysical context. Since the project covered a broad integrative topic (natural and cultural marine heritage), it required that a comprehensive baseline assessment of existing information be undertaken at regional, national and local scale to frame the project and to guide the collection of social and biological field data (within study areas and focal sites).

Team

To develop the activities (Activity 1.1, 1.2 and 1.3) of the Module 1, collaboration was initiated with Pr Christian Bouchard (PC) (Laurentian University, Ontario, Canada) a geographer specialized in geopolitical issues of the Western Indian Ocean. An MSc student (Annabel Céleste, AC) in geography was recruited to develop the regional geopolitical analysis.

Methods

This activity collated historical and current information to describe the geographic, social, economical, cultural, institutional and ecological context of the study area. The Area Of Interest (AOI) of the project has been delineated to this purpose. At national and local scale, this activity identified and described the management regimes, institutions and interventions/regulations in place, ensuring that the national and local context was properly understood with local partners. This activity pictured the principal governance institutions, territories and management tools in each of the countries, as a basis for further modules 2, 3, 4 and 5. Key regional and national issues were identified and mapped. This included the description of international relations among countries, international and transnational institutions (IOC for instance). Marine specific issues were described: Exclusive Economic Zone extension claims (CLCS), fisheries management mechanisms (IOTC), Area Beyond National Jurisdiction, national oil and gas concessions and trans-national marine protected areas networks.

Activities

E. Lagabriele travelled to Maputo in November 2014 where he met with project partners and stakeholders (environmental NGOs, oil and gas sector experts) in Mozambique. E. Lagabriele and C. Sabinot travelled to Mayotte (November 2014) where they held a set of interviews with national park authorities and French navy members. C. Sabinot travelled to Comores (November 2014) where she met with partners and local decision-makers. E. Lagabriele and A. Céleste conducted a set of interviews with local decision-makers, NGOs and the France Ambassador to Mozambique in Maputo (June 2015). A. Céleste and E. Lagabriele attended the Nairobi COP8 Meeting in Seychelles (June 2016) where they held a set of interviews with regional decision-makers from the WIO region. In 2016 A. Céleste was funded for a PhD (French national bursary) and she pursues her research at the University of La Réunion on marine spatial planning and geopolitics in the Mozambique Channel co-supervised by C. Bouchard and E. Lagabriele.

Results

Bouchard et al. (2018) summarize some of the main findings of this Module 1 on geopolitical issues focusing on the role of the European Union in the region. A broader paper on “Maritimization in the Western Indian Ocean” is underway (Céleste et al.). The European Union is an international player with significant influence and commitment in the Western Indian Ocean (East African littoral states, South West Indian Ocean islands and maritime areas). Strong territorial presence (with the outermost regions of Reunion and Mayotte) and a considerable maritime domain, leading many own actions (economic relations, development aid, CSDP operations, etc.), and strengthened through the influence and the individual actions of its

Member States (notably France and the United Kingdom), the European Community must be considered as one of the major dominant external powers in this region of the world. The factors of this power are cultural, civil (economic relations, development aid, etc.) and, since 2008, military (OP Atalante and EUTM Somalia). Faced with the growing competition with other major powers that are developing a growing interest in the region (notably the United States, China and India), the European Union has every advantage in developing a coherent and intelligent strategy combining soft power and hard power and to maintain its commitment in a region that it now considers to be strategic.

Outputs and publications

Publications

Bouchard C., Céleste A., Lagabrielle E. 2018. Factors of the power of the European Union in the Western Indian Ocean. Book chapter. Actes de colloque. Revue du droit de l'Union européenne.

Céleste A., Bouchard C., Lagabrielle E. (in writing). Maritimization in the Western Indian Ocean.

Communications

Céleste A., Bouchard C., Lagabrielle E. 2017. Factors of the power of the European Union in the Western Indian Ocean. L'Union européenne dans l'océan Indien : un modèle de puissance ou une puissance modèle ? 13-14 avril 2017, Saint-Denis, La Réunion, France. Youtube presentation: <https://www.youtube.com/watch?v=dLja8yhutjY>

Bouchard C., Céleste A., Lagabrielle E. 2018. L'Indianocéanie et la mer : enjeux et perspectives. Colloque international « Définis-moi l'Indianocéanie ». Octobre 2018. Université de La Réunion, Saint-Denis, La Réunion, France.

MSc dissertation

Céleste A. 2015. A geopolitical analysis of the preliminary steps toward regional Marine Spatial Planning (MSP) in the Western Indian Ocean. Master 2 in Geography/Development practices. Université Paris I, France.

4.2. Module 2: Ecosystem distribution, ecological connectivity and marine spatial management across scales

Overview

This Module 2 aimed to collect spatially explicit data and knowledge on habitats and species distribution, anthropogenic and climate-related drivers of ecosystem changes and marine management areas. This module also aimed to implement a simulation model to simulate marine spatial planning scenarios at regional scale.

CORDIO's and IRDs work in Module 2 has focused in four areas:

- A. connectivity modelling (Activity 2.1), initially based on Estelle Crochelet's prior work in the MOZALINK project (Crochelet et al. 2016) and to be improved for the East African coast by breaking the single reef unit up into smaller parcels. Majambo Gamoyo followed up with a new study focused on the East African coast (but not the whole Mozambique Channel), reported below and with 3 papers submitted as part of his PhD (section 2). Lagabrielle et al. (2014) published a MOZALINK paper on marine spatial planning and connectivity.
- B. compiling data layers and developing an online platform for public sharing of data (Activity 2.2), in the form of a GeoNode instance at www.maspawio.net (see section below). The first year of work followed the initial plan to scope data on key species (see Year 1 report). Following this, effort was focused on populating the GeoNode with environmental data of general utility for spatial analysis (section 3). We demonstrated the operational use of MASPAWIO for participatory spatial planning with the on-line spatial planning tool Seasketch.
- C. Scenario preparation (Activity 2.4) - originally intended to run computational scenarios based on local models run in Reunion (w. Daniel David), this work evolved with the broader interest in MSP in the region, the application of scenarios in this context, and a particular application of scenarios under development in the Northern Mozambique Channel. We focused on two

support functions for the scenario work in the Northern Mozambique Channel: a) compilation of scenario approaches already conducted in Africa and relevant to the NMC, and b) compilation of background data into national factsheets, complementing the regional datasets compiled on MASPAWIO (section 4).

Team

The work listed above was done by the following team members:

- Connectivity modeling and marine spatial planning – M. Gamoyo (CORDIO), D. Obura (CORDIO), E. Crochelet (IRD), E. Lagabriele (IRD)
- Data access and sharing for Marine Spatial Planning – J. Mbugua (CORDIO) for MASPAWIO. E. Lagabriele (IRD) and W. McClintock (UCSB) contributed to the implementation of Seasketch assisted with MSc students L. Augier (Université de La Réunion) and L. Fontaine (Université de La Réunion).
- Support for WIO scenarios – D. Obura (CORDIO), J. Mbugua (CORDIO)

Connectivity modeling and marine spatial planning

This activity built on past projects (POLARUN, ASCLME) modelling fish connectivity patterns between coral reef ecosystems of the Western Indian Ocean (WIO). Lagabriele et al. (2014) published a review paper on marine spatial planning and connectivity. In 2016 plans were established for updating of E. Crochelet's work (Crochelet et al. 2013, 2016), as her initial parameterization of her connectivity model had the main East African reef (from Angoche, N. Mozambique to Kiunga, N. Kenya) as a single unit or node in the connectivity matrix. This connectivity model was implemented in Marine Geospatial Ecology Tool an ARCGIS 10 extension toolbox. This made the model unable to infer connectivity for this stretch of coastline. However, the new parameterization was not completed. Following the first year of work in MOZALINK, M. Gamoyo selected a different model to use, and improved the resolution for reefs up the East African coast. However, due to computational limitations he was not able to parameterize the full extent of the Mozambique channel at high resolution.

Outputs are provided by Majambo Gamoyo through his PhD at the University of Cape Town (Gamoyo et al., see below). The work was mainly supported by UCT, but since he obtained the position through his work at CORDIO initially on climate analyses and then through preparation for MOZALINK, Mr. Gamoyo retained an Associate position with CORDIO and MOZALINK for his outputs. Minor funding was provided by MOZALINK for travel and project meetings, including the final meeting during the WIOMSA 12th Symposium in Dar es Salaam in 2017.

The work is described as summaries of two papers submitted for publication, the papers and PhD dissertation will be provided as the direct output, and policy briefs based on the findings will be developed subsequently, particularly in relation to the NMC. Because of the timing of his PhD submission these outputs will be developed after the end of the project (within 1 year).

The dynamics and physical processes the Western Indian Ocean

Summary: Biogeographic patterns of individuals among marine populations is determined by the general circulation and mesoscale. The small size of larvae coupled with the vast and complex fluid environment makes it difficult to quantify dispersal and connectivity. Understanding the biophysical processes that contribute to observed dispersal patterns requires integrated approaches that incorporate high-resolution biophysical modeling. Here we provide an overview of the general circulation and mesoscale patterns that influence larval dispersal and population connectivity.

