IS MY FISHERY CLIMATE-RESILIENT?

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Fisheries that are resilient to climate change have the capacity to resist, adapt, or transform in response to climate change impacts. For example, a fishery can resist climate change impacts by maintaining species and habitat diversity so that some species that can tolerate or acclimate to the impacts are able to persist in the area to support the fishery even if other stocks cannot tolerate or acclimate to the impacts. Fisheries can adapt to climate change impacts by, for example, targeting new species as ranges shift and adjusting fishing mortality rates as productivity changes. If climate-driven changes are significant enough, a fishery system may need to transform more completely, for example, by developing new sustainable sources of food and livelihoods, such as regenerative aquaculture, to replace lost fishing opportunities. It is likely that to be truly climate-resilient, fisheries must have some capacity to resist, recover, adapt, and at some point, transform.

Is your fishery resilient? Ask the following questions of yourself and fishery participants to gain insight into this:

1. Does your fishery have the basic building blocks of sustainability – some way to evaluate stock status using the best available science and local knowledge, a way to adjust fishing mortality, ways to maintain sustainable stock size and age structure, and ways to maintain desirable yields and profits year after year? Are fishermen and managers accountable to sustainability standards? Basic sustainability is required for a fishery to be resilient.
2. Can you change your regulations and fishing practices in response to new data rapidly enough to keep pace with changes in the ocean? If you can only change regulations and fishing practices slowly or not at all, resilience will be low.
3. Are fishery benefits distributed fairly? Can fishermen who invest in sustainability and resilience capture the benefits of their efforts? Inequitable distribution of benefits like catch opportunities can result in conflict, thereby reducing resilience.
4. Has your fishery been hit with a storm, a sudden increase or decrease in fish prices, or some other significant change? If so, did yields and profits return to desirable levels? If they did, this is an indication that your fishery is resilient to these kinds of impacts.
   1. What are the attributes of your fishery that allowed yields and profits to return to desirable levels? For example, were the fishermen capable of changing target species, gear, or marketing tactics? Were scientists able to document changes in the stock that translated into rapid adjustments of fishing effort or fishing mortality? Have any of these attributes changed, or are they still intact? If some of the attributes have been lost, are there efforts to rebuild them? These are the attributes you should try to maintain or build up in order to maintain or increase resilience.

A general resilience checklist for FISHE

There has been a significant amount of research and exploration into what makes one system more or less resilient than another. Various authors and groups have created lists of attributes thought to collectively characterize a resilient system, both in general as well as in relation to specific threats (e.g., the threat of climate change). Our General Resilience Attributes Checklist draws on this research, combining and adapting attribute lists from [The Stockholm Resilience Center](https://applyingresilience.org/en/the-7-principles/), [The Resilience Alliance + Transition Movement](https://doi.org/10.5751/ES-09051-220128), and a [recent examination of specific climate-resilience criteria for fisheries](https://doi.org/10.1007/s13280-016-0850-1).

For a more detailed evaluation of your fishery’s resilience, use the list of attributes below to see how resilient your fishery is and how to increase resilience if necessary. Seek to understand if each item is present, partially present, or absent in your system, and then consider ways you might work to fill the gaps where possible.

Remember, every system is different, and some attributes may be more or less important in your system than others. In general, however, the more of these attributes your system has, the more resilient it will be.

# Attributes of Resilient Systems:

* [Diversity and Redundancy](#_Toc58411413)
* [Buffers and Reserves](#_Toc58411414)
* [Appropriate Levels of Modularity vs. Connectivity](#_Toc58411415)
* [Management of Slow Variables and Feedbacks](#_Toc58411416)
* [Complex, Adaptive Systems Thinking](#_Toc58411417)
* [Learning, Cooperation, and Innovation](#_Toc58411418)
* [Participation, Social Capital, and Trust](#_Toc58411419)
* [Transparent, Accountable, Polycentric Governance](#_Toc58411420)
* [Social-Ecological Memory](#_Toc58411421)
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## Diversity and Redundancy

Having diverse and redundant system components allows some components to compensate for the loss or failure of others.

