

Building Socio-ecological Resilience to Climate Change through Community-Based Coastal Conservation and Development: Experiences in Southern Madagascar

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Abstract—Climate change impacts fall disproportionately on the world's poorest, most marginalised communities, particularly those highly dependent on direct use of natural resources, such as subsistence fishing communities. Vulnerability to climate change involves social and ecological factors, and efforts to reduce it and build long-term resilience must target both. In Madagascar, generalised strategies developed at the national level address vulnerability, adding to a variety of international initiatives. Yet, such high-level planning inevitably remains vague and indeterminate for most of the island's coastal communities, with little meaningful implementation on the ground. Therefore, local measures to build resilience and adaptive capacity are critical to ensure that resource-dependent communities are able to cope with the immediate and long-term effects of climate change. Examination of an integrated population-health-environment (PHE) programme in Madagascar, comprising a locally-managed marine area (LMMA) and socio-economic development activities, illustrates how practical initiatives can contribute to building immediate and long-lasting resilience and adaptive capacity. Such community-based approaches should play a key role in adaptation measures within the western Indian Ocean region, where many coastal communities live in severe poverty on the front line of a rapidly changing climate.

INTRODUCTION

Anthropogenic climate change is causing a number of adverse environmental impacts worldwide, from a rise in sea level and an increased frequency and severity in extreme

weather events, to increases in temperature and acidity of seawater (IPCC 2007). While increasing consumption in developed countries is responsible for the vast majority

of greenhouse gas emissions that trigger these changes, it is in developing countries - where *per capita* emissions are lowest and vulnerability the highest - that climate change ramifications are likely to be the most serious (Tompkins & Adger, 2004; Mutunga & Hardee, 2010). This high level of vulnerability is, in large part, due to an inability to sufficiently adapt to change (IPCC 2007; UNFPA 2009). The vulnerability of an individual, household, or community to the effects of climate change can be defined as susceptibility to the negative impacts of stressors (NOAA, 2009), and is a complex function of exposure and sensitivity to environmental change, as well as adaptive capacity (Marshall *et al.* 2009). Likewise, the flip side of vulnerability, resilience, may be defined as the ability of the individual, household, or community to withstand, absorb, and rebound from the effects of climate change (USAID, 2009).

Developing countries often suffer from a vicious mix of poverty, poor public health, high rates of population growth, and limited access to markets, all factors that hinder communities' resilience to climate change. Following Adger *et al.* (2005), we define social resilience as the ability of a social system to react to a disturbance and, afterwards, return to a state in which social functions, structures and processes continue as before. Social resilience reflects communities' ability to cope with changes in the short-term, including the immediate effects of climate change such as cyclones, while adapting to long-term stressors such as sea level rise (Marshall *et al.*, 2009). Similarly, we define ecological resilience as an ecosystem's ability to absorb or recover from disturbance and change while maintaining its functions and services (Carpenter *et al.*, 2001).

Social and ecological vulnerability and resilience to climate change are inextricably linked and should be considered as integrated socio-ecological systems. In these, the anthropogenic element is recognised as part of ecosystems that do not function independently of human activities (Resilience Alliance, 2010). Often, rural communities in developing countries are almost wholly

dependent on local natural resources for daily subsistence and trade. They lack alternative livelihoods or income opportunities and families are thus highly reliant on a stable and consistent supply of natural resources such as fish or agricultural produce. Instability of resources due to climate change in these situations has devastating effects on both food security and household income in the short- and long-term. Resilience in such linked socio-ecological systems can be bolstered by adaptation initiatives, conferring them greater resilience so that the population is either less affected by, or can more easily recover from, the effects of climate change. Conservation planning should incorporate efforts to reduce environmental and socio-economic sensitivity and build socio-economic adaptive capacity (Tompkins & Adger, 2004; McClanahan *et al.*, 2008). However, in many developing countries such as Madagascar, little research has been undertaken to examine the capacity of these socio-ecological systems to cope with or adapt to environmental disturbances such as climate change (Cinner *et al.*, 2009).

Given the unprecedented threats posed to developing-world ecosystems, societies, and economies by climate change, it is not surprising that resilience and adaptation – both social and ecological – are subjects of growing concern amongst communities, governments, scientists, financial donors and conservation and social development organisations. Considerable help is being given to such countries for the development of national and regional policies to mitigate the effects of climate change and integrate adaptation into existing policy frameworks and institutions.

