Fisheries Adaptations to Climate Change

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Introduction

Worldwide, nearly half a billion people derive their income from fisheries and aquaculture, and fisheries products provide about 15% of the animal protein in the diets of three billion people. Most people who depend on fisheries live in developing countries where incomes are low, food resources limited, and residents have few opportunities to substitute occupations and diets. At the same time, fishing supports regional economies and countless households in industrialized countries and regions such as Alaska where the populace is more affluent but equally dependent on resources from the sea. In both cases large-scale environmental change can pose a serious threat to the lives and livelihoods of people who depend on marine resources.

Climate change involves a complex of effects that collectively may dramatically modify the natural environment and have profound influence on the world's fisheries, most of which are likely to be judged as negative.

Alaska is on the forefront of climate change but so far its fisheries have experienced relatively subtle changes and little permanent harm to the industry. Looming on the horizon, however, are species shifts, loss of productive spawning and rearing habitat, invasive species, harmful algal blooms and emergent diseases, and threats related to ocean acidification.

As every fisherman knows, **change is a constant** in the sea—harvesters and fisheries-dependent communities have coped with change throughout history and continue to do so. For example, atmospheric and ocean temperature variability and the resultant shifts in ocean currents appear to have contributed to large-scale and catastrophic decreases in fisheries productivity, including crashes of North Atlantic cod and herring, Peruvian anchoveta, California sardine, and Alaska king crab and pink shrimp, and have caused dramatic fluctuations in the abundance of salmon. An open question is whether climate change warrants a different adaptive response from more transitory phenomena. Scientists who study climate say that the long-term trend, while frequently masked by short-term variation, may profoundly affect fisheries. This paper summarizes very briefly the state of knowledge on fisheries adaptations.

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Effects of Climate Change on Fisheries

Climate change can and in some cases already does affect fisheries in many ways; some effects have been clearly documented, and others are only a matter of speculation. Many effects are uncertain and most have not yet been quantified. While people tend to view any change from the current status as negative, **some changes may have positive effects**, such as faster growth of fish and shellfish, and extension of range into newly productive regions. Predicted fisheries effects of climate change fall into two classes: those associated with the biological health and viability of fish stocks, and those that impinge on the safety or the social, cultural, and financial sustainability of fishermen and fishing communities.

Red king crab, Kodiak, Alaska. This species supports a valuable commercial fishery, and could diminish in numbers if ocean acidification increases. (D. Csepp, NOAA AFSC)

Climate effects related to fish population **biology** include:

- Changes in primary productivity, with increases projected for some areas and decreases for others.
- Changes in species composition within regions. As the center of abundance of some species shifts, other species decrease in abundance and new predator/prey relationships become established.
- Changes in ocean currents and water column mixing, which alter larval dispersal and food availability. Typically, warm water increases stratification, decreasing productivity.
- Altered trophic level interactions, causing decreases (or increases) in abundance of valued species as well as of their predators and competitors. Jellyfish, in particular, have increased in abundance dramatically in many regions, where they eat larvae of important fish and shellfish, compete with them for food, and clog fishermen's gear.
- Redistribution of stocks and species, usually but not always from lower latitude warmer and shallower nearshore waters, to higher latitudes with deeper and cooler temperature waters.
- Introduction or survival of invasive species.
- Emergence of harmful algal blooms and bacterial/viral diseases.
- Increased areas of oxygen-minimum zones ("dead zones") where fish and shellfish cannot live.
- Changes in timing of ecological events, which could alter the biological success of those events and reduce (or enhance) opportunities of people to use resources by keying on those events (such as spawning runs).
- Elevated sea level, which may kill coral reefs and other living communities that constitute habitat for fish and shellfish, particularly in estuaries.
- Increased stream temperatures, lower water levels, episodic flooding, saltwater intrusion in heretofore freshwater systems, all of which can reduce the productivity of spawning and rearing waters.
- Lower pH (decreased alkalinity) of seawater to the point where calciferous zooplankton and shellfish cannot survive (known as ocean acidification, it is not caused by climate change but is concurrent with it and caused by the same factors).
- Potential exacerbation of pollution effects, including eutrophication and ultraviolet radiation absorption.