***Fishery-relevant examples:***

* Species diversity (number of different species present)
* Population diversity (number of sub-populations within a meta-population)
* Functional diversity (number of functions being carried out i.e. primary, secondary, herbivores; primary, secondary consumers; decomposition; remineralization; etc.)
* Functional redundancy (number of species within each functional group)
* Species Complementarity (within functional groups, small differences between the ways species are carrying out the functions)
* Habitat diversity (patchiness, asynchronous adaptive cycles)
* Human diversity (cultures, perspectives, lifestyles, leaders)
* Business diversity (seafood products; fishery sectors, vessel owners/ employers; markets; alternative livelihoods available)
* Diversity in sources of funding for fisheries management
* Institutions have “redundancy” or overlap in their governance structures (e.g., a mix of common and private property with overlapping access rights)
* Age diversity of the stock
* Genetic diversity of the stock

## Buffers and Reserves

Systems are managed to protect sufficient reserves of natural and social capital. High levels of uncertainty are incorporated into management in the form of large “buffers” around management reference points and substantial reserves to protect critical habitat areas.

***Fishery-relevant examples:***

* Fisheries managers leave buffer zones between harvest rates and targets and limits (e.g. MSY)
* MPAs are designed to protect substantial areas of critical habitat from impact
* Management agencies are sufficiently funded to allow for proactive and carefully considered management, rather than just moving from one “fire” to the next
* Fishers are financially secure enough to weather unexpected short-term declines in fishery opportunities

## Appropriate Levels of Modularity and Connectivity

System components (e.g., social networks; habitat patches; etc.) must be sufficiently modular and independent from each other to ensure that if one component is compromised (e.g., polluted; exposed to an invasive species; etc.), not all other components will follow. However, system components must also retain sufficient *inter*dependence to allow them to support each other and facilitate recovery (e.g., through immigration/ emigration; passage of knowledge; etc.). Moreover, individual patches or “modules” within the system (e.g., a patch of coral reef habitat; a single fishing community) must be able to undergo adaptive cycles (accumulation, climax, release, re-organization – see below section on Complex Adaptive Systems Thinking) separately from each other so that they are not all in a vulnerable state at the same time. If these conditions are not met there is an increased risk of crossing a system threshold – i.e., a transition from a desirable state like a fishery that is producing food and jobs to an undesirable state like a collapsed fishery – when the system experiences a disturbance. It is thus critical to find the appropriate balance between modularity and connectivity for your system. It may also be possible to develop responsive pathways between system components, such that components are freely connected *just until* a negative impact is detected at one component, at which time pathways may be closed off to prevent the spread of harm. Pathways could then be reopened once the negative forcing has been addressed or has passed to facilitate recovery.

***Fishery-relevant examples:***

* Sufficient patches of suitable inland habitat for salmon, eel, shad or other catadromous or anadromous species exist to support a robust populations of fish across all the habitat patches, but which are sufficiently modular such that fires, earthquakes, or anthropogenic activities only disrupt a portion of the patches, allowing the other habitat patches to compensate for these disruptions and maintain the populations
* Two patches of coral reef within a coral reef system would be sufficiently modular if they: 1) each contain all the necessary species/ functional groups to not be reliant on larval drift from the other patch to continue to grow and thrive; and 2) are far enough away from each other that negative impacts to one patch (e.g., pollution or an invasive species) are not likely to impact the second patch; 3) they are not harvested at the same rate, so as avoid? Synchronizing their adaptive cycles
* Learning networks to connect fishers in distant but similar fishing communities
* Formal connections between scientific agencies and management agencies

## Management of Slow Variables and Feedbacks

Complex socioecological systems like fisheries often have “tipping points”: thresholds across which relatively small changes in certain factors result in very large changes in the state of the system. Often, these large changes are highly undesirable, such as complete fishery collapse or ecological cascades. As a result, the factors that develop slowly over time but can move a fishery past a tipping point (the so-called “slow variables”) must be monitored and managed to avoid systems shifting into undesirable states. It’s also important to ensure that your fishery has certain attributes that increase resilience to “tipping:, such as feedbacks that connect system variables that are tight, but not too tight – positive feedback loops reinforce or hasten change while negative feedback loops dampen it, generally keeping a system in a stable state. Either can be desirable or undesirable, depending on the type of change.