Aim: Develop a high-resolution regional ocean model using the Regional Ocean Modelling System (ROMS) for the region to resolve both large and small scale circulation pattern that are important in driving dispersal of early life marine organisms.

Methods: Regional Ocean Modelling System is used to investigate the processes and dynamics of the region. A detailed description of this model is provided in Shchepetkin and McWilliams (2003; 2005). The model has a horizontal resolution of 4 km and uses

realistic time- and space-varying climatological forcing derived from Comprehensive Ocean-Atmosphere Data Set (COADS) and boundary conditions from the World Ocean Atlas Data (WOA).

Conclusion : Despite some differences between observational, satellite derived data and the model, in terms of the surface patterns and vertical structure, the model representation of the salient features of the western Indian Ocean was in good agreement with observations.

Estimating connectivity through larval dispersal in the Western Indian Ocean

Summary: Reef building corals of the Western Indian Ocean is one of the least known globally (Obura, 2012). Knowledge of population connectivity among individual reef habitats within a broader geographic region of coral reefs has been identified as key to developing efficient spatial management strategies and has for example been hypothesized as a main driver of patterns of coral species richness (Veron, 1995). Connectivity operates over a range of scales, from individuals, over small spatial scales (Gilmour et al. 2009), to rarer long-distance dispersal, influencing species distributions and patterns of genetic diversity (Trakhtenbrot et al. 2005). Due to the difficulty in empirically measuring dispersal of larvae in the open ocean few studies have been done in the region to determine population connectivity e.g. Crochelet et al. (2013 & 2016) where they used a low resolution ($1/3^\circ$) geostrophic currents from Aviso to modeled larval dispersal patterns. In our approach, a high resolution ($1/12^\circ$) eddy resolving model (Regional Ocean Modelling System) was used to investigate dispersal and connectivity of a generic broadcast spawning coral in the region.

Aim: We develop a high-resolution Lagrangian model for broadcast spawning coral to estimate dispersal pathways and barriers. Connectivity matrices describing relative source and potential settlement between locations are also derived.

Methods: Dispersal of model coral larvae was simulated over 7 years using an individual-based biophysical dispersal model (Ichthyop; Lett et al. 2008) driven by $1/12^\circ$ -resolution surface ocean current data from ROMS and incorporating different pelagic larval durations (PLDs).

Results: The results revealed the role played by the consistent seasonal flow driven primarily by large-scale circulation and mesoscale features on dispersal and recruitment patterns. About 60% of connections occurred within 50-100 km because of short pelagic larval duration (PLD), while few of the larvae disperse over long distances between regions linking the reefs in a stepping stone fashion. Reefs within the Comoros Basin are highly connected while reefs found in Agalega and Tromelin are isolated from other reefs in the region.

Conclusion : This study provides a regional view of dispersal paths and connectivity patterns that compliments biogeographic work (e.g. Obura, 2012) and other modelling work (Crochelet et al. 2016).

Anticipating future changes in larval dispersal and bleaching incidences in the Western Indian Ocean

Summary: Coral reefs are increasingly exposed to elevated temperatures that can cause coral bleaching and high levels of mortality of corals. The temperature threshold for coral bleaching depends on the acclimation and adaptation of corals to the local maximum temperature regime.

Aim: Use a high-resolution biophysical model to investigate whether connectivity of coral larvae between reefs of different thermal regimes could alter the thermal stress threshold of corals. Projected change in Sea surface temperature (SST) for the region are also obtained from the Global Climate Models conducted for the IPCC Coupled Model Inter-comparison Project (CMIP5) and used to calculate future bleaching scenarios (Degree Heating Weeks) thus showing regional projections of bleaching conditions based on ensembles of IPCC.

Methods: The analysis is based on sea surface temperature and ocean circulation run of 7years of ROMS and particle tracking model Ichthyop. Thermal stress threshold is

calculated for each regraded reef based on its local SST climatology and then recalculate the thermal stress threshold based on connectivity for different pelagic larval durations. For future bleaching scenarios, SST monthly data are obtained from fully coupled models in the CMIP5. Degree heating months will then be calculated by summing the positive anomalies above the warmest monthly temperature from the hindcast data 1982–2005 climatology for each 3-month period. Degree heating months will then be converted into DHWs by multiplying by 4.35 (see also Donner et al., 2005).

Future work: Explore inter-annual variability in dispersal and potential connectivity of reefs by using high resolution (1/12) inter-annual ocean model outputs then quantify how large scale climate modes (e.g. ENSO & IOD) influences connectivity in the region.

Data compilation and online data sharing for Marine Spatial Planning

Aim

The initial intent for MOZALINK was to compile data on emblematic species in the Mozambique Channel. this was reported in our first year report (October 2014) but a general challenge was that in many cases data were not fully complete or published (e.g. marine mammals, REMMOA), or owners did not want to provide the data (though links to them were possible for people to directly request data), e.g. for turtles, *Kelonia*. Concurrently, with the growing interest in Marine Spatial Planning in the region (3.1), we refocused on compiling data that might be of more general use, on key variables. During the project, coral bleaching in 2016 was a significant event, making this a focus as well. CORDIO's commitment to MOZALINK partners, to the MASMA programme and in the context of WIO regional biodiversity database discussions (see study 1, listed in 3.1) is to continue to support and build up the MASPAWIO knowledge sharing platform as an open access tool for marine data, linked to more formal governmental and international resources (see 3.2.4).

Coordination with on-going MSP efforts

Support for MSP is growing rapidly in the Western Indian Ocean, with several documents and projects providing a foundation:

- during the course of 2015, a study on marine databases and datasets compiled by the Nairobi Convention and the Indian Ocean Commission (IOC/WIOMSA 2016);
- at COP 8 in June 2015, a briefing document on MSP alignment, in the Partnership workshop (CORDIO/WIOC 2015);
- as part of the work programme of the Nairobi Convention following COP 8 in Seychelles, June 2015 (WIOMSA/Nairobi Convention. 2016);
- at the CBD-SOI Capacity Building workshop in Madagascar in January 2016, development of an action plan for support to MSP in the WIO (SBSTTA 2016);
- Both regional GEF-funded projects - WIOSAP and SAPPHIRE - have major components on conducting and building capacity for MSP, at scales relevant to their objectives (UNEP/WIOSAP 2016, UNDP/SAPPHIRE 2016).

Data layers compilation

Data layers compiled for MASPAWIO by the original funding from IUCN/AFD were compiled by Estelle Crochelet and James Mbugua (2015-16), and are listed in the full MASPAWIO metadata table at the link www.maspawio.net. Due to transfer of MASPAWIO among platforms not all have been re-uploaded at the time of this report, but work is ongoing to complete this. Currently there are 85 data layers in the MASPAWIO metadata table, of which 40 were provided or updated through MOZALINK.

This section summarizes data compiled for dissemination on MASPAWIO during 2017, which required a range of processing methods. The first data compiled in 2015-16 accessed datasets from various sources, reproducing them or conducting minimal cleaning for presentation on MASPAWIO. Based on this experience, we identified more nuanced data needs for particular compilations of data that are important in understanding coastal and marine processes, and for use in spatial planning processes. Based on ongoing events and opportunities for use, we selected:

- marine climatologies for key variables are more useful than simple mean or annual datasets. These were calculated for a) sea surface temperature (SST) because of the

importance of coral bleaching in general, and a major regional bleaching event in 2016, and b) chlorophyll a, as the primary indicator of productivity, and important in understanding fisheries and eutrophication/pollution dynamics.

- coastal elevation, and vulnerability of coastlines to sea level rise due to global warming, which on the order of 1 m during this century is below the sensitivity and accuracy of most coastal maps to differentiate shorelines with different vulnerability levels.
- coastal human population is the main driver of local pressures on marine and coastal ecosystems, and is poorly quantified for the coastal zone. Several measures of coastal population were developed: in coastal districts, in major drainage basins and living within 100km coastal strip
- a set of LANDSAT 1-8 remote sensing data was compiled to reveal land-use changes in focal coastal sites selected across the Mozambique Channel region. Remote sensing data analysis were performed by an MSc student from Comores (Z. Guy, under the supervision of Erwann Lagabriele) based at the regional SEAS-OI satellite reception in La Réunion (2017). Twitter was used to broadcast an animated GIF of multi-date LANDSAT images (Figure 5).

