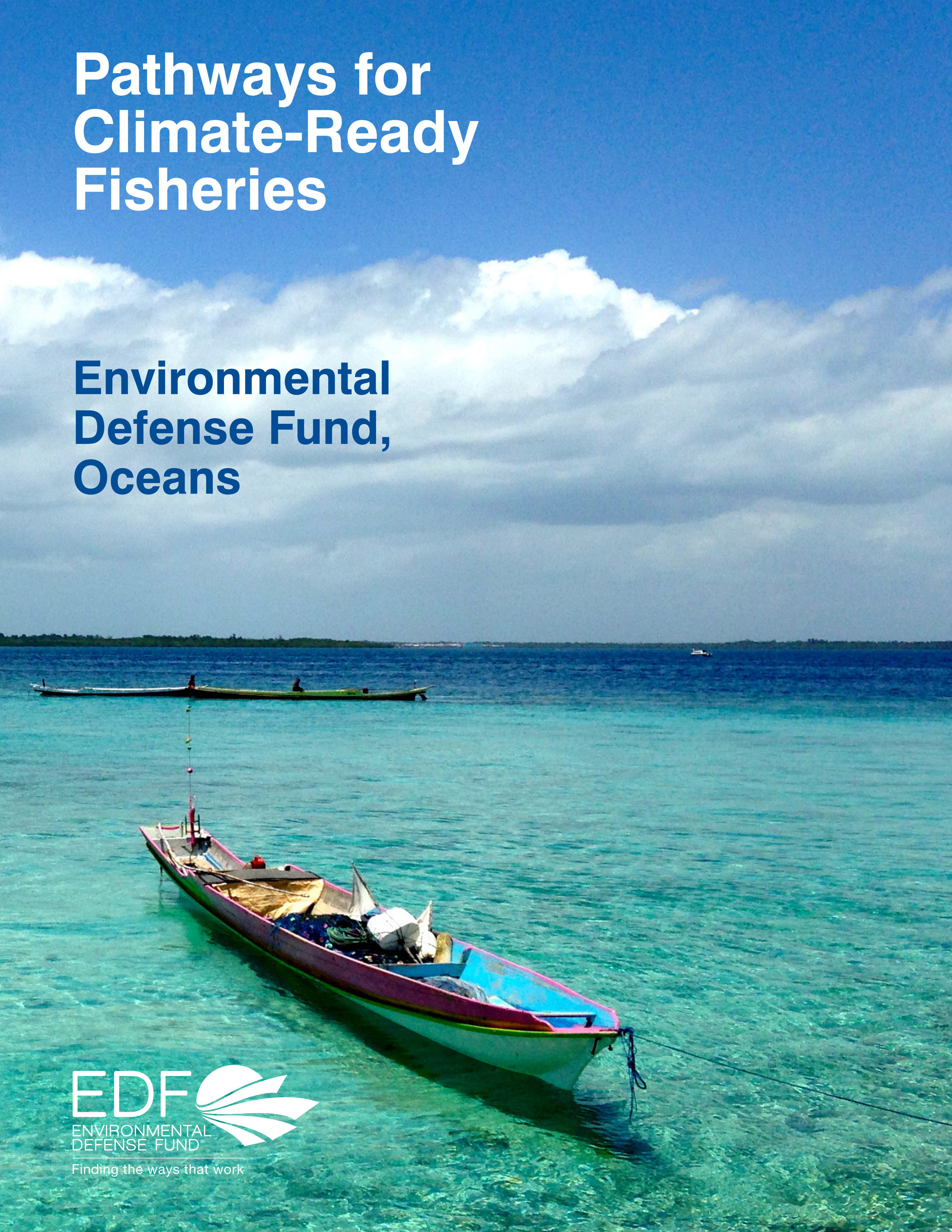
Pathways for Climate-Ready Fisheries

Environmental Defense Fund, Oceans



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Environmental Defense Fund, Oceans

