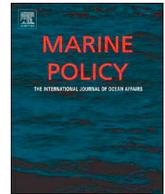




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Critical analysis of the governance of the Sainte Luce Locally Managed Marine Area (LMMA), southeast Madagascar

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ABSTRACT

The Marine Protected Area Governance (MPAG) framework is applied to critically assess the governance of the Sainte Luce Locally Managed Marine Area (LMMA), southeast Madagascar. Madagascar experiences rapid population growth, widespread poverty, corruption and political instability, which hinders natural resource governance. Community-based natural resource management (CBNRM) has been repeatedly employed to circumvent the lack of state capacity. This includes the LMMA model, which has rapidly proliferated, represented by MIHARI, Madagascar's LMMA network. The lobster fishing is the primary source of income for households in the impoverished community of Sainte Luce, one of the key landing sites in the regional export industry. However, fishers, industry actors and available data suggest a significant decline of local and regional stocks, likely due to over-exploitation driven by poverty and migration. In 2013, SEED Madagascar a UK NGO, worked to establish community-based fishery management in Sainte Luce, setting up a local management committee, which introduced a periodic no take zone (NTZ). Despite the community's efforts and some significant achievements, the efficacy of management is limited. To date, limited state support and the lack of engagement by actors throughout the value chain have hampered effective governance. The study reinforces the finding that resilient governance relies on a diversity of actors and the incentives they collectively employ. Here and elsewhere, there is a limit to what can be achieved by bottom-up approaches in isolation. Resilient management of marine resources in Madagascar relies on improving the capacity of community, state, NGO and industry actors to collectively govern resources.

1. Introduction

The Marine Protected Area Governance (MPAG) framework offers a structured, empirical approach to critically analysing the governance of marine protected areas (MPAs) [1]. It has now been applied to over 50 MPAs, with several new case studies in this issue. It has proven to be a valuable tool for assessing the governance of locally managed marine areas (LMMAs) and small-scale fisheries (SSFs) [2]. These are important applications as SSFs account for an estimated 23% of global catch [3], whilst LMMAs are increasingly employed to manage resources in developing country contexts [4], where SSFs are critical for food security and poverty alleviation [5,6] but capacity for fisheries management is limited.

In Madagascar, an island nation with 5,500 km of coast, marine resources are vitally important sources of nutrition and income for

millions of people [7–9]. Rapid population growth of 2.8% [10] is increasing fishing effort [2], it has been suggested that landings from SSFs may have already peaked, with many fisheries in decline [8,10]. Despite this, natural resource management efforts lag behind the terrestrial realm [7,11], where habitat loss threatens the endemic species of this biodiversity hotspot [12,13]. Growing recognition of the ecological and economic value of Madagascar's marine ecosystems has led to increasing efforts to manage these resources sustainably [7]. This includes a rapidly proliferating network of over 100 LMMAs [14,15], since the first was established in 2004 [16]. Represented by *Mitantana HArena Ranomasina avy eny Ifotony* (MIHARI - Marine resource management at the local level) since 2012, this network of LMMAs now covers over 12,000 km² [15,17]. These LMMAs make a key contribution to Madagascar's 2014 commitment to triple its MPA coverage [18].

The widespread use of community-based natural resource

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management (CBNRM) approaches in Madagascar, including LMMAs, is the response of non-governmental organisations (NGOs) to limited state capacity. Madagascar is subject to rapid population growth, low gross domestic product (GDP), long-term political instability and corruption [10,19]. These challenges manifest themselves in the declining rule of law [20] and a Human Development Index score of 0.519 (161th of 189), in a country where 70.7% of the population live below the US\$ 1.90 purchasing power parity (PPP) international poverty line [21]. In these circumstances, bottom-up or participatory management has repeatedly been identified as the solution to the state's lack of capacity for environmental governance [22,23]. Since the 1990s, the CBNRM approach has been employed to address terrestrial biodiversity loss by international environmental NGOs [24]. This includes encouraging the state to support the decentralisation of responsibility through legislation [25]. The new wave of LMMAs, led almost exclusively by NGOs, builds on these experiences. There is a need to critically assess this LMMA model as it is applied to a growing diversity of marine ecosystems and contexts in Madagascar. Can it offer an effective solution or must resilient and effective governance be supported by a sufficiently resourced state?

This study applies the MPAG framework to the Sainte Luce LMMA, in the impoverished Anosy region of southeast Madagascar. The community relies heavily on marine resources for livelihoods and food security. Fishing is the primary source of income for the majority of households, with spiny lobster, principally *Panulirus homarus* and *P. longipes*, being the most economically important target species [26,27]. For several decades Sainte Luce has been one of the key landing sites among around 40 coastal communities in the Fort Dauphin regional lobster fishery [28–31]. There is a widespread perception among actors throughout the regional fishery that catches have declined considerably in recent years, despite increasing effort, which is supported by the limited available data [27,29,30,32]. In response, SEED Madagascar ('SEED'), a UK NGO, initiated Project Oratsimba in 2013, which aims to promote community-based fishery management in Sainte Luce, including establishing a periodic no take zone (NTZ) for the lobster fishery [31,33]. Sainte Luce is now considered a LMMA and an active participant in the MIHARI LMMA network [15]. The governance analysis focuses primarily on the lobster fishery as this is the most socio-economically important fishery within the LMMA, available evidence suggest this has been subject to decline and lobster fishing is the subject of many of the measures introduced by the community. Where appropriate the wider governance framework and other fishery targets within the LMMA are discussed. The timing of this study is pertinent as the ongoing project enters a new phase of refinement and scale-up [34]. The results of this critical analysis of governance will have direct applications to this LMMA, as well as those across Madagascar and the Western Indian Ocean.

2. Methods

The MPAG framework [1], originally designed for MPAs, was applied to the Sainte Luce LMMA, which can be considered an International Union for Conservation of Nature (IUCN) Category VI Protected Area (sustainable use of natural resources) [35,36]. The MPAG framework provides a structured approach to collect, analyse and present empirical data to critically assess the governance of an MPA. Empirical data is collected from primary and secondary sources. Primary data was collected through interviews. Secondary data was obtained from relevant scientific and grey literature, including SEED documents related to the project available via the NGO and documents provided by interviewees. The MPAG framework structure is adopted here and provides the headings for sections 2–8, inclusive. A key component of this framework is the use of the empirical data to identify the incentives adopted within the MPA. The MPAG framework describes 36 possible incentives from five categories (Economic, Communication, Knowledge, Legal and Participation). Per the MPAG methodology, incentives

employed in the Sainte Luce LMMA are identified and discussed, highlighting those in need of strengthening or introduction, Section 6.1. The framework and methodology is described in detail here [1], and further discussed in this issue.