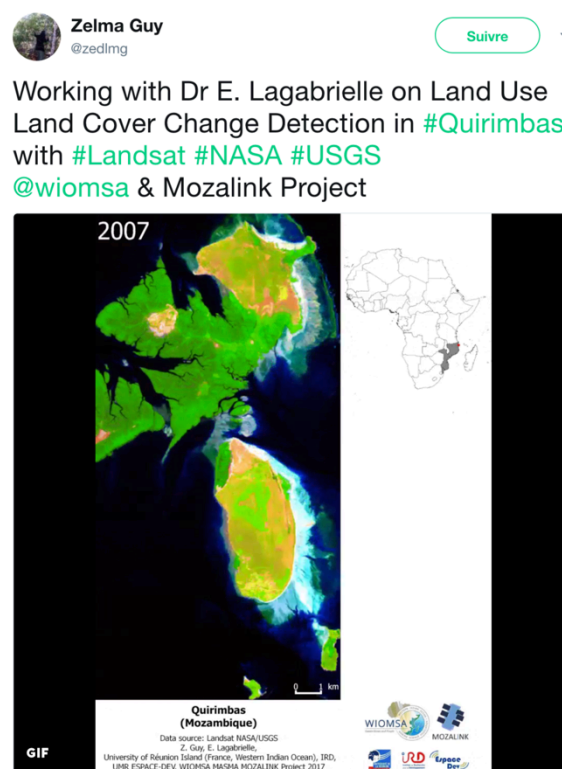


Figure 5. A GIF land-use change map published on twitter by Z. Guy

MASPAWIO data sharing platform - www.maspawio.net

Current and accurate information about the limits of maritime jurisdictions, living and non-living marine resources and the environment, underpins the sustainable management of the marine space of the Western Indian Ocean. Historically this information has been managed on a sectoral basis. Policy makers have been forced to seek information from a multitude of sources and this information has often been of variable quality. Researchers and consultants working on marine projects have had to source data from wide and disparate sources, and usually of varying quality and age that are difficult to verify. Outputs from multiple studies tend to remain in isolated computers or databases, and remain inaccessible to subsequent users.

MASPAWIO (Figure 6) specifically targets research and ocean data service outputs and needs, where appropriate mirroring existing providers to make their outputs more accessible. Further, it provides a stepping stone for users to provide data into more formal data repositories, such as the African Marine Atlas supported by UNESCO and the Nairobi Convention Clearing House

Mechanism. By targeting the more fluid nexus of research, NGO and implementation projects, MASPAWIO will improve visibility and sharing of data across multiple platforms and for multiple potential end-users.

MASPAWIO is a GeoNode platform, through discussions with its developers and the role they play in data sharing for the CBD (conversations with Piers Dustan at CBD workshop, January 2016). It was started in the MASPAWIO project, where CORDIO was on contract to IUCN Global Marine and Polar Programme with AFD funding (2015-16). MASPAWIO was first established to provide a demonstrator about the use and potential for Marine Spatial Planning (MSP) in the countries of the Western Indian Ocean. After the termination of the AFD funding, minimal support was provided through our use of MASPAWIO in MOZALINK.

We also sought support for MASPAWIO in the context of discussions led by WIOMSA that CORDIO participated in, and resulted in a proposal to the IOC, on supporting marine biodiversity databases in the WIO. As part of CORDIO's contribution, we offered to support MASPAWIO as an open repository for geo-referenced (mapped) data. However, this did not result in funding.

Finally, we were successful in raising funds from IGAD (Horn of Africa focus), for the period March-October 2017, following two spatial planning projects (in Djibouti and northern Kenya), and the need highlighted in those projects for better access to data subsequent to projects closing. The goal of this project was to build up MASPAWIO for spatial data, in parallel with a dedicated marine monitoring database platform (on Brahms v. 7 software). The latter is not discussed here.

The MASPAWIO geo-portal is an ongoing output supported by multiple projects, and support for it will be sought through CORDIO and other partners, such as members of the NGO Consortium for the Conservation of the Western Indian Ocean (WIOC).

A number of geoportals already exist, in particular the Africa Marine Atlas, maintained by the Intergovernmental Oceanographic Data and Information Exchange (IODE) of UNESCO, and the Nairobi Convention Clearing House Mechanism. These have formal foundations with governments and United Nations processes and represent the formal end of data provision for the Western Indian Ocean.

MASPAWIO is intended to provide a resource for public data from multiple sources, and the outputs of different studies and projects (whether research, commercially oriented or, for example, environmental impacts assessments) to be compiled in one place and thus accessible for further use.

Thus MASPAWIO is intended to hold data that the owner wishes to make public, or that has been published and a citation exists for it. Users have the option to upload data but not make it visible, but once made accessible, MASPAWIO operates with a default CC-BY license based on Creative Commons 4.0 (<https://creativecommons.org/licenses/>). This allows (quoted from Creative Commons):

- I. Individual creators to large companies/institutions to create copyright licenses for their work in a simple and standardized way all within the confines of copyright law and also to freely share material in any medium or format.
- II. Users to adapt creative work by defining a pool of content that can be copied, distributed, edited, remixed and built upon at least under noncommercial terms.

A full Data Sharing Agreement is still under development to support the above, where both data providers and data users acknowledge and subscribe to the license conditions and commit to abide by them.... The Creative Commons License and Data Sharing Agreement principles need to be agreed to by all major contributors and supporters (listed in the 'About' pages on the site), which here includes all MOZALINK partners and WIOMSA, as well as the initial supporters IUCN and AFD, and IGAD.

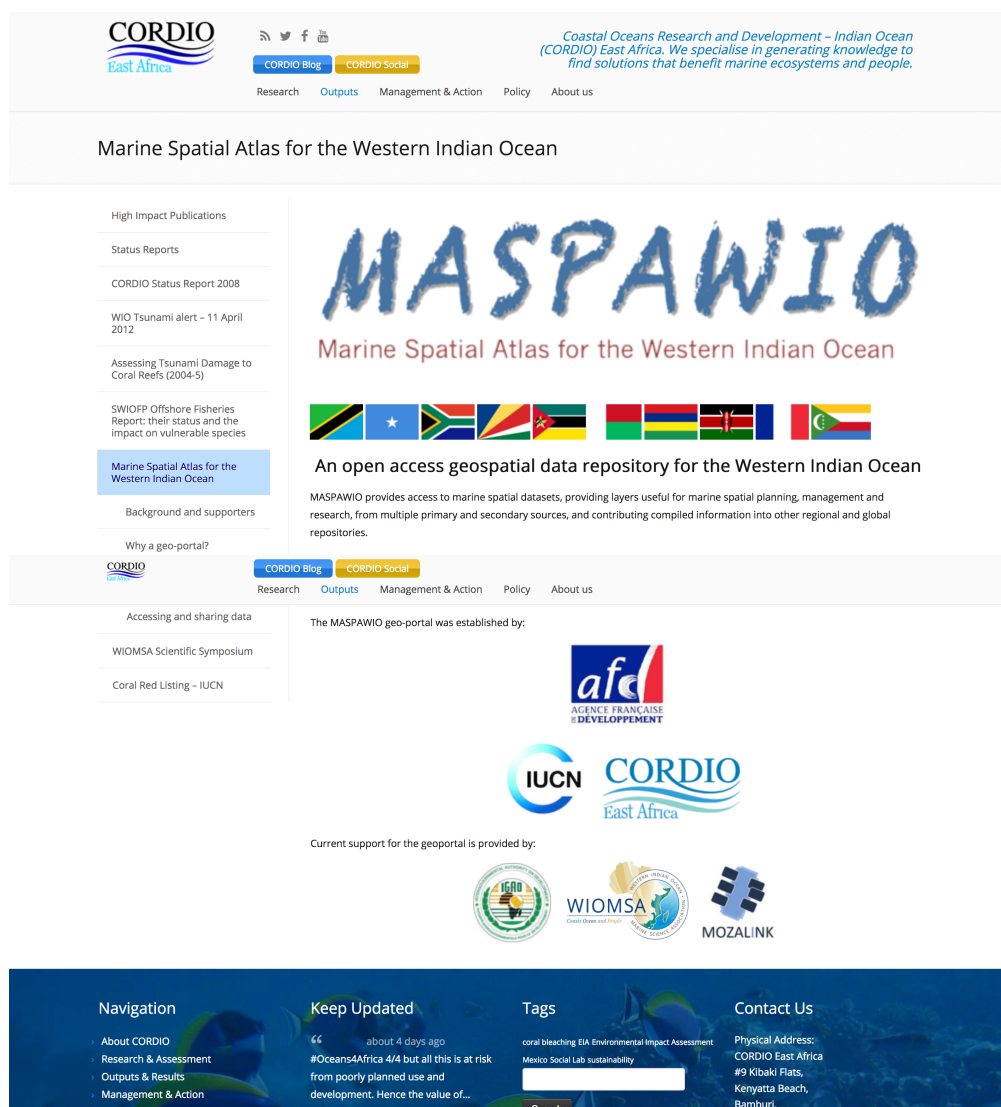


Figure 6. The MASPAWIO interface.

Sustainability and governance of MASPAWIO

As of August 2017, supported by the IGAD marine biodiversity data project, MASPAWIO is established on a GeoNode instance on Amazon Web Services at the url www.maspawio.net, and will be maintained there by CORDIO, through funding from projects. From time to time major funding will be sought to fund upgrades and improvements, and to keep up with new software and opportunities.