Climate effects on **fishermen and fishing communities** can include:

- Changes in fisheries productivity that require expensive adaptations by harvesters, processors, and dependent communities. For example, if target stocks change location fishermen may need bigger, more sophisticated vessels and processors may need floaters or processing facilities in new locations.

- Increased frequency and severity of storms or weather, and sea conditions unsuitable to fishing as well as damaging to communities on shore through flooding, erosion, and storm damage.
- Sea level rise that can flood communities or valuable habitat.

Storms and flooding can also cause:

- Disruptions to supply chain, transportation of supplies and products, and price structures of inputs such as fuel, making fishing operations unprofitable or impossible.
- Decrease in food and water security that affects societies at all levels.

Climate Change Effects That May Appear in Alaska

Historically, modest increases in atmospheric and ocean temperatures appear to have benefitted Alaska salmon, and the current Pacific Decadal Oscillation–related warm regime has supported strong runs since the mid 1970s. Further warming could support some range extension to the north, though it is uncertain whether that would result in new commercial harvesting opportunities. However, some smaller spawning and rearing streams in southeastern and southcentral Alaska are **nearing the point of summer temperature stress** and there is concern that productivity could decline. Extreme storm and runoff conditions also degrade rearing habitat and in some cases scour streambeds, taking eggs, fry, and potential food sources with them.

Oceanic food chain productivity is immensely complex and so far it is uncertain what effects a steady warming will bring to pelagic (open ocean) and demersal (bottom) species. Pacific halibut stocks have declined in recent years despite continued application of conservative fishery management, but so far biologists have not placed the blame specifically on climate. It is known that in the Bering Sea the abundance and bloom timing of ice-dependent phytoplankton influence the recruitment strength of each year class of several important commercial species, notably walleye pollock, and **extraordinarily warm conditions tend to be unfavorable** to strong recruitment to the fishery.

Invasive species are likely to become increasingly abundant, some of which may harm existing fisheries resources. Warmer water years see increased abundance of predators and competitors not normally in Alaska waters, such as tuna, blue and salmon sharks, and mackerel, as well as an increase in endemic competing species such as arrowtooth flounder. An invasive tunicate already is fouling some infrastructure in southeastern Alaska and may become widespread enough to jeopardize shellfish mariculture sites. Of particular concern is the potential for an invasion of European green crab, which has decimated clam fisheries in California and Maine. Other threats include emergent disease pathogens, and an increase in abundance and frequency of harmful algal blooms.

While most of the Alaska coast is not currently affected by sea level rise, some fishing communities in northwestern Alaska are dealing with damage from storm surge, coastal erosion, saltwater intrusion, and other forces. And nearly all of Alaska's fleets and many communities are **vulnerable to the increasing storm activity** that some climate experts say is coming.

A major concern is ocean acidification. Research shows that when seawater acidity reaches a critical level it can begin to impede shell development of shellfish such as crabs as well as bivalve mollusks like clams and oysters. At more acidic levels it can actually dissolve existing shells. Even more chilling is the prospect that eventually it will **strike at the very heart of the food web** that supports virtually all commercially valuable species—calcareous phytoplankton. If these tiny organ-

***Clione limacina*, a calciferous zooplankton. This pteropod is important prey for many commercially valuable fish including salmon. A changing ocean pH in the future may cause pink salmon decreases that would warrant adaptive action by Alaska salmon fishermen. (R. Hopcroft, UAF SFOS)**

isms are unable to build and maintain their calcium-based shells, there could be a sequential collapse of everything up the trophic levels, eventually depleting most of the important stocks. While this scenario is but a grim possibility now, some in the industry are thinking ahead a generation or two about what the future of the fisheries will be.

Adaptation

To discuss fisheries adaptations to climate change it is helpful to define terms.

Fisheries refers to the activities (commercial, recreational, and subsistence) involved in harvesting finfish and shellfish in the sea or freshwater lakes and rivers, and for this discussion can include aquaculture. Seafood processing and support industries can be considered extensions of the fisheries. Fishermen are the men and women who engage in the fisheries, and fishing communities include their families and the other people whose livelihoods are tied directly or indirectly to the harvesting of sea products. **Fisheries professionals** include biologists, economists, and planners who regulate fishing harvests and related activities. Some sociologists, anthropologists, and geographers also consider themselves fisheries professionals.

