



# Building resilience in practice to support coral communities in the Western Indian Ocean

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## ABSTRACT

Global environmental change and other site specific pressures (e.g. over fishing and pollution) are threatening coral reefs and the livelihoods of dependent coastal communities. Multiple strategies are used to build the resilience of both coral reefs and reef dependent communities but the effectiveness of these strategies is largely unknown. Using the Western Indian Ocean (WIO) as a case study, this paper combines published literature and expert opinion elicited through a multi-stakeholder workshop to assess the intended and realised social and ecological implications of strategies commonly applied in the region. Findings suggest that all strategies can contribute to building social and ecological resilience, but this varies with context and the overall strategy objectives. The ability of strategies to be successful in the future is questioned. To support effective resilience policy development more nuanced lesson learning requires effective monitoring and evaluation as well as a disaggregated understanding of resilience in terms of gender, agency and the interaction between ecological and social resilience. Opportunities for further lesson sharing between experts in the region are needed.

## 1. Introduction

Building the resilience of coral reef ecosystems to global environmental and climate change, and the resilience of the coastal communities who are dependent upon them, are issues of international concern (SDG 14, 2016; IYOR, 2018). Such socio-ecological resilience thinking has attracted considerable academic interest, focused on defining and refining the concept (e.g. Walker et al., 2004; Folke et al., 2010) or on characterising the features of social-ecological systems that are necessary to ensure resilience (e.g. Folke et al., 2002). Use of resilience concepts in policy and practice has also grown, especially in the context of disaster reduction and adaptation to climate change (Tanner et al., 2017). At the global level, the ambition to increase resilience is explicit in Sustainable Development Goals (SDGs) 1, 11, 13, and 14 relating,

respectively, to poverty alleviation; safe and sustainable settlements; combatting climate change; and sustainable use of the oceans (United Nations, 2015).

A number of tools have been developed to encourage the design of strategies that put resilience concepts into practice (e.g. Resilience Alliance, 2010). Policy and management interventions may, however, deliberately or inadvertently reduce the resilience of a system (Davoudi et al., 2012). Attention is therefore turning to evaluating the impact of resilience building strategies and the identification and measurement of resilience outcomes. Communities of practice are coming together to share experiences and lessons learnt (Gregorowski et al., 2017), but the effectiveness of many resilience building programmes and strategies is largely unknown.

Resilience to change will differ according to the magnitude and

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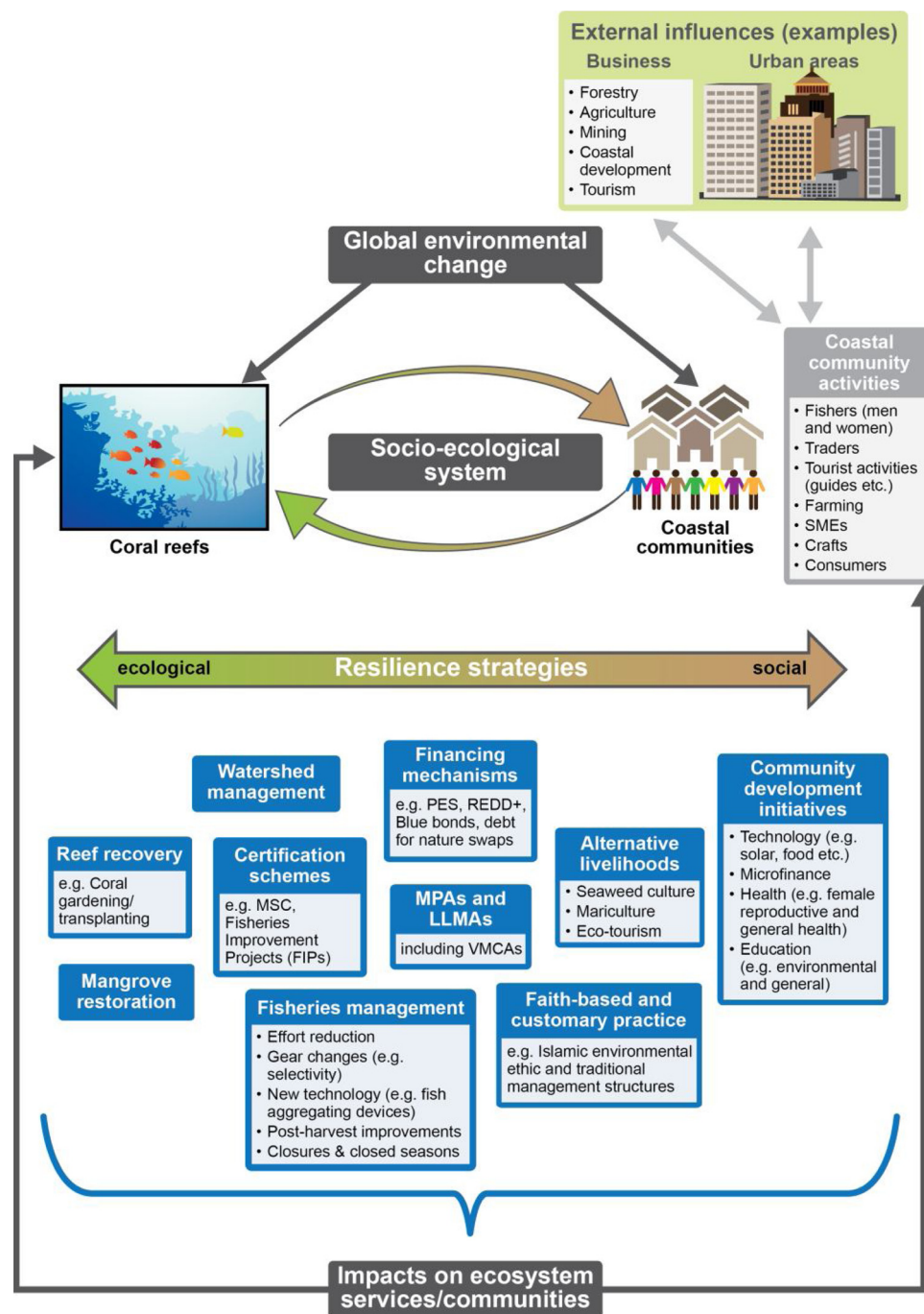
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**Fig. 1.** Conceptual framework illustrating the coral reef-community social-ecological system and the resilience-building strategies included in the literature review. MPAs = Marine Protected Areas; LLMA = Locally Managed Marine Areas; VMCA = Voluntary Marine Conservation Areas; MSC = Marine Stewardship Council; PES = Payment for Ecosystem Services; REDD+ = Reducing Emissions from Deforestation and forest Degradation supporting conservation, sustainable management and enhancement of forest carbon stocks.