MASPAWIO is intended as a stepping stone for non-government and academic data contributors (Table 2), from which data can be passed to the broader regional and global tools that have greater visibility but may be onerous for an entity to subscribe to. These may include the Africa Marine Atlas (maintained by UNESCO-IOC) and the Nairobi Convention Clearing House Mechanism, the Ocean Biogeographic Information System (OBIS), the Global Biodiversity Information Facility (GBIF), and others. Formal links for MASPAWIO resources to these platforms will be explored and negotiated individually, with appropriate options and instructions being provided to data providers for them to act as they chose.

A technical advisory committee (TAC) will be maintained for MASPAWIO, comprising representatives from major donors/supporters and partners in ongoing projects. With a representative from CORDIO it will be limited to 3-5 members, meeting virtually and confirming on an annual basis their ongoing support and membership. After 3 consecutive years on the committee in a single term, a TAC member's term will formally end, requiring re-appointment in open consideration with new TAC members.

Table 2. Responses to MASMA Programme Committee questions on Seasketch/Maspawio

QUESTION	RESPONSE
Stage of development	- The tool is fully functional as an accessible GeoNode portal on maspawio.net. It has been installed as a virtual instance on Amazon Web Service Elastic Cloud (EC2), allowing for expansion in the future. - Technical support for cloud hosting was provided by Piers Dunstan (CSIR, Australia, one of the GeoNode developers) and Michael Ngugi (Regional Centre for Mapping of Resources for Development, RCMRD, Nairobi) through an IGAD funded project.
Financial and technical requirements for hosting the tool after the completion of the project	- Financial support for the AWS instance has been provided in 2017 by an IGAD Biodiversity Management Programme grant for mobilizing marine biodiversity data, with a three-year prepayment of AWS (January 2018 to December 2020) being prepared. - Continuing technical support from RCMRD will be provided through an MOU signed between RCMRD and CORDIO, renewable every 3 years. - Through this, CORDIO's capacity for managing the GeoNode and AWS service is being built up to assure ongoing availability of the portal.
Ownership of the tool	- GeoNode is open source software, used by many geoportals, including e.g. BIOPAMA, the CBD ESPA repository and others. The instance implemented for MASPAWIO is administered by CORDIO. - The name MASPAWIO was initiated through an IUCN project with AFD funding, that contracted CORDIO (which hired Estelle Crochelet) to compile the first set of data layers. Since then, the project name MASPAWIO has been used by IUCN and CORDIO in parallel initiatives reported under the Nairobi Convention framework. - the domain name www.maspawio.net was registered by and is under CORDIO's ownership, for the purpose of supporting the MASPAWIO open data site. - MOZALINK, among other projects and sources of support derived by CORDIO, has contributed to ongoing development and expansion of MASPAWIO. <i>the name and domain name MASPAWIO are offered by CORDIO and IUCN as a support to Marine Spatial Planning and open data in the WIO, implementing part of the work described in IOC/WIOMSA 2016 and documentation under the Nairobi Convention processes.</i> - a Data Sharing Agreement specifying CORDIO's role as owner and operator of the tool, while the data/contents are owned solely by the providers, is published in the Data Sharing page.
Accessibility to different stakeholders	The tool will host open access data, to be accessed freely by anyone with the web-link. Data owners and the administrator may put data layers up that are initially not publicly accessible, with the Data Sharing Agreement indicating a commitment to make such layers freely accessible within a certain period of time (1 calendar year).
Suggestions of possible institutional hosting mechanisms	- Based on the findings of IOC/WIOMSA (2016), we propose that CORDIO provides the geoportal as a member of the "WIO biodiversity network", as one of the key organizations concerned with the collection, management and application of biodiversity information. in this regard, the MASPAWIO portal would become one of the contributing sources to a larger portal for WIO marine biodiversity data, which may be one of the three options identified in the report: hosted by a national institution, a regional science association, or an intergovernmental agency. - Given the development of MASPAWIO and a Brahms Online portal by CORDIO in the time since IOC/WIOMSA (2016), we recommend that the preferred hosting option be #2, by a regional science association, and that CORDIO play a role as a member of a Consortium of members/partners in the regional science association (most likely WIOMSA).
MASPAWIO and Seasketch	- GeoNode provides for online serving of data layers, which can be used in multiple ways and other packages. It is free and open source. It has limited mapping/editing capability. - Seasketch provides for greater mapping capability, has an ongoing cost to users, and can use multiple sources, such as layers from GeoNode. This was explored during the WIOMSA Symposium (October-November 2017) and MASPAWIO layers imported into the WIOMSA Seasketch instance for demonstration. J. Mbugua received training in Seasketch administration

Online participatory spatial planning using Seasketch - wiomsa.seasketch.org

While the MOZALINK project was being implemented, it appeared clearly that building a marine spatial planning simulation model at regional scale wasn't realistic in the timeframe of the project and that it wouldn't be an optimal allocation of the project budget. Rather, we chose to contribute to develop a spatial data infrastructure (SDI) in collaboration with the MASPAWIO project (IUCN/CORDIO). The MASPAWIO SDI enables spatial data sharing in the WIO region. The MASPAWIO SDI was then plugged to an on-line spatial planning interface (Seasketch). Seasketch enables a marine spatial planning process to set up and simulate participation-driven scenarios. Seasketch was selected as an option after initial internal development of a spatial simulation tool. The MASMA committee in Kenya (November 2016) also recommended the Seasketch option. Finally, the SeaSketch model was implemented in 2017 and tested with stakeholders and experts during a special session held during the 12th WIOMSA Symposium in Dar-es-Salam, Tanzania (November 2017) (Figure 7). This session was held by Erwann Lagabriele and Will McClintock (UCSB, Seasketch), and attended by 30 participants, including James Mbugua (Module 2), Esmeralda Mariano (Module 3), and Bernard Surugue (Module 6).

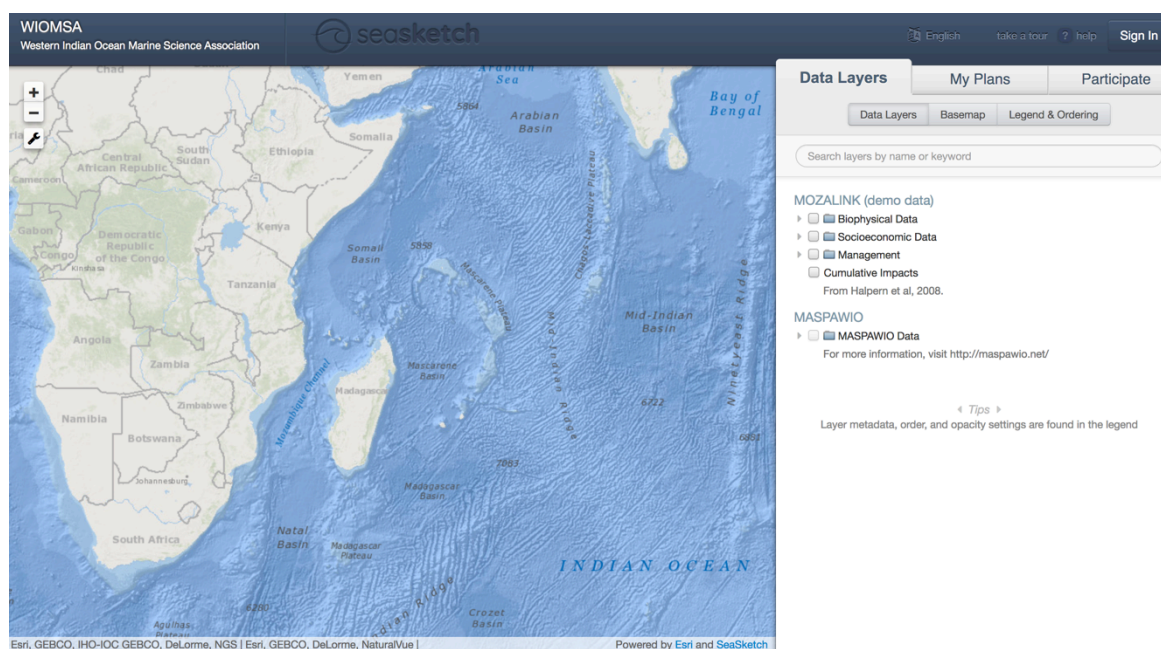


Figure 7. MOZALINK (demo) seasketch interface linked with the MASPAWIO spatial data infrastructure (wiomsa.seasketch.org)

Support for WIO scenarios

Background

A scenarios process for the WIO was initiated by CORDIO and WWF as part of the Northern Mozambique Channel initiative, but with relevance to the WIO region as a whole. Support for the scenarios process is provided by Sida to WWF Madagascar, while CORDIO's contributions of data and information are derived from the MOZALINK project and the compilation of biophysical information for Module 2. The scenarios approach used is described briefly below, and on CORDIO's website at www.cordioea.net/scenarios.

The United Nations 2030 Agenda for Sustainable Development forms the new global development framework adopted by all countries in 2015. It is anchored around 17 Sustainable Development Goals (SDGs). The Ocean goal - SDG14: "conserve and sustainably use the oceans, seas and marine resources" - contains 10 targets which countries are committed to delivering on between now and 2030.

