Chapter 13

Regulating Harvest in a Changing World

> If you wait fifty years with your worms and your wishes,
> You'll grow a long beard long before you catch any fishes.
> —*Theodor Geisel (Dr. Seuss)*

Images of clear-cut forests often serve as shorthand for environmental degradation, but such unsustainable overharvest manifests in many other forms including overfishing, enormous bycatch, and overallocation of freshwater resources. Although unsustainable use or harvest initially appears as a local disturbance, its effects ripple far from the center of destruction, cascading through food-webs and ecosystems. Often, these consequences compound or are compounded by the adverse effects of climate change. Levels of resource use that are sustainable now may not continue to be sustainable, for example, and overharvest can worsen the effects of climate change or even increase the rate of change itself.

Reconsidering when, where, and how we extract natural resources may help us develop management practices and policies that reduce the vulnerability of the resources, resource users, and related ecosystems to climate change. Reducing harvest levels or shifting harvest location and timing in response to climate change effects can increase population and community resilience, supporting connectivity and maintaining populations large and genetically diverse enough to buffer against unexpected effects of climate change.

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Redefining Sustainable Use

Overharvest is an old problem with well-known effects such as loss of biodiversity and evolutionary potential, damage to food webs and physical habitat, and a host of other potentially negative consequences. Some marine species have been fished to functional or economic extinction, including classic examples from whaling and sealing operations as well as more contemporary examples such as tuna, swordfish, sharks, and cod (e.g., Jackson et al. 2001; fig. 13.1). In extreme cases, overharvest can lead to complete species extinction due to direct harvest (e.g., Caribbean monk seal) or a combination of direct harvest and deforestation or other habitat loss (e.g., passenger pigeon).

All of these problems magnify the consequences of climate change. Most basically, reduced numbers of individuals or species decrease the ability of a population, community, or food web to successfully respond to disturbance, including climate-driven effects such as shifts in food supply, temperature, or water chemistry. Decreasing numbers of individuals or subpopulations reduces connectivity and increases the vulnerability of populations or species to extinction. Also, smaller populations typically have less genetic diversity, reducing their evolutionary options. While today's climate change is happening quite rapidly, evolutionary adaptation will still play an important role in helping some populations or species survive or even thrive in the new climate regime. Such evolutionary adaptation depends on the presence of individuals with the right genetic characteristics, however, and by reducing the pool from which these lucky winners may emerge, some opportunities are lost.

As mentioned in chapter 5, climate change could alter the population dynamics of many species, affecting key variables such as number of offspring, food availability, or predation. Failure to account for these changes could lead to unintentional

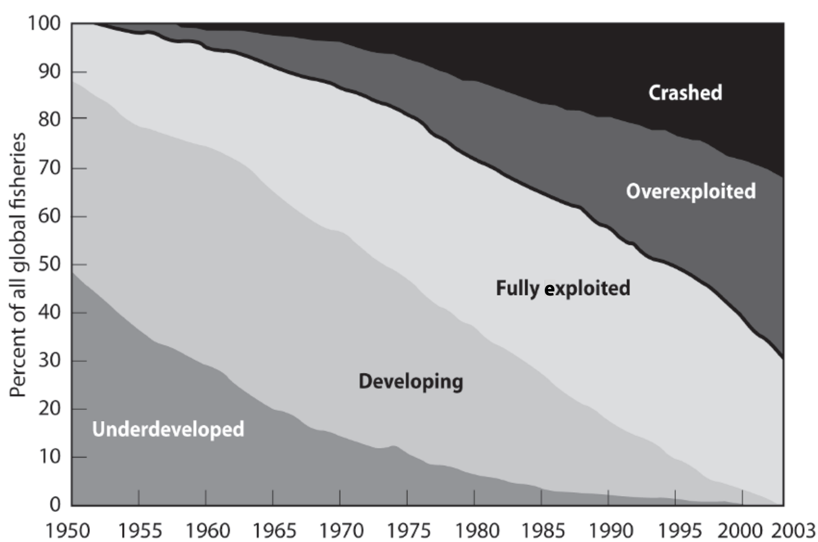

FIGURE 13.1 Percentage of global fisheries in various states of exploitation over time. After U.N. Environmental Program 2007, figure 4.13.

overharvest, unnecessarily restrictive harvest limits, or failure to create balanced harvest of species in mixed-species harvest regimes where different species respond differently to climate change. Frameworks for incorporating climate change into harvest regimes are being developed (e.g., Hollowed et al. 2009; A'mar et al. 2009), but much more refining and field-testing is needed.