duration of the shock or disturbance, the ability of the social-ecological systems to self-organise and the capacity for learning and adaptation (Folke et al., 2002). Different strategies will be needed according to the characteristics of the disturbance, the ecological and social components of the system of interest and the desired outcomes (Walker et al., 2004). Many common strategies applied in coral reef management and community development have not explicitly considered the resilience of the social-ecological system. Their implications for resilience outcomes remain an important research gap. This paper contributes new knowledge to the literature on resilience building by systematically identifying strategies in practice and assessing the intended and realised

implications for both social and ecological resilience of coral reef social-ecological systems.

We focus our analysis on the Western Indian Ocean (WIO), home to approximately 16 % of the world's coral reefs (Obura et al., 2017). These reefs are highly vulnerable to stresses associated with climate change and other site specific pressures such as fishing, pollution and coastal development (Cinner et al., 2012; Obura et al., 2017). Significant changes to coral reefs are potentially devastating to communities in the WIO due to their high dependence on these ecosystems (Cinner et al., 2009; Lalljee et al., 2018). Small island states face particular challenges in balancing economic growth, sustainable

**Table 1**

Review matrix used to extract evidence from the literature of how identified strategies impact coral reefs and dependent communities.

Review criteria
Description of strategy and purpose, including assumptions on route to and/or implications for resilience.
Impacts on ecosystem services*
Implications of impacts for ecological resilience
Impacts on coastal communities*
Implications of impacts for social resilience
Spatial scale of impacts (local, national, regional)
Temporal scale of impacts (short term < 5yrs, medium term 5-10yrs, long term > 10yrs)

\* Distinguish if evidence (E) is provided or whether impacts are based upon supposition (S).

development and resilience building (Government of Mauritius, 2014). National policy in WIO countries echoes the aspirations of the SDGs. For example, strengthened resilience to disaster risk is one of the five strategic pillars of Madagascar's National Development Plan, as well as identifying resilience to climate change as a national priority, noting the need to increase resilience in the most vulnerable sectors of society (IMF, 2017). Similarly, Mauritius seeks to “increase the resilience of our nation to unpredictable and shifting external factors such as climate change or global crises” and recognises that the ocean has a role in resilience at a national level (particularly through economic development) (MESD, 2013). Policy documents tend to propose high level strategies and intentions rather than offering detail on specific approaches. Implementation is left to actors working at more local levels with many strategies being widely applied by government institutions, NGOs and communities throughout the WIO to manage coral reefs, their associated resources and the users that depend upon these resources (Cinner, 2014). All of these strategies, intentionally or unintentionally, have implications for the resilience of both coral reefs and their dependent communities.

Through a combination of literature review and expert knowledge elicitation, this paper explores the available evidence on strategies that can build reef and community resilience across the WIO. Many of the strategies identified have been developed independent of resilience frameworks, but their outcomes can be anticipated to contribute to both social and ecological resilience. Evidence is presented for the social and ecological impacts of the different strategies, who benefits from them and whether the strategies are future proof. Cross-cutting themes are identified and discussed, as are lessons learnt and barriers to future success.