Within this context, the countries of the Western Indian Ocean (WIO) region are developing a set of regional Voluntary Commitments, presented at the recent UN Ocean Conference on SDG14 (New York, June 2017). Among the key commitments agreed upon by countries as part of this process is to strengthen ocean governance in the region, and to ensure the sustainable

management of shared fish resources and collaborative management of marine and coastal resources in the Northern Mozambique Channel.

Together with WWF Madagascar, CORDIO is facilitating this effort through a Transformative Scenarios Process (TSP) conducted by the experts Reos Partners (Kahane 2012). CORDIO's contribution to this process includes providing contextual information derived from the range of regional initiatives on which this builds, including the Western Indian Ocean Strategic Action Programme (WIOSAP 2009) by the WioLAB project, the Marine Ecosystems and Fisheries Strategic Action Programme (2011) by the ASCLME and SWIOFP projects, background work undertaken for the NMC and included in the NMC Background Document, the WIO State of Coast report (produced by WIOMSA/UNEP) and WIO Ocean Economy Report (produced by WWF/CORDIO).

The specific objectives for this work are:

- to generate a set of scenarios that can help decision-making and programme development in NMC countries to ensure sustainability in the sub-region, under the framework of SDG14 and Agenda 2030.
- under the broader framework of the Nairobi Convention, to promote implementation of SDG14 and Agenda 2030 in the region

Full information on the process, and the contents to the sections below, can be found at <http://cordioea.net/nmc/scenarios/>.

Supporting documentation

In addition to the regional data being compiled on the WIO (section 3), two specific areas were identified to support the scenarios process, summarized below. These will be used in contextualizing the scenarios developed by the NMC/WIO SDG 14 process, to be used in the 5th stage of the TSP process (Kahane 2012) where participants construct the scenarios into narratives that can be used in motivating future action.

Key drivers of change in the WIO

The Strategic Action Programmes developed by the WIO LAB and ASCLME/SWIOFP GEF programmes in 2009 and 2012 undertook extensive national and then regional assessments of key drivers and pressures affecting Western Indian Ocean ecosystems and resources. Information from these, and updated information and sources since then have been compiled into an 'outlook' report for the NMC providing critical background and contextual information for the NMC scenarios process. This document is available at https://drive.google.com/file/d/18SID1fLhMA_bnu0YledFU6yHR_HYiT3Z/view.

Scenario processes relevant to the Western Indian Ocean

A number of scenarios have already been developed, with relevance to the region, and may have differing levels of traction or buy-in in decision-making circles. It is essential that any new process builds on these, to not proliferate or duplicate work. A summary of existing scenarios was compiled into a single document, comprising the list below, and available at this link: <https://drive.google.com/file/d/1YNkQesK0s90TDdYxf96j857mPy9RBDEu/view>:

National factsheets

Data on ecosystem service values calculated in the WIO Ocean Economy Report were broken down into national figures, and are presented in the context of other national data from economic, population, conservation and other domains. National factsheets prepared from this information were prepared for use in the scenarios process. These are available on web-pages relevant to the Northern Mozambique Channel initiative (<http://cordioea.net/nmc/countries/>) and WIO countries (<http://cordioea.net/wio-ocean-economy/countries>) on CORDIO's website. Copies are appended in Annex 2.

Outputs

The output from the scenarios process will be oriented towards policy and national decision-makers, and major economic sectors, along the lines of the narratives contained in these examples: <http://www.thefutureoffood.co.za/> and <https://www.landreformfutures.org/>.

The scenarios process was initially planned to be completed in 2017, but has been delayed to completion in 2018, with a final workshop planned for 14-16 March 2018 and reporting to the Nairobi Convention COP, or its Science to Policy workshop, likely in June 2018. Accordingly, final outputs from this work are also delayed. Provisionally, the following are planned:

- a) a policy-oriented paper describing the scenarios and analysing data compiled here to illustrate the potential futures described.
- b) technical reports completing the two main support documents summarized in section 4.2 (WIO Outlook report on key drivers and pressures, and Compilation of scenarios relevant to the WIO).

These will be listed as MOZALINK outputs though they could not be completed within the timeframe of the project, as the primary data preparation and analysis has been conducted as presented here.

Outputs and publications

Articles

- Crochelet E., Roberts J., Lagabrielle E., Chabanet P., Petit M. (2016). A model-based assessment of reef larvae dispersal in the Western Indian Ocean reveals regional connectivity patterns –Potential implications for conservation policies. *Regional Studies in Marine Science* 7, 159-167
- Gamoyo M, Obura DO, Reason C (submitted) Estimating connectivity through larval dispersal in the Western Indian Ocean. *Journal of Geophysical Research: Biogeosciences*.
- Gamoyo, M., Reason, C. J., & Collins, C. (2017). A numerical investigation of the Southern Gyre using ROMS. *Journal of Marine Systems*, 169, 11-24. Access paper here. <https://www.sciencedirect.com/science/article/pii/S0924796316303293>
- Gamoyo, M., David, O., & Reason, C.J.C. (2018). Connected we stand: Connectivity and varying thermal exposure provides hope for coral reefs in the Western Indian Ocean. Submitted to *Frontiers in Marine Science*
- Lagabrielle E., Lombard M., Harris J., Livingstone T. (in press). Multi-scale marine spatial planning : a novel methodological approach applied in South Africa. *PlosOne*
- Lagabrielle E., Crochelet E., Andrello M., Schill S Arnaud-Haond S., Alloncle N., Ponge B. (2014). Connecting MPAs - Eight challenges for science and management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 24, S2, p. 94–110.
- Obura, DO. (2017) Outlook for the Northern Mozambique Channel - some key drivers and measures of current state. Mozalink/Northern Mozambique Channel Initiative. Available from www.cordioea.net/nmc/scenarios
- Obura, DO & Mbugua, J (2017) Background on scenarios relevant to the Northern Mozambique Channel. Mozalink/Northern Mozambique Channel Initiative. Available from www.cordioea.net/nmc/scenarios

PhD dissertation

- Crochelet E. 2015. Larvae connectivity modeling and implications for conservation policies. PhD thesis. University of La Réunion, Saint-Denis, La Réunion, France. <http://www.theses.fr/2015LARE0003>
- Gamoyo M, Obura DO, Reason C. (in writing) Regional scale projections of coral bleaching thermal stress in the WIO. PhD thesis chapter draft

MSc dissertation

- Fontaine L. 2016. Development of a spatially-explicit social tool to support Marine Spatial Planning (MSP) in the Western Indian Ocean. MSc dissertation, Master 2 in Remote sensing and GIS, University of La Réunion, Saint-Denis, France.
- Auger A. 2016. Review of spatial modelling tools and scenario simulation methods for Marine Spatial Planning (MSP) in the Western Indian Ocean. MSc dissertation, Master 2 in Remote sensing and GIS, University of La Réunion, Saint-Denis, France.
- Guy Z. 2017. Multi-scale change detection using remote sensing data in the Western Indian Ocea. MSc dissertation, Master 2 in Urban Studies, University of La Réunion, Saint-Denis, France.

Twitter

- Guy Z. 2017.
<https://twitter.com/zedimg/status/914409375661481984>
<https://twitter.com/zedimg/status/914406449303949312>

4.3. Module 3 – A regional synthesis of the mosaic of local knowledge and perceptions of natural and cultural marine heritage in the Mozambique Channel

Aims

Module 3 dealt with a regional synthesis of the mosaic of local knowledge and perceptions of natural and cultural marine heritage in the Mozambique Channel. The main objectives were to reveal the diversity of sea cultures and local perceptions across the Channel, to describe how similar and different are the perceptions of natural and cultural marine heritage in the Channel, and by doing this, to identify harmony or discordance among the perceptions of the different groups of actors, at local and regional levels. Module 3 results and networks contribute to share MOZALINK issues at community level through the movie, the web-based tool and the board game ; at institutional levels through web-based tool, policy brief (still in progress), participation in national/regional conventions ; and at scientific level through participation in international and local conferences and scientific publications (anthropological and interdisciplinary issues).

Team

In WP3, quite all partners of the MOZALINK projects were involved. Five are anthropologists: Esmeralda Mariano (Eduardo Mondlane University, Mozambique), Fanny Cautain (Marine Park of Mayotte, Mayotte), Georgeta Stoica (Institute of Research for the Development), and the two co-PIs Rose Mwaipopo (Dar es Salaam University, Tanzania) and Catherine Sabinot (Institute of Research for the Development). Six are in other disciplines and contributed to the direction of Master students and/or to debate regarding the results: Lala Ranaiwomana and Jamal Mahafina (IHSM, Madagascar), Salomao Bandeira (Eduardo Mondlane University, Mozambique), Hachime Abderamane, Mohammed Said Hassani and Ahmed Ouledi (Ulanga, Comoros), Erwann Lagabriele (IRD-Université de la Réunion) . Licenciatura and Master students from each country are presented in part 4: S. Baco, A Barijaona, C. Donasio, V. Moiane, Z. Maulid, I. Muhamade , Z. Tantely. Moreover, Elisio Jossias (PhD) and Hamilton Matsimbe from Department of Archeology and Anthropology (University Eduardo Mondlane) joined the team in 2017.