Individual and institutional response to climate change can be described within three broad categories: **research and monitoring**; **mitigation** (steps to halt or slow the advance of change, such as reducing emissions of carbon dioxide and other greenhouse gases); and **adaptation**. Research and monitoring provide valuable information that can be incorporated both in mitigation and adaptation, and governments, universities, and organizations across the country and around the world are conducting both. Mitigation eventually may soften the blow of climate change over the long run. But nearly everyone agrees that a significant degree of change is inevitable and already occurring in many places, and the best hope for individuals and communities is to begin thinking through steps to adapt. Adaptation consists of actions that help a population survive and prosper under conditions of change.

In discussing fishery adaptation there is a basic dichotomy of viewpoints. Fishery managers tend to think in terms of fishery biology. The literature of fisheries adaptation to climate change reveals a recurring theme of preserving the viability of fish stocks through **resource conservation measures**, mainly in the form of harvest restrictions, although stock translocation, pollution reduction, and habitat protection sometimes are included. The mantra is "reduce non-climate stressors" that exacerbate climate effects to the detriment of fish stocks. Managers also look to measures that take fishermen out of the fisheries in order to reduce pressure on stocks and to promote transition to alternative sources of income. Fishermen, on the other hand, think of adaptation in terms of changes in **technology, operations, and finances** that allow them to survive and prosper in the face of environmental upheaval.

Forms of Adaptation

Adaptation can be technological, operational, financial, sociological, or regulatory and administrative. Adaptation often is characterized as either **capacity building** or **adaptive action**.

Bottom-up adaptation is developed and applied by fisheries participants and their communities; **top-down** adaptation is conceived and implemented by governments or NGOs (nongovernment organizations) and can include such things as coastal zone land use planning, and fisheries management. **Planned** or **proactive** adaptation is developed and initiated prior to developing conditions that drive the community to adapt. Government agencies have planning responsibilities and governments commonly design planned adaptation. **Reactive** adaptation occurs after the fact, and in response to environmental, economic, or other factors while they are occurring or after they have occurred. Usually individuals and communities lacking professional planning capabilities adapt reactively.

Planned adaptation results from a process where foresight and calculation is applied to determine measures to react to change before the change occurs.

Economists, sociologists, and development specialists tend to approach the "**fisheries and aquaculture sector**" as a single entity that with enlightened guidance (and funding) will respond rationally to economic forces and will change operational behaviors to maximize financial return. Professionals sometimes believe they are responsible for fostering adaptation. But experience shows that fishermen (including aquaculturists) and their communities react mainly to observed change in their environment, and do so in accordance with their own cultural principles, needs, perceptions, and capabilities.

A first step for Alaskans, as they start to consider approaches to adaptation, is to ask what is being done elsewhere to adapt to fisheries effects of climate change.

Small-scale fishermen in Thailand are already encountering climate changes to their fisheries, and have been the first to take adaptive actions. (T. Johnson)

Adaptation Measures Currently Applied in Alaska and Other Parts of the World

To date most **public sector** (planned, top-down) adaptation programs have addressed resource depletion more directly than climate change, and are directed at promoting biological resilience, stock rebuilding, and reducing overcapacity in the fishing fleets. Examples include:

- Permit or vessel buybacks, subsidy reductions, and other means of reducing overcapacity.
- IFQ—individual quota management schemes.
- Marine reserves and other schemes for improving fish stock resilience and rebuilding.
- Ecosystem approach to fisheries (EAF) management, which encompasses the marine environment and target commercial fish stocks; adaptive fishery management.
- Programs to encourage and assist in diversifying livelihoods, including investment in marine tourism and aquaculture development. In particular, herbivorous species culture has the least impact on the environment; culturing shellfish and aquatic plants can remove wastes from polluted waters.
- Improving climate research, monitoring, and forecasting; developing and implementing disaster risk management (DRM) policies; and improving communication and information sharing on climate change and fisheries adaptation to improve collaboration.
- Developing pilot projects intended to foster resource protection and fisheries adaptation.
- Forming national and regional strategies to prevent habitat destruction such as erosion and destruction of mangroves.