## 2. Methods

Based on discussions with stakeholders from the WIO and evidence from the literature review (e.g. Folke et al., 2010), resilience was presented as the ability to resist, recover, adapt and bounce back from any kind of pressure, but not necessarily to the same state. Ecological resilience was explored in terms of changes to ecosystem services, while any evidence of social and economic change at the individual, household and community level was considered to impact social resilience.

### 2.1. Literature review

Drawing upon the knowledge of the project team (involving academics and practitioners), resilience building, coral reef management and coastal development strategies implemented with government, donor, Non-Governmental Organisations (NGO) or Community-based Organisation (CBO) support were identified for inclusion in the literature review. We reviewed fourteen strategies with the potential to build resilience even if this was not an explicit or primary objective: coral reef restoration; mangrove restoration; certification schemes such as eco-

labelling of fish and fish products; fisheries management including fishing gear change and effort restriction, fish aggregating devices and post-harvest improvements in fisheries; marine protected areas (MPAs) and locally managed marine areas (LMMAs); financing mechanisms such as payments for ecosystem services (PES); ethics, faith-based and customary practices; alternative livelihoods; and community development initiatives including environmental education, micro-finance and population, reproductive health and environment (PHE) approaches. This list, whilst not exhaustive, illustrates commonly used strategies across the social-ecological spectrum (i.e. some strategies directly target coral reef management, while others focus on social issues within reef-dependent communities) (Fig. 1).

We undertook a targeted review of each strategy (*sensu* Brown, 2014; Hamann et al., 2018). We identified literature for each strategy (English language only) using keyword searches of academic databases, including Web of Science and Google Scholar, as well as the wider Internet. This allowed the inclusion of both peer reviewed and online grey literature. The search terms used were specific to each strategy. For instance, TOPIC: [various terms used to describe the strategy] AND TOPIC (fish\* OR marine\* OR coast\*) AND TOPIC (resilienc\* OR health OR well-being OR wellbeing OR income OR poverty). A search of global literature and literature specific to the Western Indian Ocean was performed. Between five to fifteen papers were reviewed for each strategy to gain a sufficiently comprehensive understanding of the strategy, including existing review papers and publications or reports detailing the implementation and outcomes of the strategy.

Each strategy was analysed using a review matrix developed by the project team to ensure consistency among authors conducting the review (Table 1). The analysis sought to document both the assumed or intended impacts of a particular strategy and record any available empirical evidence of its outcomes. Where possible, evidence of impacts specific to the WIO were highlighted. An overview of each strategy was then presented to WIO regional experts in a multi-stakeholder workshop as a series of report cards for further discussion and analysis (see Results). A further round of review was then conducted to fill any noted gaps and identify any literature supporting the opinions and experiences expressed by regional experts in the multi-stakeholder workshop. In total, over 110 papers were reviewed across all fourteen strategies.

### 2.2. Expert elicitation in a multi-stakeholder workshop

Findings from the literature review (Tables 2 and A1) were presented to regional experts on coral reef management, coastal development, and resilience building at a two-day multi-stakeholder workshop in Mauritius (10–11 May 2017). Workshop participants (20 in total) included representatives from NGOs, government and academics from Mauritius, Rodrigues, Zanzibar, Kenya, the Comoros, Madagascar and the Seychelles (Table A2). The participants invited were secondary stakeholders, those whose well-being is not directly affected by the ecosystems, but who represent institutions and social groups that have some type of influence in coastal decision-making and policy. The workshop aimed to i) understand how resilience practices are applied in the region; ii) prioritise resilience strategies of interest to WIO stakeholders and collate evidence of success and best-practice in, as well as barriers to, their implementation; and iii) identify opportunities to improve resilience-building strategies in the future. The workshop combined plenary sessions with facilitated small group discussions to elicit expert opinion. Priority strategies were identified for detailed discussion on day two. This method has been used elsewhere to garner expert insight into the on-the-ground or in-practice outcomes of governance and adaptation interventions (*sensu* Evans et al., 2016). It is particularly well suited to research on issues that are urgent but complex, have high uncertainty and lack data (Fazey et al., 2006; Martin et al., 2012; Rai, 2013). On obtaining consent from each participant, discussions were digitally recorded and detailed notes were taken for analysis.

**Table 2**

Resilience strategies identified through the literature review and during the stakeholder workshop, their assumptions for resilience and their links to coral reefs.