By Merrick Burden and Willow Battista[1,2]

Fisheries are critically important for nutrition, food security and livelihoods of hundreds of millions of people (Barange et al., 2018; FAO, 2018; Bennet et al., 2018). The management elements necessary for fishery sustainability are relatively well-known (Worm et al., 2009; Cochrane et al., 2011) and important progress has been made — at least in some parts of the world — in building the governance framework needed to achieve fisheries sustainability (Hilborn et al., 2005; Battista et al., 2019). Now, climate change is not only significantly impacting marine and coastal ecosystems and fisheries (Barange et al., 2018; Gattuso et al., 2015), but threatening to upend that progress and exacerbate remaining problems. Indeed, climate impacts will continue to increase in severity over the coming decades and cascade ecologically, locking us into significant effects no matter what we do to further reduce emissions (Barange et al., 2018; IPCC, 2014; Pecl et al., 2017).

Even though significant uncertainty exists about the level of emissions controls the world will collectively achieve and the effects those remaining emissions will have on marine and coastal ecosystems and the fisheries they support, the general trends are clear. The developing tropics will likely lose significantly in terms of fisheries production potential, perhaps exacerbated by habitat effects and ecological cascades not yet fully understood (Barange et al., 2018). The high latitudes will likely gain maximum fisheries production and access to that production as sea ice melts (Barange et al., 2018). Areas in between will gain and lose specific resources, inducing shifting fisheries portfolios in most every part of the world (Barange et al., 2018). At the global scale, the net losses may be offset by net gains, but only if effective management and governance are put in place that address both changes in productivity and shifts in fish stock location (Gaines et al., 2018). At regional and local scales, significant adjustment and response will be essential to minimize ecological, economic and social impacts.

It is therefore increasingly urgent that we identify those actions that governments, fisheries managers and communities can take to tackle the problems we face today, and build climate resilience into management approaches, so that fisheries can continue to provide the services on which the people of the globe depend.

Policymakers and stakeholders are asking critical questions as ocean systems and wildlife begin to

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change around us, including: What do fisheries managers need to do differently in the face of climate change? How can we better protect food security and livelihoods, especially for the most vulnerable human populations? How can we enhance the structure, function and biodiversity of marine ecosystems as climate change proceeds? How might the future look different for people and nature together if we realize the potential that informed management can bring? How can we ease fisheries transitions within and among nations as climate change takes hold?

We've developed a multi-pronged framework consisting of five key tenets to help answer these questions (Figure 1). These five elements are interrelated, and actions that can move a system toward achievement of one of them may also further progress toward one or more others. While the specific tactics are likely to vary across planetary regions—especially between the developing tropics, the mid-latitudes and the poles—the basic approach remains for the most part the same.

Put in place effective fisheries management and governance as soon as possible based on the best available information.

The fundamentals of fishery management do not change as a consequence of climate change, though there are likely debates that are still needed about how to achieve "good enough" management in locations where governance is relatively weak. However, despite these differences, ecosystem-based and adaptive management will remain the best practice for fisheries management, and the tactics deployed in support of that approach should be used wherever possible, including, but not limited to:

- Scientifically-determined Total Allowable Catch (TAC) limits, or other science-based controls on fishing mortality associated with attaining clearly stated management targets;
- Secure tenure rights;
- Transparent, inclusive, participatory and adaptive decision-making processes; and
- Governance structures and accountability mechanisms to ensure compliance with agreed upon management schemes.

In all cases, the best available information should be used, from both scientific and traditional cultural sources. Where possible, improved information should be developed, with a focus on information gaps that provide the biggest potential improvement in management opportunity and results.

In low-governance contexts, ecosystem-based adaptive management may not be a realistic immediate goal, but steps can be taken to improve fisheries management in these contexts through the application of primary fishery management (Cochrane et al., 2011; Fujita et al., 2014; Karr et al., 2017; McDonald et al., 2018; Burden and Fujita, 2019). This approach uses adaptive, data-limited methods; high degrees of public participation; and co-management to minimize risk to fisheries, while building experience and capacity that lay the foundation for more sophisticated management approaches that ultimately are needed to increase social and economic benefits that fishing communities depend upon. In the developing world, this approach will likely still be appropriate even in the face of climate change, as it helps to build needed management capacity.

