The status and potential of Myanmar's marine fisheries

A fishery status evaluation and roadmap for reform in the face of climate change

Alice Thomas-Smyth, Willow Battista, Kristin Kleisner, Rod Fujita, Kendra Karr, Alexis Rife, Carlito Turner, Sarah Poon, Merrick Burden

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Executive summary

The coastal and marine ecosystems of Myanmar have been subject to wide scale overexploitation and anthropogenic stress for decades. This has fundamentally altered their status and composition. These impacts have brought with them substantial impacts to fishing dependent communities and have put at risk the resilience of Myanmar's marine socio-ecological systems. The source of these anthropogenic stressors appear to have begun increasing significantly starting in the 1960s with the rapid unmanaged growth of Myanmar's marine fishery sector and the heavy exploitation of marine resources that followed. When combined with increasing levels of coastal development, upstream mining, deforestation, agriculture, and climate change, this has led to several observed ecosystem-level changes. Available information indicates that Myanmar's marine ecosystems are far less complex, diverse, and abundant now compared to several decades ago, and are dominated by species at relatively low trophic levels. These impacts and changes to the marine ecosystem threaten the security and continued viability of Myanmar's fisheries, which are considered the second most important source of nutrition in the country after rice, as well as the second most important industry in economic terms. Many coastal communities rely on fisheries as a critical source of nutrition and one of the only viable sources of income available. All together this means that sustainable and resilient fisheries are critical for the well-being of Myanmar's people.

In this document, we use available information, models, and well established principles of sustainability and resilience to assess the status and potential of Myanmar's fisheries and their resilience to climate change. We then develop a roadmap consisting of 18 key recommendations for improving Myanmar's marine fisheries. These recommendations focus on ways to rebuild fisheries so that they are A) better able to meet triple-bottom-line outcomes, and B) that they are resilient to climate change. While our evaluation leads us to conclude that Myanmar's fisheries have been substantially depleted and are not resilient on any socio-ecological dimension, substantial opportunity exists to reform management and improve Myanmar's fisheries in meaningful ways.

Our recommendations can be summarized as:

- Implement primary fisheries management via expanding participatory co-management systems, enact adaptive management programs with data-limited methodologies, and create monitoring systems with whole ecosystem indicators.
- Enhance the resilience of the ecosystem by expanding the existing network of Locally Managed Marine Areas through targeted funding to protect the full range of habitat types that support Myanmar's fisheries as well as continuing to improve efforts to replant deforested mangroves via training programs for local communities.
- Improve the management and governance of Myanmar's fisheries with sound science, specifically research to establish important metrics such as the size at maturity for major target stocks, the size composition of catch, and spawning/nursery areas and seasons. The Department of Fisheries (DoF) should also establish participatory goal-setting for the commercial fisheries before addressing management reform.

- Establish social resilience by strengthening secure and exclusive fishing rights via clear communication to local communities about access rights and regulations and increasing the capacity to monitor and enforce exclusive fishing rights.
- Begin to build economic resilience by researching and developing alternative livelihoods for coastal and marine fishers (including aquaculture) to mitigate impacts from new management measures. It will also be important to cultivate a competitive environment with more fish buyers and processors to command better prices, particularly in the case of establishing a larger international market.
- Build climate change resilience by adopting forward-looking management and conducting further research into the anticipated impacts of climate change, particularly on stock shifts for key species, in a collaborative partnership with neighboring nations. These collaborative partnerships should also facilitate moving towards discussions of formal transboundary agreements, potentially including more distant nations depending on anticipated stock movement.
- Develop fairness and equity in Myanmar's fisheries via participatory decision-making, ensuring the inclusion of historically marginalized groups and transparency of the process, and building capacity among all stakeholders to allow complete participation.

Introduction

Marine and freshwater fish play a central role in Myanmar's culture and economy, and are also pivotal to ensuring food security in the country, accounting for nearly half the animal-source protein consumed (FAO, 2016) and second only to rice as a staple of the national diet. However, years of unmanaged fishing have greatly diminished the nation's marine resources, resulting in dramatic reductions in the ability of fisheries to produce food, jobs, and revenue; a loss of biodiversity; and a risk of ecosystem collapse, especially as ocean waters warm and acidify. Over one million fishers are registered to fish in Myanmar, and the combined vessel capacity results in a level of fishing power that is widely viewed as exceeding the regenerative capacity of fish stocks in the region. Thus, there is a critical need for understanding and detailing a path to restoration for the highly altered ecosystems and fish stocks in Myanmar, where baseline conditions are poorly understood or unknown, and where decades of overfishing have depleted key predators and altered food webs. A simplified ecosystem like this tends to be less stable and resilient in the face of changes like those associated with climate change. Similar challenges exist in many other marine ecosystems, especially in East and Southeast Asia and other equatorial developing countries. What we learn in Myanmar can therefore provide valuable lessons for other countries and regions seeking to reform their fisheries and build resilience to climate change.

Currently, governance capacity in Myanmar is extremely limited, and the existing fishery scientific and management structures are nascent at best. Thus, the appropriate approach to begin to move the country's fisheries towards sustainability and resilience is to implement "primary fishery management," as outlined by Cochrane et al. (2011). Primary fisheries management entails the use of best-available science and information in a precautionary way to facilitate sustainable use of resources; it hinges on acceptance of uncertainty and of limited management capacity, and relies on precautionary, adaptive management to address these issues. Moving towards primary fisheries management will help reform fisheries in Myanmar almost immediately – even with limited data, governance, and social capacity.

Environmental Defense Fund (EDF) has been working with fisheries and marine ecosystems in Myanmar in various capacities since 2015, and began a three-year project in 2017 to strengthen scientific understanding of Myanmar's marine ecosystems and capacity for fisheries management and addressing a future under climate change. In this document we outline recommendations for improving the sustainability of Myanmar's fisheries and developing their resilience within this primary fishery management context using the knowledge and research acquired over several years. We describe strategies for managers, policy makers, fishers and other stakeholders working to reform the fisheries of Myanmar. Executing these strategies will improve the performance of Myanmar's fisheries and also increase the resilience of the system to current and future threats, thus helping to improve the well-being of those who depend on it both now and into the future.

Defining a sustainable, resilient system

To reform fishery management systems in Myanmar and elsewhere, it is valuable to have clear goals. Finding this clarity is especially challenging in highly altered ecosystem contexts, and also in the face of climate change, which threatens to render historical baselines meaningless. In such contexts, what exactly does it mean to say we want to create sustainable, resilient systems?

Here we present a "checklist" of attributes of a sustainable, resilient fisheries management system compiled from the literature, and drawing especially on the Stockholm Resilience Centre's Principles for System Resilience (Biggs et al., 2015) and on EDF's Catch Share Design Manual (Bonzon et al., 2013). The resulting ten-item checklist (below and Figure 1) can be used to evaluate the current status of fishery management systems in Myanmar, and also to help guide interventions and actions.

Principles that confer a sustainable fishery management system:

- Limit mortality – Fishing mortality is limited to scientifically sustainable levels.
- Provide for secure, exclusive rights – Fishing privileges are assigned to an exclusive group of participants for a sufficiently long time to allow participants to realize future benefits.
- Ensure accountability – Participants are required to stay within their allocated share of the overall catch and/or comply with other controls on fishing mortality.

These three principles were developed through extensive research by EDF on fishery management systems all over the world to help confer the basics of sustainability in any fisheries management system. The more completely a program is designed to incorporate these three attributes, the higher the likelihood of a biologically sustainable fishery that confers desired socioeconomic benefits.

Principles for System Resilience:

- Maintain diversity and redundancy – System has many different components (e.g., species, actors or sources of knowledge), and sufficient redundancy among them to provide 'insurance' for the loss or failure of any individual component.
- Manage modularity and connectivity – System components are sufficiently well-connected to allow them to draw on each other in order to overcome and recover from disturbances, but are sufficiently modular (separate) to prevent the rapid spread of disturbances across the entire system so that all components of the system are impacted.
- Manage slow variables and feedbacks – Key slow-moving variables and feedbacks that maintain the social-ecological regimes which produce desired ecosystem services, as well as the critical thresholds that can lead to a reconfiguration of the system, are identified, and actively monitored and managed around.
- Foster complex adaptive systems thinking – The complex interactions and dynamics that exist between actors and ecosystems in a social-ecological system are acknowledged,

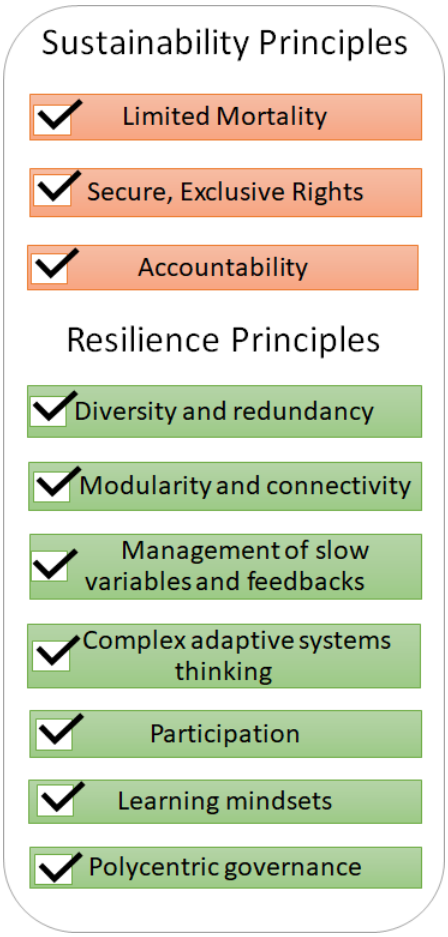
and, to the extent possible, these interactions are incorporated into management decisions.