The study approach was informed by context specific guidelines for the Western Indian Ocean [37]. For example, the interview team was selected to include one member familiar with the local context to ensure customs and communities were respected. Per this guidance the interview team selected was familiar with social science methods including previous experience conducting interviews in this region. Informed verbal consent was obtained prior to starting each interview. Verbal consent was deemed the appropriate for the context, as it was anticipated that some interviewees would have little or no literacy, based on prior experience of the region and as advised by a local NGO (SEED). All interview data was kept anonymous. Interviews were recorded, with prior permission. The study was conducted in accordance with ethics guidance from UCL and SEED.

Primary qualitative data was collected through 40 semi-structured interviews held between August and September, 2018. Interviews were held with fishers, community members, members of the *Riaky* Committee (the Sea Committee, responsible for managing the LMMA, hereafter 'Committee'), SEED employees, state representatives and industry actors. Interviewees representing these different groups of actors were initially selected opportunistically. Subsequent interviewees were identified through snowball sampling [38]. Interviews ranged from 12 to 80 min in duration and were conducted in English (some SEED employees) or Malagasy. All interviews were led by the same author, with a second author being responsible for *in situ* translation throughout the study. The translator has extensive experience translating for research purposes in rural Madagascar. Responses were reviewed with reference to the MPAG framework, to elucidate the governance approach and identify common themes.

At the time of the study five of the authors were employed directly by SEED and worked on Project Oratsimba. Additionally, one author previously worked on Project Oratsimba in a voluntary capacity and at the time of writing as an external consultant to SEED. The other authors had no prior engagement with SEED Madagascar. Thus the study should be considered partly a reflexive exercise. Naturally, the involvement of some of the authors with SEED and Project Oratsimba influences their perspective but also provided insights, knowledge and access that could not otherwise be obtained. This is explicitly acknowledged.

3. Context

Madagascar is one of the world's poorest countries, with 70.7% of the population living below the US\$ 1.90 PPP international poverty line and scoring 0.519 (161th/189) in the Human Development Index [21]. Madagascar's elevated poverty levels persist due to political instability and the island's vulnerability to extreme weather [10]. One in two children under the age of five suffers from moderate or severely stunted growth due to malnutrition, with an under five infant mortality rate of 4.6% [21]. The country's per capita GDP is amongst the 10 lowest in the world at US\$ 449.70, markedly lower than the US\$ 1553.80 average for sub-Saharan Africa [39]. In 2017 the state capacity, expressed as a mean of scores (–2.5 to +2.5) for six governance indicators (Voice and Accountability; Political Stability and Absence of Violence; Government Effectiveness; Regulatory Quality; Rule of Law; Control of Corruption) was just –0.74 (average score for sub-Saharan Africa: 0.68) [40,41]. Remarkably, Madagascar is one of just eight countries in the world whose real per capita income was lower in 2010 than in 1960, in contrast to the other seven countries in that group, Madagascar has not been subject to civil war(s) or violent conflict [10]. The country did not achieve even a single one of the UN's Millennium Development Goals [42] and arguably will similarly struggle to attain the post-2015 Sustainable Development Goals.

The country's 'Deep South' consists of the Atsimo Andrefana,

Androy and Anosy regions, where the incidence of poverty (people living on less than US\$ 1.90 per day) is 91%, even higher than the national rate [43]. In the Anosy region not a single Human Development Indicator (such as life expectancy and literacy rates) meets the national average [44]. Coastal communities in this isolated region have little access to transport infrastructure or suitable agricultural land, and so rely heavily on fishing.

3.1. Study site

In the Anosy coastal community of Sainte Luce (Fig. 1), 79% of households identify fishing as their main source of income [8], with lobster being the most lucrative target species. Other fishery targets include pelagic fish (including tuna and sardines), bivalves (oysters and mussels) and reef fish, which are targeted for subsistence and sale locally. This fishing village is a key landing site in the Fort Dauphin regional lobster fishery [9,10], relying on lobsters for both income and food security. The majority of lobsters are sold, although smaller lobsters (typically < 12–14 cm) are consumed locally. Locally and regionally there is a perception of ongoing declines in lobster stocks [8,9]. In 2013, SEED initiated Project Oratsimba, that aimed to assist Sainte Luce in adopting community-based management, including establishing a periodic not take zone (NTZ) for the lobster fishery [11,12]. The first closure was implemented in 2014 and upon opening fishers benefited

from temporarily elevated catch per unit effort (CPUE); subsequent openings saw fishers obtain higher prices from buyers [11–13].

In the following years, 2014 to 2018, the community continued to operate a periodic NTZ, expanding it to 13 km² and varying the periods of closure (Fig. 2) [33,45]. There has been some tentative engagement in community-based fishery management from the adjacent communities of Itapera, to the south and Elodrato to the north [27,33]. Elodrato serves as the landing site for fishers from Elodrato, Esohihy, Ebakika and a number of smaller hamlets.

The lobster fishery is the main economic activity within the Sainte Luce LMMA. This traditional fishery deploys baited pots, made of woven plant materials, from small non-motorised *pirogues* (wooden canoes) and is described in detail by Long [27]. Lobsters are sold at landing sites to *rabbateurs* who are residents of Sainte Luce and employed by *collecteurs* (or ‘middlemen’) (Fig. 3). These *collecteurs* transport lobster to Fort Dauphin, the centre of the regional fishery, where they are principally sold to one of three export companies Madapêche, Martin Pêcheur or Santi.

4. Objectives

The overall objective of the LMMA is taken to be the sustainable use of marine resources, aligning with the IUCN Category VI protected area definition [35]. Whilst there are no formalised objectives, the