Madagascar is ranked amongst tropical coastal countries that have the lowest adaptive capacity and very high vulnerability to climate change (Huelsenbeck, 2012, Burke *et al.*, 2011; Cinner *et al.*, 2009). The country has received millions of dollars and many years of technical support from multi-lateral investment agencies, bi-lateral donors and private foundations to address the impacts of climate change. Aims of these initiatives included increasing ecological resilience,

improving public health services to increase social resilience to disease outbreaks, strengthening infrastructure to deal with the increased frequency and intensity of storms, and adapting agricultural practices to forecast uncertainty in weather patterns. These broad objectives to reduce climate vulnerability are enumerated in the National Communications to the UNFCCC (MEEF, 2004; MEF, 2010) and the National Adaptation Plan (MEEF, 2006), while recent publication of the National Policy on the Fight Against Climate Change firmly establishes the link between climate change adaptation and achievement of the national sustainable development goals (MEF, 2010). Additionally, regional initiatives championed by organisations such as the Indian Ocean Commission (IOC), Western Indian Ocean Marine Science Association (WIOMSA) and the Western Indian Ocean Marine Ecoregion (WIOMER) have also developed climate change adaptation strategies.

While national policies and regional initiatives set the stage for many climate change adaptation initiatives to reduce socio-ecological vulnerability, bottom-up adaptation is equally important in countries like Madagascar with its widely-dispersed, poor rural populations who are dependent on ecosystems and their services that are vulnerable to climate change.

Practical, decentralised, local-level interventions can complement high-level policies to nimbly and cost-effectively address immediate and emerging effects of climate change. A decentralised authority over marine resources can facilitate rapid adaptive responses to changes in local ecological or social conditions, because decisions on resource use can be made without involving a centralised bureaucracy (Cinner, 2005). In countries such as Madagascar, with high socio-ecological vulnerability and insufficient finances for broad-scale adaptation projects, such grassroots interventions seem imperative. Over the last decade in Madagascar, national level policies such as the 1996 GELOSE (*Gestion Locale Securisé*) legislation have allowed for decentralisation of natural resource

management, thereby helping to pave the way for community-based conservation. This both increases socio-ecological resilience and mitigates non-climate stressors through socio-economic development programmes.

Building resilience within a community-based marine conservation and development initiative – the Velondriake LMMA

The coastal zone of southwest Madagascar is recognised as one of Africa's most vulnerable areas to climate change (Busby *et al.*, 2010). Climate change is already affecting the availability and stability of the marine and coastal resources in the region, exacerbating existing food insecurity and threatening livelihoods (CI-WWF, 2008; Hannah *et al.*, 2008; Tadross *et al.*, 2008). Here, increasingly severe and frequent tropical storms and cyclones may cause physical damage to coral reefs, seagrass beds and mangrove forests on which the local communities so intimately depend. These habitats, vitally important to fisheries, also act as natural physical barriers that reduce the impacts of climate hazards; damage to these critical ecosystems leads to increased coastal vulnerability to sea level rise, strong winds, waves, and storm surges, all of which cause shoreline erosion (Sheppard *et al.*, 2005; Moberg & Folke, 1999). Changes in water temperature can have a number of detrimental effects in such marine ecosystems, including more destructive weather, shifts in fish distribution and reproductive patterns, and coral bleaching and mortality (CI-WWF, 2008; Nellemann *et al.*, 2009). Climate change causes further physical risk to fishers, who are forced to harvest in harsher weather or further away from shore as shallow and nearshore ecosystems become degraded (Daw *et al.* 2009). Inclement weather also reduces the number of fishing days and can result in loss of fishing gear and damage to boats and coastal infrastructure (Sumaila & Cheung, 2010; Daw *et al.* 2009). Widespread anecdotes reveal that local fishers have detected changes in wind and rain patterns over the last decade,

making weather prediction more unreliable both in the short-term (day to day) and long-term (month to month).

A locally managed marine area (LMMA) called Velondriake and located approximately 200 km north of the coastal city of Toliara (Figure 1), has been the focus of various conservation and socio-economic development programmes for nearly a decade (Harris, 2007). Coastal communities in the Velondriake region are almost completely reliant on fisheries for subsistence and endure pervasive poverty, isolation from governmental services that could reduce vulnerability, and very high population growth rates (Harris, 2007; Harris, 2011; Harris *et al.*, 2012). This LMMA encompasses more than 1,000 km² of marine, coastal, and terrestrial environment, and is home to nearly 8,000 people (Harris, 2007). Approximately 80% of the communities rely on the direct

use of coastal and marine resources for their livelihoods (Epps, 2007).