- Broaden participation – Broad and meaningful participation is encouraged, which builds trust, creates a shared understanding and uncovers perspectives that may not be acquired through more traditional scientific processes.
- Encourage learning mindsets – There is recognition that system knowledge will always be partial and incomplete. Learning and experimentation through adaptive and collaborative management ensures that different types and sources of knowledge are valued and considered when developing solutions, and leads to greater willingness to experiment and take risks.
- Promote polycentric governance structures – Collaboration across institutions and scales improves connectivity and learning across scales and cultures. Well-connected governance structures are able to swiftly deal with change and disturbance because they are addressed by the right people at the right time. Highly centralized governance often results in management that does not account accurately for local facts on the ground.

When these seven principles are incorporated within a socio-ecological system, the system is more likely to be able to anticipate change, adapt, reorganize, and evolve into configurations that continue to produce desirable levels of ecosystem goods and services, even as climate change and other stressors interact unpredictably over time.

Additionally, these seven principles can be considered in terms of how they could manifest along three dimensions of a system: ecological, management/governance, and socio-economic. Some of the principles clearly relate to just one of these dimensions (e.g., polycentric governance structures relates to just the management/governance dimension), however most will manifest in multiple dimensions of the system. For example, the ecological dimension can be diverse and have high connectivity, but so too can the socio-economic dimension. Similarly, participation is a critical component to resilient governance and management, but it must also be a feature of other social dimensions.

Figure 1: *Checklist of Principles of a Sustainable and Resilient Fishery System*

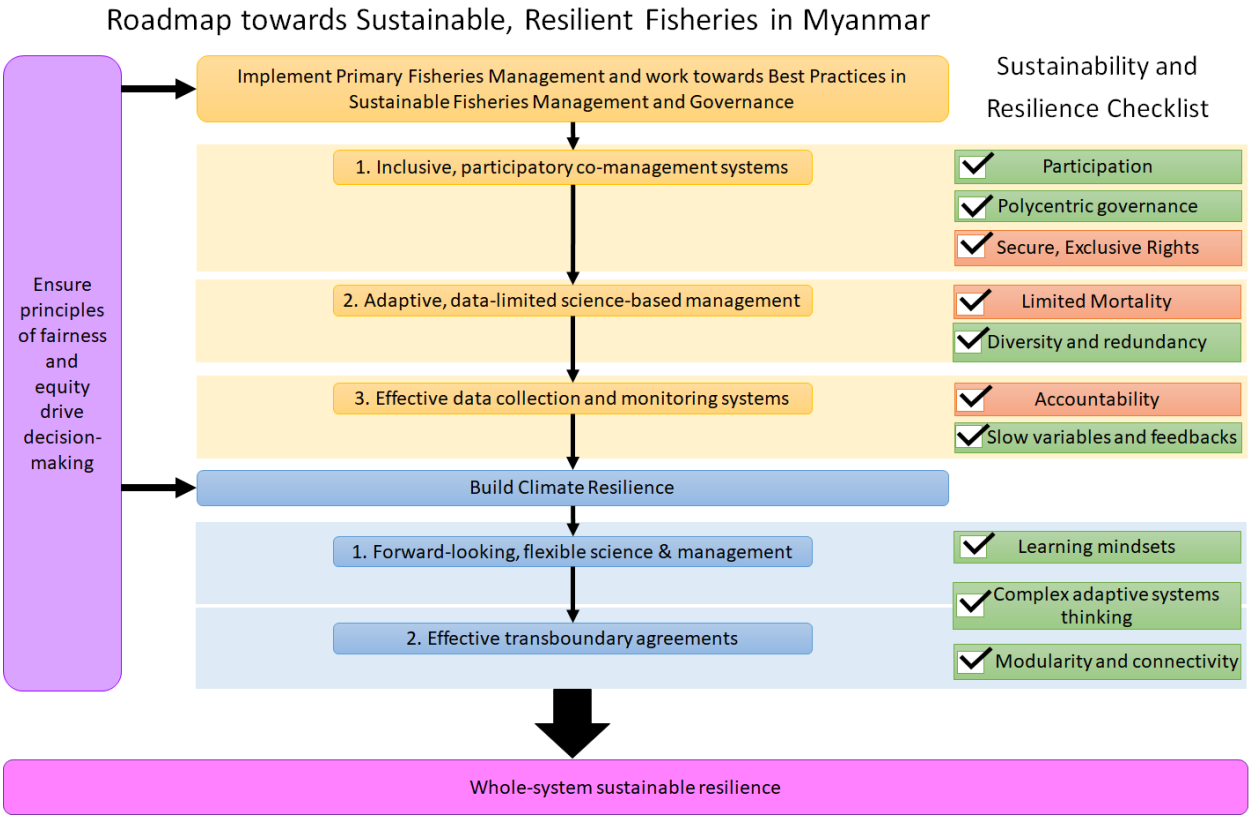


Roadmap to sustainable, resilient fisheries in Myanmar

In the following sections, we will first present an analysis of the historical and current conditions throughout Myanmar's fishery system, then explore the likely climate change-driven impacts on this system, and finally provide a set of recommendations for policy makers, fishery managers, non-governmental organizations (NGOs) and other stakeholders wishing to improve the sustainability and resiliency of the fisheries in this country. These recommendations can be thought of as a "roadmap" to sustainable, resilient fishery systems in Myanmar. Moving through this roadmap can lead to the achievement of each item on the above checklist in this highly altered and extremely low-capacity setting, and as the impacts of climate change become more extreme over time.

Figure 2 presents a schematic of this roadmap, along with the checklist items that will be improved with progress at each step. While in practice there will almost certainly be overlap between the steps of the roadmap, and progress will be made toward multiple checklist items simultaneously, we present the roadmap steps roughly sequentially here, and indicate the checklist items which will be most directly and significantly impacted by actions at each step.

Figure 2: *Roadmap to sustainable, resilient fisheries in Myanmar*



Historical and current conditions

Ecological

Fisheries

Fishing pressure off the coast of Myanmar has grown over time. Myanmar's marine fisheries were considered to be lightly exploited until the late 1960s. This is because there was generally a preference for freshwater fish, and there were no major investments in seagoing vessels, ports, and other infrastructure within the country where most fisheries were confined to the inshore areas. In 1962, the People's Pearl and Fisheries Board was established (Soe, 2008), and marine fisheries began to develop, with increasing use of motorized fishing vessels, including bottom trawlers. In the 1970s, international agencies like the Food and Agriculture Organization of the United Nations (FAO) also contributed to capacity enhancements by providing funds for fisheries development and for cold storage capacity. Additionally, from winter of 1981 through summer of 1983, FAO conducted a series of surveys to help determine the extent of Myanmar's fisheries resources and opportunities for expansion and development. The Myanmar government has remained focused on the further development of its fisheries and aquaculture sectors since the 1980s when it experienced an economic downturn (Soe, 2008). This downturn spurred the government to invite significant foreign investments and led to the firm establishment of policies that encouraged fisheries and aquaculture development as a way to improve the nutritional and livelihood demands of its population. Myanmar's fishery exports also increased from the 1980s as a means to earn foreign exchange (Booth and Pauly, 2011).

Myanmar's fisheries are divided into inshore and offshore sectors. Inshore fisheries operate within 10 nautical miles of the shoreline with vessels up to 9m in length and engines under 25 HP (Department of Fisheries, 2018). Coastal waters may have been only lightly fished prior to the onset of industrial trawling in the Bay of Bengal during the 1950s, and throughout the 1960s. The use of trawls likely contributed to the depletion of sharks and rays due to lack of selectivity. During the 1980s local fishing effort intensified, and in 1989, foreign countries began to lease fishing rights from the Myanmar government to fish in offshore waters deeper than 15 m, under the 'Law Relating to the Fishing Right of Foreign Vessels'. Offshore waters were divided into 30 by 30 nautical mile blocks, creating 144 fishing zones (Pe, 2004). The influx of foreign vessels greatly increased fishing mortality and stock depletion during the 1990s. Foreign vessels were expected to remain within the offshore fishing zones, but they often entered inshore waters, causing conflict with artisanal fishers operating there. The 1990 Marine Fisheries Law gave artisanal fishers the right and the priority to fish in all zones (Pe, 2004), which further exacerbated conflict with the foreign industrial fleets. Additionally, despite the fact that trawling was banned within 8 km of the Rakhine and Tanintharyi coastal zones and within 10 km of the Delta region, local large-scale industrial vessels are allowed to operate within territorial waters, further exacerbating the tensions with small-scale artisanal fishers and rendering the ban ineffectual (Pe, 2004). Since the 1980s, there have been some improvements in the regulation of fishing activities such as gear restrictions, but these have been relatively minor, and DoF

acknowledged that illegal, unreported, and unregulated (IUU) fishing was and is rampant (Aung and Oo, 1999).