Strategies		Assumptions for resilience	Link to coral reefs
Reef recovery: Coral gardening and reef restoration		Coral reef restoration is assumed to increase the health of reefs and support resistance to pressures such as climate change and human activity allowing continued provision of ecosystem services (Rinkevich, 2014).	Coral heads or nursery-reared corals are transplanted to restore coral reefs (Mbije et al., 2013).
Mangrove restoration		Restored mangroves are assumed to trap run-off and provide habitat, increasing the health of coral reef ecosystems, and supporting resistance to climate change and human activity (Gorman and Turra 2016).	Mangroves are important nursery areas for coral reef species, they also bind sediment and contaminants preventing them reaching coral reefs (Moberg and Rönnbäck, 2003; Berkström et al., 2012).
Certification schemes: Ecolabelling of fish and fish products		Consumers reduce the demand for, and consequently, the pressure on overfished stocks; sustainably managed fish stocks support improved catch and income for fishers (Sampson et al., 2015).	Schemes leading to MSC certification (e.g. fisheries improvement projects, fair trade schemes) are being applied to small-scale coral reef fisheries (Long, 2017).
Fisheries management:	Gear change and effort restrictions	Effort and gear management can improve fisheries sustainability thereby enhancing fishers' livelihoods and income (Mbaru and McClanahan, 2013).	Reducing effort and fishing selectivity thereby protects fish biomass and avoids tipping points in coral reef ecosystems (McClanahan et al., 2011).
	Fish aggregating devices (FADs)	Artisanal or nearshore FADs improve catches of pelagic fisheries which could contribute to increased incomes and/or enhanced food security; and reduce cost per unit effort of catching fish by reducing fuel costs and time at sea (Bell et al., 2015).	FADs may reduce fishing effort on coral reef fisheries as fishers concentrate more effort on FADs (Campbell et al., 2016).
	Post-harvest improvements in fisheries	Increases the availability, quality and price of post-harvest catch, which in turn improves livelihoods, and has health benefits (Adeyeye and Oyewole, 2016).	Used together with other fisheries management aimed at reducing pressure on coral reefs resources (Allison and Horemans, 2006).
MPAs and LMMAs	Locally Managed Marine Areas (LMMAs)	Strengthening fisheries governance through increased local participation in decision-making, clarification of property rights and collaborative management between relevant stakeholders encourages more sustainable behaviour and innovative conservation actions (Kawaka et al., 2017).	Increasingly applied in coral reef dependent fisheries in WIO region (Roccliffe et al., 2014).
	MPAs	The provision of protection will increase reef health and support resilience to pressures such as climate change and human activity (Mellin et al., 2016).	MPAs are a common fisheries management and conservation tool for coral reefs in the WIO (IUCN, 2004; Roccliffe et al., 2014).
Financing mechanisms: Payments for Ecosystem Services (PES)		PES schemes support environmental management and restoration, with income and resource benefits resulting for both user and provider of ecosystem services (Bladon et al., 2016).	Only working examples in the WIO relate to mangrove restoration (Locatelli et al., 2014), which should benefit coral reefs as identified for mangrove restoration.
Faith-based and customary practices		Conservation objectives can be met through customary and faith-based practices containing an environmental ethic (Cox et al., 2014).	Using the environmental ethic enshrined in e.g. Islam to encourage fishers to reduce their use of destructive fishing activities (Chernala et al., 2002) and support conservation activities.
Alternative livelihoods		Social resilience is assumed through increased income diversification and hence stability for fishing families and communities (Cinner, 2014).	Diverting fishers away from fishing activity will decrease direct and indirect pressure on coral reefs (Cinner, 2014).
Community development initiatives:	Environmental education	Educated populations are more likely to be effective custodians of their natural resources and are assumed better able to adapt to change and engage in conservation strategies (Nordlund et al., 2013).	Builds public awareness and appreciation of the importance of coral reefs and may reduce pressures on them e.g. through the development of alternative livelihoods (Nordlund et al., 2013).
	Micro-finance	Improved incomes enable households to better withstand difficult times, e.g. when fish catch is low or weather is bad (Crona et al., 2010).	Formal micro-finance (via banks and other institutions) and informal micro-finance (via middlemen and traders) is common among fisheries associated with coral reefs (Bakari et al., 2014; Ferrol-Schulte et al., 2014).
	Population, reproductive health and environment	Healthy, more engaged populations are more likely to be effective custodians of their natural resources and more able to adapt to change and engage in conservation strategies (Harris et al., 2012).	Paying for fish through transactional sex is reported in many African countries (Béné and Merten, 2008). Population health environment programmes have proved effective entry points into communities and upon which marine resource management can be built (Harris et al., 2012).