Methods

First, R. Mwaipopo and C. Sabinot have worked a common methodology (interview guide, drawings activities...) for an innovative comparative approach. Second, Master students and their directors collected data in each village and produced master dissertations. C. Sabinot contributed to most of these and did a two weeks field work in the two villages in Mozambique with E. Mariano, a few days fieldworks in Tanzania and Comoros and a two weeks of fieldworks in Madagascar (through a regional summer school about coral reef heritage). She organized also regular skype meeting or e-mails exchanges with all students involved in the program. Third, a comparative analysis and a regional analysis have been initiated – but not achieved because of the lack of the one-year postdoctoral student. Main researchers involved in the WP3 and in interaction with researchers from other WPs have been involved in this third part. Fourth, the WP3 team contributes to the design of MSP tool integrate local knowledge and values, especially during the 2016 meeting in Madagascar. A set of local sites has been selected for focused local studies and 'control' sites to these, presence of appropriate-sized villages (500-3,000 inhabitants), presence/absence of migrants, national prioritizations, and presence of local partners to facilitate in fieldwork and achieving impacts as a result of the project.

Activities

Module 3 had two main activities and researchers have to deal with a few difficulties to completely achieve them:

- Activity 3.1 aimed to describe the marine natural heritage as perceived by local actors. It involved interrogating the uses, knowledge and perceptions of the sea and resources specific to the Mozambique Channel; the perceptions of, and the actual movements, of people (fishers or economic migrants for instance) and the perceptions of the

Mozambique Channel as an entity in terms of socio-cultural representation. Six Master dissertations and reports and one License dissertation have been done during the 4 year program (2 in Tanzania, 2 in Mozambique, 2 in Madagascar, 1 in Mayotte) and one is still in progress in Comoros. These reports and dissertations based on anthropological fieldworks in 7 different villages of the coasts, completed by a database of verbatim, drawings and photos, are the basis for the regional and comparative analysis done by activity 3.2.

- Activity 3.2 aimed to achieve a regional-scale analysis of the perception of the marine natural heritage. A postdoctoral researcher, together with the project PIs, was planned to combine the data at higher levels, to assess similarities and differences, and higher level heritage identities (common or plural) within the project region. The module analyses strengths and gaps in heritage conceptions, and their scaling from local to regional, to determine their impact on and relevance to management, and future management options, and a role for education/awareness building to fill gaps. The postdoctoral fellow is a key scientist in the research team for confronting discourses, conceptions and actions for each group of actors, for exploring how the points of view of each group articulate with, confront or complete each other. The comparison between anthropological Master thesis can permit to identify reasons for any discordance and concordance and to categorize them (could be questioned the influence of demographic change and migration, of different political perception about the Mozambique Channel current issues and challenges, etc). One of the innovative issues of this anthropological WP is to provide spatially explicit anthropological analysis at a regional scale and to cross-analyse the resulting GIS layers describing socio-cultural perceptions with GIS layers describing biota distribution patterns and connectivity.

The Outputs of this postdoctoral research were (1) Regional maps of knowledge and conceptions relative to marine environment and to management regimes; and (2) Peer-reviewed publications. Unfortunately, this recruitment the one-year postdoc couldn't be achieved at the University of Dar es Salaam. He/She was supposed to be the only one recruitment in anthropology in MOZALINK program. He/she was the one who would have time to provide a deep regional-scale analysis of the perception of the marine natural heritage in combining the data at higher levels, in assessing similarities and differences, and higher level heritage identities (common or plural) within the project region. Consequently, we are not in capacity to provide the deliverables concerning the regional analysis on time. We hope to find time for pursuing this issue later. The set of matrices needed for the cross-analyse couldn't be fully developed to compare ecological and socio-cultural patterns in a unified analytical framework. At this stage, only socio-demographic matrices would inform the sea-sketch tool.

Results

Ethnography and anthropology in MOZALINK program contributed to better understand knowledge, practices and perceptions relative to the coastal sea and the Mozambique Channel entity and governance issues at local, national and regional governance.

Six License and Master thesis with major anthropological issues have been written during the four year project and contained the main results of each local sites (around 70 pages for each dissertation, sometimes 147!). One Master thesis is still in progress in Comoros. Each thesis was co-directed by partners from different countries. Eight researchers were engaged in the achievement of the dissertations of students.

Each study aims to answer to four key questions:

- . What are the uses, the knowledge and the perceptions of the sea and resources specific to the Mozambique Channel?
- . What are the perceptions of, and the actual movements, of people?
- . What are the perceptions of the Mozambique Channel as an entity in terms of socio-cultural representation?
- . What do people know about local and regional management of marine resources?

Three common similar issues have been described in each country.

- First, ocean is a place of sense and value.
- Second, Mozambique channel and coastal seas are places of interactions between local inhabitants and new local and foreign actors
- Third, asymmetrical visions and discrepancies relative to space, its uses and its governance

We observed that people know the Mozambique Channel through diverse "paths", such as media (cyclone announcement in Andavadoake, Madagascar), tourist excursion to go to Eparses islands (Ankatafa, Madagascar), fishing activities and oral history of sea sinking (Comoros and Tanzania), school (Tanzania and Mayotte) and/or management intervention tools (Marine Park in Tanzania and Mayotte).

We noticed that local name for Mozambique Channel are various: *andrefa*, literally West side in Andavadoake; *maji ya voidnzé*, literally water of outside, *m'péguélén*, literally depth, or *voidnzé naou moimba*, literally outside the coral barrier in M'zouzia (Mayotte) ; *Mkondo mkubwa*, literally big current in Msibanti (x).

The perception of this Mozambique Channel is also very different depending on the livelihood activity of people we interviewed and place one lives. It can be conceived as a place of traffic, a pathway, a place of human interactions, but also as a place of danger (big animals, cyclons). It can be considered as a coral reef barrier or a productive marine area, but also as a place for individual income or for national economy (« place of money »).

To conclude with, it does exist many common perceptions as well as specificities regarding generations, genders, affiliations to environmental associations...

This Module conducted also to describe and analyse asymmetrical visions and discrepancies relative to space, its uses and its governance. A further analysis is still needed but we can yet distinguish four main results : (1) there are discordances of perceptions in most of places ; (2) there are conflicts of uses between actors, especially between migrant and local ; (3) questions of articulation between local customary management and local institutional management are occurring very often ; (4) issues of migration for cross-boundary governance of resources are omnipresent. We are still working on a spatially explicit matrix to perform cross-analysis with other data.

Outputs and publications

Articles

Three publications on Mozambique issues are in progress (one was submitted in 2017):

Mariano E. and Sabinot C., *submitted*. The Ibo and the Inhaca islands: the sea and its resources between norms, culture and daily needs, *African identities*.

Two publications on Tanzania issues are in progress.

One publication on Mayotte issues is planned for 2018.

A regional comparative approach paper is planned for 2018.

Communications

Lagabrielle E. and Sabinot C., 2017, Power, knowledge and data in marine spatial planning: The interdisciplinary MOZALINK project in the Western Indian Ocean, Wiomsa congress, Dar es Salaam, Tanzania.

Sabinot C. et Mariano E., 2016, Ibo e Inhaca : o mar e seus recursos entre normas, culturas e necessidades quotidianas, Abordagens cruzadas sobre as dinâmicas sociais em moçambique, Conferências da Associação Franco-Moçambicana de Ciências Humanas e Sociais, Maputo, Mozambique, 10-12 octobre.

Mariano, Muhamad, Sabinot, 2016, Conhecimentos e percepções locais sobre património natural e cultural do Canal de Moçambique. Mar Nosso, Maputo 2016, Mars, 16th.

Posters

Mwaipopo, Maulid, 2017, Sabinot, Perceptions on the Mozambique Channel as an entity in terms of socio-cultural representation and its relevance to management and local livelihoods, Wiomsa congress, Dar es Salaam, Tanzania.

Mariano E., Sabinot C., 2017, The Ibo and the Inhaca islands: the sea and its resources between norms, culture and daily needs Wiomsa congress, Dar es Salaam, Tanzania.

Maulid, Mwaipopo, Sabinot, 2015, An assessment of knowledge and perception of natural and marine cultural heritage among age groups in the community, the case of Mnazi Bay Ruvuma Estuary , Wiomsa congress, Durban, South Africa.

Tantely, Barijoana, Mahafina, Ranavoanana, Stoica, Sabinot, 2015, How do people perceive the high seas in two contrasted villages in the West coast of Madagascar? Wiomsa congress, Durban, South Africa.

Donasio, Mwaipopo, Sabinot, 2015, The Mozambique Channel in Relation to Livelihood of the Local Communities in Mnazi Bay-Ruvuma Estuary Marine Park, *Wiomsa congress*, Durban, South Africa.

Seminaries

Maulid, 2016, An assessment of knowledge and perception of natural and marine cultural heritage among age groups in the communities along the Mnazi Bay Ruvuma Estuary Marine Park in Mtwara, Tanzania.