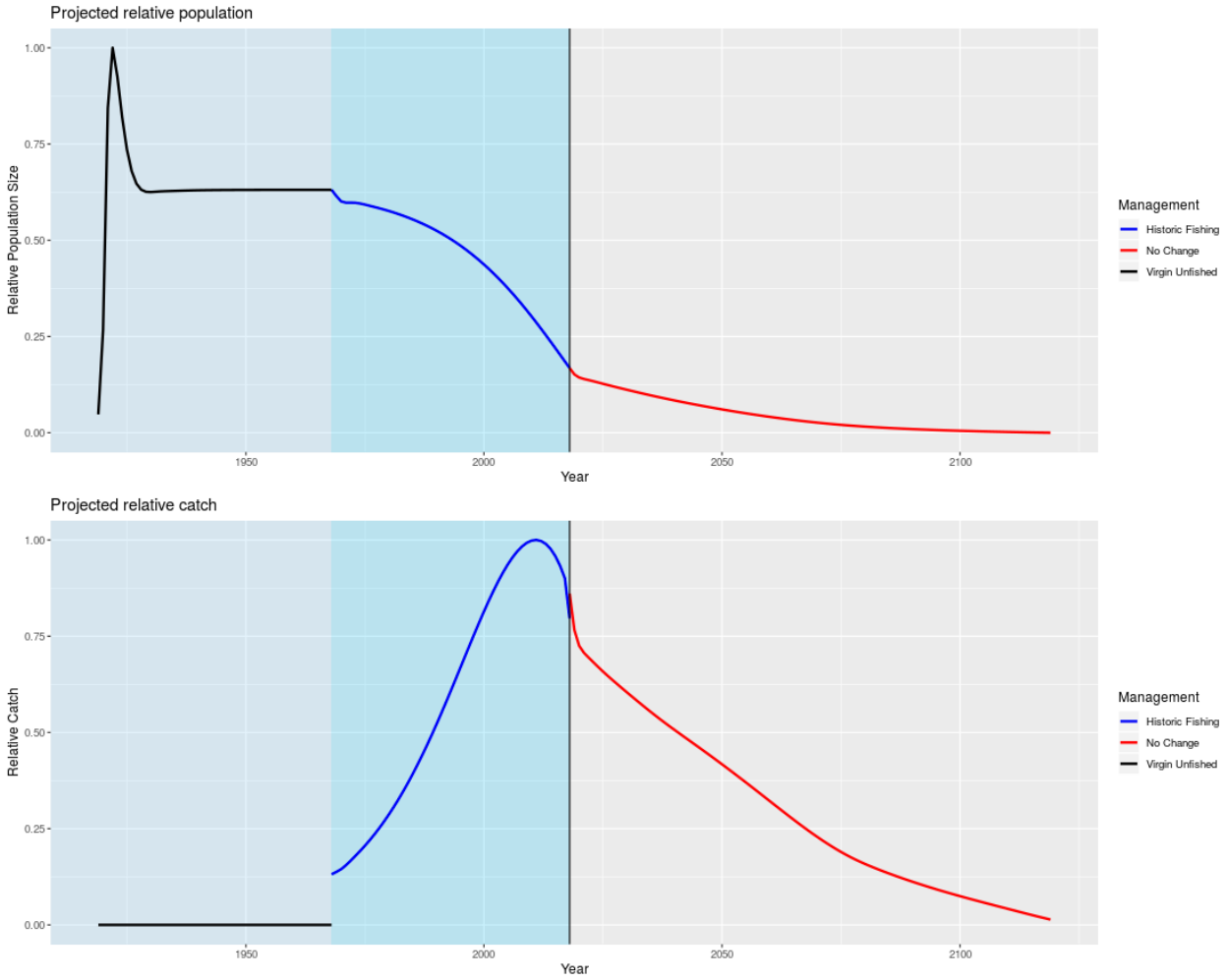


Figure 3: *Projections of relative population size and catch from Myanmar's commercial offshore fishery including estimated historical fishing effort if no changes are made to Myanmar's current fishery management regulations and fishing mortality remains the same as estimated. Projections sourced from EDF/WCS multispecies model (see section b.iii. for more information).*

IUU fishing has impacted the system over time in a largely unmonitored way, and it thus creates feedbacks that push the system towards an undesirable state. In other words, the additional unmeasured fishing pressure coming from the IUU vessels reduces stock health and catches. Ultimately this compromises the ability of the system to withstand additional fishing pressure (either legal or illegal) regardless of the management of the legal fisheries. Increasing fishing pressure may also cause many fishermen to increase their fishing effort as catches decrease in response to stock depletion, in order to maintain profitability. This further reduces stock health and catches, resulting in a negative feedback loop (see Figure 3). Legal and illegal fishing pressure may be pushing the system towards a threshold beyond which it will not be able to recover. In fact, in the case of much of Myanmar's coastal ecosystem, such thresholds may

have already been crossed as a result of destruction and alteration of important habitats through pollution, shoreline hardening and other factors, perhaps including overfishing. Observed ecosystem shifts include the replacement of highly biodiverse reef or mangrove-based habitats to lower-diversity, muddy bottom systems. Monitoring and managing with a consideration for such feedbacks will be critical for creating system resilience.

Ecosystems

Historical records from the late 1880s suggest that Myanmar's coastal waters abounded with a great diversity of fish species, including many species of large sharks and rays (Day, 1889). Unfortunately, this is not the case today. The focus of the Myanmar government on increasing fisheries and aquaculture production through investments in vessels and infrastructure (rather than in science and management) has contributed to the depletion of marine resources.

Starting in 1979, Myanmar has participated in fishery-independent surveys conducted by the Norwegian Research Vessel Dr. Fridtjof Nansen, which surveyed both environmental factors like habitat type and hydrographic conditions as well as fish abundance. The results of both pre- and post-monsoon surveys were used in 1980 to set an estimated maximum sustainable yield for the offshore fishery in Myanmar's exclusive economic zone (EEZ), marking a significant improvement in science-based management. The R/V Dr. Fridjof Nansen has returned to Myanmar's EEZ three more times since 2013 and has requested to survey again in 2021, with each survey trip expanding to accommodate more advanced abundance estimation methods and more oceanic indicator research including microplastic levels in the water and in fish. While these changes in survey design have rendered comparison between surveys difficult, it was estimated that between 1980 and 2013, the standing stock biomass of Myanmar's pelagic fish decreased by 80% from one million tons to 190,000 tons. Similarly, the demersal fish standing stock biomass decreased by 50% and size compositions revealed a significant reduction in the most valuable commercial species such as: threadfin bream, croakers, sea catfish, and snappers.

Furthermore, the impacts of overfishing have been exacerbated by upstream impacts, including increased runoff due to extensive deforestation; altered water flow patterns due to damming and irrigation; pollution resulting from poor waste management infrastructure and agriculture; direct impacts stemming from coastal development and increased population size as people have moved from agriculture to fisheries livelihoods; and the impacts of climate change (see below). Overfishing also appears to have depleted large-bodied predators such as sharks and rays, resulting in simpler, less complex food webs, which tends to reduce marine ecosystem resilience, thus magnifying the effects of other stressors. Together, these changes have led to drastically altered habitat structures and ecosystem mosaics throughout the country's coastal waters. Ecosystem modularity and connectivity have been reduced as mudflat habitats have expanded, and coral reefs, mangroves, and seagrass habitats have fragmented, shrunk, and disappeared from many areas.

Management structure and regulations

Existing regulations

The current management of Myanmar's fisheries is highly centralized in the DoF. Within the DoF, there is a central, federal management branch as well as a division for each of Myanmar's six coastal states, and within each of those there are smaller regional offices. Most of the current fisheries management regulations are set at the federal level and apply to all regions, with a distinction between regulations for the offshore and inshore fisheries. The regional offices primarily manage licensing for their local fisheries and are responsible for enforcement (with the assistance of the Navy). Thus, the system is far from "polycentric" (where multiple governing bodies interact to make and enforce the rules). Polycentric governance structures tend to be more effective for managing common pool resources such as fisheries (Ostrom, 1990), as well as more resilient because responsibilities are shared between different groups, including more localized groups that can have stronger incentives to carry them out (as opposed to a central authority), have access to better data, and/or have local knowledge on which to base management decisions. The government has recently been working to decentralize some of the regulatory and enforcement authority (see next section), which should improve this situation.

Due to limited capacity, the DoF relies on a few key regulations to manage the country's fisheries. The most significant of these is the country-wide closed season applying to both the offshore and inshore fisheries with slightly different terms. From May to August, there is a total moratorium on all fishing activity in the inshore fisheries, although compliance with the closed season is low. Similarly, there is a restricted season in the offshore commercial fishery from June through August. Historically, due to pressure from the industry, this restriction has been only a decrease in fishing pressure – allowing 75% of normal fishing activity – which was voluntarily agreed to by the fishers. However, years of negotiations have recently resulted in agreement to a total moratorium of fishing activity in the closed season starting in 2019, and both the government and the industry have noted improvements in catch rates following this closure. Despite this, many stakeholders have voiced concerns with the nationwide closed season due to the lack of science to support the closure dates. It is not clear what research informed the timing of the closure, as very little is known of the temporal or spatial reproductive habits of key target species, or of how suitable the seasonal closure is to the wide variety of species targeted in the inshore and offshore fisheries. The closure can be viewed as an element of primary fishery management, in that it is a precautionary reduction in fishing pressure (if fishing pressure does not increase above status quo levels during the open season, which would obviate the effects of the closure). As more information is gained on target species life cycles and fishing patterns – especially with respect to spawning, grow-out timing, and the timing and locations of fishing effort – the closed season can be more precisely designed to optimize stock rebuilding, yields and profits, and to reduce costs to fishermen.

Other controls for Myanmar's fisheries include ensuring licensing and registration of fishers and their vessels, closed areas and restrictions on certain gear types and configurations. Registration is handled regionally, where there is often a complete moratorium on new entrants

to the fishery. Both in the commercial fishery and in smaller, inshore fisheries, licensing has proven to be an effective measure to understand fishing effort, but does not appear to have been effective at controlling fishing effort or fishing mortality (at least for the inshore fisheries). This is due in part to the lack of capacity for enforcement of licensing regulations. Myanmar's EEZ contains multiple closed areas designated for conservation or other purposes, as spatial management is a highly prioritized conservation strategy within the country. These closed areas include fish and crab conservation areas and habitat-based closures for corals and mangroves, though it is unclear how effective these closed areas may be as very little data is available. Many types of gears have been prohibited in Myanmar, including pair trawling, electric/explosive/poison fishing, and push nets.

The DoF also prohibits bottom trawling close to shore (within 5 miles) and sets a minimum mesh size based on gear type. These sizes include differentiation for trawling, set nets, and the target (primarily 2" for fish and 1.5" for shrimp). The mesh size regulations face myriad criticisms due to the uncertainty and lack of substantial science to support the selected sizes, with many fishermen believing the mesh size is too small and should be set higher to avoid catching juveniles and protect the stock. This is complicated by the fact that illegal fishers use much smaller mesh sizes, undermining efforts by legal fishers to harvest more sustainably. In the offshore fishery, this concern arises primarily from illegal fishing vessels from nearby countries entering Myanmar's waters and fishing with small-meshed trawl nets; the presence of these illegal fishers from neighboring countries is considered a fact throughout the DoF and the offshore commercial fishing industry, though very little research into the topic has taken place. In the inshore fishery, many communities believe fishers from nearby villages are using illegal mesh sizes to fish, which is evidenced by campaigns by the DoF and the Navy to seize illegal gear and burn it on the beach.