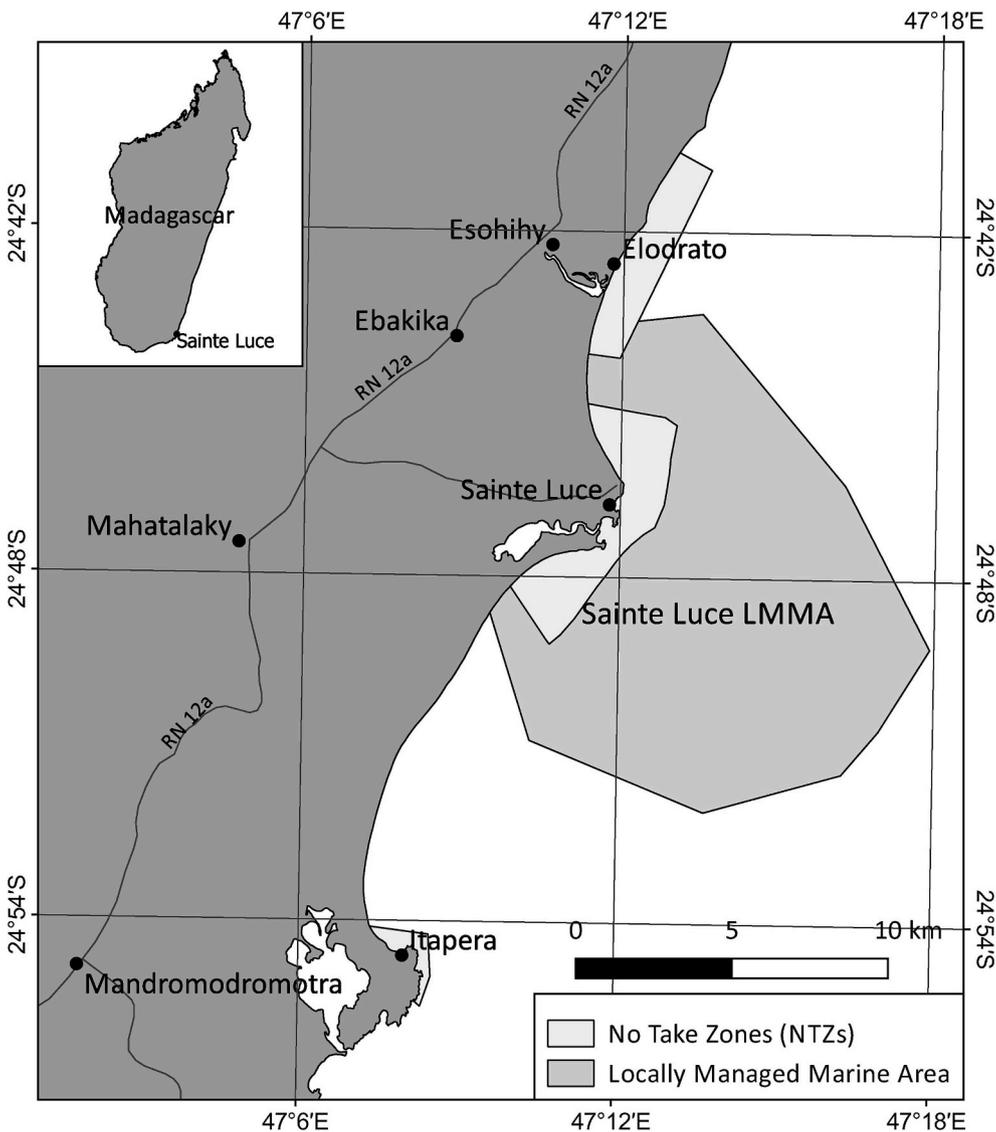


Fig. 1. Map showing the lobster fishing communities of Sainte Luce, Itapera and Elodrato in the Anosy region, southeast Madagascar. Sainte Luce is formed of three smaller hamlets (Manafiafy, Ampanastomboky, and Ambandrika), which are not drawn. Elodrato serves as the landing site for fishers from Elodrato, Esohihy, Ebakika and a number of smaller hamlets, which are not drawn. The ~160 km² Locally Managed Marine Area (LMMA) of Sainte Luce is shown, including its ~13 km² periodic No Take Zone (NTZ), which has operated since 2014. The ~160 km² LMMA area shown is a minimum convex polygon (MCP) encompassing all tracks from six GPS data loggers that were opportunistically placed on *pirogues* (wooden canoes) in Sainte Luce for ~10 day periods. Tracks were recovered from a total of 32 different *pirogues* between 02/05/15 and 15/09/15 (unpublished data). Also shown are the boundaries of periodic NTZs introduced in Elodrato and Itapera in 2015 and 2016 respectively, though these have not been operating consistently since.

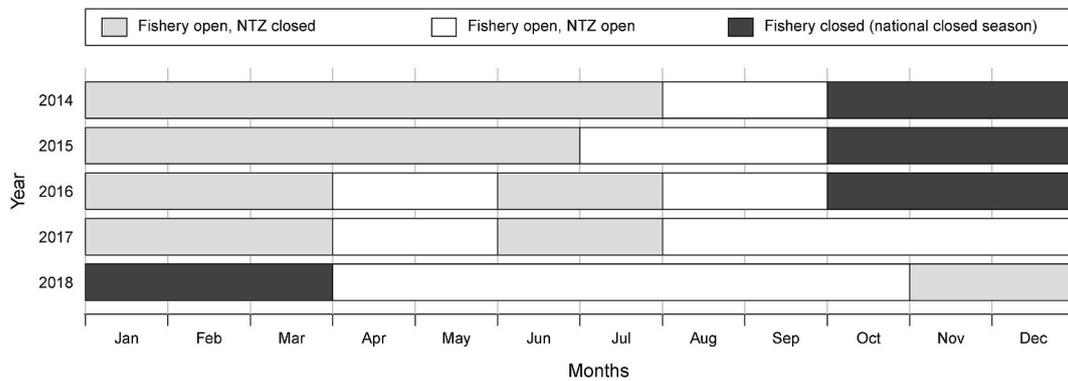


Fig. 2. Timing of periodic no take zone (NTZ) closures and national closed season in the Sainte Luce lobster fishery, southeast Madagascar.

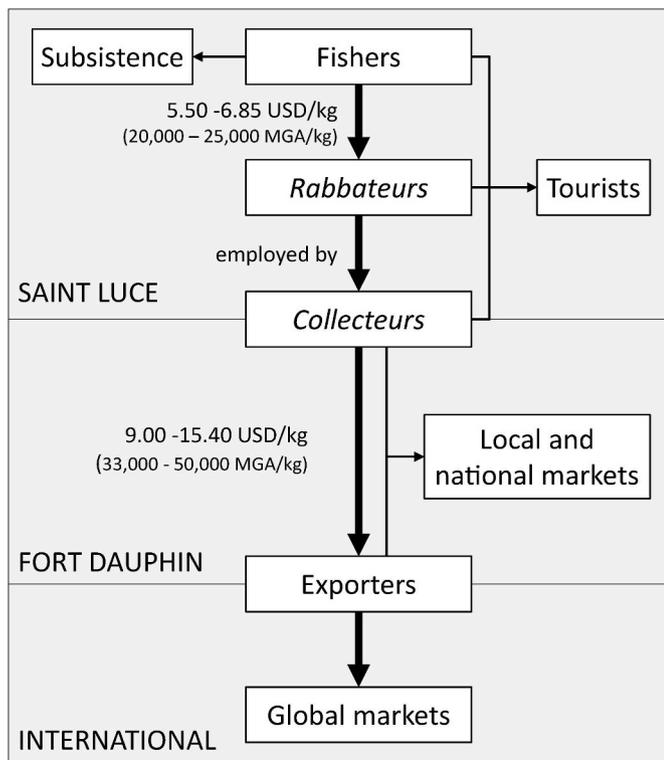


Fig. 3. Value chain in the Sainte Luce lobster fishery. Thicker arrows indicate the primary route of lobsters to market. Where known prices are indicated (US \$/kg). Note, *rabbateurs* are residents of Sainte Luce who act at the first point of sale and are employed by *collecteurs* (or ‘middlemen’), who then sell lobsters on to exporters.

management measures introduced by a *dina* (local customary law) address the lobster and finfish fisheries, in an area estimated to be 160 km². The Sainte Luce LMMA is a member of MIHARI, Madagascar’s LMMA network, that seeks to support and represent the objectives of member LMMAs at a national level [17,46].