As climate impacts accelerate, building fisheries management and governance capacity will be even more important in the developing world where fundamental management underpinnings do not yet exist. In some cases, regional or local level governance actions may be sufficient, but in other cases, novel solutions—working, for instance, across small-scale fisheries as opposed to typical hierarchically organized governance systems—may be called for. New or expanded non-governmental institutions may provide alternative pathways to success.

While the need for core fishery management capacities do not change, climate change brings a set of risks, uncertainties and challenges that will cause the way in which these systems and tactics are deployed to differ from what is done today. In particular, fisheries scientists and managers will need to increasingly embrace:

- Enhanced monitoring of ecosystem conditions to measure and respond to changing ocean conditions;
- Management systems and policy decision-making processes that are more nimble and quick to respond to change (refers to the speed of institutional process, as well as to forms of institutional structures like co-management);
- Stock assessment approaches and underpinning systems that anticipate and account for environmental changes and varying life-history traits;
- Management measures that are robust to identifiable uncertainties, such as the degree to which species will move and change in abundance (ramped vs. stepped harvest control rules tying fishing mortality to biomass is one example);
- The allocation of quotas and fishing opportunities in ways that can accommodate changing mixes and abundance of stocks (portfolio management is one approach that could work in some contexts);
- Stock management that protects age and genetic diversity to the extent practicable, maximizing intra- and inter-species resilience;
- Habitat conservation measures that protect sufficient portions of the diverse habitats needed by changing suites and distributions of species;
- Proactive management of emerging stocks, and responsible management of those that will move out of management jurisdictions;
- Catch control tools that allow the fishing industry to be more flexible and adapt to changing fishing opportunities on their own, such as diverse target stock portfolios (Cline et al., 2017) or responsive harvest control rules (Kritzer et al., 2019).

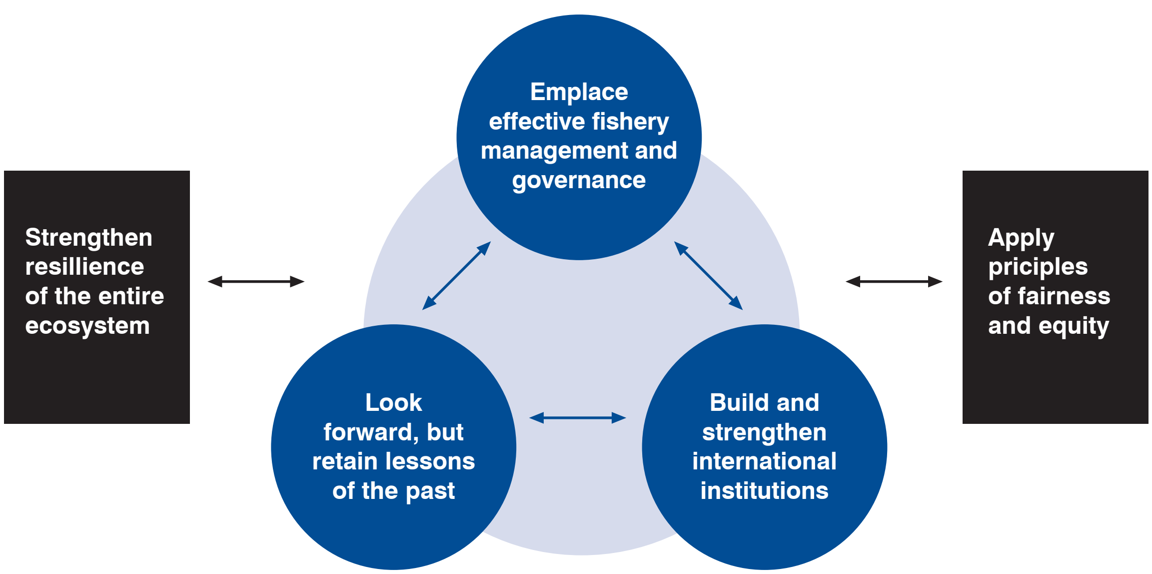

Figure 1: Multi-pronged framework of elements for creating climate-resilient fisheries