BOX 13.1 CHANGING FISHERIES MANAGEMENT IN THE BERING SEA

The Bering Sea is highly productive, providing nearly half of the annual seafood catch of the United States. In addition to its rich fisheries, many marine mammal species and millions of migratory birds feed in the Bering Sea for at least part of every year. Aboriginal groups and rural households rely on these natural resources for subsistence. Dramatic warming has caused equally dramatic declines in seasonal ice coverage, with ecosystem-wide consequences. Managers and legislators can do little to directly compensate for sea ice loss, but there are actions that can slow ice loss (mitigation of greenhouse gas emissions), as well as actions to increase ecosystem resilience (e.g., adjusting fishing to levels that can be supported under the new climate regime and adjusting fisheries management to the northward shift of fish stocks).

By unanimous approval in June 2007, the North Pacific Fisheries Management Council (NPFMC) designated a northern boundary for bottom trawling based on essential fish habitat for the Bering Sea, and in January 2009 it approved a fisheries management plan that prohibits commercial fisheries in the U.S. Arctic "until adequate scientific information on fish stocks and how commercial fisheries might affect the Arctic environment are available" (NPFMC 2009). This plan grew out of the council's recognition of "heightened national and international interest in the Arctic and potential changes in this region that might arise due to climate warming."

Two programs in particular are helping to build climate change into Bering Sea fisheries management. The North Pacific Climate Regimes and Ecosystem Productivity (NPCREP) study uses monitoring, modeling, and experiments to investigate how climate variability and change affect the physical and biological controls on ecosystems in this region. This information is used to develop indices and assessment tools the NPFMC can use in determining each year's total allowable catch, as well as fish recruitment predictions that include the effect of climate change. The NPCREP program also provides online access to environmental and ecosystem data for the Bering Sea that allow the NPFMC to track trends that feed into management recommendations. A related program, the Bering Sea and Aleutian Islands Integrated Ecosystem Research Program (BSIERP), also generates and provides data that will help in the management of fisheries, marine mammals, and seabirds. The BSIERP project also works to document, characterize, and quantify local subsistence and cultural use, as well as indigenous understanding of the Bering Sea ecosystem, and to integrate this knowledge into ecosystem models.

The concept of sustainable use applies to nonliving as well as living resources. Human demand for water has increased over the years in response to population growth, changes in agricultural practices, and other forces, and water is now being removed from many rivers, lakes, and aquifers faster than they are being refilled. The Ogallala Aquifer, which provides 30 percent of all groundwater irrigation in the United States, has been severely depleted: water levels in parts of the aquifer have dropped by more than 150 feet in the last half century. Climate change simulations for the region vary, but all predict further reductions in aquifer recharge (Rosenberg et al. 1999). Thus current rates of water use will deplete the aquifer even faster than before. As with the Colorado River (see chapter 3), we must consider the changing availability of resources—especially water—as the climate changes, and adjust their use and extraction accordingly if we want continued access to them in the future. Such adjustments typically include a combination of decreased overall extraction and increased efficiency of use.

Droughts, Floods, and Pestilence

Overharvest itself can cause climatic change. On a local scale, clear-cutting forests causes warming and drying due to loss of shade and altered hydrological cycling. This problem is particularly pronounced in the tropics, and farmers in Africa and elsewhere have realized that by allowing some trees to grow in their fields they can decrease drought and increase yield. Clear-cutting can also affect regional climate: the warming and drying that have caused extinctions in Costa Rica's cloud forests result from a combination of global climate change and lowland deforestation. Lowland forests supplied significant moisture to the air that flows up and over the mountains, feeding the cloud cover that supported a rich forest ecosystem, but much of that forest has been converted to agriculture.

Deforestation even affects the global climate. Decreased forest cover by itself means decreased carbon uptake and storage, increasing the rate at which carbon dioxide builds up in the atmosphere; when fires are used to clear forests, the effects can be even stronger. During the 1997–1998 El Niño, which created extremely dry conditions in some areas, forest-clearing fires in Indonesia ran out of control and the combustion of both forests and rich peat soils emitted greenhouse gases equivalent to 13 to 40 percent of fossil fuel combustion that year (Page et al. 2002). These emissions contributed to global climate change, while the smoke changed weather patterns for thousands of miles and the loss of forest changed regional climate patterns.