5. Drivers/conflicts

The main conflict that the LMMA is focused on addressing is over-fishing of lobster stocks around Sainte Luce. Available evidence, from studies of the local and regional fishery, suggests catches in Sainte Luce, the adjacent landing sites of Elodrato and Itapera and the wider regional fishery have been declining in recent years [27,29,30,32]. This is supported by data from Turner et al. [30] presented here, showing increasing effort and decreasing CPUE as reported by fishers in Sainte Luce and adjacent communities (Fig. 4).

Older fishers interviewed in the current study indicated that daily lobster catches were typically 20 kg lobster/fisher/day 65 years ago, whereas by 1990 this had decreased to 10kg/fisher/day. Currently a catch of one kg/boat/day, where boats have between three and five fishers, is considered a good catch in Sainte Luce. The available evidence suggests catches were previously significantly higher than at present and that lobster stocks have severely declined due to over-exploitation. Two key underlying drivers of over-exploitation are identified.

5.1. Poverty and a lack of alternative livelihoods

Approximately 82% of the Anosy population live below the poverty line, a figure which is likely to be higher in the rural areas such as Sainte Luce [44]. Impoverished fishers rely heavily on lobster fishing for food security and income [26] and are forced to disregard legislation prohibiting the landing of berried females (those carrying eggs) and lobsters below the minimum landing size (MLS) of 20 cm [27].

There are few viable alternative livelihoods as a consequence of a poor education system, lack of transport infrastructure and unsuitable land for agriculture [43]. Education lags behind the rest of the country, 51.5% of children aged 6 to 10 in Anosy having never attended school (nationally 20.3%), whilst the literacy rate among over 15s is just 40.8% (nationally 71.6%) and predicted to decline [43]. In this context it is not surprising that there are increasing drivers into lobster fishing, as an activity with few barriers to entry, producing a high-value commodity [27].

5.2. Migration and population growth

Madagascar has an annual population growth rate of 2.8% [10], which is estimated to be even higher in coastal regions [8]. Anecdotal evidence indicates that 65 years ago there were only approximately 20 fishers in Sainte Luce, whilst it is estimated that contemporary fisher numbers in Sainte Luce range between 400 and 600. Population growth in Sainte Luce has also been driven by migration to join the lobster fishery [47], which has few barriers to entry [27]. The rate of population growth through reproduction and migration means current forms of subsistence agriculture and fishing are increasingly inadequate and unsustainable in the face of diminishing natural resources [30]. Fishing effort is increasing; data from 2015 to 2017 shows an increase in the number of boats operating in Sainte Luce and the number of pots being deployed [48], highlighting a longer term trend (Fig. 4a). Fishers suggested that migrants are less likely to respect rules, employing prohibited gears and disregarding periodic NTZ closures, which has been highlighted by another study [30].

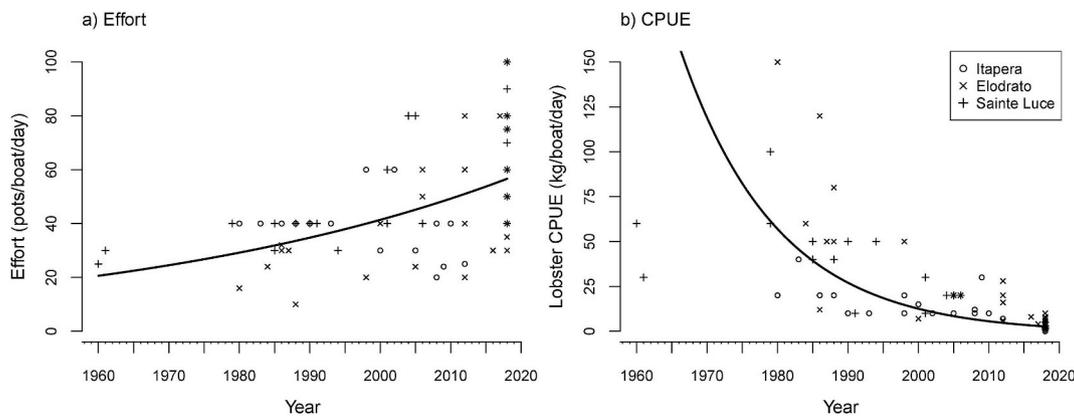


Fig. 4. Temporal trends reported by interviewed fishers ($n = 52$) in three communities from the Fort Dauphin regional lobster fishery, southeast Madagascar; Itapera (open circles, $n = 17$), Elodrato ('x's, $n = 18$) and Sainte Luce (crosses, $n = 17$). Where a) shows trends in effort (pots/boat/day) and; b) shows trend in catch per unit effort (CPUE) (kg/boat/day). Each fisher interviewed provided an estimate for a) effort and b) CPUE for the year they entered the fishery and the current year, with the exception of fishers in Itapera, who were not asked how many pots they deployed in the current year, see a). Linear models, represented by a black line, were fitted to log (response variable + 1) and showed significant relationships for a) effort ($F_{1,85} = 34.58$, $p < 0.001$) and b) CPUE ($F_{1,102} = 226.45$, $p < 0.001$). Data: Turner et al. [30].

6. Governance framework/approach

These driving forces are exacerbated by the low state capacity, reflecting the government's limited ability to enforce national legislation, including lobster fishing regulations. The responsibility for managing fisheries falls to the Directions Régionales des Ressources Halieutiques et de la Pêche (DRRHP, Regional Fisheries Authority) and Centre de Surveillance des Pêches de Madagascar (CSP, Fisheries Surveillance Centre). These subsidiaries of the Ministère des Ressources Halieutiques et de la Pêche (MRHP, Ministry of Fisheries and Aquatic Resources) lack the resources to carry out their mandates. Reportedly, most DRRHPs have just one or two agents, whilst the CSP is responsible for patrolling an exclusive economic zone (EEZ) of 1 million km² with just three boats [11]. In the absence of the state, community-based management is a solution often identified as having the potential to fill the void. However, in practice peer enforcement remains a challenge in this rural community, in common with other examples of CBNRM in Madagascar [2].