Supporting Case Study

The Pacific sardine fishery off the U.S. West Coast is notorious for wide swings in abundance as a result of changing ecological conditions. Scientific researchers have been able to measure clear and strong correlations between water temperature and stock abundance. This relationship is "lagged," meaning that a change in water temperature affects the harvestable biomass of sardine in a subsequent time period. By utilizing sardine biomass assessments that account for this environmental variability, managers have developed a science-based harvest control rule that changes the future harvest rate of sardine according to current water temperature indices (Chavez et al., 2017). The result is effectively a "hard-wired" adaptive management system, based on ecosystem indicators, that helps ensure harvest rates are in line with stock productivity.

Look forward, while retaining lessons learned from the past.

We have learned a great deal about what it takes to manage fisheries well over the past several decades. If fisheries are to survive and thrive in the face of climate change, we must not forget these lessons, but we must also understand that a sustainable future cannot be based on an expectation of conditions that no longer exist. Our perspective of what a prosperous fishing community should look like is often based on something we have seen or experienced in the past. Similarly, what we aim to do with fish population and assemblage abundances is often rooted in the past performance and based on scientific observations collected in prior years. This will need to change so that we allow for visions of the future that may look different from what we have previously experienced. We need to reimagine what fisheries of the future can look like, based on an understanding of issues that may arise as climate change alters conditions, and make decisions that can balance conservation and utilization in this changing environment. Fisheries managers will need to examine:

- How fishery management goals need to be changed in light of changing ecosystem dynamics (including potentially drastic changes to the species mix and population abundances present both regionally and in a local area);
- What policies will be needed to meet new management goals and handle shifting dynamics;What tradeoffs are likely to be associated with various policies;
- What appropriate management benchmarks are, in light of these expected changes, and what scientific adjustments are needed to track performance relative to these new benchmarks (e.g., changes to stock assessment processes);
- Whether or not the information suggests that there will be disparate impacts on different human communities as a result of climate change that raise issues of equity and fairness; and
- What kinds of uncertainties can be identified about possible future conditions and what actions can be taken to minimize risk under those uncertainties.

The appropriate process to achieve more forward-looking management may depend on the available resources, capacity and developmental state of a given fishery and its governance structure. In more developed contexts, forward-looking science can characterize uncertainty and risk and evaluate tradeoffs through predictive scenario modeling in order to inform decision-making (Pinsky and Mantua, 2014; Punt et al., 2014; Busch et al., 2016; Szuwalski and Hollowed, 2016; Tommasi et al., 2017; Karp et al. 2018). In developing world contexts, it may be necessary to rely on expert judgement and an adaptive, precautionary approach to articulate benchmarks intended to avoid risk and maintain the resilience of the ecosystem (Cochrane et al., 2011; Fujita et al., 2014; Karr et al., 2017; McDonald et al., 2018).

Supporting Case Study #1

Lithuania manages several Baltic Sea stocks with Individual Fishing Quotas (IFQs). Recently, the relative abundance of Baltic stocks has been changing dramatically, with a precipitous decline in cod abundance and an increase in stocks like sprat. Lithuanian cod fishermen are seeing their fishing opportunity disappear, while sprat fishermen are constructing new, sophisticated vessels. This disparity is undermining social support for an otherwise sustainable system. One solution to this problem that EDF brought to the Lithuanian fisheries ministry is to first acknowledge that a change in the mix of species in the region may very well be permanent, and to focus on ensuring equity of opportunity generally rather than to a specific species. The particular solution arising from this forward-looking perspective is to move from a set of single species IFQs to a portfolio IFQ system where commercial fishers are allocated long-term shares for a fishery or species complex (as opposed to shares of either cod or sprat) and receive pounds of individual species every year commensurate with their shares and species abundance. They would then trade these annual pounds among themselves each year as they see fit. As the abundance of stocks shifts under climate change, this forward-looking "portfolio" approach could help provide for more stable opportunities for Lithuanian fishers, while ensuring overfishing does not occur for either species.