### 3. Results

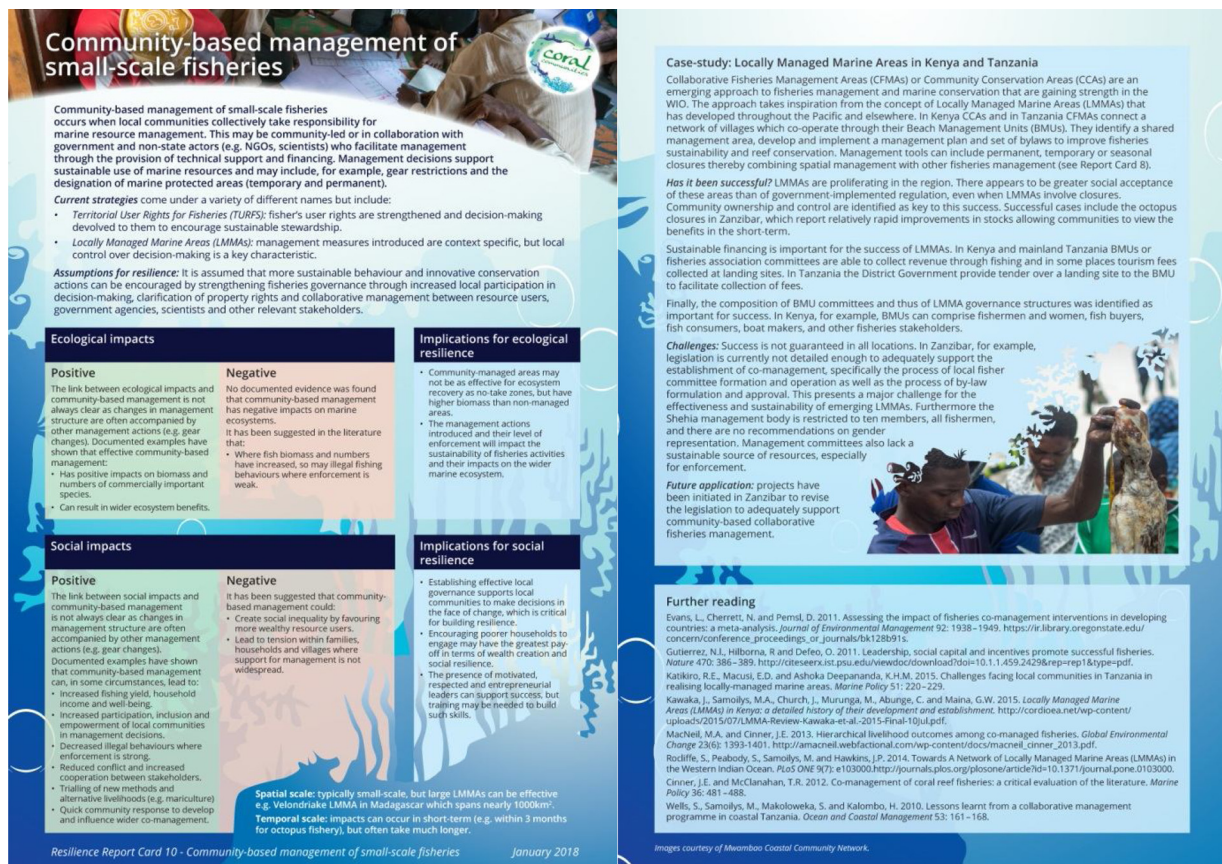
#### 3.1. Impacts of strategies on resilience

The detailed findings from the literature review are presented as report cards (available at [https://pml.ac.uk/Research/Projects/Coral\\_Communities](https://pml.ac.uk/Research/Projects/Coral_Communities)) that summarise information for marine managers and development practitioners (Fig. 2). Here we report overall and illustrative findings from the review (Tables 2 and A1) alongside data from the expert elicitation workshop.

With the exception of Marine Protected Areas (MPAs), the literature review found limited evidence evaluating the impacts of the different strategies in the WIO. Instead, the impacts of the strategies presented

(Table A1) largely builds on global literature. Of the papers or reports that do present evaluation evidence, they typically focus on either social or ecological impacts (e.g. Turner et al., 2007). Notable exceptions include Crona et al. (2010) and Kittinger et al. (2012), who explicitly use a resilience or social-ecological systems framework in their studies. Generally, the social or ecological impacts, and any implications for resilience, are assumed or anecdotal in nature.

During the workshop, participants prioritised four strategies for further discussion on the basis of interest: micro-finance, alternative livelihoods, reef restoration and payment for ecosystem services (PES). The group focusing on micro-finance also discussed community-based management of small-scale fisheries (also known as Community Conservation Areas or Tengefu in Kenya and Locally Managed Marine



**Fig. 2.** Example report card presenting literature review and workshop findings for community-based management of small-scale fisheries. Each report card provides a brief description of the strategy, the documented and/or supposed ecological and social impacts resulting from the strategy, the implications of this for social and ecological resilience, a case study from the WIO and further reading. 14 report cards are available in total.

Areas in the international literature, from herein LMMAs).

### 3.2. What has been successful for social and ecological resilience building?

The 14 strategies reviewed vary in the extent to which they have been applied in the WIO region. Some are used extensively, such as the introduction of alternative livelihoods and the designation of MPAs. Others are more niche, such as coral gardening, which is of considerable interest but typically small-scale in terms of on the ground activity. Strategies such as PES schemes are relatively new to the WIO region and are still to be fully-tested. Only one functional coastal scheme was identified in Kenya (Mikoko Pamojo – Mangroves Together), although others are in development (e.g. Blue Ventures Blue Forests project in Madagascar). LMMAs are not entirely new to the region (e.g. Makoloweka and Shurcliff, 1997), but have gained increased traction in the last two decades (Rodcliff et al., 2014). Of the strategies prioritised by workshop participants, evidence of the positive impacts on social and ecological resilience in the WIO was available for three: micro-finance, alternative livelihoods and LMMAs. The fourth priority strategy, coral reef restoration, was thought to support primarily ecological resilience, with only limited impact on social resilience, as suggested by Ng et al. (2016). Community level benefits were only known when coral gardening is applied with other strategies (e.g. creation of artificial reefs using reef balls and in conjunction with management planning).

