

Learning from risk reduction pilot projects for enhancing long-term adaptation governance: the case of Mauritius Island (Indian ocean)

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Abstract

In Mauritius island in the Indian Ocean, as in most low-lying coastal areas and Small Island Developing States in particular, coastal risks affect community livelihood, economic prosperity and the degradation of natural ecosystems. Risks of coastal erosion and marine flooding result both from climate-related ocean changes and anthropogenic drivers such as inappropriate coastal development and structural protection measures. Poor development planning and lack of coordination between public and private actors have increased the exposure of human assets along the Mauritius coastline. To reduce these risks, the government leads risk reduction activities in coastal zones, functioning on a centralized top-down governance approach. In recent years, this governance framework has been evolving by opening up participatory channels and exploring a long-term adaptation perspective. Progress is driven by international engagements and demonstration projects to embrace soft measures, nature-based options and integrated solutions. We review a selection of pilot projects undertaken by the government that illustrate flexibility in a ‘learning by doing’ model. However, we find that certain governance arrangements do not allow to draw the most from ad hoc projects because they do not feed into a long-term comprehensive plan. We consider the role of evidence and risk assessments, learning processes and coordination mechanisms as key governance mechanisms required for a robust and evolving national coastal risk reduction and adaptation policy framework.

Keywords: climate change adaptation, governance, coastal risks, small islands

Introduction

About 65 million people live in Small Island Developing States (SIDS) and it is estimated that more than 80% live near the coast where marine flooding and coastal erosion already pose serious problems (Nurse et al., 2014; UN-OHRLLS, 2015). In addition, climate-related changes to the ocean, including the projected combination of higher rates of sea level rise and occurrence of extreme sea levels, together with the impacts of ocean warming and acidification on climate-sensitive ecosystems such as coral reefs (Hoe.g.h-Guldberg et al., 2018; Bindoff et al., 2019; Oppenheimer et al., 2019), increasingly threaten land, soil and freshwater resources, therefore challenging island sustainability. Island nations have been leaders since the end of the 1980s in raising international awareness on the risks associated with sea level rise and extreme weather events such as tropical cyclones. As early as 1989, the United Nations (UN) adopted a specific resolution on the potential negative effects of rising sea levels on islands and coastal areas, thus officially recognizing the high climate vulnerable profile of SIDS. The special case of small islands was re-emphasized at the 1992 UN Conference on Environment and Development (Earth Summit, Rio de Janeiro, Brazil), and at the first UN Global Conference on Sustainable Development of SIDS held in Barbados in 1994. The Second and Third Global Conferences took place in Mauritius (2005) and Samoa (2014) to take stock on progress at a decadal rate. Such a dynamic in policy and international climate negotiations, e.g. through the Alliance of Small Island States (AOSIS), helped SIDS get access to more international financial support and subsequently to the development of adaptation-labelled projects (Ourback & Magnan, 2017; Robinson, Dornan, & Gilfillan, 2017; Robinson & Gilfillan, 2017).

The convergence of SIDS at the frontline to climate change impacts and gaining international attention, lays foundations for making them potential pioneers to climate change adaptation (Ourback

& Magnan, 2017). In comparison to other coastal contexts, small levels of action and resources can rapidly lead to effective adaptation-compatible responses to risk. However, this depends not only on changing hazard levels (extent and frequency) and on international funding, but also on the ability of island societies and institutional systems to learn from pilot projects and drive broader climate change adaptation-compatible risk reduction strategies. This paper focuses on this latter point, using the example of Mauritius Island in the Indian Ocean. It first describes the coastal risk governance landscape in Mauritius and, secondly, analyses national risk reduction responses through three recent pilot projects. Third, it discusses some gaps in the governance system that prevent lessons to be learnt from these pilot projects, and concludes on some challenges ahead to bridge this strength/weakness gap to ensure being on track to long-term coastal adaptation.

1. Site study

Mauritius is the main island of the Republic of Mauritius, which is also composed by the Rodrigues island and the coral archipelago of Agalega and St. Brandon. Mauritius island is the largest (1 868 km², 93% of the country's total land area) and the most populated (96% of the 1,265,637 inhabitants). It is also the economic hub of the country, known since the 1980s as an “economic miracle” (Minogue 1992), as reminded a few years ago by the economist Joseph Stiglitz². Since its independence in 1968, the country successfully diversified its economy, from a sugar cane-based monoculture inherited from colonial times (since 1638, successively under the Dutch, French and British) to textile and tourism, and more recently a surge in cyber activities and finance.

Mauritius has a coastline of 322 km, 83% of which are made of sandy beaches bordered by fringing and barrier reefs (Cazes-Duvat and Paskoff, 2004). These low-lying coastal areas are highly exposed to the strong distant-source swells originating from the southwest (e.g. in 1976, 1987, 2007, 2008, 2018) and to the heavy swells generated by tropical cyclones (in 1960, 1975, 1994, 2002, 2007), which have caused increasing beach erosion (McIntyre and Walker, 1964; Bheeroo et al., 2016) and flooding (MMS, 2008; JICA 2015) over the past decades. A recent island-wide study found that 23% of beaches were experiencing erosion, while 22 sites (3,400 people and 1,100 buildings) were affected by storm-induced flooding (JICA, 2015). Beach erosion results from the combination of numerous natural and anthropogenic drivers, including, on top of extreme storm events, rapid sea-level rise, marked reef degradation due to human activities (water pollution, sediment dredging, fishing and boating activities, etc.) and bleaching events (e.g. in 2009, Ramessur 2013, and in 2016, McClanahan et al 2019), and the disruption of sediment transport by coastal developments and engineered structures (Baird and Associates, 2003; Duvat, 2009; JICA, 2015). It is noteworthy that Mauritius experienced a relative sea-level rise of 4–6 mm year over the past 30 years, indicating an absolute sea level rising 2–3 times faster than the 20th century Global Mean Sea Level (Becker et al., 2019).

Coastal areas in Mauritius have a high economic value, especially due to the emergence of coastal tourism in the 1950s and take-off in the 1970s. Together with activities involving information and communication technologies (ICT), tourism contributed in 2018 to 76% of the GDP and to 67% of employment³. The island registered more than 1,875,800 international tourists in 2017 for a bed capacity of more than 13,500 rooms, mostly located in hotels. It has been estimated that already in the beginning of the 2000s, ~90% of the hotel bed capacity was located in sandy coastal areas in the North, West/South-West, East and, emerging at that time, the South (respectively 46.0, 27.0, 18.0 and <10% of the 2002 bed capacity) (Magnan, 2007). Tourism development also played a role in the growth of recreational activities on the coast by the local population, which progressively generated some tensions around the status of the coastal fringe and the use of beaches (Magnan, 2007). Such economic and social dynamics led to important coastal developments, including for residential purpose and consequently to an increase in the exposure of people, assets and infrastructure to coastal hazards such as marine flooding and erosion.

² <https://www.theguardian.com/commentisfree/2011/mar/07/mauritius-healthcare-education>.

³ <http://statsmauritius.govmu.org/English/StatsbySubj/Pages/INTERNATIONAL-TRAVEL-and-TOURISM.aspx>

2. Data collection and analytical framework

Research gap

The purpose of this paper is to use a pilot project analysis to explain the significance of governance arrangements for successful coastal risk reduction, and discuss implications for national adaptation to climate change. Pilot projects are the means of applying and testing innovations in a confined field setting that enable to learn from the innovation and context, where outcomes can feedback into management practices and policies (Vreugdenhil et al., 2010). At the same time, “good governance” is earmarked as a framework and process for effective risk reduction and adaptation to climate change (Renn & Schweizer, 2009; Amundsen et al., 2010; Bauer et al., 2012; Janssen, Van Der Voort & Janssen, 2017). We identify components of good governance in the literature that apply to the management and reduction of coastal risks (Penning-Rowell et al., 2014). These aspects refer to having in place legitimacy, transparency, accountability, rule of law, responsiveness and effectiveness in decision-making processes, policy design and implementation (Keping, 2018). Important criteria include the clear allocation of responsibilities, mobilizing adequate funding and cross sector policy coherence among others (see OECD, 2015). As far as integrated approaches are emphasized for adaptation, then processes of good governance actively engage stakeholders through partnerships and consultations and use coordination mechanisms to mobilize stakeholders in project design and implementation (Renn & Jäger, 2008; Renn & Schweizer, 2009). This is especially important to cope with uncertainties in adaptation planning, where the co-design of projects can create consensus on risk acceptability and risk ownership (Losada et al., 2019). An in-depth analysis of the design and implementation of pilot projects allows to surface the success and gaps of these various governance arrangements.

Case studies shed light on levers and barriers to implementing pilot projects in risk reduction and the relevant enabling conditions for adaptation (Granberg & Elander, 2007; Bauer et al., 2012). These studies explore a variety of political, economic and social contexts that shape risk governance regimes. Many SIDS such as Mauritius engage with international actors to address coastal risks through funding mechanisms and bilateral arrangements, which often include a governance component. However, it is not always clear how these international engagements take into account idiosyncratic institutional arrangements to address coastal risks in the context of small islands, where adaptation planning will have to balance risk reduction with varying stakeholder interests along the coast, including the importance of the coast for economic development.

Material and methods

We evaluate changes in the governance of managing coastal zones in Mauritius using a time-line to track the introduction and revisions of policies, legislation and institutional actors (Duvat et al., *submitted*). Firstly, we conducted desktop research on the laws, policies and government reports related to coastal risk reduction and adaptation dating back to 1988 (Supplementary Material SM1) and identified the main institutions involved in policy making and implementation (see SM2 for a stakeholder map). The aim of this exercise was to position the analysis of the pilot projects within their current institutional context. Since an exhaustive review of climate change adaptation policies in Mauritius was not the purpose of this paper, we built on a study by Gary and Lalljee (2012) providing useful insights on the role of institutions and governance issues. To complete the desktop research, most documents were accessible through government websites, while others were obtained during fieldwork visits and interviews with stakeholders. Pilot projects were informed by technical reports and Environmental Impact Assessment (EIA) studies, which included data on the project design and location study.