Supporting Case Study #2

The Humboldt Current system is one of the most productive ecosystems on earth. Anchoveta and other economically valuable species like sardines are managed by a relatively rapid adaptive management system, drawing on specific monitoring of these species and concurrent environmental conditions. However, many other species are unmonitored, representing a gap in the knowledge of how the ecosystem is changing as a result of climate change. Therefore, a more holistic monitoring system that captures the dynamics of both the biological and the physical system will be needed to ensure that the Humboldt Current countries can respond appropriately to climate change and interpret signals that illuminate pending change. This need for better and more synoptic forecasting and rapid response tools to ensure effective and efficient adaptive management in the face of climate change has led to 1) a three-country collaboration (facilitated by EDF) to develop an early-warning system that will flag pending change for scientists, managers and stakeholders, and 2) a pooling of the technical expertise in the region to better understand the implications of climate change and how to use information from early-warning systems in management decisions. By developing these systems with partners, we are building the scientific capacity for forward-looking management in the face of climate change.

Build and strengthen international institutions.

One of the most frequently identified ways that climate change will impact fisheries is through the shifting stock distributions as species move to preferred temperature ranges (Gaines et al., 2018; Perry et al., 2005; Dulvy et al., 2008; Poloczanska et al., 2013; Pinsky and Mantua, 2014). These shifts will often result in movement across international boundaries, with some estimates predicting that most stocks will shift across political boundaries due to climate change (Cheung et al., 2010; Gaines et al 2017; Pinsky et al. 2018). This will require significantly more international cooperation than has been achieved to date in order to ensure that aggregate stock-level fishing mortality rates remain sustainable and that incentives remain aligned with sustainable fishing as stocks move in and out of jurisdictions. In working to foster such cooperation, it will be critical to address issues of equity that will arise as stocks shift between developed and less-developed fishing powers. These needs will be important all over the globe, but are especially acute in the high latitudes, where both new stocks and greater access are emerging, and in areas where existing governance structures are weak.

Principles of collective action can be used to help identify ways to foster needed cooperation, but it will be increasingly important to pursue:

- Strengthening of existing or development of new multi-national agreements to ensure adequate authority to effectively manage new stock conditions and distributions and inclusivity of affected parties;
- Agreement and collaboration on the basic science concerning the stock(s) of interest;
  - This can be facilitated through enhanced assessment and data-sharing agreements.
- Regional agreement on management goals for changing stocks and stock portfolios (e.g., small pelagics, reef fishes, groundfish, etc.);
  - For instance, should countries agree to manage fisheries resources to a specific single-species (e.g., MSY or MEY) or multi-species (e.g., stock complex MEY/MSY) reference point?
- Access and resource sharing agreements, which may include mechanisms such as:
  - Transferable permits and/or cross-border vessel access agreements;
  - Portfolio-based access agreements that shift in response to real-time data;
  - Side payments (e.g., where country A compensates country B for the protection of a key life history stage of a stock in country B's waters).
- Supportive domestic institutions and policies that can carry out the necessary functions of the international agreement, including through dedicated funding for creating new institutions where necessary;
- This will require, in part, that domestic policies and politics are aligned with the international agreement's goals and purpose.