Micro-finance schemes were considered to be successful because all community members can typically access them to invest in new or existing businesses or to help out in times of hardship (e.g. Corona et al. 2010). Success (in terms of resilience building) was reported to be more likely where members are supported to develop by-laws to guide

repayment of loans and where members are trained in business or project start-up and management. Contributions to ecological resilience were deemed possible but not guaranteed. Participants highlighted that micro-finance is not always linked to incentives to discourage unsustainable behaviours.

The success of alternative livelihoods to fishing was reported to vary according to country. In low income countries such as Comoros and Madagascar, eco-tourism and mariculture (e.g. seaweed farming and sea cucumber production) were seen as important opportunities. The introduction of seaweed and sea cucumber farming to fishing families in Madagascar by the NGO Blue Ventures (Ateweberhan et al., 2014) was considered a particularly successful model, supporting marine resource management and increasing the income of participating families. Women were reported to particularly benefit. Women were commonly early adopters of mariculture looking to supplement household earnings. In countries with higher wage expectations, participants doubted the replicability of this strategy. In Mauritius and Seychelles, eco-tourism is promoted as an alternative to fishing as well as professional level occupations, including ‘green collar’ jobs. What-ever the alternative livelihood introduced, participants considered that its success depends upon it meeting the needs, expectations and skills capacity of the communities involved; that there is a real commercial market for the good or service resulting from the alternative livelihood; and that communities can feel that their effort is real and has tangible success.

For LMMAs, literature review findings and workshop participants’ observations concurred that success varies by location and according to the ability of local communities to make decisions about local resource use (e.g. Kawaka et al., 2017). Examples in Madagascar, Kenya and mainland Tanzania were reported to build both social and ecological

resilience following changes in legislation to support local decision-making. Participants highlighted that early attempts to replicate this in Zanzibar failed, largely because decision-making power was not held in local communities and differing political allegiances affected collaboration between key stakeholders. Furthermore, legislation supporting the establishment of LLMA is enabling rather than directive and relies on communities choosing to implement it. Many communities, however, lack the knowledge, capacity and confidence to do so. More recently, facilitated by NGOs, temporary closures for octopus and other species with clear and rapid benefits for communities have required the establishment of by-laws enabling local decision-making, consequently enhancing resilience. Appropriate legislation and external support may therefore be important to resilience building.

### 3.3. Who benefits?

The objectives of the resilience-building strategy will determine who or what benefits. For example, mangrove and coral reef restoration aim to create ecosystem benefits, but these benefits are also anticipated to support the direct and indirect users of these ecosystems (Abelson, 2006; Rönnbäck et al., 2007; Okubo and Onuma, 2015). In contrast, population health and environment (PHE) strategies focus on improving community health and family planning, acting as an effective community entry point and setting the foundations for engagement in resource management (Harris et al., 2012). Similarly alternative livelihood strategies aim to support individual households and communities while at the same time relieving pressure on fisheries resources and coastal ecosystems (Wibowo et al., 2012; Cinner, 2014).

Evidence from the literature indicates that all strategies reviewed can provide both ecosystem and societal benefits (Table A1), but the degree to which they can achieve this as singular strategies varies. For example, participants noted that micro-finance, while beneficial to the individual receiving the credit (e.g. fishers), may have negative impacts on fish resources. Credit may encourage further exploitation of vulnerable stocks unless associated with strategies to reduce unsustainable fishing practices. The same may be true of earnings from alternative livelihoods. Workshop participants highlighted, however, that strategies are rarely implemented in isolation and often require, as a minimum, education, training and sensitisation, and may involve compliance eligibility.

For some strategies, the literature indicated that only a small proportion of a community may benefit. For example, alternative livelihoods and MPAs may not involve all community members (e.g. Katikiro, 2016). The importance of equitable distribution of benefits was recognised by workshop participants. According to one participant, this is particularly so for PES schemes; how benefits are distributed can be a source of conflict, even before any monies have been received. Participants noted that the sharing mechanism needs to be transparent.

Other strategies, such as micro-finance, may potentially benefit all community members. Schemes often target women, however, supporting them to develop businesses and other income sources. Only one formal example of micro-finance was known to participants, the VICOPA (Village Community Banks) in Tanzania (Kamat, 2018), but participants reported that community saving schemes are used in some coastal communities (e.g. in the Comoros and Madagascar). Participants knew of little evidence beyond anecdotes about the benefits these schemes had created.

In some cases, not all benefits were reported to accrue to the communities involved with the strategy. For example, the tourism sector was considered an important beneficiary of reef restoration. Participants indicated how this provides opportunities for other strategies, such as the development of alternative livelihoods, and further emphasises the need for multiple strategies for successfully resilience building.