Donasio, 2016, Gendered perceptions on Mozambique channel and their relation to marine management within the Mnazi Bay/Ruvuma estuary marine park. Postgraduate seminary of the University of Dar es Salaam.

MSc dissertations

2 MSc students in Madagascar

2015-2017 Simondi Antonio Barijoana. *Master en Océanie Appliquée*, IHSM, Madagascar.

Connaissance locale et perception relatives au canal du Mozambique suivant l'âge et le sexe: cas de la population du village d'Ankatafa (zone de la réserve de biosphère de Sahamalaza-Iles Radama). Codirected by J. Mahafina (IHSM), C. Sabinot and G. Stoica (IRD).

2015-2017 Zola Tantely Tsipy. *Master en Océanie Appliquée*, IHSM, Madagascar.

Patrimoine local et régional en question dans le village d'Andavadoaka. Co-directed by J. Mahafina, L. Ranaivomanana (IHSM), C. Sabinot and G. Stoica (IRD).

1 MSc student and 1 Licenciatura student in Mozambique

. 2016 Vicência Moiane. Licenciatura *Anthropology*, Eduardo Mondlane University.

"O conhecimento local e as percepções do património natural marinho e cultural no Canal de Moçambique: Estudo Ilha de Inhaca".

Directed by E. Mariano (Eduardo Mondlane University).

. 2017 Issufo Muhamade. Master *Anthropology*, Paris University.

"Pesquisa sobre conhecimentos e percepções do património natural, marinho e cultural local sobre o Canal de Moçambique."

Directed by E. Mariano (Eduardo Mondlane University) and C. Sabinot (IRD).

2 MSc students in Tanzania

. 2015-2016 Zuhura Maulid. *Master Anthropology and gender studies*, Dar es Salaam.

Knowledge and perceptions in managing natural and marine cultural heritage by gender and age (a case of communities in Mnazi Bay and Ruvuma Estuary Marine Park, Mtwara). Co-directed by R.Mwaipopo, Univ. Dar es Salaam, and C. Sabinot, IRD.

. 2015-2016 Christina Donasio. *Master Anthropology and gender studies*, Dar es Salaam.

Gendered Perceptions on Marine Resources and their relationship to resource management. A Study of communities within Mnazi Bay/Ruvuma Estuary Marine Park, Mtwara). Co-directed by R.Mwaipopo, Univ. Dar es Salaam, and C. Sabinot, IRD.

1 Msc student in Mayotte

. 2016 Salima Baco. *Master de Géographie Spécialité Analyse territoriale de l'environnement et de la santé*, Université de Rouen.

Savoirs, savoir-faire et représentations du milieu marin à Mayotte. Le canal du Mozambique et sa valeur patrimoniale pour les habitants d'une commune vivant au

bord du lagon. Co-directed by F. Cautain, Parc naturel marin de Mayotte, and C. Sabinot, IRD.

Moreover two of MOZALINK/Module 3 students from Mozambique and Madagascar have obtained bursaries and admission in higher degrees in European countries where their native languages are not the media of instruction:

- Issufo Muhamade, Mozambique > Christian Geffray award bursary, French courses and one year MSc, France (2017-2018)
- Zola Tantely, Madagascar > Norway bursary, two years MSc, Norway (2015-2017)

Issufo Muhamade is still working on fishers in Ibo research field and plan to achieve a new Master dissertation untitled "Dialogues between local and global: The practice of artisanal fisheries in view of the creation of marine protected areas in Ibo district".

4.4. Module 4 – Sharing perceptions of the Mozambique Channel heritage using educational games with coastal communities (kids and adults)

Aim

In this module we used a pedagogical (teaching/explication) game (i.e. toolbox) to explicit the social representations of marine heritage. The MARECO toolbox (i.e., game set) initially developed for coral reefs (see description below) was adapted and used to this purpose. MARECO served as both a teaching and a measuring tool, whereby the current perceptions of participants could be measured by the outcomes and statements of the game, at the same time as they will be learning from it (about themselves, about others, about the socio-ecological system).

Team

P. Chabanet, J. Ferraris and C. Sabinot conducted this module together with the national co-PIs.

Methods: the MARECO toolbox

The Coral Reef Teaching Toolbox MARECO has been developed through a scientific program with a goal to disseminate and communicate results of research conducted on coral reefs (languages: French and English). It is composed of three educational games focusing on the importance and vulnerability of coral reef ecosystems and their management. MARECO allows discovering the coral reef biodiversity, their perturbations and management and brings together three games (a card game, a picture book, a board game) and a handbook as teaching aids for activities. The toolbox is aimed at all children from age 4 upwards, mainly of primary school age but with the possibility of extending the scope to secondary level and even to the general community. The key knowledge and concepts, which MARECO aims at transmitting are:

- 1) The diversity and fragility of the coral ecosystem in the face of natural and human-induced disturbances (Game 1: picture book The Colours of the Reef);
- 2) The identity, role and interactions of the living organisms of the coral ecosystem (Game 2: card game Coral Reef Happy Families);
- 3) The services to humans generated by the coral ecosystem, the place of humans within the coral ecosystem, and the necessity of cooperation between stakeholders to ensure the survival of the coral reef (Game 3: board game See You At The Reef).

The teaching toolbox brings together a handbook (English/French) written for teachers and the three games.

Activities

Two activities were planned: (1) adaptation of the toolbox to the Mozambique Channel context, (2) playing the MARECO toolbox with local communities and assessing its impacts on the perceptions of marine and coastal issues. The adaptation of the toolbox to the Mozambique Channel context was the first activity 4.1. of the Module 4. The first step was to translate the games into national languages (Portuguese, Swahili, Malagasy) to allow children to appropriate games. The adaptation of the board game to the regional Mozambique Channel geographical

context was not identified as a priority by Pi. Indeed the board game is relatively generic and reflect part of the Mozambique Channel environments with coral, mangrove and sandy environments.

Playing the MARECO toolbox game with local communities and assessing its impacts on the perceptions of marine and coastal issues was the objective of the second activity 4.2. The representations of marine heritage had been done in this WP in Madagascar and Mayotte.

Research methodology was based including the use of MARECO, and observes that there are relevant differences in coral reef representations before and after the use of the toolbox to.

Research methodology was based on an interdisciplinary approach in ecology, ethno-ecology, anthropology, and biostatistics, including children's drawing and the use of a teaching toolbox to evaluate the impact of environmental awareness campaign. After the 1st drawing (step 1) use to analyse how children represent sea and coral reef, the teaching toolbox was left on the school for 2 months (step 2). To ensure a similar use of the educational toolkit in each classroom, the children participated in nine activities involving the three tools which were demonstrated by the scientists. The kit was then left to the teacher to use during the following two months. After this period of familiarization with the games, the children did their second drawing (step 3). After each drawing, the children were interviewed to census the different element of the drawing. At total around 350 drawings have been realized in Madagascar and Mayotte in order to analyse how they perceived coral reefs in relation to their own experiences and knowledge. For data analysis, the drawings were analysed using a reading grid - build together with anthropologist, ethno ecologist, biologist and biostatistician – in order to describe and explain the social representations of the coastal marine ecosystem and the coral ecosystem of the sample considered. Finally, a multivariate analysis and statistical tests to identify the representation of children according to different factors was used.

Results

Due to the limited budget attributed to the WP4 in MOZALINK, activity 4.2 was mainly performed through other financial supports (2015 FEDER Reunion for the edition of the toolbox and 2016-2018 Fondation de France for research program). From a reading grid built jointly between the natural sciences (ecology) and the human sciences (anthropology), the qualitative information has been coded in quantitative data through a very long process. The preliminary results showed clear different representations of coral reef by children in the two countries targeted. The children in Madagascar have a good knowledge of the fish with fisherman present in main drawings while in Mayotte children represented the sea often empty or with few marine organisms or reef users. Despite the presence of many environmental awareness activities that are underway in Mayotte and the fact that most of population live near a reef included in a MPA, the reef is very little known by children. The region effect is then very marked, qualified by the criteria of choice of schools (urban, rural or coastal), but with a small impact of proximity to a marine protected area or a fishing community. In the French context (Mayotte), unlike foreign countries where fishing is a vital means of livelihood (Madagascar), the representation of the sea by children is more related to recreational or social activities and influenced by the contextual and geographical environment.

The second drawings pointed an evolution of the coral reef representation in the two sites. The impact of awareness campaign with MARECO toolbox is undeniable with a better knowledge of marine organisms, a more ecosystem-based representation and an awareness of the importance of natural or man-made hazards, and co-management.

The use of MARECO in different localities showed that this toolkit is adaptable to various environment and may help the children to better understand what are coral reef ecosystems and the need to maintain their health. Such educational toolkit may also be used to point out the importance of collaborative management initiatives between research, education, political institutions and the general community. Numerous perspectives emerge from this program whose main achievement consists in proposing an innovative and transferable interdisciplinary methodology of analysis of the representation of Nature and the interactions between Man and Nature, and the sensitization of the actors tomorrow's coastal ecosystems through scientific but fun educational activities.