Supporting Case Study #1

We have already seen how a lack of effective cooperation can lead to overfishing and stock declines among countries with otherwise good domestic management, such as the recent experience in Northern Europe over Atlantic mackerel. Here a shift in the geographic location of mackerel to the north and west brought Iceland and the Faroe Islands into the fishery due to increased abundance in their waters. Disagreements about how to share the harvest of the mackerel stock among these relative new comers, the EU and Norway led to overfishing and a loss of that fishery's seafood sustainability certification.

Supporting Case Study #2

The Parties to the Nauru Agreement (PNA) is an example of an agreement that has come together among like-minded countries to collectively manage South Pacific tuna resources. By combining their collective EEZs, the PNA countries are able to cover enough geographic scale to effectively manage shared resources. Many of the conditions underpinning this agreement are consistent with principles of collective action, such as shared experiences, leadership, common goals and enhanced compliance. In addition, the way in which harvest opportunities are shared among countries appears to be somewhat durable to geographic change of stocks, with access opportunities changing over time in response to changes to where fishing activity is concentrated.

Supporting Case Study #3

The U.S./Canada albacore treaty is an example of an agreement that allows vessels to transit international boundaries in pursuit of target species. Under the terms of this treaty, Canadian vessels have historically fished off of the U.S. coast, and U.S. vessels have sometimes fished off the Canadian coast.

Supporting Case Study #4

Supportive domestic institutions are an important aspect of an international agreement among countries. One example where conditions appeared ripe for international cooperation is over stocks shared by the U.S. and Canada that reside on George's Bank. In this case, the two countries worked to develop an international agreement. When it came time for the U.S. to ratify the treaty, domestic regional politics undermined the agreement and led to its unraveling.

Strengthen the resilience of entire marine ecosystems.

Thriving fish stocks and other marine species depend on healthy marine and coastal ecosystems. These systems are already impacted by a wide variety of stressors, now increasingly including climate change. The importance of improving ecosystem health is not new to fisheries management, but climate change will overlay today's relatively predictable changes with less well anticipated ecological cascades. Thus, climate change poses a significant risk to ecosystems even though the full impact may be difficult to predict.

Improving marine ecosystem health will also bring together a more diverse set of people and interests with stakes of different kinds so that investments from each can help augment the others. Many people who care about the ocean focus their interest on only a few elements: fisheries, biodiversity, carbon sequestration or any of many other human uses. Joint design and planning for different uses of ocean resources can help make sure that we get the most from each.

In particular, the growing awareness that investments in decarbonization can also benefit fisheries (e.g., through blue carbon), but also that fisheries management could have a much bigger impact on carbon cycles that is currently widely recognized.

Regardless, one essential response to unpredictable, substantial risk is enhanced