Consistent with this context of very low state capacity, the Sainte Luce LMMA's governance approach can best be described as 'governed primarily by local communities under collective management arrangements' [2]. The LMMA operates without state funding and is governed from the bottom-up by the appointed Committee. Management measures are introduced by a *dina*, a customary system of law where rules are collectively developed and applied by communities [49,50]. Rakotoson and Tanner [2] describe three kinds of *dina*: i) a traditional unwritten *dina*, ii) one aligned with national law, and iii) one formally recognised through a legal instrument. In the case of the latter *dina* have been incorporated into national law since 1996, meaning that once ratified they can be enforced by the state [49]. Those *dina* intentionally aligned with national law and/or achieving legal ratification are often the result of co-operation between the community and third parties, typically NGOs or state actors. In the case of Sainte Luce, SEED were responsible for encouraging the development of a *dina* and sought to ensure alignment with national legislation and liaison with authorities. The Sainte Luce LMMA *dina* has yet to obtain formal ratification and recognition by the state, this is despite ongoing efforts of SEED since at least 2015. Nevertheless, it enjoys *de facto* state support, evidenced by public endorsement by both DRRHP and the *Gendarmerie* (military police).

The *dina* consists of 45 articles, which predominantly relate to lobster fishing but also provide for the management of other target species and activities within the Sainte Luce LMMA. The key measures are: i) gear restrictions, including the prohibition of snorkels and net restrictions; ii) prohibition on landing berried females, in accordance with national legislation; iii) a minimum landing size (MLS) for lobster

of 20 cm, in accordance with national legislation; iv) a prohibition on fishing at night; v) the requirement for community members to report infractions; vi) fines for infringing the *dina* of up to 100,000 MGA (~US \$ 28) and one *zebu* (a humped cattle); vii) a no take zone (NTZ), closed periodically (Figs. 1 and 2); and viii) a provision to invoke state authorities when enforcing the *dina* as required.

The Committee is responsible for implementing the periodic NTZ, enforcing the *dina* and liaising with other actors (NGOs, state, industry) (Fig. 5). The intention is that fines levied against those who break the *dina* can be used to fund patrol activities and other management costs. The DRRHP, Unité de Recherche Langoustière (URL, a parastatal lobster fishery research organisation) and local *Gendarmerie* have been engaged to varying degrees since the inception of the LMMA. The DRRHP and *Gendarmerie* have endorsed the community's *dina*, giving it *de facto* legal status and in theory support the Committee with issues of enforcement. There is at least one example where a recalcitrant offender was incarcerated briefly to expedite the payment of a fine that had previously not been forthcoming [33]. SEED provides training and facilitation, promoting cooperation between actors. In the case of state authorities this is formalised by Memorandums of Understanding (MoUs), which exist between SEED, URL and DRRHP.

6.1. Incentives

The incentives employed in the LMMA are presented below, those

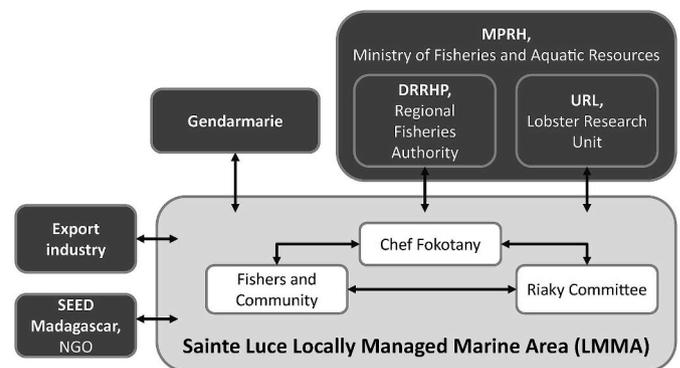


Fig. 5. An organigram depicting the governance structure of the Sainte Luce LMMA (light grey box), showing relationships between community-level (white boxes) and external actors (dark grey boxes).

Table 1

Incentives employed, or needed, in the Sainte Luce LMMA, southeast Madagascar. A more detailed account is given in the Supplementary material (Supplementary Table 1). Those incentives particularly in need of strengthening or absent but particularly in need of introduction are identified. (Y = used; Y* = Used but particularly important priority in need of strengthening; N* = Not used but particularly important priority in need of introducing). From the 36 incentives identified by Jones [1].