***Fishery-relevant examples:***

* *Slow variables:* low levels of illegal fishing; fishing mortality rates that are slightly too high; ghost fishing gear; build-up of nutrients leading to dead zones; fishing down the food web; overfishing of grazing species in a coral reef; modification of hydrological and sediment flow; sea surface temperature increase; increase in ocean acidity; changes in ocean productivity related to climate change; etc.
* *Positive (enhancing) feedback loops:*
  + Desirable –
    - Rights-based management encourages sustainable fishing practices, which increase available stocks, thereby improving welfare and reducing incentives to overfish (e.g., poverty)/ increasing incentives to fish sustainably (e.g., trust in the management measures), in turn resulting in healthier stocks and higher profits, encouraging fishers to maintain sustainable fishing practices
  + Undesirable –
    - Fishermen fish harder in response to price decline to maintain their revenues, which results in in more supply and lower prices, in turn driving fishermen to fish harder
    - Fishermen invest in larger boats and more efficient gear as stocks decline to maintain catches, resulting in indebtedness which incentivizes them to fish harder, resulting in more stock decline
    - Introduction of an invasive species that outcompetes native species for space and resources, causing native species to die off faster and making more space for the invasive species
    - Inequitable management systems create/ worsen marginalization of some groups, resulting in their exclusion from participatory management processes, further reducing efficacy of new management measures
* *Negative (dampening) feedback loops:*
  + Desirable –
    - Price declines, causing fishermen to fish less, which reduces supply and drives prices up
    - Effective enforcement systems that reduce illegal fishing, thereby improving sustainability of the fishery and eventually improving welfare, reducing drivers to overfish/ fish illegally
  + Undesirable –
    - Inequitable policies and system structures lead to poverty and power imbalances that reduce people’s capacity to organize and act to effect change

## Complex, Adaptive Systems Thinking

Social-ecological systems are complex because there are multiple connections on multiple levels, and multiple perspectives and values. They also undergo adaptive cycles, both as whole systems and in patches within the system, in which natural and social capital is accumulated (think of a young forest, re-growing after a fire), resulting in a so-called “climax state” of the system (think of a mature forest), followed by release of capital in response to internal dynamics (think of the mature forest losing many big trees as a large cohort of trees age), and then re-organization of the capital (think of the worms and fungi converting the wood of the fallen big trees back to soil and nutrients).  The complexity of socio-ecological systems also results in large amounts of unpredictability and uncertainty. It’s thus critical to foster adaptive thinking and management to allow for adjustment as more information is gained and systems change.

***Fishery-relevant examples:***

* Systems analysis can be used to characterize SESs with respect to their state variables (key actors and reservoirs), processes, ecosystem goods and service flows, and resilience attributes and help identify high leverage interventions to enhance resilience attributes and/or disrupt undesirable feedback loops
* Ecological variability should be recognized and managed for, rather than controlled.
* Adaptive management + Ecosystem-Based Management are key, but it’s also necessary to coordinate between jurisdictions and non-fishing sectors to manage the socio-ecological system holistically

## Learning, Cooperation, and Innovation

Constant revision of knowledge and updating of best available information is critical to system resilience. Fostering innovation by placing emphasis on learning, experimentation, locally developed rules, and embracing changes in practice following disturbance allows for the development of new solutions to difficult challenges.