### 3.4. Are the strategies future-proof?

Global environmental change is likely to result in significant change to coral reefs in the WIO region, with some reefs predicted to suffer severe annual bleaching by 2033 (van Hooidonk et al., 2016). Evidence also indicates that the capacity of many reefs in the Indian Ocean region to keep pace with rising sea levels is diminished (Perry et al., 2018), which will increase coastal wave exposure. While strategies may demonstrate success in building resilience to present conditions, it is highly uncertain how effective these strategies may be in the near-future.

Participants raised particular concern about reef restoration through coral gardening. Participants were positive about selecting corals resilient to previous El Niño events for transplantation, but highlighted how the causes of reef decline (e.g. climate change, fishing and pollution) remain unmanaged. It was considered a mitigation measure. Similarly, micro-finance, when unlinked to sustainable resource use, was considered a significant barrier to resilience building. Donor support for micro-finance schemes was also recognised as a key weakness, with anecdotal evidence of schemes collapsing once donors have departed. Workshop participants recommended a move towards competitive grant schemes for specific community conservation related projects as an alternative source of finance.

Strategies reliant on international markets (e.g. sea cucumber and seaweed production, carbon trading and other potential PES schemes) also raised concerns. Participants blamed falling prices for sea cucumber and seaweed farming on over promotion, supplier saturation and excess production. The literature, however, suggests that this is more a consequence of low quality production and processing, and the absence of Good Manufacturing Processes and Hazard Analysis Critical Control Point methods (Perez and Brown, 2012; Robinson and Lovatelli, 2015). Both issues illustrate the need to understand international market requirements and for external support for communities wishing to engage with them. This includes Governmental support as well as from other agencies (such as NGOs) for hard and soft resources (e.g. financial resources, policy promotion and knowledge exchange).

Many participants viewed the development of LMMA as important to the future resilience of coral reefs and dependent communities, a view supported by the literature (Cinner and McClanahan, 2012; Cinner et al., 2016). Community-level decision-making about local resource use in the face of change was considered essential for resilience building and is relevant to the successful implementation of many other resilience building strategies. Workshop participants suggested that appropriate assistance needs to be in place for LMMA success including formal devolution of decision-making power to local communities; creation of appropriate co-management relationships; support for the development of resource management plans by communities; and availability of resources for monitoring and enforcement.

### 3.5. Cross-cutting themes

Cross-cutting themes important to the success of all resilience building strategies emerged from the literature review and workshop discussions. These included education, an awareness of local values and customary practices, and improved monitoring and evaluation. Education was identified as necessary in any resilience building strategy because it can lead to informed decision-making, acceptance of resilience building measures, but also skills development. Participants recognised a need for training in business, product or service development, but also for decision-making and conflict resolution and avoidance.

Awareness of and influencing communities through faith-based and customary practices was discussed at length between workshop participants. Although not relevant in all societies, faith and customary leaders can be influential actors within communities (Cox et al., 2014; Steenberg, 2016). They can provide important entry points into

communities and act as agents of change. Compliance was considered greater with resilience building strategies that aligned with local values and priorities.

The general absence of monitoring and evaluation data hampered both the literature review and workshop participants to articulate the successfulness of strategies at building social and ecological resilience in the WIO. While recognising that monitoring can be resource intensive and may require skilled personnel (e.g. reef monitoring), all participants considered that better monitoring and evaluation data were urgently needed. They also highlighted how this must be accompanied by sustainable sources of finance, skills training, and the sharing of experiences across the region.

#### 4. Discussion and implications for policy

##### 4.1. Better monitoring, evaluation and lesson learning needed

Our understanding about which strategies are successful in building resilience is challenged by the relative absence of evidence for each strategy. The multi-stakeholder workshop helped fill gaps and identify lessons, such as the need to link strategies to sustainable behaviours, adapting strategies to context and the importance of decision-making at community levels. If resilience related policy objectives are to be met, however, long-term monitoring and evaluation is needed to support more effective decision-making (Ferraro and Hanauer, 2014; Stem et al., 2005). Existing monitoring and evaluation efforts are often too short and undertaken within specific project lifetimes that rarely reflect the scales of stress accumulation (Ferraro and Pattanayak, 2006).

From a process perspective, programme success is often hard to assess because programmes are rarely implemented with evaluation in mind. Evaluation must be planned from the outset, with both social and ecological data collected before and after implementation (Stem et al., 2005). Communities could contribute to monitoring and evaluation, enabling it to last beyond the lifetime of a project and which may itself encourage engagement in the resilience building strategy (Uychiaoco et al., 2005). Resilience however is complex, comprising objective as well as subjective and relational aspects (Brown and Westaway, 2011). Research evaluating how different local and scientific knowledge systems reflect complexity thinking and capture information important for understanding resilience trends found that many resilience ‘indicators’ were missed in local knowledge and participatory monitoring approaches (Evans, 2010). New evaluation methods are needed that allow the capture of the multi-dimensional components of both social and ecological resilience within the constraints experienced in many developing country contexts.