Category	Incentive (I)	Used	How/why?
Economic	3. Reducing the leakage of benefits	Y*	The community discourages outsiders from fishing in the NTZ through dialogue, with some success. The value chain could be manipulated to reduce the leakage of benefits from fishers.
	4. Promoting profitable and sustainable fishing and tourism	Y*	Management measures are introduced by the <i>dina</i> to increase the sustainability of fishing, including a periodic NTZ. Better implementation of the periodic NTZ, national closed season, MLS and ban on landing berried females is required. A permanent closed area may yield additional benefits.
	6. Promoting diversified and supplementary livelihoods	Y*	There is limited agricultural potential. 'Volun-tourism' offers some limited opportunities. SEED's 'Stitch' livelihood project has trained women in embroidery and generated 37 million MGA (~US\$ 11,400) in revenue in the six months from October 2017 to March 2018 [54]. Seasonal fishing for tuna and sardines provides income and nutrition. A lack of ice facilities and other infrastructure means there is no export route for these and so markets are local and prices low.
	7. Providing compensation	N*	Committee members want compensation for patrolling the NTZ, to offset income lost whilst not fishing.
	8. Investing MPA income/funding in facilities for local communities	N*	The Committee are supposed to use the money collected from fines to develop local infrastructure but there is little evidence of this and Committee members were not forthcoming when interviewed. This appears to be a source of mistrust between the Committee and community, see I-26.
	10. Provision of NGO, private Sector and user fee funding	Y	LMMA establishment and operation has been supported by SEED, through funding from FAO-SmartFish (2013–2016) [33] and the UK Government's Darwin Initiative (2018–2021) [34].
Communication	11. Raising awareness	Y*	A comic book promoting sustainable fishery management was distributed in Sainte Luce and Elodrato [33]. The Committee and SEED hold community meetings on an <i>ad hoc</i> basis. Some fishers stated they would like more regular meetings.
	12. Promoting recognition of benefits	Y	All interviewees were aware of potential NTZ benefits, from experience with previous closures, participation in MIHARI (the national LMMA network) and a cross visit to the Velondriake LMMA [45].
	13. Promoting recognition of regulations and restrictions	Y	The <i>dina</i> is displayed in Sainte Luce; all residents interviewed stated they are aware of the <i>dina</i> , though they were less familiar with national legislation. Broadcasts on regional radio have been used to raise awareness of the <i>dina</i> [33,45]. Buoys have been used to mark boundaries of the NTZ. Transgressors are often migrants, with less awareness of, or respect for, the <i>dina</i> .
Knowledge	14. Promoting collective learning	Y*	Fishery monitoring data has been used in community and stakeholder meetings to promote evidence-based decision making [33], though data could be better used. Data are shared via an open-access repository [55]. In 2018 this monitoring was extended to Itapera and Elodrato.
	16. Independent advice and arbitration	Y*	SEED works alongside independent researchers with expertise in marine conservation and fisheries science, including to interpret participatory fishery monitoring data [27,48]. URL could potentially do more to collect robust data and utilise the data they have collected to support decisions by managers.
Legal	17. Hierarchical obligations	Y*	Madagascar committed to triple the coverage of MPAs within 10 years as a signatory of the Sydney Promise at the 2014 IUCN World Parks Conference. The national Biodiversity Action Plan (2015–2025) commits to Aichi targets and sets the goal of adequately conserving 15% of marine areas by 2025 [56]. LMMAs can contribute to these obligations.
	18. Capacity for enforcement	Y*	There is no money to support patrols. Peer enforcement led by the Committee is challenging due to potential for loss of social capital, fear of retribution and impacts on intra-community relationships. State support is needed from DRRHP or <i>Gendarmerie</i> , which also lack resources. In 2016 the DRRHP reprimanded transgressors, who subsequently complied. Previously, the <i>Gendarmerie</i> in Mahatalaky has successfully intervened.
	19. Penalties for deterrence	Y*	The penalty for breaking the <i>dina</i> is 100,000Ar (~US\$ 28), a zebu and confiscation of any prohibited gear, though the full fine is never imposed. Challenges with enforcement limit the efficacy of penalties.
	20. Protection from incoming users	N*	There are no legal or administrative barriers to entering the fishery, thus no protection against incoming migrants and increasing effort.
	22. Cross-jurisdictional coordination	Y*	DRRHP, <i>Gendarmerie</i> and the <i>Chef Fokontany de Sainte Luce</i> (elected mayor of Sainte Luce), have attended stakeholder meetings [33]. There is little coordination in the management of marine resources between neighbouring communities.
	23. Clear and consistent legal definitions	Y	The <i>dina</i> is formalised as a written document and a summary is displayed in Manafiafy. The <i>dina</i> is consistent with national regulations on MLS, closed season and berried landing ban for lobsters.
	24. Clarity concerning jurisdictional limitations	N*	There is a need for involvement of the <i>Gendarmerie</i> when people refuse to pay fines, as there is great respect for their power and authority. There is a reluctance to involve <i>Gendarmerie</i> due to cost, with it being considered a 'last resort' by Committee members. Escalating cases to state authorities needs to be undertaken on a clear and consistent basis.
	25. Legal adjudication platforms	Y*	The <i>dina</i> is applied by the Committee and community, a process of collective adjudication. The <i>dina</i> is not yet formally ratified but enjoys <i>de facto</i> state support, as evidenced by actions of DRRHP and the <i>Gendarmerie</i> to support its application [33]. When state actors engage they serve to support, modify or reject the collective consensus of the Committee and community and in doing so act as adjudicators. Formal ratification of the <i>dina</i> and increasing the judicial capacity for appeals would help in ensuring justice and accountability.
	26. Transparency, accountability and fairness	N*	A lack of transparency regarding how the Committee uses the money from fines causes significant distrust. Peer enforcement can be unfair, particularly where relationships exist between transgressors and Committee members.

(continued on next page)

Table 1 (continued)

Category	Incentive (I)	Used	How/why?
Participation	27. Rules for participation	Y	The <i>dina</i> provides the rules for participation.
	28. Establishing collaborative platforms	Y*	The LMMA Committee provides an important collaborative platform. The Sainte Luce LMMA is a member of the MIHARI LMMA network [57], a collaborative platform with regional and national meetings, attended by members of the Committee [33].
	29. Neutral facilitation	Y	SEED attend and often informally facilitate Committee meetings, as well as participating in discussions regarding the NTZ and provide neutral input and interpretation of monitoring data [27,33].
	30. Independent arbitration panels	N*	Committee meetings are often long and unproductive, often being ‘all talk, no action’ due to disagreements. An independent panel to arbitrate on disagreements could be advantageous.
	31. Decentralising responsibilities	Y*	The LMMA model gives the community decentralised responsibility to manage marine resources through the use of a <i>dina</i> with <i>de facto</i> state recognition. A closer partnership between the state and community is needed.
	32. Peer enforcement	Y*	The <i>dina</i> relies on peer enforcement, which is not without considerable challenges. Improved state enforcement support would reduce reliance on peer enforcement and help promote it.
	33. Building trust and the capacity for cooperation	Y*	Community meetings have led to decisions on NTZ closures, attended by relevant actors (including DRRHP, Gendarmerie, Chef Fokontany and URL), representing new cooperation. There is some distrust of the Committee among the community. This could be addressed by re-electing the members to improve buy-in and sense of representation, along with strengthening I-26.
	34. Building linkages between relevant authorities and user representatives	Y*	State authorities were involved in the initiation of the LMMA. The DRRHP helped align the <i>dina</i> with national laws concerning the MLS and berried female restrictions [31]. Authorities have on occasion supported the application of the <i>dina</i> . The Committee is now less willing to involve DRRHP due to a loss of enthusiasm from both sides, and are hesitant to involve the <i>Gendarmerie</i> due to cost and the social implications.
	35. Building on local customs	Y	The LMMA builds on the customary use of <i>dina</i> to manage resources. It promotes (through restriction of other gears) the use of artisanal methods for lobster fishing.
	36. Potential to influence higher institutional levels	Y*	The Sainte Luce LMMA has little political power or capacity to influence an insouciant government, other than through its involvement in the MIHARI network of LMMAs in Madagascar, which acts to influence the MRHP.

incentives considered a particularly important priority for strengthening, or introducing, to improve the effectiveness of governance are also highlighted (Table 1).

The interactions between incentives currently employed and their linkages are illustrated as a web (Fig. 6). The web of incentives clearly demonstrates the central role of participation incentives in the governance approach of this LMMA, both in terms of the number of participation incentives and the linkages within and between categories (Fig. 6). There is a need to strengthen many of the incentives (Table 1), this includes the need to introduce and improve connectivity, especially within and between economic and knowledge incentives, which have limited interaction (Fig. 6).

7. Effectiveness

A score of one out of five is assigned, indicating that some impacts are beginning to be addressed [1]. This is largely based on the steep decline in CPUE (Fig. 4), highly likely due to over-exploitation [27,29]. Based on the available data, a reasonable inference is that stocks have ‘crashed’ (< 10% unexploited biomass) and that the fishery and stocks are ‘bumping along the bottom’. Nevertheless, the depleted stock continues to yield sufficient catches to economically justify the continuation of fishing, due to the low availability of alternative livelihoods and the relatively high prices of lobster attained by fishers (~US\$ 6.80/kg where most people live on less than US\$ 1.90 per day).