Communities within Velondriake are dependent on sparse, unsanitary, and heavily salinated groundwater for drinking water. Rising sea water level, in addition to increasingly arid conditions, is likely to cause saltwater intrusion into meagre existing groundwater supplies. Reports of migration away from certain islands after water shortages are common, and island communities must often transport drinking water from the mainland or from other islands in the area. This problem will only become more acute, as the southwest is predicted to experience a higher frequency and intensity of droughts in years to come (CI-WWF, 2008). As the inland areas of the southwest become more arid and unable to support agricultural crops, migration from inland villages to the coast may increase (Cripps, 2009).

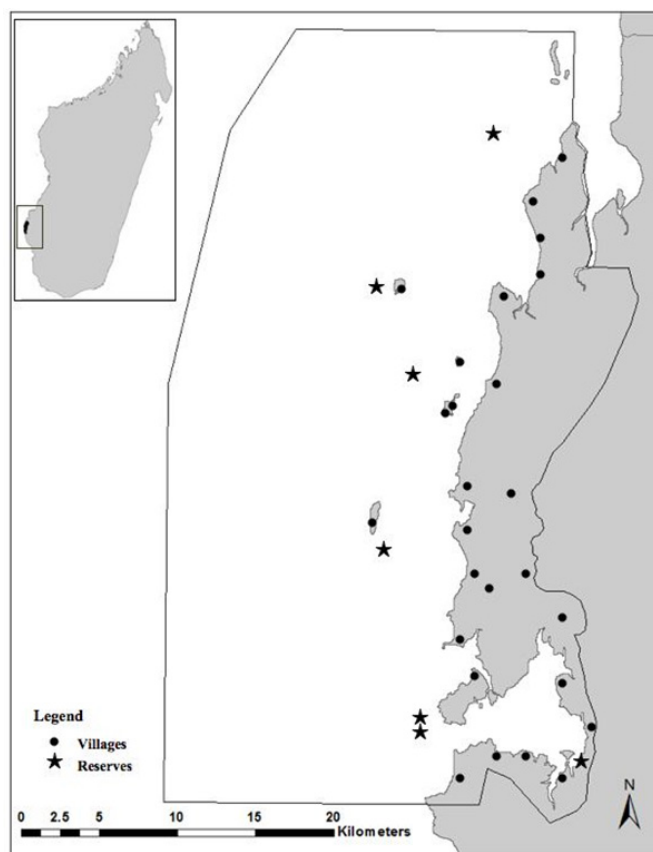


Figure 1. The Velondriake locally managed marine area (LMMA).

Strengthening ecological and social resilience

The LMMA, in tandem with social development interventions discussed below, addresses vulnerabilities in an integrated socio-ecological framework and is the mechanism through which resilience to climate change is being fostered in Velondriake. Local conservation management is implemented through a local set of laws, called a *dina*, which was created, and is now enforced, by local communities through a democratically-elected local management committee. In Madagascar, a *dina* can be used to complement formal legislation and carries authority that is recognised by national law (Rakotoson & Tanner, 2006; Andriamalala & Gardner, 2010). Velondriake's *dina* controls access to, and use of, marine resources through various

forms of fisheries restrictions, which have been developed and agreed upon by local stakeholders in village meetings and regional workshops (Andriamalala & Gardner 2010). We elaborate these below.

Ecological resilience

Reducing non-climate anthropogenic stressors, such as overfishing, can help to foster ecological resilience to climate change within the marine environment (Colls *et al.*, 2009). A by-product of ecosystem-based management activities in the LMMA is the assured flow of ecosystem services to communities in the face of climate change, thereby contributing to food security and livelihoods.

Restrictions ban destructive or unsustainable fishing practices such as poison fishing, beach seine netting and physical damage to corals throughout the managed area. In an ecosystem where climate change is likely to increase water temperatures and ocean acidification, leading to coral mortality, restrictions such as these are essential to reduce some key non-climate stressors to the reefs and related ecosystems. Furthermore, six zones of coral reef and one of mangrove forest have been designated as permanent no-take-areas to further reduce anthropogenic stress in Velondriake. These core protected areas were identified via a participatory process with local communities, and the coral reserves were chosen on account of their unusually high coral cover, fish diversity, and general reef health - ecological indicators generally used to infer high reef resilience to climate change (Colls *et al.*, 2009; Cripps & Harris, 2009). Protection of such areas of high biodiversity and good ecological health will increase the resilience and recovery potential of coral reef and mangrove habitats to climate change, and provide larval recruits and juvenile habitat to aid the recovery of other more degraded habitats.