Outputs and publications

The valorisation is still under process, the acquisition of the drawings and the standardization of the reading grid for drawing having been a very time-consuming process. The publications on the social representation of coral reef heritage and their evolution following the use of the toolbox will be finalized in 2018-2019.

An educational network for connecting young generations beyond their borders in Indian Ocean is planned for the next 5 years. In this objective, a relevant commitment (IRD and WIOMSA) has been proposed at ocean conference in New York (SDG 14, June 2017): MARECO Project, Increasing the awareness of children for the sustainable use of coral reefs and their resources in the SW Indian Ocean (see the link below).

Webpage

<https://oceanconference.un.org/commitments/?id=18623>

Movie

<https://www.youtube.com/watch?v=C5GcUezajvk>

Article

Ferraris J., Stoica G., Garnier C. & Chabanet P., 2015. Représentation sociale des écosystèmes marins côtiers à partir de dessins d'enfants. Une étude comparative entre Tuléar (Madagascar) et Perpignan (France). *TrajEthos* 4(1) : 49-67.

Communications

Stoica G., Masse L., Ferraris J., Chabanet P., Madi Moussa R., Carriere S. & Sabinot C., 2015. Social representations of the coral reef ecosystem: local knowledge, perceptions and challenges. The example of Madagascar and Reunion Island. 9th *Western Indian Ocean Marine Science Association Conference*, South Africa (communication).

Massé L., Stoica G., Madi Moussa R., Carrière S., Sabinot C., Riou A., Chabanet P. Ferraris J., 2015. The impact of the MARECO educational toolkit on the coral reef social representation of children in the South Western Indian Ocean. 9th *Western Indian Ocean Marine Science Association Conference*, South Africa (communication).

Stoica G., Ferraris J., Chabanet P., Sabinot C., Carrière S. Draw me the coral reefs. An interdisciplinary research methodology on the representation of marine ecosystem by children. 10th *Western Indian Ocean Marine Science Association Conference*, Tanzania (poster).

4.5. Module 5 – Contributing to the future governance of the Mozambique Channel World Marine Heritage

Aim

This Module5 aimed to feedback findings of the project, through multiple channels to actors and stakeholders at local, national and regional levels. The module was also aimed at producing policy briefs and information toolkits that will present the main results of the project in a accessible format.

Team

This Module brought together the entire team under the supervision of Erwann Lagabrielle.

Methods

The methods employed in this module involved interdisciplinary work (Gibbons et al., 1994, Figure 8) articulated around the integration of boundary products developed in the Modules 1-4 of the MOZALINK project (e.g., MARECO toolbox, Seasketch platform, movie).

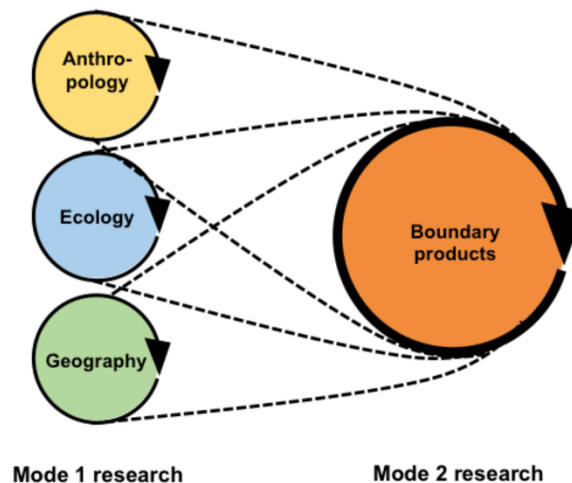


Figure 8. Conceptual framework showing the Mode 1 research (disciplinary) and Mode 2 research (interdisciplinary) in MOZALINK (Gibbons et al., 1994).

Activities

The first activity (5.1) aimed at identifying local marine resources management and governance issues in the study sites. The second activity (5.2.) aimed to support the Marine World Heritage inscription in the Mozambique Channel. We estimated that this inscription was beyond the timeframe of the project and chose not to focus on this specific inscription issue. The third activity (5.3) was aimed at identifying and sharing emerging challenges for the Mozambique Channel heritage. Mostly this Module 5 is a wrap-up work package involving cooperation among MOZALINK team members across Modules. To identify and frame the broader challenges of conservation and marine spatial planning, an on-line collaboration was developed with Juliette Delavenne (Museum National d'Histoire Naturelle, Paris, France) and a paper framing conservation issues within broader marine spatial planning challenges, methods and tools was published out of this collaboration (Lagabrielle and Delavenne, 2018). Lagabrielle and Delavenne (2018) described the steps of the Systematic Conservation Planning protocol and its affiliated criterion, practices and softwares, exemplified with international case studies. Based on a brief historical review Lagabrielle and Delavenne (2018) inspected factors explaining the worldwide dissemination of this now classic method while examining its limitations, including an oversimplification of political and social issues. Lagabrielle and Delavenne (2018) then discussed challenges related to the integration of marine conservation planning within the broader framework and agenda of Marine Spatial Planning (MSP). They stressed the need to enhance transparency together with science and consistency as pillars of future marine conservation planning practices and solutions, as stated in the 2014 EU directive on MSP. To achieve this ambitious objective, interdisciplinary approaches involving the full spectrum of biological and social sciences are needed to describe and accompany « marine conservation planning as it is », not only « as it should be ».

A Leaflet of the MOZALINK Project was produced after E. Lagabrielle attended the “Path to impact” WIOMSA training session organized in Mombasa, Kenya (2016). A major publication of this Module 5 is still underway (Lagabrielle et al.) and will associate all Module team leaders. A publication by David et al. (in press) is also relevant to Module 5.

Outputs and publications

Articles

Lagabrielle E., Delavenne J. (in press). Marine spatial conservation planning: Methods, debates and perspectives. Book Chapter published by the French Biodiversity Agency.
David G., Chabanet P., Lagabrielle E., Quod J.-P. 2018. Chapter 37 : Low tech conservation planning strategies for human-coral reefs cohabitability in a changing world In: Coviability of Social and Ecological Systems: Reconnecting Mankind to the Biosphere in

an Era of Global Change Vol.2 : Coviability questioned by a diversity of situations. Ed. Barrière et al.

Lagabrielle et al. (in writing). Scale, power and contingencies in Marine Spatial Planning: an interdisciplinary study in the Western Indian Ocean.

Leaflet

Lagabrielle E, Sabinot C. 2017. In troubled or clear water ? Obstacles and solutions to marine spatial planning in the Western Indian Ocean. Leaflet of the MOZALINK Project. 3 pages.

4.6. Module 6 – An audiovisual documentary “The Mozambique Channel Natural and Cultural Heritage”

Aim

This module 6 aimed to produce a 52 mn documentary on the MOZALINK project in French and English.

Team

Several researchers of the Modules 1, 2, 3 and 4 participated to the MOZALINK movie with B. Surugue. The IRD audio-visual service is fully involved in this project. It has a long experience on scientific movies and co-ordinated the entire film production process, from conceiving a film to actually making, distributing and promoting it. It acts as an intermediary between scientists and film and television professionals. The IRD Audio-visual unit operates in partnership not only with other public institutes specialized in research and disseminating knowledge, but also with universities, international organizations, film production companies, television channels and public and private broadcasting networks. They had produced more than 250 movies, which are distributed all over the world.

Methods

The film is a very good mean to show and share the different cultures and approaches of the natural environment. It is a way to exchange between the communities of several countries concerned by the program to point out differences and similarities between them. The film will be shown to the communities where it had been made. The film is also a way to explain to a very large public the interest of surveying and protecting our natural as well as cultural heritage. If possible, it will be broadcast on local (Madagascar, Mayotte, Mozambique) and French TV.

Activities

The MOZALINK movie was shot in 2015 and 2016 :

- in Mozambique (Ibo) with E. Mariano, I. Muhamade and C. Sabinot,
- in Madagascar (Tulear) with Z. Tantely, J. Mahafina, E. Lagabrielle and C. Sabinot,
- in South Africa (Durban) with E. Lagabrielle, P. Chabanet and J. Harris,
- in Mayotte with P. Chabanet and D. Obura

The movie was cut at IRD Bondy in France.

Output

A preliminary version of the audiovisual documentary “MOZALINK” (52 mn) was displayed by B. Surugue at the 2017 WIOMSA Symposium in Dar es Salam, Tanzania during the special MOZALINK session held on “Collaborative Marine Spatial Planning with SeaSketch - Perspectives in the Western Indian Ocean” (Figure 9).



Figure 9. Extracted sequences of the MOZALINK movie (B. Surugue, IRD, 2018)

ACKNOWLEDGEMENTS

We kindly acknowledge Dr. Julius Francis, Lilian Olomo and Innocent Wanyony from WIOMSA for their help, support and patience. We also thank the MASMA Programme Committee members including Lena Gipperth, Ian Bryceson and Gilbert David. We thank all the women and men, old or young, rich or poor, who, across the Mozambique Channel, shared their thoughts, their time, their place and their sense of place with us.

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