In addition, fifteen semi-structured interviews (22 persons in total) were carried out between 6 and 24 May 2019 with each of the fifteen most relevant public and private stakeholders concerned with coastal risk management, including academic institutions and NGO's (Table 1). These interviews helped gather information on three main topics (i) the governance arrangements for coastal zone management and risk reduction, (ii) the role of different institutions, and (iii) the history of the design and implementation of local risk reduction pilot projects (for an overview see SM3 and SM4).

Information obtained from stakeholder interviews was compared to desktop research, to enable the identification of levers and barriers to implement risk reduction pilot projects and plan for long term adaptation. Specific question dealt with available risk knowledge and information to inform policies, and the introduction and revision of any coastal risk and vulnerability assessments. Questions also related to the creation of new institutions, legislations or policies and coordination mechanisms (vertically within a multi-level governance framework) and horizontally across related policy areas (e.g. land use and urban planning on the coast, tourism, environmental and water). To capture the role of institutional actors to manage the coast, we asked about the allocation of responsibilities to carry out: coastal risk and vulnerability assessments, risk reduction projects, maintenance and surveillance, monitoring and evaluation, and decision-making on coastal land-use and development. Finally, to understand the context of pilot projects for coastal risk reduction that are either underway or planned for in the future, we investigated issues related to the inception of the project idea (national project or through international engagement), its design phase (main steps, constraints and decision-making process, multi-stakeholder consultations including with the community), funding (sources and amounts) and implementation phase (main steps, constraints, achievements). Hereafter, specific information raised in a given interview is referred as 'Int.1_XX_2019.05.Z' where Int.1 refers to Interview n°1, XX refers to the institution, and 2019.05.Z specifies the date of the interview (see third column in Table 1).

Table 1. List of interviews carried out with relevant stakeholders in Mauritius between 6-24 May 2019

Stakeholder	Title*	Responsibilities	Interview code
Ministry of Housing and Lands	Chief Town and Country Planning Officer & Senior Town and Country Planning Officer	In charge of land use and urban planning, including the development of building codes. Manages the GIS system and relevant urban plan maps. Representatives interviewed were in charge of overseeing urban plan maps and the issuing of leases of state lands to private entities.	Int.1_MoH_2019.05.09
Ministry of Environment (MoE)	Assistant Director	Drives and coordinates national environment and sustainable development policies. Representative interviewed oversaw the activities of the ICZM and CCD.	Int.2_MoE_2019.05.09
Integrated Coastal Zone Management Unit (ICZM)	Chief of the Division & Agent	Carries out studies and implements projects to address coastal risk reduction, specifically on erosion. Representatives interviewed design adaptation policies for the coast and carried out beach surveys, monitoring and re-profiling.	Int.3_ICZM_2019.05.09
Climate Change Division (CCD)	Chief of the Division & Agent	Develops a national climate change adaptation and mitigation framework. Representatives interviewed carry out national communications on CCA and conducted climate change modelling.	Int.4_CCD_2019.05.09
National Disaster Risk Reduction and Management Centre	Police inspector	In charge of disaster risk reduction and preparedness activities, with a focus on crisis management, rehabilitation and recovery. Representative interviewed was specialized in preparing and managing critical infrastructure (i.e. telecommunications, water system) during disasters.	Int.5_NDRRMC_2019.05.22
Beach Authority	General Manager	Carries out daily monitoring of activities on public beaches. In charge of landscaping and the management of public beach amenities. Representative interviewed was in charge of overseeing activities, checking reports and studies of beaches and liaising with the MoE.	Int.6_BA_2019.05.10
Adaptation Fund project office	Project Assistant	Coordinates with the UNDP and the Adaptation Fund projects underway. Representative interviewed was in charge of stakeholder consultations with the community, relevant government bodies and the private sector. In particular, they led the Riviere des Galets project and another project at Mon Choisy (installation of artificial reef).	Int.7_AFPO_2019.05.16&22
Black River District Council	Head of Land Use and Planning Department	Local level administration in charge of overseeing that planning and development adheres to standards. Representative interviewed ran the Department.	Int.8_BRDC_2019.05.09
University of Mauritius	Associate Professor (Environmental and Coastal Sciences) & Senior Lecturer & Professor (Department of	Representatives interviewed contributed to a training manual on cost benefit analysis for coastal risk adaptation measures carried out in 2015. As part of this project led by the MoE, the Department carried out a series of CBA trainings with government stakeholders.	Int.9_UoM_2019.05.22

Economics)			
Business Mauritius (BM)	Energy, environment & regional cooperation project manager	Independent association that represents over 1200 local businesses in Mauritius. Representative interviewed was in charge of member relations and coordinating with MoE (e.g. drawing a MOU between BM and MoE)	Int.10_BM_2019.05.13
Association for restaurants and hotels operating in Mauritius (AHRIM)	Sustainability Manager (Sun Resorts) & Corporate Manager (Sun Resorts)	Association of private business operators in the tourism, hotel and restaurant sectors. Representatives interviewed were members of the AHRIM and in charge of managing Sun Resorts in Mauritius, with particular attention to environmental policies to ensure sustainability of operations.	Int.11_AHRM_2019.05.13
ARUP SIGMA consultancy group	Director	Private consulting firm that works on coastal risk assessments and the design of risk reduction solutions for private companies (e.g. hotels). Representative interviewed was head of the Mauritius office and directed several adaptation projects for hotels.	Int.12_ARUP_2019.05.16
VLH Hotels and Resorts	Chief Projects and Development Officer	Large scale hotel-resort operating in Mauritius. Representative interviewed was a member of the AHRIM and in charge of overseeing developments of VLH hotels and resorts in Mauritius, with particular understanding of land use and leasing arrangements along the coast.	Int.13_VLH_2019.05.13
Mauritian Wildlife Foundation	Conservation Director	Non-governmental organization working on biodiversity conservation in Mauritius. Representative interviewed was in charge of nature based adaptation perspectives in the smaller islands of Mauritius.	Int.14_MWF_2019.05.17
Aret Kokin Nu Laplaz (NGO)	Member	Association led by community members in Mauritius committed to the protection of public beaches and conservation of environmentally sensitive areas. Anonymity assured of representative interviewed.	Int.15_AKNL_2019.05.28

* Interviews were conducted with officials and other important stakeholders involved in coastal zone management. Given the sensitivity around coastal zones, it has been agreed with interviewees that while their names would not be mentioned, their functions and responsibilities should be highlighted in the sake of the robustness of the scientific approach and results.

3. Coastal risk governance landscape in Mauritius

Over the last few decades, the coastal governance framework in Mauritius has adapted to tackle coastal risks and reduce their effects. To explain how the current governance framework took shape, the time-line in Figure 1 illustrates shifts in risk management approaches and analyses the factors that drove these changes. Shifts also refer to the introduction of institutional actors and public policies. We survey the evolution of the governance landscape to address coastal risks, while taking into account two institutional norms: a top down centralized approach and a legal structure of coastal land entitlements derived from colonial history.

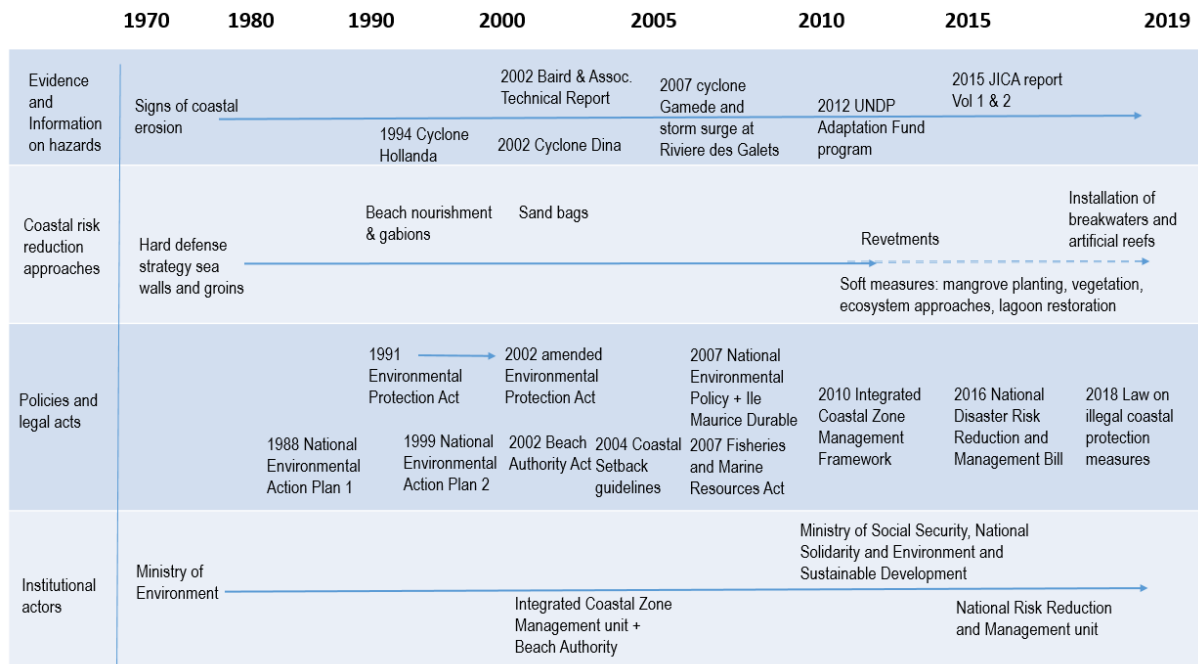


Figure 1. History of coastal risk governance in Mauritius.

Sources: (Baird and Associates Coastal Engineers LTD., 2003; Duvat, 2009; Government of Mauritius, 2002, 2003, 2004, 2007; Gray & Lalljee, 2012; UNDP, 2012; JICA, 2015)

The state owns up to 90% of the coast established by the ‘*loi des 50 pas du Roi*’ or ‘*loi des pas géométriques*’ (Crown Lands Act, 1874). The ‘*pas géométriques*’ date back from the 1800s and was a form of measurement used at the time under French colonialism to demarcate the coastal strip of land from the High Water Mark. As the government owns most of the coastal land, there are two main categories of land titles, proclaimed public beaches (129 at present) and leased land issued by the state to private developers for hotels or household residents (Beach Authority, n.d.). Leases are issued for thirty to sixty years and go through a process of renewal with the Ministry of Housing and Lands (Int.1_MoH_2019.05.09). In addition, there are marine protected areas and mangroves managed by state agencies, vested areas (leased areas to a government organization) and uncommitted areas that do not fall under any category (Government of Mauritius, 1998; Hammond et al., 2015). In this paper, we focus on the management of proclaimed public beaches that fall under the auspices of the central government.