##### 4.2. Disaggregated understanding of resilience is missing

Who benefits from resilience strategies remains unclear. Evidence in the literature rarely reports the disaggregated ecological or social effects of strategies, yet this has implications for the design of resilience policy. For example, fisheries management may restore biodiversity, but species function may be more important to ecological resilience than overall biodiversity (Bellwood et al., 2003). Marshall and Marshall (2007) suggest that social resilience should be measured in terms of perception of risk, ability to plan, cope and level of interest in change yet no evidence was found linking strategies to these themes. Gender equity is also largely missing from the social-ecological resilience framework (Kawarazuka et al., 2017). Strategies to date have not sought to understand or address the question of how men and women negotiate natural resources and how they are affected by, and able to respond to, shocks in the ecosystem (Kaijser and Kronsell, 2014; Kawarazuka et al., 2017), yet gender mainstreaming is recognised as central to sustainable development and environmental policy and practice (Arora-Jonsson, 2014). With the possible exception of PHE initiatives, a similar critique may be leveled to the lack of focus on household dynamics and resource

allocation, with little consideration of how decisions made within individual households impact wider resource management. For example, who has access to income within a household could have a greater influence on household resilience than a simple increase in income (Weeratunge et al., 2014).

Resilience policies and the strategies implemented to deliver them therefore need to focus on ways that different groups of actors construct ideas of resilience. Engaging with organisations that tap into individual, household and community values (e.g. women’s organisations, health services, faith-based organisation, customary institutions) may be an important route for supporting the more subjective and relational aspects of resilience building. Multifaceted strategies with mechanisms for equitable benefit sharing and capture between individuals, communities and sectors are also needed.

##### 4.3. Greater recognition needed of multiple people-nature interactions

Strategies must take into account the myriad ways that people and nature co-exist, incorporating both social and ecological resilience. For example, while evidence indicates that no-take marine reserves may provide the best opportunity for increasing reef ecological resilience, they may lead to growing inequality, loss of income and ultimately an erosion of social resilience (Bennett and Dearden, 2014). Similarly, strategies for increasing income (e.g. through improved access to micro-finance or the development of alternative livelihoods) may provide a good opportunity for building social resilience, but unless accompanied by strategies that encourage sustainable fishing practices, they may lead to increased fishing pressure and a decrease in reef resilience (Crona et al., 2010). Cinner et al. (2016) suggest that the most successful strategies may not generate the greatest social or ecological gains but make a contribution across the social-ecological spectrum.

Consideration of the role of agency, the choices individuals make in determining which strategies they undertake, is also needed. People and communities are not passive in the face of change; they have their own priorities that may be distinct from those of the external organisations supporting the implementation of resilience building strategies (McLaughlin and Dietz, 2008). People’s own individual framings therefore affect the choices they make and the way they perceive and experience vulnerability. Understanding individual and social values, as drivers of behaviour, is central to building resilience in terms of identifying what might be acceptable strategies for an individual and a community, and hence the policies needed to promote them.

#### 5. Conclusions

This paper identified multiple strategies currently applied to improve ecological and social outcomes for coral reefs and dependent communities. It documented how these strategies are assumed to influence social and ecological resilience and evaluated the existing evidence, using the WIO as its focus. It found that while numerous strategies are being implemented across the region, often in combination, the mechanisms to document and share results and develop best practice to support resilience building and effective policy design is currently missing. Practitioners in the region are a wealth of expert knowledge but are not sufficiently connected to each other to share and compare experiences. Systematic processes of monitoring, evaluation and data-sharing are also lacking. Important insights into trade-offs between social and ecological resilience or the different beneficiaries of key strategies remain ad hoc reducing the ability of decision-makers to design policies targeted at resilience building. If the Sustainable Development Goals and regional resilience objectives are to be achieved, there is a clear opportunity to strengthen knowledge networks, processes and systems in this region with this paper providing a baseline of current understanding of resilience in practice.

## CRedit authorship contribution statement

**Caroline Hattam:** Conceptualization, Funding acquisition, Methodology, Investigation, Project administration, Writing - original draft, Writing - review & editing. **Louisa Evans:** Conceptualization, Funding acquisition, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Karyn Morrissey:** Conceptualization, Funding acquisition, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Tara Hooper:** Conceptualization, Funding acquisition, Methodology, Investigation, Writing - original draft, Writing - review & editing. **Kathy Young:** Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Writing - review & editing. **Fazlun Khalid:** Funding acquisition, Investigation. **Mark Bryant:** Investigation, Visualization. **Ali Thani:** Investigation, Writing - review & editing, Resources. **Lorna Slade:** Investigation, Writing - review & editing, Resources. **Chris Perry:** Funding acquisition, Investigation, Writing - review & editing. **Susanne Turrall:** Funding acquisition, Investigation, Writing - review & editing. **Dominica Williamson:** Funding acquisition, Investigation, Visualization, Writing - review & editing. **Andy Hughes:** Investigation, Visualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.envsci.2020.02.006>.

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