Social resilience

While the LMMA enhances ecological resilience to climate stress, it also fosters social resilience by reducing sensitivity and promoting adaptation to change. A large body of literature describes key indicators

of social resilience, such as diversity of income sources, the level of education, participation in decision-making, ability to self-organize, and access to credit (e.g. Tompkins & Adger, 2004; Adger *et al.*, 2005; Marshall *et al.*, 2009; Andrade Perez *et al.*, 2010; Busby *et al.*, 2010). In communities displaying high social vulnerability to climate change, investments in social development programmes such as poverty alleviation and the creation of infrastructure are central in developing basic adaptive capacity; this then allows communities to further capitalise on conservation opportunities to build adaptive capacity (McClanahan *et al.*, 2008). Social development programmes elaborated below are implemented throughout Velondriake by Blue Ventures, an NGO, targeting areas of social vulnerability and building social resilience to climate change.

Community networks and communication: The Velondriake Association

Social networks contribute to increased socio-ecological resilience, as communication, adaptive management, and good governance are central in fostering adaptive capacity in communities (Adger, 2003; Tompkins & Adger, 2004; Marshall *et al.*, 2009; Ostrom, 2009). The Velondriake Association brings together representatives from isolated villages, and local leaders that might not have interacted and solved problems before now collaborate on a regular basis to manage the region's marine resources. The Association was originally created in 2004 as a committee to coordinate seasonal octopus closures, but quickly evolved to manage the larger, more ambitious LMMA. This elected entity led development of a current 5-year management plan, is responsible for upholding the *dina*, and meets regularly to discuss management strategies. While the *dina* rules focus on sustainable resource use, and thus might be considered primarily a means of achieving ecological resilience, the process of developing and enforcing the *dina* requires cooperation between communities that share the ecosystem, and thus the *dina* is also a means to increasing social resilience. The recent distribution of short wave radios and the

advent of cell phone coverage have allowed for greatly improved communication between these isolated communities; messages about approaching adverse weather, for example, can be better relayed and prepared for than before.

Increased economic opportunities

Poverty increases vulnerability to climate change, decreases resilience and hinders adaptation (Marshall *et al.*, 2009). Increasing individual, household, or community income enables people to better prepare for climate disasters – houses constructed of more durable materials are better able to withstand strong storms; and families with an income are able to purchase food if there is a shortage due to drought, a decline in fish stocks or they are unable to harvest crops due to flooded fields. More indirectly, disposable income can be used for school fees or as capital to start a small business – enabling adaptation in the longer term.

Management measures in Velondriake also aim to increase and stabilise income from an important income-generating activity in the region, the harvest of octopus. Since 2004, communities have chosen to close selected reef flats to harvest within the LMMA for periods of two to three months, allowing quick-growing reef octopus (*Octopus cyanea*) to increase in abundance and size (Benbow & Harris, 2011). Octopus comprise one of the primary export fisheries for the region's fishing communities (along with sea cucumbers) and, through over 85 temporary closures to date, Velondriake communities have become experienced in managing this important export commodity, while increasing fisher income.

Diversifying income-generating activities to incorporate sources that do not directly depend on natural resources further increases social resilience to climate change; in events such as droughts or storms, these livelihoods can continue to contribute to household income. Furthermore, these activities can provide environmentally sound alternatives to subsistence fishing, which further reduces anthropogenic stressors on marine resources and contributes to ecological resilience. To this end,

a community-based aquaculture programme within Velondriake works with local fishermen and their families to raise hatchery-reared sea cucumbers and cultivate seaweed. These mariculture products, sold on the international market through regional export companies, allow families to earn additional income without further exploiting marine resources within the LMMA. Velondriake's draw of tourists also provides some community members with opportunities for income through ecotourism and handicraft production.

Increased access to family planning services

Increasing access to family planning services and lowering the population growth rate can greatly improve resilience to climate change (Jiang & Hardee, 2011). A high population growth rate magnifies vulnerability to climate change by increasing the number of people living in potentially impacted areas. At the household level, large families make coping with food insecurity and insufficient resources much more difficult. Any disposable income is spent on bare necessities (basic food, shelter, and clothing) and does not allow for improved housing to withstand climate hazards, the payment of school fees, saving for times of need, or increasing income through alternative sources. Poverty is strongly correlated with the number of children in a household (Kates & Dasgupta 2007). Where women are not empowered to plan their families, mothers are commonly overburdened by large family sizes and are less able to contribute to household income through agriculture, fishing or employment. At the community level, high population growth rates result in more exposure to climate risks and greater dependency on the direct exploitation of natural resources. Population pressures can also undermine community efforts to organize the sustainable management of their natural resources (Agrawal, 2001; Ostrom, 2009). At the country level, high population growth rates make it difficult to serve the growing needs of citizens for health services and education, further reducing the per capita investment available for climate change adaptation.