Traditionally, the government opted for hard structural measures to reduce the effects of erosion and flooding (Ramessur, 2002; Duvat, 2009; Int.3_ICZM_2019.05.09). The construction of seawalls, groins and then from the mid-1990s to the mid-2000s gabion structures, predominated as a coastal risk management strategy (Duvat, 2009). Increased tourism and development led hotels and private residents to put in place their own structures to protect their beachfront from hazards. The absence of control over structural measures marked a period of uncoordinated risk reduction activities along shorelines.

The risks of erosion and flooding coupled with development pressures for the growing tourism sector led to the implementation of environmental policies and legal acts in the 1990’s. The new Environmental Protection Act (1991) and revised Environmental Action Plan (1999) addressed coastal zone management and the protection of sensitive areas, including the control of sand extraction. The legislation however did not include risk assessments or an evaluation of a comprehensive risk reduction approach. Without a scientific basis of the local physical context, decision-makers continued ad hoc approaches to coastal risk management. In particular, the government decided to transfer in gabions that had been successful in South Africa against erosion (Duvat, 2009). Gabions were favoured due to easy access to materials, ease of installation and their supposed quick effectiveness. However, in some areas they were inappropriately designed to the coastal morphology of the site and

more generally were not well-maintained, resulting in their rapid degradation and ineffectiveness to control coastal risks. Without evaluation or monitoring policies in place, gabions and sea walls eventually fell apart making them dangerous and at times catalysts of risks. According to several interviews with government institutions (e.g., Int.3_ICZM_2019.05.09, Int.2_MoE_2019.05.09) and a recent review of the climate change adaptation policy and institutional framework in Mauritius (Gray & Lalljee, 2012) governance gaps remained due to a lack of scientific evidence to inform practices and absence of accountability measures to monitor structural measures.

Experiences with failed coastal risk management approaches and growing importance of climate change impacts in SIDS, incentivized the Mauritian government to partner with international actors for support on scientific risk assessments. In 2002, a technical study on erosion carried out by the consulting firm Baird and Associates put forward a first important evidence to guide decision-makers (Baird and Associates Coastal Engineers LTD., 2003). This awareness and introduction of risk assessments supported public policy amendments in the Environmental Protection Act (EPA) 2002 by enforcing integrated coastal zone management approaches as well as reinforcement of the Environmental Impact Assessment (EIA) for large developments on the coast. In 2002, the Ministry of Environment created an Integrated Coastal Zone Management Division (ICZM) to carry out beach surveys and coordinate risk reduction activities. In parallel, the Beach Authority was set up to monitor daily conditions of beaches and the provision of public amenities. In 2008, the EPA was amended again adding new bodies such as an EIA/Preliminary Environmental Report monitoring committee. These steps were mentioned by interviewees in public institutions as improvements towards scientifically informed public planning and increased monitoring of the coast.

Following initial assessments, the ICZM did not build capacities to carry out its own risk assessments, calling for further collaboration. Between 2012 and 2015 a second wave of governance shifts occurred towards endorsing long-term coastal adaptation strategies and capacity building triggered by international interventions. With the status of a SIDS, financing mechanisms of the United Nations Development Program (UNDP) and Adaptation Fund facilitated site-specific risk assessments and pilot projects to experiment with alternative risk reduction approaches (UNDP, 2012). In addition, in 2015 the Japanese International Cooperation Agency (JICA) compiled a two volume detailed technical analysis on coastal vulnerability of fourteen sites with recommendations for risk reduction projects (JICA, 2015). These projects emphasized a long-term perspective by incorporating the effects of climate change.

Since 2015, according to almost all interviews with public and private stakeholders (Int.1_MoH_2019.05.09; Int.2_MoE_2019.05.09; Int.3_ICZM_2019.05.09; Int.10_BM_2019.05.13; Int.11_AHRM_2019.05.13; Int.12_ARUP_2019.05.16; Int.9_UoM_2019.05.22), the JICA report serves as a base-line risk assessment and reference guide for ad hoc risk reduction projects led by the Ministry of Environment and ICZM. The projects demonstrate different measures, such as installing revetments, mangrove planting, beach re-profiling and redesigning structural measures. Pilot projects present opportunities to increase understanding of risks and build capacities by incorporating lessons learned in the governance framework. However, the projects do not take into account the underlying drivers of vulnerability and exposure nor involve the private sector, maintaining the status quo of an uncoordinated risk reduction strategy (Gray & Lalljee, 2012).

Taking a closer look at a selection of projects implemented, we review governance levers and obstacles for delivering a long-term vision towards comprehensive coastal risk reduction and adaptation.

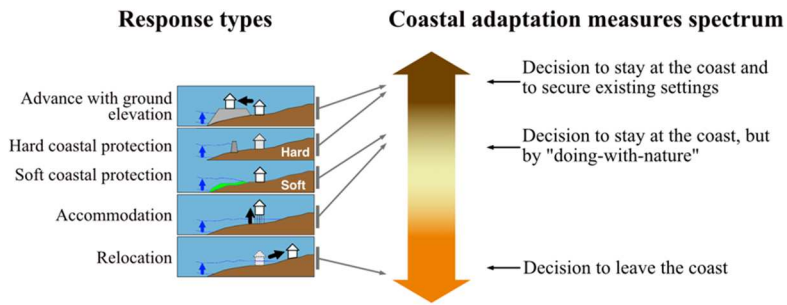
4. Pilot projects as potential triggers for enhanced coastal risk governance

We review three coastal risk reduction pilot projects (Fig. 2) for which we gathered robust enough material (on history, funding processes, public consultation, etc.) to allow for an in-depth analysis. In addition, these projects are representative of a wider range of actions, as they cover different locations (South and East), hazard and vulnerability contexts (various degrees of urbanisation), and risk

reduction measures (hard protection, beach re-profiling and nature-based measures, assets relocation). They have been carried out by the Ministry of Environment and the ICZM with the aim of reducing exposure of communities and infrastructure to coastal surge, marine flooding and erosion. The three sites have the status of public proclaimed beaches and are therefore managed by the state.

The methodologies of the pilot projects consider measures that schematically range at the two opposite sides of the adaptation response spectrum discussed in the literature. These adaptation responses go from protection (using hard engineered structures or soft measures such as mangroves replanting) to advance with ground elevation (reclaimed elevated lands), accommodation (e.g. houses on stilts) and coastal relocation (people, assets and infrastructures) (Nicholls, Wong, Burkett, Codignotto, & Hay, 2007; Oppenheimer et al., 2019; van Slobbe et al., 2013) (Fig. 2 panel A, left hand side). The variety of measures adopted in Mauritius (Fig. 2, panel A, right hand side) reveals flexibility to adapt measures to local contexts. The literature agrees that there is no ‘one size fits all’ adaptation solution because measures are most effective when designed to site-specific exposure and vulnerabilities. Decision-making processes behind choosing between risk reduction options is complex and involves quantitative and qualitative analyses (Jonkman et al., 2003). Governance arrangements such as communication channels and coordination mechanisms can help facilitate dialogue across stakeholders to co-design and implement a risk reduction project where consensus and acceptability are important components of the decision-making process (Barquet & Cumiskey, 2018; Losada et al., 2019). These kinds of governance arrangements are analysed in the three projects to shed light onto levers or barriers of transition via experimentation in a ‘learning by doing’ model (Wittmayer & Loorbach, 2016).

Panel A



Panel B

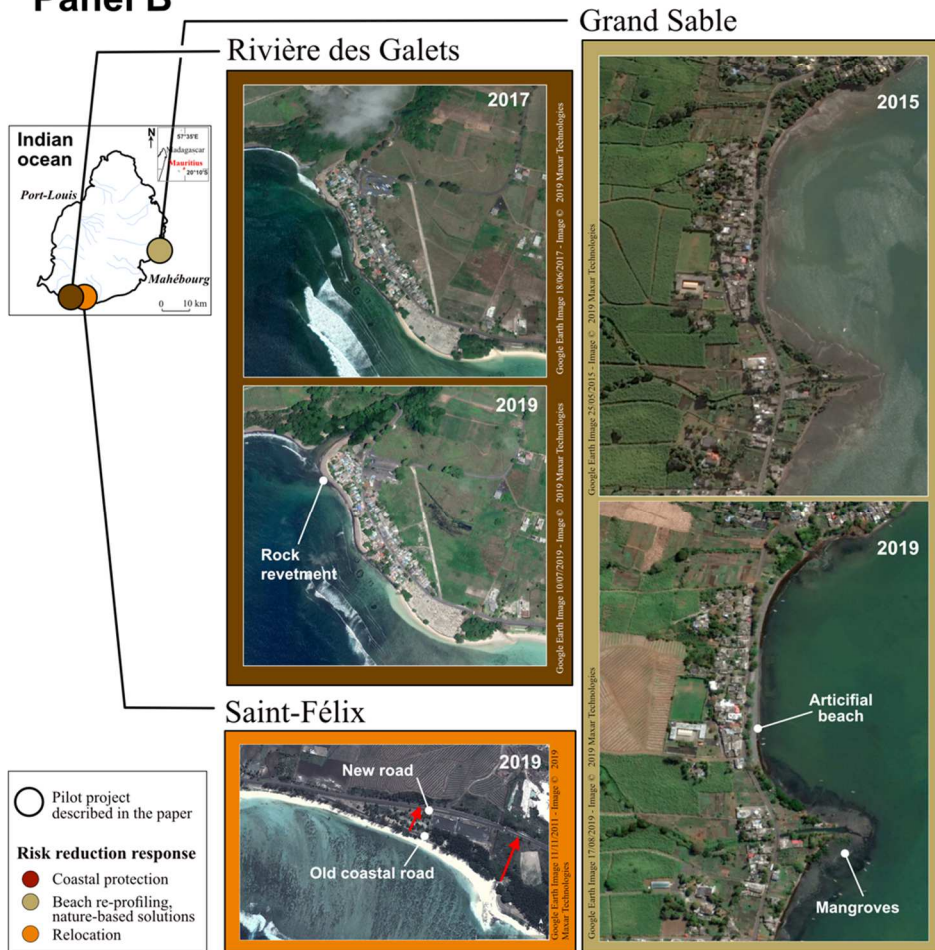


Figure 2. Coastal risk reduction projects in Mauritius. Panel A describes the continuum of responses to sea-related risks as described in the literature and going from securing current settings (dark brown, top of the arrow) to relocation (orange, bottom of the arrow); inspired from Oppenheimer et al. (2019) and Magnan et al. (2019). Panel B locates and illustrates the three pilot projects discussed in this paper. The colours of the map circles and background of field images refer to the continuum of responses in panel A.