Co-Management and Locally Managed Marine Areas

In recent years, there has been an increased interest in de-centralizing fisheries management particularly through co-management with local communities. These communities have subsequently developed a system of conservation-focused areas and sustainable fishing areas. In 2017, Myanmar officially recognized the creation of three Locally Managed Marine Areas (LMMAs), which are areas located in diverse coral and marine habitats within the Myeik Archipelago. The management of these areas has been granted to the local fishing communities often collaboratively with the DoF, and these fishing communities have exclusive fishing rights. LMMAs must be managed to include the existing fisheries laws as well as locally established laws to help achieve the LMMA objectives, which are developed by the local communities to improve sustainability and health of the area. Most often the LMMAs rely on community enforcement, however a process was developed to escalate infractions to the DoF and the Navy if they exceed the capacity of the local communities.

Along with LMMAs, in recent years Myanmar has been decentralizing fisheries management further via establishing Inshore Co-Management Areas, though there are no federal policy provisions specifically for marine fisheries co-management thus far. These co-management

areas are designed by local communities and approved by the DoF and regional government, and allow local fishing communities to come together and manage their nearshore fisheries. Local communities must form stakeholder participatory groups and develop a management plan for their area which, like the LMMAs, must include all existing fisheries laws as well as new regulations that can sometimes permit exclusive fishing rights to the communities. The first formal co-management area was designated in Mon State in 2017 for crab conservation, followed by the Kyeintali Inshore Co-Management Area in Rakhine state, officially designated in 2018 and the first with multispecies management.

Scientific and management capacity

As discussed above, management capacity is very limited, but is improving throughout Myanmar. While previously the heads of the DoF have not had experience with marine science or fisheries, they are taking measures where possible to incorporate more science into their management processes. Resources for this process, however, are insufficient, and the capacity for science within the DoF remains limited. Very few indicators of system or species health or change are consistently measured or tracked, and in general, management measures are not based directly on any form of scientific assessment.

However, scientific capacity throughout Myanmar is slowly improving, according to faculty at the universities. There are three universities in Myanmar with Marine Science Departments (Mawlamyine University, Myeik University, and Pathein University), and a fourth university dedicated to fisheries studies (both inland and marine) is in development. At two of these existing universities, faculty have seen an increase in enrollment to the Marine Science Departments and since 2016 university staff and students have been partnering with international institutions to perform and publish research in Myanmar. Because of this, academic understanding of biological and ecological processes is fairly high in the country, with particular focuses on coral reefs and mangroves. However, the capacity to synthesize key findings from research and convey the importance of the research or how to move from research to practical management steps is limited, creating a disconnect between new research emerging in the country and management measures.

Along with increased scientific capacity, capacity to establish sound management practices in fisheries via goal setting is increasing with assistance from non-profit groups and academia, made possible by efforts to collect fishery dependent data. As part of these efforts, in 2018 Wildlife Conservation Society (WCS) partnered with EDF to develop a multispecies model for the offshore fishery using data-limited methods to present to the DoF. We used fish life history data from multiple publicly available databases to construct a size spectrum model of many of the key species in the commercial fishery and the results of the Nansen surveys to estimate swept area biomass for Myanmar's three primary coastal zones. This model can project estimated future biomass and yield for the offshore fishery under several different management scenarios to demonstrate the different potential outcomes (Figure 4). The goal for this model was to illustrate the variety of management controls available to the DoF, the regulatory and enforcement effort necessary to enact them, and how different management controls meet

different goals. We returned in 2019 to present an updated version of the multispecies model with changes requested by stakeholders to more accurately reflect the fishery industry and management landscape of Myanmar including approximations of the impact of climate change, and the ability to account for variable compliance and a lack of enforcement. The DoF was enthusiastic about the potential for the model to help with the early stages of the management process and interested in developing further data collection and sharing arrangements to better support their decision-making. In particular, the model creates a tradeoff plot for the final year of the projection (up to 100 years in the future) that most highlighted the concerns and negotiations present in the offshore fishery management regulation process: comparing the relative ending biomass of the stock and the yield for the fishing industry (Figure 5).

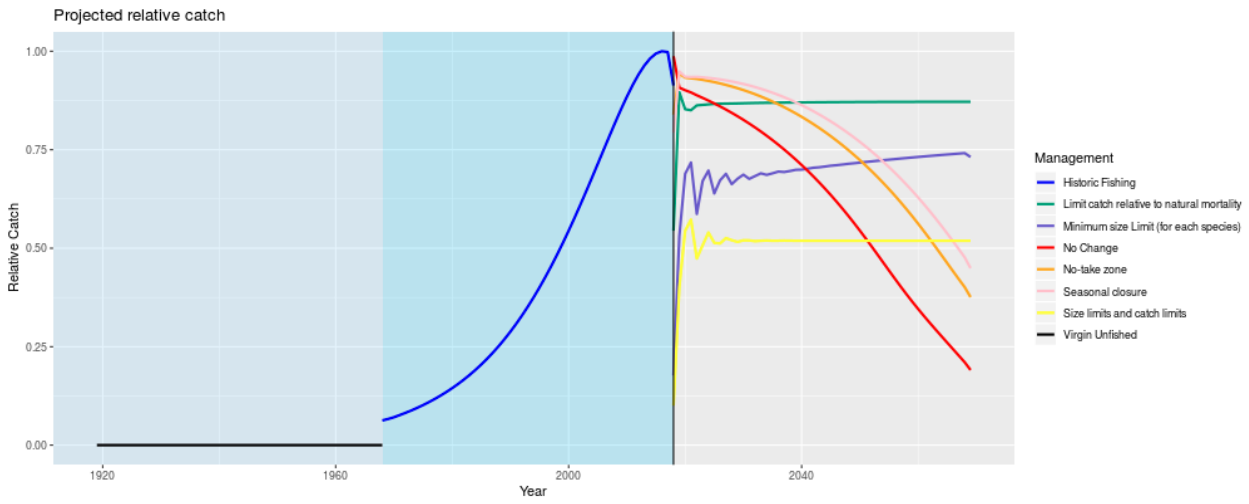


Figure 4: *Projections of relative catch from Myanmar's commercial offshore fishery including estimated historic fishing effort under a variety of management scenarios that impact the gear selectivity or fishing mortality of the fishery. This includes a scenario where no changes are made to Myanmar's current fishery management regulations and fishing mortality remains the same as estimated.*

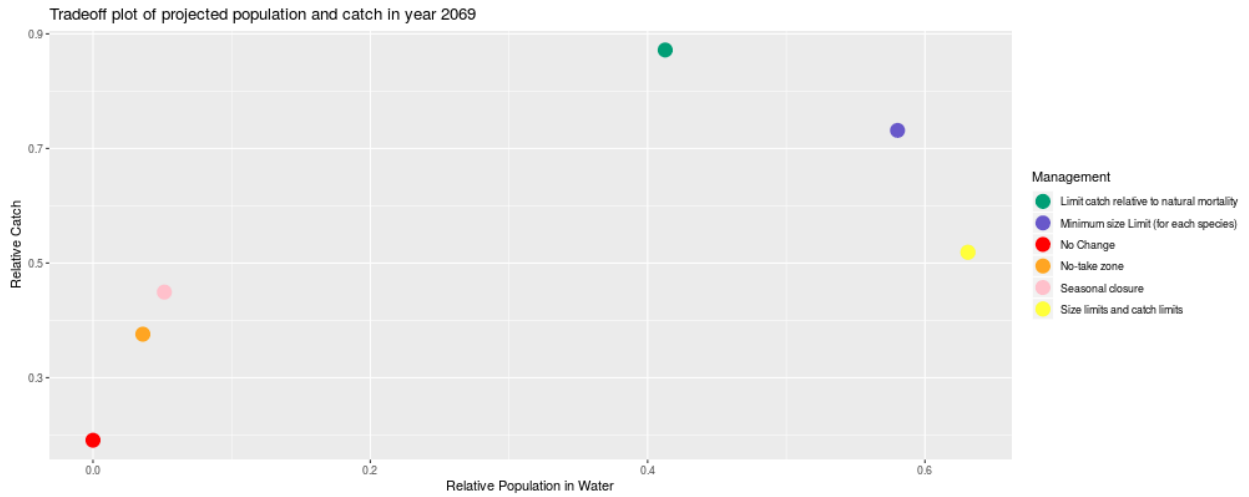


Figure 5: *Tradeoff plot of the total relative population size and catch for the final year of the projection (2089) under a variety of potential management scenarios for Myanmar's offshore*

commercial fishery. This includes a scenario where no changes are made to Myanmar's current fishery management regulations and fishing mortality remains the same as estimated.

Unfortunately the capacity for management enforcement is almost entirely nonexistent, with the DoF joining with the Navy and occasionally the Army to enforce regulations. The best source of current enforcement capacity lies in the co-management organizations, where close knit communities and social pressure provide incentives to comply with management regulations. However illegal fishing from outside groups (fishing vessels from neighboring countries in the offshore fishery, neighboring community fishers in the inshore fisheries) plagues all levels of fishery management in Myanmar.

In summary, most of the fisheries regulations set at the federal level are either ineffective because they are not based on scientific guidance, or undermined by illegal fishing activity, or both. Furthermore, a chronic lack of management capacity has led to the creation of static regulations that focus on controlling inputs to the fishery (e.g., fishing effort), rather than on directly controlling fishing mortality (which is essential for rebuilding stocks and maintaining them at levels capable of supporting sustainable, high yields) or on managing the entire system such that it can continue to generate desirable levels of a diverse array of ecosystem goods and services. This latter criticism is not unusual for fisheries management systems across the spectrum of governance and management capacities – many of the most sophisticated management systems in the world have failed to effectively implement ecosystem based fisheries management. However, implementing an adaptive management program is feasible in even the most rudimentary management context, and could be designed with the goal of gradually moving towards whole-system management, with each iteration of the decision-making process benefiting from improved knowledge and increased data availability, providing that an effective scientific data collection program is also initiated.