***Fishery-relevant examples:***

* Collaboration and information sharing between fisheries globally needs to be improved - modeling of likely climate impacts and adaptation methods that could be implemented should be shared widely so that fisheries with less scientific capacity can learn from others
* Innovation should be fostered, both in terms of fishing techniques to allow for access to new and shifting populations, as well as market innovations to help match supply with demand

## Participation, Social Capital, and Trust

Building of trust and shared understanding of the problems through participatory decision making are fundamentals of collective action. Social capital, which is the capacity of communities to response cohesively to stressors, results from trust, well-developed social networks and effective leadership.

***Fishery-relevant examples:***

* Participatory decision making with regard to fisheries rules and regulations.
* Cooperative/ collective management
* Tapping into local ecological knowledge
* Build social networks
* Doing things together as a community, even if they are not related to the fishery, such as building a school or improving a road

## Transparent, Accountable, Polycentric Governance

Multiple governing bodies reflecting degrees of centralization, regionalization, and localization that interact can support responsible collective actions in times of change but must also be sufficiently transparent and have effective and accountable decision-making policies.

***Fishery-relevant examples:***

* Co-management systems ensure greater local buy-in and more rapid adaptation of new regulations
* Fisheries are governed by multiple entities at different scales, with clear responsibilities and authorities that are integrated across these scales,
* Transparent and participatory processes hold decision makers and stakeholders accountable to commitments and mandates

## Social-Ecological Memory

Remembering how a fishery successfully adapted to a stressor in the past, or how fishing practices once resulted in sustainable harvests and good jobs, can contribute to resilience.

***Fishery-relevant examples:***

* Reference to/ revitalization of more sustainable traditional management practices/systems or integration with science-based management
* Care should be exercised to avoid supplanting a traditional knowledge, management practices, and stewardship norms with science-based concepts and financial incentives unnecessarily
* Inclusion of local system experts in management design and decision-making.
* Retention of stories and oral histories

## Acceptance of Change and Future-Focus

Communities and policies must recognize that resilient systems *will* often undergochange. Resilience is security against *radical* change or change which diminishes the ability of the system to provide services we desire from it. Resilient communities embrace change as an opportunity to re-imagine and redesign systems to maintain desired services, or even to realize improvements. Systems and structures must be flexible and adaptable to allow for desirable system transformation and evolution.

***Fishery-relevant examples:***

* Forward-looking science and management that replace historical benchmarks (e.g., historic catch/ what the system used to look like) with objectives realistic to future conditions (e.g., incorporating emerging stocks, goals for diverse fisheries and communities)
* Fishery regulations are designed to allow fishery mobility and/or gear switching (to target different species), and to encourage adaptation and innovation
* Supply chains are responsive to fluctuations and consumers are open to eating new species depending on what can be sustainably caught in a given season

## Equity

Equitable systems are more resilient. Power, resource, and knowledge imbalances reduce system members’ abilities to proactively respond to system change. In order for a system to be equitably resilient, issues of social vulnerability and differentiated access to power, knowledge and resources must be addressed. Equitable resilience starts from people’s own perceptions of their positions within their human-environmental system, and accounts for their realities and their need for a change of circumstance to avoid imbalances of power into the future. Equity also depends on addressing the structural determinants of power imbalances and inequitable practices, and ultimately upon reducing the implicit determinants of discrimination and power imbalance (e.g. implicit bias). Furthermore, as climate impacts change the system, care must be taken to ensure equity is not reduced. When climate risks are greater for certain sections of the community, system transformation should be promoted to distribute these risks equally among all groups.

***Fishery-relevant examples:***

* *Recognitional equity:* The differential experiences and knowledge of various stakeholder groups (e.g., indigenous communities, minority groups, women) are recognized and valued in resource assessment and management decision-making
* *Procedural equity:* all impacted stakeholders are meaningfully included in decision-making around management of the fishery
* *Distributional equity:* The needs and values of vulnerable and marginalized communities (e.g., women, minorities, subsistence fishers) are prioritized in fishery management decision-making, especially in decisions around allocation and access to resources.