Rivière des Galets

Rivière des Galets (Fig. 2, Panel B) is a community of about 150 people across 40 plots of land located on the southern coast highly exposed to strong southern swells and flooding from storm surges. Extreme weather events hit the area in 1976, 1987, 2007, and 2018⁴ (Ministry of Environment, Solid Waste Management and Climate Change, 2019). The most disastrous flooding occurred in 2007 triggered by a storm surge and failure of the old structure (gabion backed onto a seawall) to provide adequate protection (Int.7_ADPO_2019.05.16&22). In the aftermath, the community had difficulty to

⁴ <http://environment.govmu.org/English/Pages/afbp/Coastal-Adaptation-Works.aspx>

recover due to the extent of damage and high socio-economic vulnerabilities (UNDP, 2012). A majority of the community is living in poverty, half of the households are makeshift and many do not have proper sanitation facilities (UNDP, 2012). On account of vulnerability of the community and poor conditions of the protection structure, Rivère des Galets was selected as one of the most critical sites to address in the UNDP Adaptation Fund project portfolio in 2012. As previously mentioned in the governance timeline (Section 3) this partnership between the Mauritius government and UNDP allowed to develop important coastal risk assessments and mobilize funding for the implementation of adaptation projects.

Following the selection of Rivière des Galets as a pilot project, in 2014, the ICZM unit (Ministry of Environment) and the UNDP project office discussed two main options to reduce exposure of the community to storm surge (Clarke & Persand, 2014; Int.7_AFPO_2019.05.16&22). The first was the installation of a concrete parapet wave-return wall and rock revetment. This option entailed the redesign and reinforcement of the existing sea wall bordering the community and up until the adjacent cemetery. The second option suggested managed retreat of highly exposed households. In first instance, a financial appraisal was carried out between these two options. UNDP calculated that reinforcing the structural measure would be less costly than relocation, estimated at \$2.8 million for the former and \$9.2 million for the latter (UNDP, 2012). Despite the higher costs of relocation, some decision-makers still favoured this option. A multi-stakeholder consultation process showed that the disaster risk reduction and management agency considered retreat to be in line with building long-term resilience, given uncertainty about available resources to cover future capital costs of maintenance and reinforcements of a sea wall that might have capacity-limits to future extreme weather events (Int.5_NDRRMC_2019.05.22). Therefore, the cross institutional consultation process surfaced questions about the governance arrangements in place to ensure a proper budget for maintenance, which suggests concerns about follow up monitoring and evaluation procedures.

In addition to the economic evaluation of risk reduction measures, risk perception of communities and the acceptability of stakeholders play a role in choosing risk reduction options in participatory governance frameworks (Barquet & Cumiskey, 2018). To evaluate the two options for the project, the UNDP and the ICZM spent a year leading raising awareness initiatives in the community and carried out a consultation process (Int.7_ADPO_2019.05.16&22). These activities reflect the use of bottom up participatory channels and community engagement in the decision-making process (Huitema et al., 2009; Wehn et al., 2015). A household survey showed unwillingness of over half of the community to move because of strong family and cultural ties to the area (Clarke and Persand, 2014). Given this risk perception among community members, the sensitivities behind relocation and a lack of full consensus, relocation was no longer a viable option. Therefore, the second option was put in motion. In 2016, the newly designed sea wall and 430 meters of rock revetment were installed with the help of local consulting and engineering firms hired by a procurement process and international resources (Clarke and Persand, 2014).

Reducing the exposure of the community was the priority behind the project at Rivière des Galets and the sea wall reinforcement option was chosen following a consultation process with the community. However, there are limitations of structural measures to building long-term resilience discussed in the scientific literature and as posed by the Mauritian disaster risk reduction agency (Hino et al., 2017). Limitations include capacity limits and the need for proper governance arrangements such as monitoring, evaluation and resources to carry out maintenance to ensure their effectiveness over time (Shreve & Kelman, 2014; Schneider, 2017). The institutional consultation process surfaced issues of securing long term investments in monitoring and evaluation, since funding was made available only for the implementation phase. In addition, there is also a risk that structural measures give a false sense of security thereby incentivizing further development in hazard-prone areas (Burby, 2006; Kates et al., 2006; Gordon & Little, 2009). Accordingly, the raising awareness initiatives launched as part of the project should be continued, especially with the installation of the sea wall to reinforce risk perception in the community about climate risks. Moreover, the government will have to design appropriate oversight mechanisms to avoid unintended side effects of this structural project that could increase exposure and vulnerability to future flood risk.

The project puts forward two complex governance issues. Firstly, the *acceptability* of risk reduction options across stakeholders. Consensus is important and engaging communities in the decision-making process can increase acceptability (Renn & Schweizer, 2009). However, as displayed in this pilot project local risk perception is important and can favour structural measures that are probably more familiar to community members. Secondly, the project reveals the complexity of relocation and managed retreat as an option, as reported more broadly in the scientific literature (Siders, 2019; Siders et al., 2019). The state has to balance obligations between protecting society and respecting cultural rights (Hino et al., 2017). While moving infrastructure requires political willingness and resources, the relocation of a community has additional concerns on the sensitivities behind family and cultural ties to the land (McNamara & Des Combes, 2015). Decision-making processes and policies behind when and how to plan and finance relocation could be something to further consider when similar cases arise in the future. It should involve measures to increase learning tools about climate risks and facilitate participation of the community.

Grand Sable

A large stretch of the eastern coast of Mauritius is characterized by dense mangrove forests, intermittent coastal communities and a long coastal road. Grand Sable (Fig. 2, Panel B) and Petit Sable are two communities located in this part of the island exposed to yearly tidal flood risk. Given the physical area of the sites conducive to the growth of mangroves, UNDP and the ICZM unit decided to implement a pilot project planting additional trees to serve as a natural buffer against flood risk (Connelly et al., 2019). Mangrove forests have the capacity to filter water, and shelter coastal zones from erosion and flooding by dissipating wave energy and absorbing excess waters (Gattuso et al., 2018; Oppenheimer et al., 2019; Wilson & Forsyth, 2018), as well as they play a key role in fishing activities by nourishing an ecosystem for marine species (Spencer et al., 2016). The latter component of the site offers important social and economic benefits to the local community at Grand Sable, where many fishermen rely on the lagoon's healthy ecosystem.

The site at Grand Sable presented an opportunity to explore nature-based adaptation options along the coast following a trend of the Mauritian government to test alternatives to well known structural protection measures. Specifically the project consisted of planting one hectare of mangrove propagules along the coastal belt between Grand Sable, Petit Sable, and Pointe du Diable in 2013 (Government of Mauritius, 2013). The propagules are bud nurseries that ensure a high survival rate in the reef flat (Connelly et al., 2019). In addition to planting mangrove in Grand Sable, a gravel beach was created (250-m long, 10m-wide and 2m-high) based on recommendations by JICA to serve as a buffer and thereby reduce flood risk (Onaka et al., 2015: 570). However, the project design and implementation revealed some gaps between cross sector coordination. While the Ministry of Oceans Economy (formally Ministry of Fisheries) is in charge of managing and overseeing mangroves across the island, a representative from the ministry for the project provided only technical assistance. With the ICZM unit in lead in partnership with the UNDP, involving the expertise from other relevant departments would be important for opening up learning opportunities on the management of coastal risks and mangroves across the island.

The project also focused on community engagement for capacity building and raising awareness. First, a consultation phase for the design of the project was carried out with the local community and considered an effective way to raise awareness about environmental issues along the coast (Connelly et al., 2019). To increase ownership of the project, implementation involved different segments of the community. The local Grand Sable Fisherman Association and Grand Sable Women Farmers Planters Entrepreneur Association planted and harvested mangrove seeds, while women from the community sewed together cloth sacks to use as seedpods for the propagules (Government of Mauritius, 2013). These activities point to the emergence of bottom-up participatory channels and capacity building for local actors in the governance framework.

The project illustrates success in involving local communities in risk reduction projects, as mangrove farming complimented by a raising awareness campaign reduced both exposure and vulnerability of the community to flood risk. In addition, as the project included the reinforcement of an important lagoon ecosystem beneficial to local fishing activities, it suggests that there can be synergies between

risk reduction and some socio-economic uses. While engagement with the community was a positive aspect, the design and implementation of the projects revealed inconsistencies in the consultation process across institutional stakeholders (Int.2_MoE_2019.05.09), where the engagement of lead departments in managing mangroves could offer expertise. At a more general level, such inclusiveness facilitates cross sector coherence, especially to coordinate the management of mangroves, ecosystems and coastal risks for long term adaptation.

St. Felix

At the southern end of the island at Pointe aux Roches, the St. Felix public beach and recreation area (Fig. 2, Panel B) was created between 2017 and 2018 after the inland relocation of the main coastal road (Int.3_ICZM_2019.05.09). Part of the former coastal road was highly exposed to flooding triggered by distant-source swells⁵. Yearly flooding disrupted traffic circulation for commuters between the southern part of the island, the capital Port Louis on the west and growing business center inland at Cyber City. In addition, erosion of the embankment slope threatened public safety. Since 2000, the High Water Mark had moved inland, increasing wave energy against the overhanging and further erosion⁶.

The push for this coastal risk reduction project fell within an opportune moment where infrastructure works were going on around Mauritius, including the renovation of roads to ease access to touristic sites in the southern part of Bel Ombre. Therefore, the relocation of the road was part of a broader economic development program to reinforce accessibility to hotels and resorts in this part of the island. Based on interviews and parts of the EIA study available online, another component of the project was a public private land exchange agreement that enabled the Road Authority, in coordination with the Ministry of Environment, to relocate the road (Int.12_ARUP_2019.05.16). The northern part of the site is located in Late Lava Coastal Plains, and was owned by Saint Felix Group of Companies (SFG), one of the biggest landowners in the south of Mauritius⁷. Out of 6 000 acres of land owned by SFG, 1 000 was used for sugar cane production, the rest for deer farming and tourism property development⁸. In line with changes in the business model of SFG to diversify operations and phase out of sugar cultivation to increase revenues, the group was willing to make the land swap for the project with the public sector.