Socioeconomic dimensions

Social

The participation and buy-in of stakeholders to management regulations is important for good performance and resilience in any fishery. Due to the limited capacity for enforcement in Myanmar's fisheries, and lack of a clear path to increase this capacity, stakeholder participation and buy-in is even more critical. Deterrence of illegal fishing behavior through enforcement is not the only way to improve compliance with fishery regulations; indeed, building buy-in to regulations such that fishermen comply because they believe that is the right thing to do and/or that compliance will benefit them may often be superior to an approach based solely on deterrence.

Myanmar's inshore fishing communities are often long-standing fishing towns that pass fishing traditions down within families, thus developing a sense of stewardship among the community.

They often express a desire to manage their fisheries themselves and conserve the stocks that they rely on for nutrition and livelihoods, and that can support their children when they are old enough to go fishing. This mindset can also lead to a displacement of blame for dwindling catches, with legal fishers often claiming it is illegal fishers from outside the community that cause stock decline by using illegal gear. However, often when pressed these communities will acknowledge that legal mesh sizes are too small to actually protect juvenile fish, and that they would like to abide by or even extend closed seasons. Competition for limited resources and a lack of assurance that everyone will abide by more restrictive regulations prevents the fishers from voluntarily adopting effort controls that would be more effective in rebuilding depleted stocks. Multiple communities have explained they would like to take these steps, but only if all fishers in other villages do the same. Otherwise they fear that their share of the catch will be reduced and that they will lose income, while their conservation efforts will come to naught.

Meanwhile, in the offshore fishery, the Myanmar Fisheries Federation (MFF), a fisheries sector advocacy group, exerts considerable pressure over the regulations set by the DoF due to the importance of the commercial fishery export industry. The voluntary reduction of fishing effort during closed seasons indicated that the commercial fishery is open to participating in management reforms and that they see the benefits for the fisheries. In particular, they have acknowledged that currently they are catching only 10% of what they caught ten years ago and that they are catching different, smaller species and rarely seeing the large predator species they used to catch.

Thus, the offshore fishing industry has voiced support for sustainable management interventions in the fishery, however they do not agree with many suggested effort controls such as expanded gear restrictions. Primarily the industry focuses on seasonal and area closures as management options in the fishery, and expresses a desire for better research into the movement patterns and life histories of their target stocks to allow these management measures to be successful. Once again, as seen in the inshore fishery, the commercial industry blames reduced catches mainly on illegal fishing by vessels from neighboring countries, but also Myanmar fishers. The offshore fishery repeatedly calls for increased enforcement by the DoF to prevent this illegal fishing.

Thus, it seems that fishers in both the inshore and offshore sectors want to participate in fishery management decisions, perhaps laying the foundation for creating more inclusive processes that would increase the effectiveness and resilience of fishery management. In those fisheries where they have had this opportunity (i.e., the inshore sector and in the communities that have begun to adapt co-management agreements), they are engaged and enthusiastic. They also stress the need for more and better science on which to base management decisions, thereby indicating a desire to cultivate learning and adaptation. There does, however, seem to be some resistance to the idea that legal fishing activities – i.e., their own activities – might be negatively impacting their systems, and this is exacerbated by an open access system that encourages competition for limited resources and a race to fish. The effectiveness of recent collective action (to abide with the closed season, resulting in increased catches) could serve as evidence that

while illegal fishing probably impacts stock status and yields, reductions in legal fishing effort also have a strong impact and can lead to higher catches and profits.

Economic

Myanmar has seen considerable economic growth in recent years, reporting an annual GDP growth rate of 6.4% compared to an average for ASEAN countries of 5% (The World Bank, 2017), likely due to changes in governance and accessibility; however, Myanmar also has the highest share of its population living below the poverty line of all ASEAN countries (Asian Development Bank, 2019). The Government of Myanmar has identified fisheries as the second most important sector in the country following agriculture for its economic value and nutrition contribution. This has contributed to the current levels of overexploitation, with total production from marine fisheries nearly doubling from 2009 to 2018 according to the DoF.

Livestock and fisheries in Myanmar accounted for an estimated 8% of the GDP in 2017-2018, with some estimates of fisheries (both marine and freshwater) contributing 4% to the total GDP. Estimating a complete value of marine fisheries in Myanmar is extremely difficult, as the DoF does not report the value of catch that remains in the country. However, the total value of fish exported is reported yearly by the DoF, and in 2018 over US$710 million of fish, shrimp and other marine/freshwater species were exported, representing approximately 10% of total production from fisheries. Because we also know that marine fish catch typically accounts for 54% of total fish production in Myanmar, we can infer the economic value of marine fisheries to be very high for not only international exports but also local economies. Very little fish is wasted in Myanmar as bycatch discards. What cannot be consumed locally or exported is used in non-food industries such as fish oil and feed supply, accounting for nearly 30% of all fish production in 2018 (Department of Fisheries, 2018).

Offshore commercial fishing companies typically maintain their own jetty in the major ports of Myanmar and operate much of the ex-vessel processing themselves, as starting in 1988 the Government of Myanmar sold or began leasing all state run processing operations to private industry. In total, there are 123 processing plants in Myanmar for both marine and freshwater fisheries, of which 20 are approved to export wild caught fish internationally. The number of people employed in non-fishing fishery industry jobs has not been reported in Myanmar, but in 2015 the DoF reported that there were over 500,000 marine fishers in Myanmar split evenly between full-time and part-time fishing, with another 917,000 reported as ‘occasional’ fishers. It is not reported the proportion of inshore versus offshore fishers, however over 93% of registered fishing vessels in Myanmar are inshore vessels of 30 feet or less, indicating that a majority of the marine fishers in Myanmar participate in the inshore fishery (Department of Fisheries, 2018).

Livelihood and income generating opportunities are generally limited in small inshore fishing communities. Fishing is one of the few reliable income generating activities available to many, with agriculture and animal husbandry as other common livelihood sources. In these communities, we found that women play a large role in the fishing industry, with wives often joining their husbands at sea or partaking in post-harvest activities. Women often play an active role in the seafood trade in the communities we visited. As a result, household income

generating opportunities are closely tied to nearshore fisheries production. Traders purchase fish from individual fishers and sort catches by species, size, and quality. These fish are sold within the local communities or aggregated and sent to larger markets. In some fishing communities, traders work for, or are associated with major processing and exporting companies, such as Mawlamyine Holdings in Mon State, which purchase catches directly through arrangements with traders living in the communities. Once sufficient volumes of fish are aggregated, catches are then sent to regional facilities.

Traders also often serve as money lenders to fishers, maintaining accounts so fishers can access capital to purchase fishing equipment, repair vessels, or for other uses. Conditions of the loan may require that fishers receiving loans sell their catch to the collectors. It has been documented that fishers receive approximately 10% less than market price for their catch as a result of this arrangement. While fishers within the communities typically seem content with this arrangement, a few have expressed a desire for wider markets to develop competitive pricing (Salagrama, 2015).

Many of the inshore communities, particularly those with international NGO participation that we visited, have established Village Development Committees that serve a variety of functions to improve the community including income/livelihood and fisheries. In some places, this has led to the development of microfinance programs where individuals can access funds that can be used for fisheries related purposes such as the purchase of ice boxes. These groups can also help communities finance ice machines and cold storage to allow for better processing and the ability to increase sales, however they are only recently serving in this capacity.

In summary, there is little economic resilience in Myanmar's marine fisheries for both the offshore and inshore industries. A change in catch composition from larger, more valuable species to smaller ones as well as a decrease in overall catch has put considerable economic pressure on fishers and companies to continue fishing harder. While the DoF began a project in 2005 to develop aquaculture practices in inland and coastal communities to support rural development and alleviate poverty, very few alternative livelihoods exist for inshore fishermen. Many community members report that illegal fishing during closed seasons or with illegal gear occurs because of the lack of alternative income sources, and express some resistance to more restrictive management measures that would reduce their incomes.

Climate change – anticipated impacts

Climate change is altering the marine and coastal ecosystems in Myanmar in a number of ways, with important implications for the country's marine fisheries. Regional climate models project continued increases in temperature, sea level rise, precipitation patterns, extreme weather events, and ocean acidification (NECC, 2012). More erratic rainfall and more severe rainfall events have already been observed, and these changes are expected to worsen. In combination with increased droughts and continued deforestation, these changes in rainfall patterns would be expected to increase sedimentation, nutrient inputs from upland farmlands, and freshwater flow into nearshore waters. All of this could negatively impact important coral cover and seagrass habitats. In addition, projected moderate increases in sea surface temperatures (Mora et al., 2013), could result in more frequent and severe mass coral bleaching and die off events if warm anomalies persist and are unmitigated by injections of cold water due to increased stratification of the water column. Higher than average rates of sea level rise are also projected for low-lying Myanmar (Rietbroek, 2012), which could negatively impact mangroves, seagrass meadows, and coral reefs, all of which have maximum vertical accretion rates which, if exceeded, can result in the loss of these biogenic habitats that depend on photosynthesis. The negative effects of sedimentation, higher temperatures, and larger freshwater inflows on vertical accretion of coral reefs and perhaps of seagrass meadows make this more likely. In other words, these habitats are facing a double threat: their ability to keep up with sea level rise is being reduced, even as sea level rise accelerates.