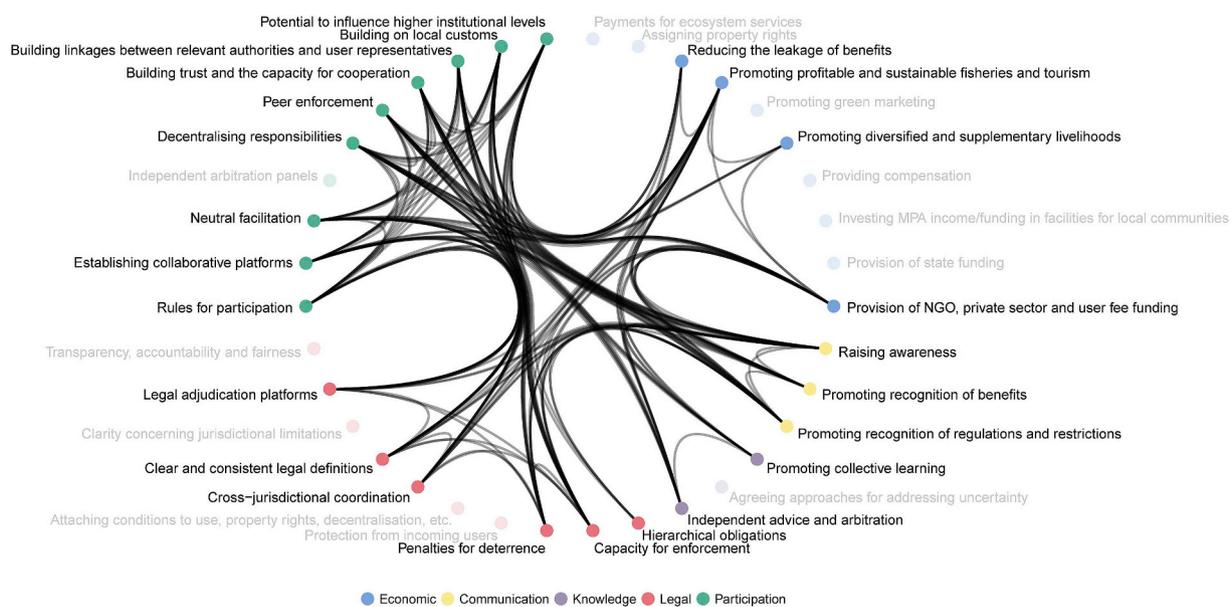


Fig. 6. Incentive web for the Sainte Luce LMMA. All 36 incentives are shown for reference. Those identified as in use are shown by a coloured dot (according to category) and black text. Those not in use are drawn semi-transparent. A line drawn between individual incentives indicates a functional connection between two incentives that materially impacts the governance.

Community-based management led by the Committee has been established. This includes the implementation of a periodic NTZ (Figs. 1 and 2). Initial openings in 2014 and 2015 were successful, fishers report daily catches increasing from a usual average of 1 kg per day to between 6 and 8 kg per day. Significant temporary increases in CPUE have been associated with increased prices, as buyers competed over the abundant lobster supply and fishers held out for higher prices [27,31,48]. These positive experiences have been described as having a 'community catalyst' effect, increasing buy-in for community management and fostering tentative interest in adjacent communities [27], as has been observed with NTZs elsewhere in Madagascar [51].

However, the total duration of NTZ closure periods has diminished year-on-year (Fig. 2). Capacity for enforcement remains an issue in Sainte Luce. Community members are reluctant to report transgressors due to the potential social backlash. This is despite the incentive of receiving 50% of the fine and an obligation under the *dina* to report breaches of NTZ and other restrictions. There is also a lack of transparency around how fines are utilised by the Committee, with many residents believing members share it amongst themselves. Fines equate to a significant amount of household wealth and therefore transgressors are often reluctant or unable to pay the imposed fine. Consequently, fines are rarely, if ever paid in full, resulting in inconsistent application of the *dina*. Obtaining support from the *Gendarmerie* incurs costs paid to the *Gendarme* (officer), which the Committee may be reluctant or unable to pay. Compliance with the MLS of 20 cm and law against landing berried females is habitually ignored, with both undersized and berried lobster being bought by *collecteurs*. Low compliance has been shown by analyses of participatory lobster fishery monitoring data, for example it is reported that 42.8% of catch is < MLS [27,48]. Low compliance with national law reflects the financial necessity of landing catch and limited appetite and/or capacity for state enforcement. Neither DRRHP nor URL owns a functioning patrol boat or four-wheel drive and are therefore unable to conduct patrols or travel to Sainte Luce regularly.

Crucially the incentives applied do not effectively address the two drivers identified above, especially in the context of weak state capacity. There remains a lack of alternative economic activities for fishers. Price increases at the first point of sale have been achieved, attributed to the impact of NTZ openings [27,33] and competition from the entry of Santi, a new Chinese export company. This partially addresses poverty but does not decrease reliance or pressure on the fishery. There are currently no direct efforts to manage migration or restrict access to the fishery. The state capacity remains weak, although developing linkages between community managers and state actors could yield a more resilient governance structure and has contributed to enforcement in some cases.

8. Cross cutting issues

8.1. Role of NGOs

SEED's Project Oratsimba began in 2013, with funding from FAO-Smartfish, to mitigate the reported declines in lobster stocks [45]. SEED initiated the LMMA process with an exchange visit for some local fishers to the Velondriake LMMA, southwest Madagascar [45]. The Velondriake LMMA was established in 2004 with assistance from Blue Ventures (an international NGO) and was the country's first LMMA, aiming to ensure the sustainability of the artisanal octopus fishery [16,52]. Building on this first LMMA, Blue Ventures have played a critical role in establishing Madagascar's LMMA network and developing MIHARI as an organisation to represent them [46]. Blue Ventures has provided guidance, technical and financial support to SEED in establishing the Sainte Luce LMMA and are partners in the current UK Government funded third phase of Project Oratsimba [34].

From the initiation of the LMMA to present, SEED led the development and direction of the project, securing ongoing funding to support refinement and scale-up [34]. Throughout SEED have organised

meetings between the stakeholders (fishers, community, state actors, industry and scientists) and provided training and support to the Committee in Sainte Luce. Since January 2015 SEED have also overseen the ongoing participatory monitoring programme [27,33].

Looking ahead to the third phase of the project, SEED aims to strengthen and refine the existing model in Sainte Luce supporting further periodic NTZ closures and exploring the possibility of introducing a permanent NTZ. Simultaneously, the project seeks to promote community-based management in adjacent communities, building on the tentative experiments with NTZs in Elodrato and Itapera (Fig. 1). These less established initial experiments with NTZs by neighbouring communities were seemingly catalysed by experiences in Sainte Luce [27].