Managed retreat of the coastal road at St. Felix beach has been successful in both reducing exposure and contributing to the Mauritian community life by establishing a new public beach area, including facilities such as a huge parking area (Int.3_ICZM_2019.05.09). The old road now serves as a promenade for Mauritian people, e.g. for cycling and running. According to our observations and an interview with the Beach Authority, the St. Felix recreation area has become a prime location for weekend activities (Int.6_BA_2019.05.10).

Based on interviews with representatives from the private sector, this project presented a rare opportunity in Mauritius for public and private sector engagement in a coastal risk reduction project (Int.11_AHRM_2019.05.13). Multi-stakeholder engagement processes are inherent to integrated flood risk management approaches (Thaler & Levin-Keitel, 2016). The St. Felix project provides a still rare example of coordination between the public and private sector to reduce the risk of important infrastructure along the coast and in particular highlights that common interests along the coast could present similar opportunities in the future (e.g. tourism and access to hotels, social benefits for the community and diversification of land use). As the concept of public private partnerships in the governance framework has not yet blossomed, creating coordination mechanisms could help increase investments and leverage expertise in the private sector to manage coastal risks. It appears to be a new area explored by the Mauritian government, reflective of a recent memorandum of understanding signed with the national association of hotels and restaurants to promote sustainable growth

⁵ <http://environment.govmu.org/English/eia/Documents/Reports/reprofilingstfelix/chap%205.pdf>

⁶ <http://environment.govmu.org/English/eia/Documents/Reports/reprofilingstfelix/chap%205.pdf>

⁷ http://environment.govmu.org/English/eia/Documents/Reports/res_pointefelix/ch3.pdf

⁸ http://environment.govmu.org/English/eia/Documents/Reports/res_pointefelix/ch3.pdf

(Int.10_BM_2019.05.13; Business Mauritius, 2019). Moving forward such engagement and partnerships will be especially important to overcome the challenges of segmented coastal zones managed by different stakeholders and inform adaptation planning along the entirety of the Mauritian coastline with a coherent approach.

Cross-cases reflection

In Mauritius, the governance model of the last decade for coastal risk reduction involves a series of ad-hoc projects. The government is experimenting with alternative measures to hard measures (e.g. soft, and nature-based) by embracing integrated approaches and long-term adaptation taking into account climate change effects. The projects reveal flexible policies and governance arrangements to adapt measures to fit site-specific vulnerabilities, and partly as a result of public engagement in the design (e.g. Rivière des Galets) and implementation (e.g. Grand Sable) phases of the projects. Flexibility can help ensure compatibility with local socio-economic and cultural contexts, thereby increasing acceptability across stakeholders (Cinner et al., 2018). Although, the governance framework continues to function on a top down approach, the projects also point to new channels of bottom up engagement and multi-stakeholder coordination, reflective of participatory governance.

5. Assessment of gaps and areas of improvement

While progress stems from the introduction of risk assessments and implementing alternative risk reduction solutions, it is questionable if ad-hoc projects will provide their full value by feeding into a comprehensive long-term coastal risk management and reduction plan. Despite that the Mauritian government has put in place an integrated coastal zone management policy framework and recognized climate change adaptation as a priority, there remains a disconnection between national policies and the individual projects. The field interviews we conducted reveal that one way to explain this gap is missing governance arrangements necessary to draw the most from pilot projects to inform long-term policies. We highlight three issues and their significance to an adaptive governance framework.

Firstly, the role of scientific analyses and evidence is paramount to developing effective policies and legitimacy behind decision-making processes. In the current framework, there are no comprehensive risk and vulnerability assessments to inform coastal risk reduction policies (e.g., Int.3_ICZM_2019.05.09). For a majority of projects, ad hoc risk assessments are used to inform the design of risk reduction measures. These assessments are mostly carried out by international actors and tend to focus on particular sites and do not address the underlying drivers of exposure. For instance, lack of a national coastal risk assessment or flood exposure map, has hindered risk-informed development planning and building codes. Since 2004 coastal setback guidelines are in place developed by the Ministry of Housing and Lands that restricts new developments at least 30 meters from the high water mark and six meters from a classified road (Ministry of Housing and Lands, 2004). While a risk reduction-compatible initiative, our field interviews show that it is unclear where the evidence behind 30 meters came from (Int.3_ICZM_2019.05.09) and to what extent this threshold has been really applied to aggressive development pressures for tourism along the coast. The role of risk assessments and maps are important communication tools that help standardize development and coastal risk management across public and private actors, as well as protect sensitive areas.

Secondly, there is room to put in place systematic learning processes to incorporate new information and review existing policies. While pilot projects are useful initiatives to build capacities, they are not complemented by institutionalized learning processes. Therefore, the projects risk ending up as piecemeal endeavours (Int.12_ARUP_2019.05.16). Moreover, as found with the pilot projects analyzed, they lack any kind of monitoring and evaluation policies for follow up. Monitoring and evaluation are useful methods to take stock on progress made or issues, for example through using scorecards to help assess progress in the reduction of exposure or vulnerability. Coastal zones are dynamic and exposure changes according to interactions between biophysical processes and human developments. Reviewing the projects and their effectiveness can lead to well-informed replications in other sites or a better

understanding of drivers of exposure. Setting up learning processes sets in motion feedback loops that can build on information gathered and capacity building in the long-term.

Thirdly, the complexity of coastal zone risk management has led to consider the benefits of integrated approaches and multi-stakeholder participation, including raising awareness initiatives, as shown in Grand Sable cases. However, a comprehensive approach to manage coasts in Mauritius is prevented by institutional fragmentation across ministries working on mangroves, environmentally sensitive-protected areas, coral reefs, coastal zones, climate change, disaster risks and land-use planning. This governance landscape characterized by silo working groups means that agencies tend to stick to their own provisions and activities (e.g. Int.1_MoH_2019.05.09). This approach was highlighted by the limited scope of cross institutional involvement in the design and implementation of pilot projects. In the end, a lack of attention to the interconnectedness of relevant policies fails to address the complexity of managing risks along dynamic coastal systems. For example, coral reefs are in dire condition due to non-eco-friendly tourism activities, agricultural run-off, acidification and polluted waters, which have impacts on erosion (Ramessur, 2002; Ramessur, 2013). The Mauritius Oceanography Institute, a parastatal body of the Ministry of Oceans Economy surveys and monitors these fragile ecosystems but is not involved in the activities of the ICZM. Furthermore, in-land agricultural practices and questionable canal systems means that run-off from storms repeatedly damages coral reefs (Int.6_BA_2019.05.10). To support integrated approaches, there is a need to set up structured coordination mechanisms across sectoral policies.

6. Conclusion

As in the case of almost all Small Island Developing States (SIDS), adjustments in the governance model in Mauritius has the potential to create pathways for pilot projects to inform a long-term coastal risk reduction and climate change adaptation strategy. This would be particularly beneficial in Mauritius where a wide diversity of measures and approaches have been tested over the last decade, increasingly supported by international engagement and funding. Results show that despite such a context, there are still some gaps in moving towards a robust learning-by-doing process. In particular, the absence of a comprehensive, nation-wide risk and vulnerability assessment creates difficulty to consistently inform coastal risk policies and track evolutions. Some institutional units that are critical to planning risk reduction, such as the ICZM Division in the Ministry of Environment, do not have vulnerability maps. While international and regional cooperation agencies play a role in fostering hazards and vulnerability studies, they are often scaled to local sites for the design of specific projects. In the case of Mauritius, this led to an associated risk that internal scientific capacities for such assessments have remained under-developed. In addition, the collection of vulnerability assessments is not exhaustive, geographically speaking (i.e. they do not cover the entire coast of the island), therefore hampering both coordinated management along coastal strips and the identification of priority action areas by institutions, leaving such hierarchizing to external expertise.

Furthermore, different property types along the coast are managed by a patchwork of environmental-, marine resources-, housing and lands government agencies, and private residents and hotel resorts. As shown in section 5 of this paper, institutional fragmentation has resulted in segmented coastal strip management that is uncoordinated between actors. At the same time, this prevents cross-institutional decision-making processes. This is particularly detrimental to coastal risk reduction policies as the climate change adaptation challenge precisely calls for more integrative approaches to vulnerability and risk reduction (Magnan, 2018; Oppenheimer et al., 2019).

As a main conclusion, we argue that in the absence of such proper governance arrangements, ad hoc projects do not contribute to a long-term coastal risk reduction strategy in Mauritius, and therefore is a missed opportunity from a climate change adaptation perspective. However, caution is made to the fact that the country has been experimenting with an ad hoc pilot case-type approach for only a decade, which can be considered as a very short time period for a governance system to learn lessons and change. The Mauritius case suggests that improving cross-institutional coordination and flexibility

to draw from experimental projects should be integral to any international interventions and the focus of small island states in their efforts towards climate change adaptation.

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Supplementary Material SM1

Laws, policies and government reports related to coastal risk reduction and adaptation in Mauritius Island.