The frequency and intensity of cyclones, storm surges, and cyclic variations in ocean productivity are also projected to increase. Prior to 2000, cyclones made landfall about once every three years but between 2006 and 2010, three major cyclones made landfall (Mala in 2006; Nargis in 2008; and Giri in 2010). Cyclones generally reduce fishing effort and fishing mortality, which may allow heavily fished stocks to recover somewhat but may also result in extensive habitat damage, particularly to habitats with biogenic structure such as mangrove forests, seagrass meadows, and coral reefs which make up much of Myanmar's nearshore ecosystem mosaic. Models also suggest that EEZs within the Indo-Pacific may experience relatively large reductions in phytoplankton and zooplankton density (Blanchard et al., 2012). This could result in reduced ocean productivity and fishery landings off Myanmar, but this is highly uncertain as it will also likely to be dependent on local upwelling and/or land-based nutrient inputs, as well as individual species growth rates. Finally, while models predict relatively small amounts of ocean acidification in Myanmar waters, the available evidence suggests that aragonite saturation values are well outside the natural range of values to which Myanmar corals and other calcifying organisms (e.g., mollusks, crustaceans, crustose algae, etc.) are adapted (Friedrich et al., 2012). This would be expected to result in reduced productivity of these species and/or poleward range shifts.

All of these projected changes could exacerbate the transition from hard bottom and coral cover to unvegetated mud bottom habitat. These changes would in turn have strong effects on species composition, abundance, and distribution and hence on the amounts and kinds of seafood produced by Myanmar's capture fisheries, as well as on fishing-related jobs and

revenue. Fishers throughout the country are already observing changes in the composition of their catches, as well as in the locations where key target species are likely to be encountered. Currently, species richness appears to be still relatively high despite significant habitat degradation in the past and intense fishing pressure. A shift from the current mosaic of mangroves, coral reefs, hard bottom, and seagrass meadows to more extensive muddy bottom habitat may not reduce net productivity of coastal waters, because muddy bottoms and silty, brackish, nutrient-rich waters can be very productive (if hypoxic events are rare). This could also become a quite resilient ecosystem state if the drivers (erratic rainfall with high precipitation events, higher sediment and nutrient loading, higher sea temperatures, and accelerated sea level rise) persist. However, species diversity would be expected to decline, with a shift from domination by reef fish such as grouper and snapper toward benthic invertebrates such as crab species, small coastal pelagic species (especially those favoring warmer temperatures), and a higher dependence of fisheries on offshore migratory stocks such as mackerel and tuna.

Evaluation of Myanmar's fisheries against the sustainability and resilience checklist

Based on the above exploration of the current conditions in Myanmar's waters and fisheries, and the impacts of climate change that are already emerging and likely to worsen in the coming years, it is clear that the fishery system in this country is not yet sustainable or resilient. We can clarify our understanding of this situation by exploring each of the ten items on our checklist as they currently stand.

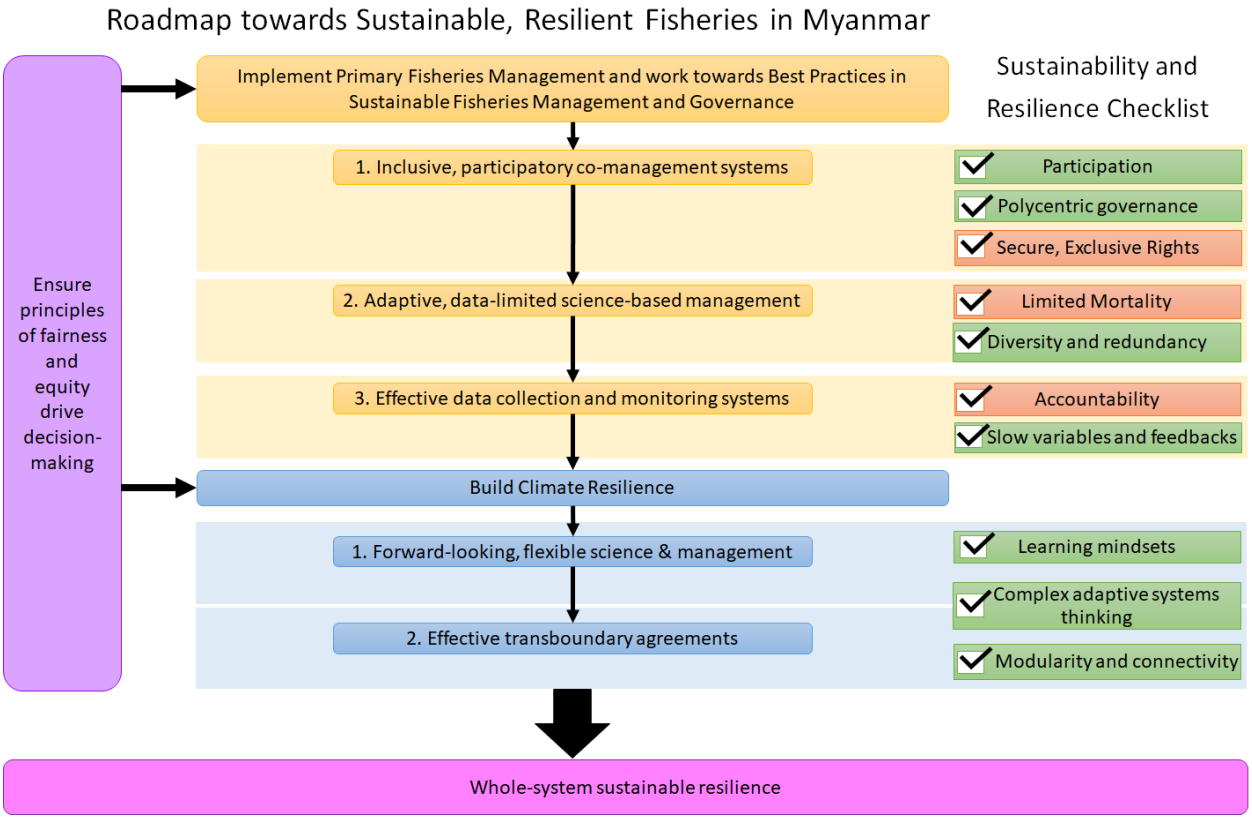
The first three items on the checklist, which are the principles of a sustainably managed fishery system – limiting mortality to scientifically sustainable levels; enumerating secure, exclusive fishing rights; and ensuring accountability to regulations – are all but completely lacking in Myanmar. The current fishery management mechanisms are failing to sufficiently limit fishing mortality because they are not set based on scientific guidance, and those regulations that do exist are regularly undermined by pervasive IUU fishing from various sources. The excessive fishing pressure that has persisted for decades has drastically altered the ecological community throughout the country's waters. There has been discussion of implementing secure and exclusive fishing rights as part of the fishery co-management system similar to the rights granted in the LMMAs, which is in its nascency in a few pilots in the country, however as yet that has not happened. Thus, across the country's coastline the fishery management system is highly unsustainable. We recommend implementing primary fisheries management (see next section) as quickly as possible to begin to remedy this situation.

There are also critical gaps in the seven principles of resilience – maintaining diversity and redundancy; managing modularity and connectivity; managing slow variables and feedbacks; fostering complex adaptive systems thinking; broadening participation; encouraging learning mindsets; and promoting polycentric governance structures – across all fishery system dimensions (ecological, management/governance, and socio-economic) in Myanmar. Ecological diversity and redundancy have been severely reduced through decades of unmanaged fishing pressure that has targeted top predators and drastically simplified the food webs. Ecosystem modularity and connectivity have also been reduced by overfishing, compounded by other system stressors such as deforestation, coastal development, damming, irrigation, pollution, and climate change-driven alterations to the weather and wave patterns. A dearth of scientific and management capacity, and of effective formal systems for adaptively incorporating science into management limit the capacity for learning, to manage slow variables and feedbacks, and to move towards complex adaptive systems thinking and management. Recent efforts to decentralize management authority and engage local community members in decision making has improved participation and the polycentricity of governance systems, however improvements and expansions in both of these areas are still needed. All of these factors limit the resilience of these systems to the impacts of climate change as well as to other, existing or developing system stressors.

Recommendations

In the remainder of this document we lay out a suggested path through which both system functioning and resilience can be improved despite the extremely limited-capacity context that characterizes Myanmar's fisheries. Here again is the schematic of our suggested roadmap to sustainable and resilient fisheries in Myanmar:

Figure 2 (repeated): *Roadmap to sustainable, resilient fisheries in Myanmar*



Implementing primary fisheries management

Implementing primary fisheries management should be the first step in Myanmar. Doing so will help to achieve all three of the fishery sustainability principles as well as help move the system towards a number of the principles of resilience (see Figure 2).

> **Recommendation 1:** Develop and expand inclusive participatory co-management systems with substantial local community involvement.

In Myanmar co-management is already being piloted in a handful of communities, and these efforts should be expanded throughout the country. Furthermore, efforts to build the scientific

and management capacity of these co-management bodies are needed. Finally, existing traditional tenure systems should be validated and promoted by the government.

> **Recommendation 2:** Implement adaptive management programs that utilize practical, scientifically sound and socially acceptable fisheries management methods and technologies, relying on data-limited methods such as size limits; closed areas and seasons; gear restrictions; and traditional rotation of fishing grounds.

Existing and new co-management bodies in Myanmar should be empowered to develop and implement their own adaptive management systems and management plans, with guidance and coordination from the central governing body. Greater uncertainty in the face of lacking science and worsening climate change necessitates the use of precautionary methods such as buffers and reserves.

> **Recommendation 3:** Create a system for monitoring and analysis based on indicators that encompass an ecosystem approach, within the capability of the community.

Focus should be placed on ensuring that scientific information on the state of fish stocks and of the supporting ecosystems feeds back into management decision making. For example, simple studies on size at maturity could be used to set more rational size limits, or to better understand the distribution and timing of spawning to set closed seasons/areas. Interpretation should be based on local knowledge and qualitative analysis of indicators and reference points, based on locally-determined risk preferences.

Progress is already being made toward the goal of implementing primary fisheries management in Myanmar across the three system dimensions: ecological, management/governance, and socio-economic. Below we summarize this progress, and provide specific suggestions and recommendations for next steps to continue to move toward the goal of sustainable, resilient fisheries in Myanmar.