While forests remove greenhouse gases from the atmosphere, it is possible for clear-cutting to have a cooling influence if the new vegetation cover absorbs less heat than the forests it replaces. Models indicate that global replacement of grasslands with trees could warm the planet by up to 1.3°C, while replacing forests with grassland results in cooling of roughly 0.4°C (Gibbard et al. 2005). Clearly, getting rid of all forests is not a good conservation plan, as the innumerable negative effects of such a

BOX 13.2 THE BIGGEST OVERHARVEST ISSUE OF ALL

While overharvesting fish and trees can compound the adverse affects of climate change, it is overuse of fossil and forest fuels that is at the root of the problem. Wood can be a renewable resource given proper forest management, but fossil fuels are not renewable on human timescales. It is useful to consider societal attitudes about harvest and use of all natural resources when constructing solutions to both the causes and effects of climate change. At some point, our profligate use of these precious resources must be resolved if we are to develop sustainable solutions to the many problems caused by overuse.

choice far outweigh any benefits for mediating global temperature. To paraphrase Ken Caldeira, we should focus on stopping climate change to save the forests, not saving forests to stop climate change.

This highlights the danger of assessing our choices and actions through a single lens. Here, the benefit of reducing global temperatures by replacing all forests with grassland is more than balanced by the loss of habitat biodiversity and the ecosystem services provided by forests. In a similar fashion, many are concerned that the use of biofuels as a strategy to reduce climate change could lead to biodiversity loss, widespread introduction of nonnative invasive species, and higher food prices. We must continue to weigh the costs and benefits of each measure in a holistic fashion, and make sure decisions result in an overall net gain of sustainability for the planet and ourselves.

Loss of forest cover can contribute to flooding as well as drought. During rainstorms, intact forests slow the rate and volume of water runoff, meaning more moisture stays in the forests for gradual release later and less floods straight into streams, lakes, and rivers. Over the longer term, forest loss increases sedimentation of rivers and streams, shrinking the volume of water they can hold before overflowing. Thus in areas where climate change is likely to cause an increase in heavy rains, adjusting harvest levels and techniques to account for local flood and erosion risk can help to reduce vulnerability. Similarly, reducing overharvest of mangroves in coastal areas can decrease erosion and increase sediment retention, reducing the rate at which shoreline is lost to rising seas.

Reducing harvest is not the only path to adaptation: strategic shifts in the timing, location, or methods of harvest, or even increasing harvest in some situations, may also help. One example is the pine beetle infestations of forests in North America stretching from Colorado to Alaska. The government of British Columbia has proposed a strategy for both economic and ecological protection by *increasing* harvest (Nelson 2007). The first phase was to shift from harvesting healthy trees to harvesting infested trees to limit the spread of infestation. The second phase was to harvest dead and weakened trees. This salvage phase has an economic interest—harvest of timber for sale—as well as a management interest—reducing fire risk from massive stands of dead trees. Some retrospective discussion has centered on whether more dramatic harvest early in the outbreak might have limited the area affected, while others have proposed that managing for maximum yield suppressed natural fire regimes and made the forests more vulnerable. Even with natural fire regimes, however, it may be that temperatures no longer get cold enough to suppress pine beetle infestations in some parts of their range. Discussions of triage and engineered approaches to climate change adaptation will require continued exploration of the role of harvest and other proscriptive actions, although many find them counter to traditional conservation principles.

The Web of Life

As is clear from the deforestation examples above, harvest levels and techniques can have effects well beyond the target place or species. Gill nets targeting a range of fish species also kill hundreds of marine mammals and turtles each year. For every pound of shrimp that shrimp trawlers keep, they typically bring up 8 to 10 pounds of other species that are simply thrown overboard dead or dying (Davies et al. 2009). The loss of wolves throughout much of their original range in the United States allowed deer to flourish, reshaping native forests in ways that may increase their vulnerability to climate change. Determining harvest levels or resource allocation must be done with an eye toward these indirect effects and their influence on system-wide climate vulnerability. In some cases this may lead to a need for increased harvest levels (e.g., deer), in others to decreased levels.

The problem is deeper than just reduced population sizes or species loss. We are "fishing down the food web," harvesting species from higher trophic levels to the point of economic extinction, then moving down to the next trophic level (Pauly et al. 1998). Climate change may make it more difficult for these overfished systems to return to their previous state. For instance, the tenfold increase in Bering Sea jellyfish in the 1990s may be partly linked to climate change, and these jellies will reduce the food available for larvae of many commercially harvested species in the area as well as consuming the larvae themselves. An explosion in jellyfish populations in the Black and Asov Seas in the 1980s, while not directly linked to climate change, virtually wiped out once-productive fisheries there.