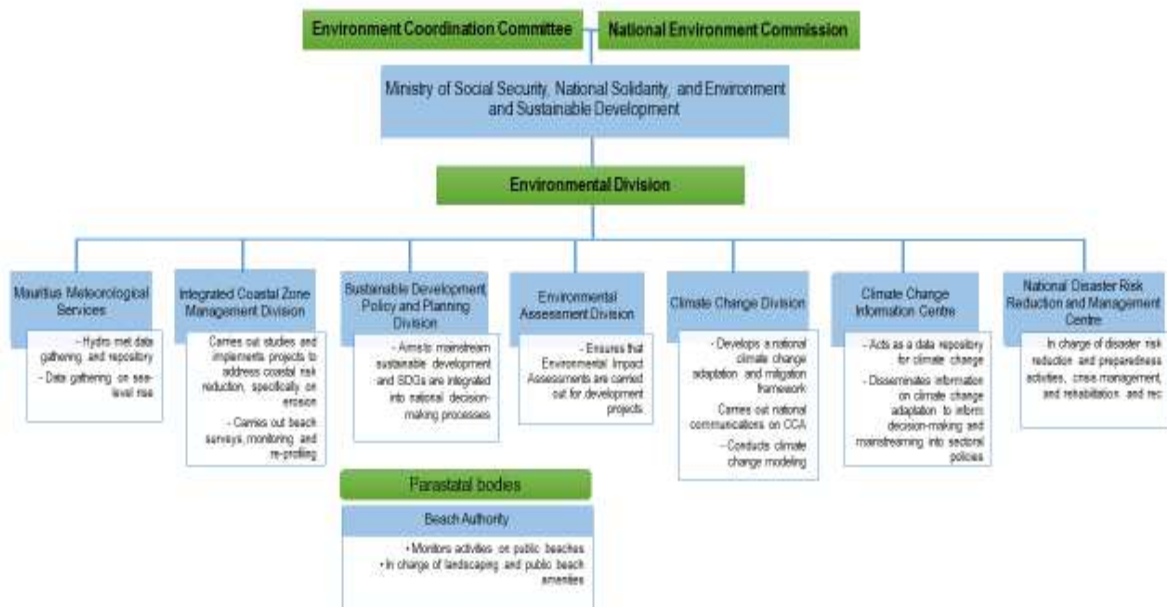
Directly related to the environment and coast				
Year	Policy plan or law	Lead Agency	Main objectives	Implications on the governance of managing coastal systems
1988	National Environment Action Plan 1	Ministry of Environment	National strategic plan for environmental management and protection Supported by the Environmental Investment Program (EIP) Covers: institutional strengthening, economic development, the management of land and solid waste and conservation plans for terrestrial and marine resources	No reference, which suggests that the vulnerability of coastal zones and relevant management and risk reduction policies were not treated as a separate environmental policy item in 1988 in the national environment action plan.
1993	EIA process established	N/A	Establishment of an EIA process for all large developments	Large developments on the coast are required to carry out an EIA. The process aims to establish standards for regulating public and private developments along the coast and a committee was established to oversee this procedure to ensure accountability.
1999	National Environment Action Plan 2	Ministry of Environment	10 year national strategic plan for environmental management and protection supported by Environmental Investment Program 2 (EIP2) Refines strategic direction in: priority sectors, terrestrial biodiversity, conservation and integrated coastal zone management	Introduced strategic policy plan to guide integrated coastal zone management with the aim to mobilize a multi-stakeholder approach and provide openings to alternative risk reduction options, such as nature based approaches. This policy plan led to the creation of Integrated Coastal Zone Management unit in 2000, which leads coastal risk reduction projects within the Ministry of Environment.
2002	Environmental Protection Act (EPA) (amends the EPA 1991)	Ministry of Environment	Sets out the legal and institutional framework for environmental protection and management Environmental Impact Assessment contents and administrative procedures	National Environmental Standards for surface waters set (fresh and coastal) EPA Part VII refers to Coastal and Maritime Zone Management on the protection and management of coastal marine environment Official establishment of the Integrated Coastal Zone Management Committee (ICZM). Revisions to the Act aimed to create policies towards the sustainable use of the coast and relevant marine ecosystems and reinforce the EIA process. However does not include any accountability mechanisms (reporting) or set out any allocation of institutional roles and responsibilities.
2002	Beach Authority Act	Ministry of Environment	Same as 'Reference to Coastal Systems'	Provisions set out for the Beach Authority to: properly control and manage public beaches (only proclaimed public beaches) by 1) implementing projects related to: conservation and protection of the environment, uplifting and landscaping works, infrastructure and amenities works, enhancement of sea water quality, provision of leisure activities, cleaning and maintenance 2) security and safety management 3) traders' licenses 4) set standards and guidelines 5) advise the minister . The role of the Beach Authority is important for the daily surveillance of beaches, however there is little coordination with other institutional bodies.
2004	Residential Coastal Development	Ministry of Housing and Lands	Restrict the development of new buildings and modify existing buildings within a limit of 30 meters from the HWM. Previously the coastal setback was at 15 meters.	Coastal setback changed from 15 meters to 30 meters, however no complimentary policies no ensuring the adherence to this guideline.
2003	Baird & Associates study and technical report on coastal erosion	Ministry of Environment	Same as 'Reference to Coastal Systems'	Study on coastal erosion and technical report identifying key areas. This report serves as a baseline vulnerability and risk assessment for all institutions working in coastal zones and specifically for the ICZM unit the study is used to design risk reduction projects.

2007	National Environment Policy + Ile Maurice Durable	Ministry of Environment + National Development Unit	Aims are to foster harmony between quality of life, environmental protection and sustainable development Integrating sustainable development into policies on: land resources, water resources, air quality, biodiversity, the coastal zone, waste management, environment (including natural disasters) and health	Addresses key concerns and challenges to coastal zones (Section 3.6). Sets out strategies in Marine/Coastal Zone Management (Section 7.5). Serves as policy guidance and explores risks and vulnerabilities along the Mauritius coast. Does not provide any particular strategic guidance or initiatives, however shows political support on sustainable development and climate change adaptation.
2007	Fisheries and Marine Resources Act (amends Act of 1997)	Ministry of Ocean Economy, Fisheries and Shipping	Sets the legal framework surrounding fisheries and fish farming in the waters surrounding Mauritius Framework of penalties against individuals responsible for pollutions impacting fisheries resources Provisions for Marine Protected Areas Regulation for the removal of coral and seashell 2006	In relation to coastal zones, this Act provides points on the i) protection of the aquatic ecosystem and ii) on the protection of mangrove plants. However, it does not make specific references to any coastal zone management plan.
2010	Integrated Coastal Zone Management Framework	Integrated Coastal Zone Management Division	Same as 'Reference to Coastal Systems'	Sets forth the legal aspects regarding coastal zone management and adaptation works, including the role of the ICZM unit in the Ministry of Environment. This is an important framework to establish the roles and responsibilities of the ICZM unit.
2015	Japan International Cooperation Agency (JICA) report on: Capacity Development on Coastal Zone Protection and Rehabilitation in the Republic of Mauritius (Vol 1 & Vol 2)	Ministry of Environment	Same as 'Reference to Coastal Systems'	Comprehensive study on coastal hazards and risk assessments across Mauritius that specifically looks at erosion and accretion, reef health and failure, vulnerable areas to disaster risk of cyclones and storm surges in the context of climate change and future changes such as sea-level rise The report includes: 1) identification of 14 critically affected sites 2) formulation of coastal conservation plans 3) Implementation of demonstration projects to validate the effectiveness of the coastal conservation plans 4) Strengthening of technical capacity of stakeholders. This study compliments the Baird and Associates study to help inform risk reduction policies and projects along the coast.
2016	Guidelines for Coastal Setback	Designed by JICA in coordination with the Ministry of Housing and Lands	Same as 'Reference to Coastal Systems'	Provides guidance framework for coastal setback of 30 meters. The document is used as a reference guide and adopted by the Ministry of Housing and Lands. However the document lacks any empirical evidence or studies as references to inform the decision on 30 meters, nor any enforcement mechanisms.
2016	National Risk Reduction and Management Bill	National Disaster Risk Reduction and Management Council	Sets the institutional and policy framework for the prevention and reduction of the risk of disasters, including mitigation, disaster preparedness, response and management of post-disaster activities in recovery and rehabilitation Sets up the National Disaster Risk Reduction and Management Council at the highest level of government and the National Disaster Risk Reduction and Management Centre as well as local bodies and a crisis management committee	No reference made, which suggests disaster risk reduction and preparedness is not integrated with coastal management.
2018	National Climate Change Adaptation Policy Framework for the Republic of Mauritius	Ministry of Social Security, National Solidarity and Environment and Sustainable Development	Frames the national climate change adaptation strategy, action plan and three year investment plan	Addresses investment plans for climate change adaptation in tourism and coastal management Coastline management plans for marine inundation. This was led by the Ministry of Environment and supports the work of the Climate Change Division.
Other policies and plans that have impacts on the environment and coastal systems				
Year	Policy plan or law	Lead agency	Main objectives	Reference to coastal systems
1993/94	National Physical Development Plan	Ministry of Housing and Lands	Framework for urban planning development and control Cultural heritage protection Framework for public sector investment planning	Sets out: Policy No. R.6 Coastal Footpath Policy No. MQ/5 Control Sand Extraction from Lagoons Policy No. NE.4 Special Protection Areas (Wetlands, Environmentally Sensitive Zones) Policy No. NE.12 Marine Parks

				These policy items in the NPDP establish the criteria to demarcate and characterize relevant areas along the coast, which helps to inform EIA procedures and oversee development does not harm particularly sensitive areas along the coast such as marine protected areas.
2001	Building Act	Ministry of Housing and Lands	Sets up the legal framework to guide general building requirement, issuance of building permits, and materials for construction	No reference made, which suggests land use and urban planning standards are not designed for the coast and/or coastal risk reduction and adaptation is not mainstreamed into urban planning policies.
2002	National Development Strategy	Ministry of Housing and Lands	Guides public and private sector infrastructure and development projects within the context of sustainable development Development should consider agricultural lands and environmentally sensitive areas	The strategy aims to ensure development is sustainable along the coast and covers development and issues related to resources, biodiversity, coastal erosion, coastal ecosystems, coastal development, climate change, natural and environmental disasters.
2003	Review of National Physical Development Plan	Ministry of Housing and Lands	Review of the National Development Strategy to ensure public and private infrastructure development and planning is carried out in the context of sustainable development	Review includes: Section 4.14 is devoted to Coastal Development and Growth to take into account issues related to expansion of hotels and resorts on the coast. Formulation of Planning Policy Guidance (PPG) specifically on: Coastal Development and Residential Development Section 10.5 covers Coastal Zone Management Section 10.6 focuses on Landward Coastal Zone Area. These various initiatives aims to set up policy guidelines and accountability mechanisms to oversee development along the coast.
2004	Planning and Development Act	Ministry of Housing and Lands	Sets up the Legal framework on development in Mauritius	Defines the 'coastal frontage land', which guides the process of leasing agreements carried out by the Ministry of Housing and Lands along the coast.