Ecological

Myanmar has already begun to address ecological sustainability in their fisheries, particularly with respect to vulnerable habitats like mangroves and coral reefs. LMMAs are a recent tool that the DoF has established, beginning in the Myeik Archipelago. These areas employ precautionary management based on thorough ecological assessments, while also prioritizing local sustainable fishing for community livelihoods. While similarly thorough environmental assessments may not always be possible for future LMMAs without international assistance, this has set a precedent for a scientifically-based, ecological conservation-focused management process going forward in Myanmar's waters. Expansion of the LMMA system will carry Myanmar further into the primary fisheries management process, especially if areas are created to protect more ecosystem types than just coral reefs, which now cover only a small portion of Myanmar's waters. In addition, habitat-based conservation may prove challenging in an ecosystem as

degraded as Myanmar, so expanding this approach to focus on important areas for fisheries that may not be connected to vulnerable habitats will also be critical to success.

Mangroves are one key habitat that has been the focus of a number of protection and restoration efforts along Myanmar's coasts and estuarine channels recently. Many of the co-management areas already established and in process include provisions for the protection of their local mangroves, noting them as a key nursery area and sensitive habitat for fisheries. The co-management area in Mon also includes a mangrove replanting area to counter previous deforestation and degradation. International NGOs with participation from Myanmar's government and Worldview International Foundation (a Myanmar-based NGO) have committed to planting hundreds of thousands of mangroves throughout Myanmar, focusing on previous mangrove habitats that have been deforested for agriculture or aquaculture in Rakhine, Ayeyarwaddy and Tanintharyi. Through these efforts over six million trees have been planted since 2012 and local communities near the planting sites have been trained to assist in planting and maintaining saplings which are vulnerable to disturbances when isolated from established forests. In particular, innovations in training local community members to operate drones to remotely plant sapling pods in topographically assessed areas are pushing these efforts forward where the technology is capable.

Recommendation 4: Expand and strengthen the network of LMMAs, and support their efficacy through targeted funding.

Recommendation 5: Ensure new LMMAs are designed to protect the full range of habitat types that support fisheries and ecosystems in Myanmar, as well as to protect the ranges of target species that are not directly connected to specific habitats.

Recommendation 6: Continue efforts to replant Myanmar's deforested mangroves across the country's coastline, as well as associated training programs to ensure local communities can help to maintain delicate saplings. Employ innovative technologies such as sapling-planting drones whenever possible.

Management

The DoF has already taken some first steps towards primary fisheries management by approving co-management areas throughout the country's inshore fisheries. A key factor of Myanmar's co-management area development is the highly decentralized approach, where the DoF must approve of the management plan and may assist in enforcement when necessary, but the plan for managing the area, the scientific research necessary to create the plan, and the social structure of management and enforcement is handled entirely by the local communities. This partition of responsibility is so strong; however, it may prove to be a detriment to building long-term co-management systems without first establishing the management capacity within communities. So far, local communities lack the capacity or knowledge of necessary structures to start co-management associations, and international NGOs have participated in the formation of each existing or developing co-management area. A clear desire for increased capacity exists

within the communities, but a concerted effort that includes the DoF to develop a scalable capacity-building program, as opposed to the current system of addressing individual communities separately, is needed. This includes scientific and monitoring capacity to understand the current state of local fish populations and habitats, as well as the knowledge to set management goals and enact regulations that target those goals. Another significant barrier to the success of this decentralization effort is the lack of central government guidelines or standards that local management plans must meet to establish a co-management area. Without such guidelines there is no way to systematically judge the quality and completeness of the individual co-management plans, and thus no way to ensure the consistency of management throughout the country. For primary fisheries management to succeed in Myanmar, the process for communities to form co-management areas needs to be made clearer, and barriers to participation to achieve inclusive co-management systems must be removed. Myanmar already has a long history of tenured access rights in their freshwater fisheries and aquaculture, indicating that a formal system is possible in marine fisheries as well.

International NGOs have been instrumental in developing co-management systems in the inshore fisheries in Myanmar, as well as pushing to develop the capacity of the stakeholders in the fisheries. Organizations like WCS, the Darwin Initiative, the Gulf of Mottama Project, and the MFF have been involved in piloting co-management over 10 areas throughout Myanmar, including establishing Fisheries Associations in historical fishing villages and assisting in the development of co-management plans. Plans for further co-management areas in Tanintharyi and Mon States are currently being developed in partnership with international NGOs, which provide the expertise on organizing the communities and the process of drafting management plans and setting management goals. The current (and pending) co-management areas rely primarily on spatial management to modify existing DoF regulations, as well as increased gear restrictions and minimum mesh sizes. The co-management associations are partnering with international NGOs to pursue funding for data collection on site selection and fishing activity in order to better manage their fisheries under data-less conditions.

In the commercial offshore fishery and in the inshore fishery, the early steps towards resilience are taking place. Participant buy-in to more precautionary management decisions like seasonal and area closures is increasing, and management is encouraging science-based decision-making via encouraging participation in the R/V Dr Fridjof Nansen surveys and data-limited methods.

Recommendation 7: Conduct a simple study of size at maturity for the major target stocks combined with a study of the size composition of the catch to resolve uncertainty about the effectiveness of current mesh size restrictions for protecting juveniles. This can be completed in one year.

Recommendation 8: Conduct a simple study of spawning and rearing locations and timing to develop rational, science-based closed seasons that would allow more fish to spawn and more juveniles to reach maturity, greatly increasing fish stock productivity.

Recommendation 9: The DoF as well as the MFF should participate in adaptive management processes such as goal setting before addressing management reform to establish sustainable management with participation from stakeholders.

Socioeconomic

The most critical component to social and economic resilience in Myanmar's fisheries is secure and exclusive fishing rights, which does not exist in either the offshore or inshore fisheries. The inshore fisheries are closest to achieving this key sustainability principle, as the Myeik Archipelago LMMAs and some of the fishery's co-management areas grant exclusive fishing rights to the local fishing communities that manage them. However, as both the central government and the local communities lack the capacity to enforce these exclusive rights, they are not secure and do not provide the necessary incentives for a sustainable fishery. The DoF has acknowledged this issue but to date have not released plans to address it.

Recommendation 10: Develop clear communication on regulations and restrictions regarding exclusive access rights to nearby fishing communities and increase capacity both within the government and local communities to monitor and enforce exclusive fishing rights. The first may address the underlying issue of restricted fishing access, that it is not a familiar concept to local fishers and/or the areas that are restricted to co-management members only may not be known to those outside the participating communities. The second will protect the exclusive fishing rights of the co-management associations and allow them to fully participate in more sustainable management practices while minimizing the income they sacrifice.

Addressing economic resilience in Myanmar will be incredibly challenging due to the heavy reliance on fisheries as not only sources of income but also of key nutrition. The government of Myanmar has recognized this issue particularly in the inshore fishery and has begun to take good steps towards resilience. The Aquaculture for Rural Development project has largely focused on inland communities and freshwater species and should be expanded further to develop capacity within inshore fishing communities where aquaculture of marine fish species or mud crabs is possible.

Recommendation 11: Conduct research into and development of alternative livelihoods for coastal and marine fishers, including aquaculture where appropriate, as any new management decisions are likely to temporarily or permanently impact the livelihoods of fishers and other fishery-dependent jobs given extensive stock depletion.

Recommendation 12: Cultivate more competitive fish buyers and processors for Myanmar's fisheries to build economic resilience by allowing fishers to command better prices for their catch. This could be particularly effective in established co-management areas that can market their catch as sustainably managed, which represents a growing national and international market.

Building climate resilience

In general, in order to be resilient to climate change, fisheries will need to be able to respond to both species range shifts and changes in their productivity rates. Implementing best practices in sustainable fisheries management and governance is the first step to achieving this. A growing body of research shows that healthy, sustainably managed fisheries are the most resilient to climate change (Free et al., 2019; Sumaila and Tai, 2019). Furthermore, unsustainable fishing practices in Myanmar are currently preventing fisheries from reaching their full potential in terms of yield as well as biomass in the water. Implementing primary fisheries management, as described above, should thus be the focus of reform efforts in Myanmar in the short- and medium-terms.

However, while such efforts to bring fishing impacts into alignment with system bounds may delay the onset of climate-driven changes, these actions cannot mitigate climate drivers, or prevent a certain amount of system change that is already unavoidable. It will thus be necessary to begin working towards achievement of the remaining principles of system resilience (Figure 2). We suggest two additional steps that can help to do so in Myanmar and other contexts. These are: implement adaptive, forward-looking management to manage greater uncertainty and prepare for a climate-altered ecosystem; and build and strengthen effective trans-boundary agreements to manage stocks as their ranges shift.

As climate change impacts marine species and ecosystems around the world it will alter what is possible in a given system. Thus, maintaining current fishery system conditions, or returning to the systems of the past, may no longer be possible. It will thus be necessary to develop realistic goals and implement adaptive, forward-looking management and science throughout fishery systems the world over. Doing so involves developing an understanding of the likely climate impacts in a given system, and adjusting management benchmarks, goals and targets to reflect the realm of possibility. It also means accepting and incorporating more uncertainty and change into management systems by making them more responsive and flexible.

Implementing such systems in the primary fisheries management context of Myanmar requires a focus on adaptive and precautionary management frameworks that prioritize the preservation of buffers around management targets, coupled with very low-data methods for predicting likely climate impacts. This latter challenge is an area where EDF has already begun to work in Myanmar. We have done so by first identifying a suite of possible climate impacts based on IPCC regional climate projections merged with local knowledge and expertise (summarized above), with a model that forecasts the future distribution of thermal habitat for species relative to Myanmar's EEZ (Gaines et al., 2017), and by applying a data-limited ecosystem risk assessment tool – the Comprehensive Assessment of Risk to Ecosystems – designed to engage local stakeholders in the conversation around climate change and fisheries management, and to elicit climate vulnerability scores, along with relative risk scores for other system threats, through these conversations.