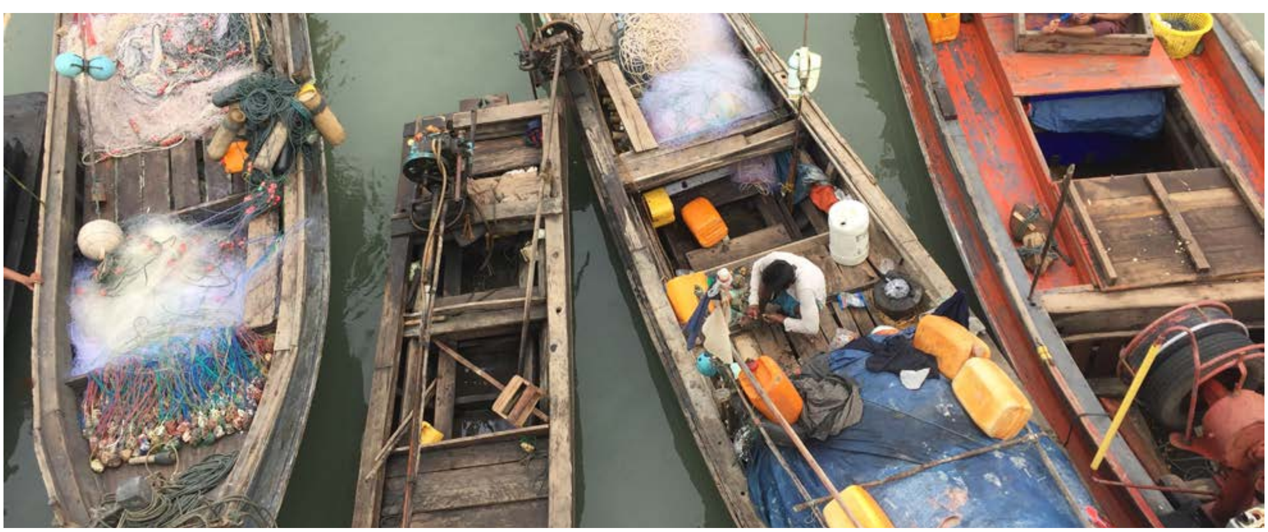

Photo by Alexis Rife

ecosystem resilience. Enhancing the resilience of marine and coastal ecosystems can limit the negative impacts of shocks and disturbances related to climate change and facilitate maintenance of healthy structure and function, even as warming drives directional change. How to build resilience is increasingly well-established, in theory (Gunderson, 2000; Carpenter et al., 2001; Walker and Salt, 2006; Folke et al., 2010; Kerner and Thomas 2014; Sellberg et al., 2017), but the translation of that theory to real-world application—especially in the marine world—is in its infancy.

Nonetheless, some essential actions are clear and available today:

- Make current management systems work well, including for fishing and other known key threats;
- Implement adaptive management systems;
- Reduce the cumulative stresses placed on marine ecosystems from both climate and non-climate stressors (for example, by reducing sedimentation, nutrient loading and overfishing);
- Prioritize stressors to address through science-based prioritization-support frameworks when management resources are limited;
- Protect and restore diverse habitats, prioritizing those habitats that are critical to target stocks that are likely to remain present in the region, as well as those likely to move in;
- Consider how sea level rise will impact existing and future habitat areas, and enhance use of resilient coastal infrastructure that will yield concomitant benefits for coastal communities and built infrastructure;
- Maintain or increase species biological, functional and genetic diversity; and
- Foster greater habitat connectivity, including through the use of science-based networks of reserves—and other types of area-based protection—to conserve key habitats and imperiled species that cannot otherwise be protected.

While some of this is beyond the scope of conventional fisheries management, these actions will be necessary to ensure that marine and coastal ecosystems can continue to support life and the fisheries-based livelihoods we desire from them.

Supporting Case Study #1

The literature outlines a clear set of actions that socio-ecological systems can do in order to build resilience (Gunderson, 2000; Carpenter et al., 2001; Walker and Salt, 2006; Folke et al., 2010; Kerner and Thomas 2014; Sellberg et al., 2017), and we have experience with many of them. One example is salmon of Bristol Bay, Alaska, which is often described as one of the greatest migrations of wildlife on the planet. In this ecosystem, habitat complexity, system diversity, genetic and biological diversity and management that ensures large populations of salmon are able to spawn every year, among other factors, have worked to support an ecosystem that is highly productive in spite of multiple disturbances and shocks over the decades (Hilborn, 2006).

Supporting Case Study #2

The Chesapeake Bay has been experiencing a significant recovery along several metrics in recent years, even in the face of a clearly changing climate. Efforts to reduce nutrient loading, runoff and sedimentation from upstream farms, halt overfishing and restore waterways, among other interventions, have increased system resilience by reducing multiple sources of stress. The result has been significant recovery of many aspects of the ecosystem. These include an increase in eel grass and blue crab abundance, an increase in abundance of benthic organisms and a decline in undesirable conditions (such as harmful algal blooms). This example shows that with some assistance, ecosystems can rebound in the face of climate change.

Apply principles of fairness and equity to guide policy decisions.