Supplementary Material SM2

Stakeholder map of government institutions in charge of environmental issues related to coastal zone management



Supplementary Material SM3

Structuring items developed in the field interviews, and main outcomes.			
Governance aspect	Significance to effective adaptation policies	Mauritius	Reference to institute described in Table 1 (Interview code)
Lead institution driving the strategic orientation of coastal adaptation policies to climate change	Effective leadership guides the strategic vision and sets goals in adaptation to climate-related coastal risks. It supports and coordinates relevant stakeholders to achieve those objectives	Leadership for climate change adaptation is undertaken by the Ministry of Environment, and specifically the ICZM is the lead agency that coordinates, mainstreams and manages coastal risk reduction and adaptation activities within the framework of ICZM (set out in the Environmental Protection Act amended 2002, 2007).	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)
Cross-cutting adaptation policies	Mainstreaming climate change adaptation helps to ensure that all development plans and investments in projects take into account climate related risks which strengthens resilience of the economy and society	There are efforts to mainstream coastal risks and climate change adaptation (CCA) in other sectoral policy areas mainly done through stakeholder consultation processes on individual projects. Coastal development is a driving risk factor, yet it is not clear to what extent CCA is incorporated into land use and development planning besides coastal setback guidelines, which lacks any enforcement mechanisms.	Ministry of Housing and Lands (Int.1_MoH_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)
Clearly defined roles and responsibilities of relevant stakeholders	To ensure organizational coherency relevant stakeholders should be aware of their roles and responsibilities within the governance framework.	Interviews revealed that stakeholders know their roles and responsibilities and often refer to an Act which outlines their structure and mandate.	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Beach Authority (Int.6_BA_2019.05.10) Climate Change Division (Int.4_CCD_2019.05.09) National Disaster Risk Reduction and Management Centre (Int.5_NDRRMC_2019.05.22)
Risk reduction or adaptation targets/goals (medium-long term) are set	While adaptation is a process, risk reduction or vulnerability reduction targets create defined objectives to prioritize activities in the short and medium-long term.	It was not clear from interviews or policy documents if there are targets set for coastal risk reduction. However, the ICZM carries out yearly reporting and sets three-year work programs to carry out pilot projects organized with international actors.	Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)
Hazard and vulnerability maps are drawn up (scales: national, regional, local) and assessments carried out of different hazards (erosion, sea-level rise, flooding, extreme events) If yes, are these reviewed continuously?	Hazard and vulnerability maps are important visual tools in risk communication and important to inform decision-making and risk reduction activities, especially in regards to land use and urban planning.	There are efforts to carry out hazard and vulnerability assessments and draw up relevant hazard maps. Most of these efforts are coordinated with international agencies. The role of JICA is important here: JICA's study (Vol 1 and Vol 2) in 2015 set out 14 critical sites that guide ICZM's activities in coastal risk reduction. This also includes the UNDP Adaptation Fund study and projects, for example in Grand Sable and Riviere de Galets, notwithstanding others.	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Ministry of Housing and Lands (Int.1_MoH_2019.05.09) UN Adaptation Fund Project Int.7_AFPO_2019.05.16&22 VLH Hotels and Resorts

		Additional points to consider is the fragmentation of conducting different kinds of maps across government agencies (see more on coordination across policy areas).	Int.13_VLH_2019.05.13 ARUP SIGMA consultancy (Int.12_ARUP_2019.05.16)
Climate change modeling and/or scenarios are used to understand potential changes in coastal risks	Climate change models and/or scenarios can help to understand the potential impacts of climate change and the adaptation response options to these changes over different time horizons (immediate and anticipated futures). They help facilitate long term adaptation planning.	Climate Change Division in the Ministry of Environment carries out climate change modeling, however it is not clear what these are used for except communications to international climate change adaptation policy dialogue (e.g. National Communications to the United Nations Framework Convention on Climate Change (UNFCCC)).	Climate Change Division (Int.4_CCD_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)
There are methods in place to prioritize risk reduction activities and/or the use of cost-benefit analysis (CBA) to evaluate different adaptation options	Due to limited public budgets and the need to allocate financing for various projects, it is important to make priorities for investments in risk reduction activities to target key areas of need. Cost benefit analysis can be a method to evaluate different measures for specific projects and the overall net social/welfare and environmental (ecosystem) benefits.	It appears that there is no formal process to prioritize risk reduction and adaptation projects aside from suggestions given by the JICA study and the focus on 14 then 12 critical sites identified. In addition, the ICZM carries out yearly reporting and sets out three year plans on projects that they engage with international actors. CBA is not used to evaluate different adaptation options, despite a training manual designed in 2015 by the research centers in the University of Mauritius which was complemented by a series of trainings for public officials at all levels of government (central and local).	Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) University of Mauritius Int.9_UoM_2019.05.22
Coordination across policy areas (horizontal)	Coordination across sector policies (e.g. line Ministries and departments) fosters an integrated approach to CCA and helps to overcome any conflicting policies.	While consultation is made across ministries and relevant agencies for coastal risk reduction and adaptation projects, EIA studies and construction of amenities for public beaches there is little coordination when it comes to some key areas such as hazard mapping, building codes and implementation to regulate land use and urban planning. ICZM, Ministry of Housing and Lands, and NDRRMC all have their own maps and do not coordinate amongst each other – so it is questionable how much land use/development planning takes into account coastal hazards and how much ICZM takes into account risks of extreme events which falls under purview of the NDRRMC. In addition, coral reef assessments are carried out by the Ministry of Oceans Economy which does not have interaction with the ICZM. There are also several issues with the management of Environmentally Sensitive Areas and Protected Areas that risk to be developed.	Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) National Disaster Risk Reduction and Management Centre (Int.5_NDRRMC_2019.05.22) Ministry of Environment (Int.2_MoE_2019.05.09)
Coordination across multi-level government (vertical)	Coordination ensures consistency between national level adaptation policies and local level development and management plans on coastal areas	Top down governance approach with limited role of local governments.	Black River District Council Int.8_BRDC_2019.05.09

<p>Multi-stakeholder engagement: private sector, civil society, NGO's and academia</p>	<p>A holistic approach to the governance of climate change adaptation calls for engagement with a range of stakeholders to: 1) increase knowledge and information to help make informed policies 2) create an agreed upon approach and goals 3) leverage on private sector's skills and capabilities</p>	<p>Consultation carried out with stakeholders. Increasingly bottom up channels and participation of public sector in projects.</p>	<p>Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) National Disaster Risk Climate Change Division Int.4_CCD_2019.05.09 Reduction and Management Centre (Int.5_NDRRMC_2019.05.22) Aret Kokin Nu Laplaz (NGO) Int.15_AKNL_2019.05.28 Mauritian Wildlife Foundation Int.14_MWF_2019.05.17 VLH Hotels and Resorts Int.13_VLH_2019.05.13 ARUP SIGMA consultancy (Int.12_ARUP_2019.05.16) Association for restaurants and hotels operating in Mauritius (AHRIM) Int.11_AHRM_2019.05.13 Business Mauritius (BM) Int.10_BM_2019.05.13 University of Mauritius Int.9_UoM_2019.05.22 Adaptation Fund Project Office Int.7_AFPO_2019.05.16&22</p>
<p>Human resources (personnel)</p>	<p>There are sufficient personnel to support and carry out the work agenda on coastal climate change adaptation</p>	<p>ICZM has five personnel. In consideration of all the activities that fall under the ICZM it is not certain that this is a sufficient number of personnel. The role of external consultants is important here. Most projects hire an external consultant (international or local) to make the study, design the project and implement.</p>	<p>Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)</p>
<p>Financial (how the budget is decided on and allocated)</p>	<p>There are financial channels to finance the work agenda on coastal climate change adaptation</p>	<p>Role of the Ministry of Finance is important. Financing for government projects in Mauritius works on a top down approach, where the Ministry of Finance allocates a yearly set budget and ad hoc allocations for specific projects. Since Ministry of Finance allocates ad hoc budgets; government agencies are competing against one another for project funding. The ICZM has a budget of 3 million USD per year.</p>	<p>Ministry of Environment (Int.2_MoE_2019.05.09) National Disaster Risk Reduction and Management Centre (Int.5_NDRRMC_2019.05.22)</p>
<p>Technical (capacity-building)</p>	<p>There is adequate technical capacity to support and carry out the work agenda on coastal climate change adaptation</p>	<p>Most technical studies for risk reduction projects are hired out to external consultants creating pathways for public private partnerships.</p>	<p>Adaptation Fund Project Office Int.7_AFPO_2019.05.16&22 Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) University of Mauritius Int.9_UoM_2019.05.22</p>

Accountability/reporting measures on implementation of actions and budget spending	Accountability mechanisms ensure that those in charge are carrying out their responsibilities and that budgets are allocated for their intended purpose. Reporting measures can be an important form to keep track of implementation.	An EIA process is in place and legally backed by a law in 1993 and reinforced by the Environmental Protection Act 2002. However, very few projects appear to have follow up reporting or monitoring.	Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09)
Monitoring and evaluation measures in place for specific projects and in general of sites (surveys)	Monitoring and evaluation of specific projects ensures proper implementation, while regular surveys on vulnerable sites help to keep track of any change to vulnerable areas	For some projects such as in Mon Choisy where an artificial reef barrier and landscaping project is being developed by the Ministry of Environment, ICZM and the UNDP Adaptation Fund. However no consistent monitoring and evaluation is carried out for projects.	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Beach Authority (Int.6_BA_2019.05.10)
Legal instruments	Legal instruments that involve penalties can serve as good incentives to prohibit activities that go against adaptation efforts	Coastal setback guidelines are provided that requires for new developments to be built at least 30 meters from the High Water Mark. A law was enacted in October 2018 that makes it illegal to construct any informal structures on public beaches.	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Ministry of Housing and Lands (Int.1_MoH_2019.05.09)
Trainings and exercises	Carrying out regular trainings and exercises ensures informed and competent stakeholders to carry out their roles and responsibilities	Some multi-stakeholder trainings have been organized within the scope of the UNDP Adaptation Fund project on several themes including CBA. However, regular trainings and exercises are not carried out. - ICZM trainings – not clear if regular trainings are carried out - Beach Authority trains all employees that monitor the beach	University of Mauritius Int.9_UoM_2019.05.22 Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Adaptation Fund Project Office Int.7_AFPO_2019.05.16&22
Strengthening resilient communities (raising awareness initiatives)	Bottom up mechanisms to engage the community can help increase awareness, individual and community protective behavior and a resilient society	There is a lot of initiative to increase participation in coastal risk governance. Most projects that include bottom up channels are led by international engagements (JICA, UNDP).	Ministry of Environment (Int.2_MoE_2019.05.09) Integrated Coastal Zone Management unit (Int.3_ICZM_2019.05.09) Climate Change Division Int.4_CCD_2019.05.09 National Disaster Risk Reduction and Management Centre (Int.5_NDRRMC_2019.05.22) Aret Kokin Nu Laplaz (NGO) Int.15_AKNL_2019.05.28 Adaptation Fund Project Office Int.7_AFPO_2019.05.16&22 Black River District Council Int.8_BRDC_2019.05.09
Transparency of climate and coastal zone data and information	Open communication of climate data and hazards along the coast enhance awareness of the community and stakeholders	Climate Information Centre will serve as a climate data platform. No public information on erosion rates, sea level rise, or disaster risks	Climate Change Division Int.4_CCD_2019.05.09 Adaptation Fund Project Office Int.7_AFPO_2019.05.16&22