Recommendation 13: A clear next step of this work will be to work with stakeholders to interpret the results of this analysis in order to prioritize limited management resources in the short- and longer-terms.

The former suggestion – expanding management buffers to account for increased uncertainty – is especially challenging in Myanmar (and similar contexts) because local communities are so heavily dependent on fisheries prosecuted at current levels, and alternative livelihood options are limited. One way around this is through the use of technology. Technology can be deployed to gather data rapidly and more cheaply than is possible using conventional data collection methods (e.g., scientific surveys with research vessels, human observers, etc), thus reducing uncertainty (and in Myanmar, perhaps blunting opposition to management measures based on perceived lack of scientific justification) (Burden and Fujita, 2019). For example, enumerators can now easily collect catch volume and length composition data using feature phone apps such as Vericatch (https://vericatch.com/); thousands of data points have been collected by enumerators in Indonesia via the Vericatch app, resulting in data of sufficient quality for data limited stock assessment. Rare has developed a smartphone app called OurFish which allows buyers to log their fish purchases easily while bypassing literacy and language barriers, and helps remove barriers to access the data (which can also be linked to the GPS on the fishing vessels if present) which previously has been incredibly difficult to collect and use. This app is being tested by buyers representing over 14,000 fishers in southern Myanmar (https://rare.org/program/fish-forever/). Inexpensive smart camera systems with analytical service subscriptions (e.g., the Shellcatch system: https://www.shellcatch.com/) could be used on a small number of fishing vessels to estimate the spatial and temporal distribution of adults and juveniles in order to develop rational closed seasons. Inexpensive underwater drones such as the Open ROV Trident drone could be deployed by academic researchers to generate fishery-independent estimates of abundance and length composition, the best data for conducting stock assessments. Computer vision (machine learning or AI) methods could probably be used to estimate length at maturity for many species if labelled datasets were available (photos of fish of various sizes of known maturity stage), which could be used to set rational size limits.

The second climate-resilience strategy – building and strengthening international institutions and transboundary agreements – is likely to be more difficult to address in the near-term in Myanmar because doing so will depend on stronger management and governance capacity than are currently present. However, this does not mean this challenge should be ignored. As stocks shift to track their preferred temperature bands and habitat conditions, they are likely to shift across international boundaries, into new jurisdictions and out of areas where they have historically been found. Whether, and to what degree, major stocks in Myanmar will shift needs to be fully explored in order to begin the process of building transboundary agreements to address climate change impacts.

Recommendation 14: Conduct research into the anticipated impacts of climate change on the preferred ranges of Myanmar's key commercial and subsistence fish species,

ideally in a collaborative effort with neighboring nations to create cohesive understanding of the needs for transboundary agreements.

In order to ensure stocks are fished sustainably throughout their transitions, and to address the inequities that may result as stocks move in mass away from the poorest and most fishery-dependent countries, governments will need to come together to develop international agreements and plans that face these issues head on. Countries like Myanmar, which have not been responsible for significant portions of the carbon emissions that are contributing to climate change, but which are likely to bear the brunt of the negative impacts on their fisheries, would do well to band together to increase their political influence and collective bargaining power around this issue, as has been done around the higher-level climate change negotiations (e.g., the efforts of the Alliance of Small Island States).

Recommendation 15: Begin scoping feasible entry points for opening discussions with neighboring and more-distant nations with whom formal agreements may be necessary to ensure the continued health of stocks and sustainability of fishing activities, as well as the continued well-being and equity of Myanmar's fishing-dependent communities, in the face of climate change.

Applying the principles of fairness and equity

For all of the above recommendations to be successful it is critical that the principles of fairness and equity drive all policy and management decisions. Inequity in terms of poverty, education, and access to resources is prevalent throughout Myanmar, and stems from systemic constructs that have developed over the course of history which are maintained by strong disparities in power and wealth. Climate change is likely to worsen these inequities, and inequity is likely to worsen climate change outcomes. Making fisheries management effective and resilient to climate change will demand truly inclusive, transparent, and participatory management decision-making, incorporation of local and traditional knowledge, empowerment of marginalized people with rights and resources, and efforts to develop local capacity and leadership on these issues. These are all tenants of primary fishery management and are thus in line with the rest of the strategy outlined in this document. These are, however, concepts that are easy to get wrong, and that are often discussed on paper but not implemented in practice. It will be critical as efforts progress to reform fisheries and build climate-resilience in Myanmar to prioritize equity and fairness at every step of the way.

Fishery management systems must be designed to address and avoid inequity in three critical areas: 1) in the distribution of benefits and damages from different management decisions; 2) in the decision-making process itself; and 3) in the historical and ongoing systematic marginalization of different groups and individuals impacted by those management decisions, and the resulting different levels of vulnerability and capacities for participation and adaptation of those different groups. All three of these types of inequities are currently impacting communities throughout Myanmar. Further development of co-management can help to address some of these inequities, but to be truly equitable, fishery management decision making must

be fully participatory, inclusive, and transparent. Achieving this goal in Myanmar will require substantial capacity building programs for historically marginalized groups, as well as targeted efforts to identify and engage all stakeholders impacted by fishery management decisions, to ensure they all have equal access to all the available information influencing those decisions, and to "level the playing field" to allow for equitable negotiations between stakeholder groups.

Recommendation 16: Create structures that facilitate meaningfully participatory fishery management decision-making that is inclusive of all historically marginalized groups, and ensure the factors impacting decisions are transparent and accessible to all impacted stakeholders. It may be necessary to implement measures to help "level the playing field" between different groups of stakeholders, such as appointing advocates for marginalized groups in negotiations.

Recommendation 17: Implement efforts to build the capacity of all impacted stakeholders so that they can participate in fishery management decision-making. Special efforts should be made to identify and support historically marginalized groups with such capacity building efforts.

Recommendation 18: Identify and seek to address the root causes of existing inequities, for example by strengthening legal rights to address historical power imbalances.

Summary and conclusion

Myanmar's marine and coastal ecosystems have been highly altered over the past 50 years by rapid and unmanaged growth of fishing pressure, compounded by a variety of other chronic system stressors. The fishing communities dependent on fishery activity suffer from very high rates of poverty and unemployment, and often have limited livelihood options. Climate change is already impacting these systems, and these impacts are expected to increase in the coming decades, adding further stress to a system already suffering on ecological and social dimensions. In order to recover the state of Myanmar's marine ecosystems and the well-being of people dependent on them, it is necessary to engage in reforms of Myanmar's fishery sector that adequately take into account climate change. In this document, we presented a ten-item checklist that captures key principles for building a sustainable and resilient fishery management system in the Myanmar context. We provided a roadmap through which we suggest each item on this checklist can be met.

In evaluating Myanmar's fisheries, we conclude that Myanmar's marine fisheries should be considered "not resilient" on ecological, social and management/governance dimensions. The introduction of climate change on top of a depleted and not-resilient system poses a great deal of risk to the ecosystem and the people dependent on it. Fortunately, there are opportunities to restore and build the resilience of Myanmar's fishery system, and if this can be done, research indicates that the ecosystem could be made more healthy, fish stock abundance could improve, fishing communities could stabilize, and the system could be made more resilient to the effects of climate change.

- Myanmar's ecological dimension is not resilient due to the loss of biodiversity over time due to overfishing and habitat degradation. Sustainable fishery management coupled with initiatives to reduce the drivers of habitat degradation will be necessary to restore the capacity of Myanmar's marine ecosystems to generate the much larger amounts of food, income and jobs that they are capable of.

- The social dimension is not resilient due to a variety of factors. One of the most important things that can be done to build social resilience in fisheries is the establishment of secure fishing rights. This can help to ensure fishing groups and communities see the benefits of good management. Diversification is another way of enhancing resilience, and in places where limited livelihood options exist, the establishment of other forms of income and sustenance (such as mariculture) can help make communities resilient. Finally, many coastal communities would appear to benefit from additional competition among fish buyers so as to enhance the negotiation leverage of fishers and return a greater share of the profits generated from seafood-related activity back to fishers and coastal communities.

- The governance and management dimension are not resilient because of the high tendency for centralization within a system that has limited resources and limited personnel capabilities. Resilience in this part of the system can be enhanced through

greater degrees of decentralization and additional resources and personnel capabilities. Greater decentralization than exists today can allow for more rapid adaptation and management that is more responsive to local conditions, while resources and personnel capabilities can help to ensure management measures are technically sound and appropriate to given challenges.

Given the current status and the limited management and governance capacity that exists in Myanmar, we recommend focusing initially on the implementation of primary fisheries management in order to begin restoring Myanmar's fisheries and to establish resilience. Primary fisheries management is an approach which combines the use of best-available (though frequently very limited) science and information, the precautionary approach, and co-management in order to facilitate sustainable use of resources. Adaptive management is deployed in this system in a way that fosters learning in order to address issues related to uncertainty and limited management capacity, with an eye toward improvements over time. Technology being tested and deployed in Myanmar shows great potential to help enhance learning, document and record data, and speed up management improvements.

Several fishery reform bright spots exist in Myanmar that hold a great deal of promise in their own right, and also as a model for other areas of the coast to follow suit. The bright spots are taking the form of community-based co-management systems and they are in the very early stages of designing and implementing fisheries management in ways consistent with the primary fisheries management approach. Much can be done to help advance the efforts of these bright spots, to expand these models into other communities, and even into offshore fisheries.

Despite the depleted status and the significant challenges facing the management of fisheries in Myanmar, reform of Myanmar's marine fisheries is well worth it. The implementation of good fisheries management promises to restore populations of marine species, help restore marine ecosystem function and form, and enhance the fishery sector. Implementation of good fishery management in Myanmar would go a long way toward restoring aspects of resilience that will help as climate change increasingly takes hold and will establish a foundation from which more sophisticated types of management approaches can be developed to further improve ecological and social outcomes.

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