The impacts of climate change will be heterogeneous across geographies and socio-economic groups, and this heterogeneity threatens to create new inequities and exacerbate existing ones. Climate change will drive inequality at large scales (e.g., between high-latitude and low-latitude geographies) and at more local scales (e.g., changing mixes of species in a place will benefit some and harm others in that place).

Specifically, communities in the developing tropics, those dependent on coral reefs and those where small-scale fisheries are disproportionately important to the health and well-being of coastal peoples will experience the most acute negative impacts. Notably, these areas also tend to be rife with existing socio-economic disparities. Addressing these inequities, especially for communities that already face problems concerning food security and livelihoods, has value in its own right and is the topic of many treaties and international agreements. Moreover, inequity also threatens to bring social instability and a rejection of policies that may otherwise be sustainable. These issues matter for human rights and for both domestic management and international cooperation.

Implementing effective sustainable fisheries management, including the best-practice fundamentals outlined above, can help improve the status of fisheries (Hilborn and Ovando, 2014) and build resilience to climate change (Free et al., 2019; Sumaila and Tai, 2019), which can in turn help to mitigate some of the local consequences of climate change. However, the pervasiveness of inequities created by climate change require that it be one of the main considerations of policy. By striving to avoid the creation of winners and losers, we can help ensure that policies aimed at sustainably managing fisheries in the face of climate change are embraced.

In order to apply the principles of fairness and equity as we build climate change resilience, we must:

- Carefully identify where and how climate change is going to worsen existing inequities and generate new inequities through application of existing tools (like climate vulnerability assessments) and development of new tools designed for this purpose;
- Meaningfully engage marginalized and vulnerable groups in both the discussion of climate changes and likely impacts, and in the development of potential solutions (Farbotko and Lazrus, 2012; Matin et al., 2018; Cohen et al., 2019);
- Expand solution development to engender (Meerow et al., 2019):
  - › Distributional equity (i.e., equity in access to resources and in distribution of impacts);
  - › Recognitional equity (i.e., acknowledging and respecting different, intersecting identities (e.g., race, gender, class, etc.), and understanding how these have been shaped by historical injustices and can impact individual vulnerability and inequity); and
  - › Procedural equity (i.e., truly equitable participation in decision-making processes and the development of plans);
- Foster fundamental changes in the system and across scale-boundaries to address the root causes of climate-driven inequities, with focus on transformations deemed desirable by the impacted communities (Matin et al., 2018);
- Avoid letting the discussion of climate-driven inequities obscure the underlying causes of existing inequities, such as unequal access to power, knowledge and resources;
- Avoid letting the discourse around climate change further undesirable “victim” or “refugee” narratives that may reduce agency and self-determinism of impacted groups or spur privileged groups to make fear-based decisions (e.g., efforts to prevent “climate refugees” from migrating).

Supporting Case Study

The inequities potentially created by changing fishery opportunities resulting from climate change and the social problems created by actual or perceived unfairness can be well-described by referring to recent civil unrest in Chile over the sharing of the Humboldt squid resource (a fishery resource that has been changing its geographic range) (Li, 2018). In response to policy decisions regarded as unfair, some segments of the fishing industry engaged in civil unrest that caused disruptions in some of Chile's largest cities (van der Spek, 2019; Lombrana, 2019). Policymakers have since addressed this problem successfully by revisiting their earlier decisions, but it remains a clear example of how fairness and equity considerations in one segment of the ocean economy can impact society broadly.

Summary and conclusions

It remains critical that society act to reduce carbon emissions. However, even under the most optimistic scenarios, there is no escaping a certain amount of warming, acidification, rising sea levels and cascading global change in the coming decades. Fisheries managers, stakeholders and governments must accept and prepare for this coming change, and adjust governance structures, policies, management programs and actions accordingly to ensure the continued provision of fishery benefits. Recent research (Gaines et al., 2018; Free et al., 2019) indicates that if we take the above actions soon, we may be able to engender holistically-improved fishery systems that not only can continue to produce jobs and food and support abundant marine life, but that can continue to contribute to livelihood and food security goals.

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