Supplementary Material SM4

Guidance for interviews with stakeholders to help inform SM3

Indicators	Criteria
<p>Degree to which policy document takes into account the risk of coastal flooding-erosion (= taking into account the complexity of the hazards and their influencing factors)</p>	<p>Extreme events (which refers to the issue of drivers of impact and climate variability):</p> <p>(1) How accurate is assessment of waves generated by cyclones? E.g. figures quoted abstractly on a global scale, or more precise figures for frequency and probability (FP)</p> <p>(2) How accurate is the assessment of waves generated by distant source swells? E.g. figures quoted abstractly, or more precise figures for FP</p>
	<p>Erosion: detailed consideration of the complexity of the issue, by</p> <p>(1) Presentation of the elements specifying the extent of the problem (e.g. figures and/or maps for PF or some site-specific information)</p> <p>(2) Identification on the key factors driving erosion; both environmental (e.g. lack of sediment, extreme events, etc.) and human factors (e.g. sand removal, poorly calibrated protective structures, etc.)</p>
	<p>Risk reduction of erosion has clear and accurate targets, are quantified and include time-frames (e.g. reduce the risk of erosion by X% by T = 2050). Success criteria is defined (precise thinking on what might look like successful adaptation to erosion risk and how to measure it)</p>
	<p>Coastal submersion: Takes into account the complexity of the subject, by</p> <p>(1) Preparing a presentation of elements specifying the extent of the problem (e.g. figures and / or maps for the PF or some emblematic sites)</p> <p>(2) Identification of the key factors explaining coastal submersion; both environmental factors and human factors (e.g. constructions in naturally exposed areas, clearing of coastal vegetation, etc.)</p>
	<p>Risk reduction objectives against coastal submersion are clear, accurate, quantified and include time-frames (e.g. reduce the risk of X% submersion by T = 2050) defined success criteria (e.g. thinking about what a successful adaptation to the risk of submersion could look like and how to measure it)</p>
	<p>Elevation of the Global Sea Level vs. local :</p> <p>(1) use of a global average or a local average (at least for the PF territory, if not by archipelago)?</p> <p>(2) Taking into account an average figure (e.g. + 60cm) or a range (e.g. between +40 and +80 cm)?</p>
<p>Flexibility of policies contributing to coastal risk management to manage uncertainties</p>	<p>Takes into account uncertainties relative to potential impacts: takes into account a varied range of coastal risk scenarios, for example through different ranges of sea level rise and/or different possible limits of coastal submersion and/or others</p>

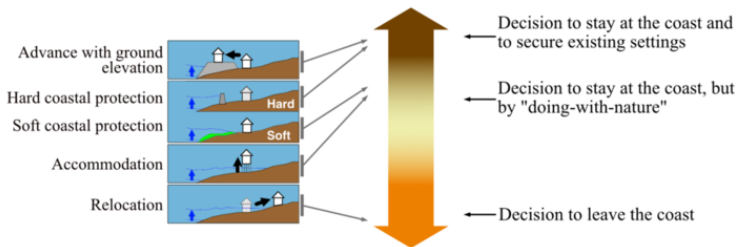
	<p>Flexibility of management policies and/or anticipation of the risk of erosion. (1) in the short term: does the policy/institutional framework make it possible to readjust erosion control strategies in the event of an exceptional event (e.g. respond quickly to a peak of erosion) and/or according to local specificities (e.g. not the same between two sites)? (2) in the long term: in a more anticipatory way, does the policy/institutional framework allow readjustment of erosion control strategies with new knowledge and information (observed or projected for the future)?</p>
	<p>Flexibility of management policies and/or anticipation of submersion risk. (1) in the short term: does the policy/institutional framework make it possible to readjust the strategies to combat coastal submersion in the event of an exceptional event (e.g. respond quickly to a peak of coastal submersion) and/or depending on local specificities (e.g. not the same even between two sites)? (2) over a longer term, in a more anticipatory way: does the policy/institutional framework make it possible to readjust the strategies against coastal submersion with new knowledge and information (observed or projected for the future)?</p>
<p>Degree of engagement of stakeholders in the development of coastal risk management plans</p>	<p>Demonstration of cross-cutting approaches, i.e. involving (at minimum) key ministries (e.g. environment, transport, coastal economic sectors, etc.) for the development of coastal risk management, in particular to address erosion, flood and submersion risks</p>
	<p>Frequency of meetings (annual, semi-annual, quarterly, monthly, other)</p>
	<p>Quality of the transversal works, measured through the degree of precision of the objectives of the meetings and guide for implementation (in relevant documents): are the issues on erosion/submersion/coastal risks treated specifically (e.g. the theme of one or more specific meetings)? Can we clearly see the concrete participation of various stakeholders involved in their development (progress at each meeting, taking into account other policies (conflicts or synergies)).</p>
<p>Degree of clarity of the methods and tools for implementation and evaluation</p>	<p>Assigns roles and responsibilities to relevant stakeholders in relation to different aspects of risk management/policy implementation: is there a clear division of responsibilities or is it very vague?</p>
	<p>Roadmap : (1) Has a work plan been established that specifies the key steps and timelines for the implementation of the policy? (2) And how precise is this roadmap ("very vague", "accurate" with large steps associated with approximate time frames, "very precise" with detailed sub-steps and not very precise time frames)?</p>
	<p>Procedures are set for the implementation of coastal risk management and in particular detailed procedures to address the risk of coastal submersion and erosion: (1) tools and means to implement the roadmap (2) Communication of strategy and management measures across stakeholders (communication of the impacts of coastal risk management, dissemination plan and broad awareness</p>

	(website, consultations, social networks, workshops)
	<p>Detailed procedure for carrying out monitoring and evaluation:</p> <p>(1) Has an evaluation/monitoring procedure been established that specifies the key steps and timelines for monitoring and evaluating the implementation of the policy?</p> <p>(2) How precise is this procedure ("very vague" because it is not clear which indicators are used or who will do the work, "precise" because generic indicators are proposed and evaluators are identified; "very precise" because the indicators are detailed and the evaluators are identified)?</p>
<p>Human resources (takes into account the importance of human capacities in terms of number of people for monitoring implementation, and the skills of these people with regard to coastal risks)</p>	<p>There are trainings for stakeholders in coastal risk management and in particular to address the risks of coastal submersion and erosion (planned? Carried out?)</p>
	<p>Frequency of trainings</p> <p>(annual, half-yearly, quarterly, monthly)</p>
	<p>Quality of the trainings</p> <p>(Relevance of the choice of trainers/content of the trainings)</p>
	<p>Number of people</p> <p>(state, territory, municipalities) trained in the specificities of current and future coastal risk management (approaches and tools?)</p>
<p>Financial resources (Takes into account the importance of financing in terms of volume, sustainability and specificity with regard to coastal risk issues)</p>	<p>Specific funds set up dedicated to the management of coastal risks (in particular, for the implementation of the studied policy) and in particular to the risks of coastal submersion and erosion (mobilized? Provisional?)</p>
	<p>Sustainability of funding: amount of funds defined/allocated for the management of risks of coastal submersion and erosion (insufficient, moderately sufficient, sufficient or low, medium, high); Period covered by defined budgets (1 year <x <5; 5 <x <30; x> 30)</p>
	<p>Specific criteria outlined for the allocation of funding: specified in the document (e.g. allocation according to the degree of risk, amount of the planned per site)</p>
	<p>Support and monitoring of the financing allocated to activities in coastal risk management and in particular targeted at the risk of coastal submersion/flooding and erosion (detailed funding request procedure, management of funds used for this purpose)</p>

Panel A

Response types

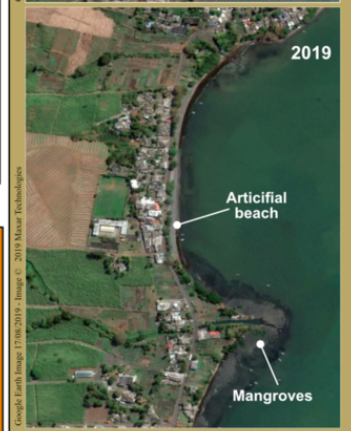
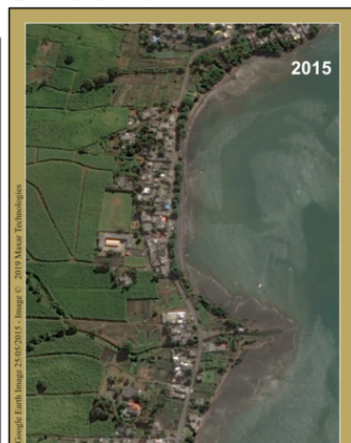
Coastal adaptation measures spectrum



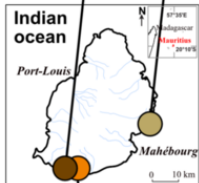
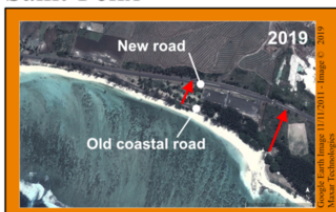
Panel B

Grand Sable

Rivière des Galets



Saint-Félix



○ Pilot project described in the paper

Risk reduction response

- Coastal protection
- Beach re-profiling, nature-based solutions
- Relocation

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