As the project continues, SEED could position themselves more actively to act as neutral brokers in order to address those incentives in need of strengthening. It should be recognised that SEED are not strictly neutral, having their own objectives and a vested interest in the success of the LMMA. In particular SEED could facilitate improvements addressing the need for transparency, accountability and fairness (I-26), as well as continuing to help build trust and the capacity for cooperation (I-33) and build linkages between relevant authorities and user representatives (I-34). There may also be a continued need for some NGO funding (I-10) and neutral facilitation (I-29), as well as for several other incentives that are currently supported by SEED.

Given the lack of state capacity, there is a long history of NGOs taking an active lead role in natural resource management in Madagascar, from national policy level to working with communities, in marine and terrestrial contexts [24]. The challenge faced by SEED, in common with numerous NGOs elsewhere in Madagascar, is to develop community-based natural resource management to the point where it is self-sustaining in the long-term. This can only be achieved by identifying and providing the support and facilitation required in the short-term. This is a tricky balance for NGOs and rarely achieved [53]. Arguably, a key pre-condition is significant strengthening of the national state capacity and the political will to apply this capacity to promoting the sustainable use of natural resources.

8.2. Equity issues

The limited mobility of fishers and lack of resources means that, as with other SSFs in developing countries, prices at the bottom of the value chain are low. Most fishers do not own their own pirogues due to cost (~500,000 MGA, ~US\$ 154) and risk, as they can be lost, broken and typically only last a few years. Instead pirogues are provided by *collecteurs* and/or exporters, often through loans to fishers as a form of indebtedness to tie them to that *collecteur* and/or exporter. This serves as a control mechanism obliging fishers to sell to only one *collecteur*, which reduces competition and depresses the price.

Recently, around 2014, Chinese export interests moved into Fort Dauphin and operate under the name Santi. They are willing to pay higher prices to outcompete other exporters (Madapêche and Martin Pêcheur). At the same time periodic spikes in landings in Sainte Luce associated with NTZ openings have been linked to price increases as *collecteurs* and exporters compete to maximise market share [27]. These developments have added a degree of dynamism to the value chain with positive impacts for fishers and the price they receive.

Whilst fisher's receive a flat rate for all lobster (~22,000 MGA/kg, ~US\$ 6.80/kg), more complex price structures exist between *collecteurs* and exporters, dependent on size, species and quality. The most common species, *P. homarus*, is sold by *collecteurs* to Chinese exporters for 33,000 MGA/kg (~US\$ 10.10); some 50% higher than fishers receive. More strikingly, exporters pay around 50,000 MGA/kg (~US\$ 15.50) for the prized *P. ornatus*. Clearly there is a potential to reflect this price structure, of which fishers are currently unaware, at the point of first sale. This would likely require an external actor such as SEED to instigate and could have two benefits. Firstly, a more equitable value

chain would improve incomes for fishers reducing the leakage of benefits from communities to actors further up the value chain. Secondly, it may better incentivise fishers to return undersized lobster if their value is significantly less. Resolving the lack of equity in the value chain and addressing the loss of the price signal promoting the return of undersized lobsters is critical to achieving a sustainable fishery. Fundamentally it must be economically beneficial for fishers to adopt sustainable behaviours.

The Committee's lack of transparency and accountability may mean that some individuals on the Committee could be benefitting financially, or are vulnerable to the impacts of that perception. There is a belief held by some in the community that the Committee are keeping collected fine money for themselves. This undermines the Committee's legitimacy and social capital on which peer enforcement is dependent. A process of democratically electing Committee members coupled with ensuring transparency, accountability and fairness in the functioning of the Committee, perhaps brokered by SEED, could restore fishers' sense of equity and representation. This would foster the communities' trust in the legitimacy of the Committee's actions and confidence that the Committee functions solely to achieve collective sustainable exploitation objectives. At present there is a risk that the erosion of such trust and confidence could critically undermine the social capital that is needed to form the foundations of this LMMA.

9. Conclusion

Initiating community-based management is a significant achievement of the various actors in the Sainte Luce LMMA. The implementation of a periodic NTZ, now in its sixth year, has proven to be effective as a flagship measure. The community have experienced positive impacts on price associated with short-term increases in lobster catches, though this does not suggest that there has been an increase in biomass [27]. Fishery monitoring data from 2015 to 2017 indicates that overall catches remain stable [48]. However, current catches are extremely low, compared to historic catch per unit effort (Fig. 4), supported by the consensus that catches have declined strongly in recent decades [27]. It appears that the regional stock is in a severely depleted state. Successful management will require improved compliance with national legislation and the *dina*. This includes observing the prohibition on landing berried lobsters, the MLS, local closures and the national closed season. Operating on a precautionary basis some or all of these measures may be critical in supporting the recovery of the regional stock. Further, there is a need to introduce new, more ambitious measures such as a permanent NTZ to have greater ecological impact.

Poverty and a lack of alternative livelihoods is a critical source of concern for fishers and the wider community. Coupled with migration this drives the long-term increases in effort in an already over-exploited fishery. Tuna and sardine stocks are important targets for fishers, especially when NTZ closures coincide with their availability. However, the economic potential of these pelagic fisheries remains unrealised. Recent developments offer scope to promote equity in the value chain, with benefits to fishers, though this alone will not reduce pressure on the lobster stock or improve the fishery's sustainability.

Now established for over five years this LMMA faces some significant governance challenges, which must be overcome to secure positive environmental and socio-economic outcomes in the long-term. The role of the Committee is pivotal; its legitimacy is threatened by limited state support and lack of transparency leading to growing distrust. Entering into a third phase of the project, SEED are positioned to act as a strategic third party, working with stakeholders to introduce and strengthen those incentives currently lacking in the governance framework. At a community-level, re-invigoration of the Committee and continued buy-in from fishers is required. This must be consistently supported by state actors (DRRHP, *Gendarmerie*, URL, MRHP and the *Chef Fokontany*), whilst the industry needs to be engaged in making the value chain more equitable. The spatial scale at which ecological

processes occur in marine environments means this project must achieve scale-up to adjacent communities and beyond. Effective management of the regional lobster fishery should to some extent be co-ordinated at a regional scale, perhaps through a network of LMMAs. The effectiveness of LMMAs in Sainte Luce and elsewhere relies on a diversity of actors and incentives they are able to collectively employ in order to build resilience. As with many protected area initiatives in Madagascar, it is critical to address widespread poverty, political instability, lack of rule of law, lack of political will and widespread corruption that undermines effective and equitable management initiatives [19]. In the interim, NGOs can provide a supporting 'stopgap' role, in trying to promote sustainable use and the equitable distribution of benefits, particularly the strengthening and introduction of the incentives highlighted in this assessment. However, they remain limited in what they can achieve until the extreme contextual challenges present in Madagascar are addressed.

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Appendix A. Supplementary data

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