As in much of the developing world, Madagascar is characterised by a young, rapidly growing population. In the southwest where Velondriake is situated, women give birth to an average of 6.2 children, causing the population to double in less than 30 years (INSTAT & ICF Macro 2010). Regular clinics in several main villages and local community health practitioners in 30 villages now provide family planning and community health services to Velondriake's isolated communities, previously unreached by reliable family planning services. Provision of basic reproductive health services has resulted in an increase in contraception in the population from approximately 9% to >35% in five years (Blue Ventures, unpublished data). Additional education and outreach in Velondriake villages focuses on maternal and child health, clean water, hygiene and sanitation. These activities address many of the area's greatest causes of morbidity and mortality, and aim to reduce the need for large families. If families are confident that children will survive, they feel less pressure to have a large number of children.

Educational opportunities

Access to formal education has been found to increase resilience to climate change disasters by increasing potential household income, increasing awareness and understanding of possible climate change risks, and increasing access to risk information (Wamsler *et al.* 2012). Likewise, studies show that literacy and education rates are positively correlated with the conservation of wildlife in Africa (de Boer *et al.* 2013; Kideghesho *et al.* 2007).

The average community member in Velondriake receives only three years of education and very few students enter secondary school (Epps, 2007). The LMMA promotes formal education as a path towards individual success and community wellbeing. A school scholarship programme, funded by donations from Velondriake tourists and

further supported through grants, provides financial assistance to over 200 motivated children and young adults from Velondriake villages to attend local primary and secondary schools each year; a separate programme provides assistance for undergraduate, MSc, and PhD students interested in pursuing higher education in environmental sciences.

The primary and secondary school scholarship programme focuses on girls, as their dropout rate is particularly high – often because of early pregnancy and/or an inability of parents to fund school attendance. Poor education for girls in Velondriake results in reduced development, health, equity and overall well-being. An improved education will equip participating girls with the skills needed to pursue viable alternative livelihoods. Linking to the family planning programme, women given access to education, economic opportunities and other health services choose to have smaller families later in their lives than women without access to these basic needs (UNFPA, 2009).

Ongoing informal education of members of the Velondriake Association focuses on increasing local capacity for resource management. Training includes record-keeping, bookkeeping, habitat monitoring techniques, and management and leadership skills to oversee the LMMA. A separate programme has been established to help community members observe and understand the efficacy of management techniques, enhancing natural resource stewardship by participants in Velondriake's villages. Community members visit the permanent coral and mangrove reserves, as well as the seasonal octopus fishery management sites, to measure the number of fish, crab holes or octopus dens in them under trained facilitators. Although the methods used are not robust ecological sampling or monitoring techniques, the results are extremely valuable in improving local understanding of ecological principles and the benefits of good management.

Local level interventions support socio-ecological resilience and adaptation

One should consider both the human and the ecological systems to successfully foster resilience to climate change in vulnerable communities (Tompkins & Adger, 2004). The effects of climate change and anthropogenic pressure on ecosystems will continue to increase in severity over the next generation, and preparing for these changes now is imperative.

In isolated areas, integrated population, health, environment and livelihood programmes, such as the Velondriake LMMA provide pragmatic, nimble solutions to build socio-ecological climate resilience and adaptive capacity in both the short- and long-term. Unlike national level policies that are slow to leave the political arena, these actions commence building resilience immediately and, because they are managed at the ground level, they are relatively cost-efficient, adaptable to different areas, and have a better chance of functioning without government support or national level policies. The establishment of effective socio-ecological resilience and adaptive capacity would be difficult in rural coastal Madagascar without implementing community-based interventions because governmental resources are limited.

Given the threats of global climate change, scientific consensus indicates that coastal managers should aim to protect 20-30% of marine habitats to maintain their ecological resilience and long-term processes (IUCN, 2005). Madagascar has over 80,000 km² of inshore fishing area; interventions to build the resilience of Madagascar's marine and coastal environment to climate change must therefore be scalable to achieve spatial coverage. Integrated community-based programmes such as the Velondriake LMMA are replicable at the scale needed to accomplish grassroots climate change resilience and adaptive capacity because of their low cost, rapid adaptability and social acceptability.

This case thus demonstrates how integrated programmes focusing on resource management, community health, and economic development can build socio-ecological resilience, bolster

adaptation, and thereby reduce vulnerability to the effects of climate change in remote, resource-dependent communities.

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