Private sector (mainly reactive, bottom-up) adaptation measures currently include:

- Purchasing larger, more sophisticated vessels with multi-fisheries capabilities to travel farther, migrate to different locations that offer better fishing opportunities, diversify fishing activities, and exploit a wider range of species and stocks.
- Maintaining multiple licenses or permits to allow shifting from one target species to another.
- Development of flexible fish product processing capacity for utilizing emergent resources.
- Diversifying incomes into non-fishing activities, which may include aquaculture and tourism.
- Spreading risk through insurance, cooperatives, and alternative forms of financing.
- Improving operational efficiencies, such as fuel efficiency and improved product handling, storage, and preservation.

Shellfish farmers are adapting to changes in water temperature, low-oxygen water, and increased acidity by:

- Selecting grow-out sites where cold water comes up from nearby depths.
- Developing processes for lowering culture rafts to greater depths when surface waters are warm.
- Closing off seawater intake systems and recirculating hatchery water when available seawater is low in oxygen or suffers periods of low pH.

What Does This Mean for Alaska Fisheries?

Compared to most other parts of the world, Alaska's fisheries are characterized by participants with ready access to information, capital, technology, and managerial expertise. Alaska has sophisticated fishery management systems that can adapt to changes in the environment, and that are tasked under federal and state law to manage for biological sustainability. State and federal governments offer programs to help the industry with technology transfer, financing, and other forms of assistance. In short, the fisheries of Alaska **are**

positioned to make timely and effective adaptation to climate-related changes in the marine environment.

However, many of Alaska's fisheries target a single species within limited geographical boundaries, making them vulnerable to modest environmental change. Furthermore, mobility is constrained by a complex system of limited entry permits, vessel quotas, and harvest regulations that restrict the locations and the types of gear and in some cases even specifications of the vessels that may be used. Most of Alaska's fisheries production goes to distant markets that determine acceptable species, product form, quality, timing, and other factors, leaving fishermen little flexibility to substitute alternative species. Located at the northern limit of abundance for some key species, in an ocean environment characterized by less species diversity than occurs at lower latitudes, product substitution in **Alaska's fisheries are constrained biologically**. High equipment and operating costs also limit Alaska fishermen's ability to experiment with new resources and **methodologies.**

In short, Alaska's fishing industry has advantages in adapting to climate-related change, **but also is vulnerable** in ways that some other regions are not. A great deal is at stake, but because fisheries effects of climate tend to lag behind climate change effects in the terrestrial environment, and because not enough is known about the eventual effects of these changes, the industry has not yet begun a serious dialog on planning for adaptation.

Alaska's shellfish aquaculture industry is paying close attention to climate factors, due to well-publicized outbreaks of harmful algal blooms and illness related to potentially temperature-induced pathogens, and to shortages of oyster spat resulting from low-oxygen and low pH water at shellfish hatcheries in Wash-

Shellfish farmers like these at Peterson Bay on the Kenai Peninsula are on the forefront of climate change in Alaska. Some shellfish farmers have already modified their grow-out procedures to avoid outbreaks of water temperature–related pathogens, and some are experiencing a shortage of oyster seed due to climate-related shortfalls at Pacific Northwest shellfish hatcheries. (D. Partee, Alaska Sea Grant)

ington and Oregon. As noted above, **shellfish farmers are already developing procedures** for protecting their farms from at least some of the biological effects of elevated temperatures, though it is far too early to know whether those measures will be effective and adequate.

In most capture fisheries the situation remains "business as usual" with the exception of a few Bering Sea crab and finfish fleets that have had to shift operations farther north to find concentrations of their target species.

Steps to Adaptation: How Can Alaska's Fishermen and Fishing-Dependent Communities Adapt?

1. Become fully informed on climate change in the ocean environment, and keep up to date on research developments.
2. Do a vulnerability assessment to determine where problems or opportunities may occur.
3. Look beyond the headlines to the less obvious ways climate change could affect daily operations and long-term viability. Look for ways to spread risk, for example, through innovative insurance and cooperative operation arrangements.
4. Begin developing strategies for increasing resilience to environmental change and, where possible, for taking chances to exploit new opportunities. Strategies are likely to emphasize operational flexibility, and diversification of products and even forms of income generation may become necessary. Long established norms of vessels, gear, target species, products, seasonal commitment, and other familiar patterns of the fishing industry lifestyle may have to give way. In other words, "business as usual" may be replaced with "whatever it takes."

Large vessels like this pollock trawler are highly mobile and able to expand their range of operations if target fish stocks shift to the north. (T. Johnson)

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