On coral reefs around the world, the loss of herbivores due to overharvest or disease is decreasing reef resilience to climate change. In the absence of grazers, mass coral-bleaching events are followed by an explosive growth of seaweed that makes it difficult for the reefs to recover (Hughes et al. 2007). Supporting healthy herbivore populations is thus an essential element of avoiding a shift from coral- to algal-dominated systems under climate change.

This interaction of climate change with overharvest and other stressors is also playing out in the Chesapeake Bay. The initial collapse of oyster populations resulted primarily from overexploitation, but poor water quality, climate change, new diseases, and

BOX 13.3 DON'T PICK JUST ONE

Although this book discusses categories of adaptation options in separate chapters, an adaptation strategy should encompass multiple options. For example, the salmon discussed in this chapter need streams with cool water and good gravel habitat, plenty of food in the ocean, and large enough populations to insure against occasional disaster. Protecting them will require not just limiting salmon harvests but also potentially removing dams, decreasing the human demand for water from salmon-bearing rivers, maintaining and restoring riparian vegetation, protecting water quality, and a host of other approaches. It is important to consider how each of these factors will be affected by climate change and to adapt our strategies accordingly. Adjusting harvest levels, timing, and techniques is one approach for creating more robust systems.

interactions among these stressors have prevented its recovery. The loss of the oysters' immense water filtration capacity (at its peak the Chesapeake oyster population is said to have filtered the entire bay in a single day) combined with increasing nutrient pollution and warmer water is causing massive phytoplankton blooms, leading to a growing hypoxic "dead zone." Warmer water due to climatic changes has also allowed southern oyster parasites to expand their range northward into the bay. Finally, efforts to restore sea grass and invertebrates are hampered because the bay may no longer be climatologically suitable for species that once called it home. It may be that overharvest, pollution, and climate change have pushed Chesapeake Bay into a new state from which it will be difficult to recover.

Climate-savvy harvest management may also be critical for protection of places and resources that seem unrelated to the stock in question. For example, depletion of salmon populations from the ocean affects not only marine food webs, but also the streams where salmon spawn and the forests that line the riverbanks. Salmon bring nutrients from the oceans back to the streams where they spawn, die, and decay, releasing nutrients directly into the water column or indirectly to the surrounding terrestrial ecosystem through the work of scavengers. Gresh and coauthors (2000) estimate that nutrient input from salmon in the United States' Pacific Northwest is just 7 percent of historical levels. This has caused shifts in production and composition of stream, lake, and riparian communities (e.g., Naiman et al. 2002). Whereas the Chesapeake Bay suffers from too much nutrient input, the problems in these streams stem from too little. Just as with the Chesapeake Bay, however, warming conditions and altered water flow due to climate change may further compound the community shifts. This is particularly true for the Pacific Northwest, given the likely negative effects of climate change on salmon populations in that region. Reducing salmon harvest, removing dams, and other measures to increase salmon success may be some of the best bets for not only increasing salmon resilience, but also affording their freshwater habitat some buffer to the effects of climate change.

Shifting Time and Space

Many harvested species already are or will be exhibiting range shifts. For example, North Pacific pollock distribution shifted significantly northward between 1999 and 2007. In the Bering Sea and Arctic Ocean, some fisheries management councils are beginning to grapple with what this will mean for the future of fishing (see box 13.1). During past ice ages many tree species shifted their ranges across entire continents, and there is some evidence that tree populations at the warmer ends of their ranges are already suffering from warming trends. Maximum sustainable yields will change for different regions as populations move into or out of traditional management areas. Growth rates, a key component of many fisheries harvest models, will also change with climate change. For example, models suggest that the yield of walleye in Ontario, Canada, will increase in the north and decrease in the south in a warmer world. Limits on fisheries will need to change to protect species or ensure sustainable yields as locations and population dynamics shift in response to changing climatic conditions.

Climate change is creating temporal as well as spatial change, such as changes in when seasonal events happen and increased variability in populations or resource availability over time. In many cases, harvest regulation and management is already designed to cope with variability. The Pacific Coastal Pelagic Fisheries Management Plan already adjusts harvest for periods of high or low productivity, such as for sardine stocks in relation to Pacific Decadal Oscillation or El Niño–Southern Oscillation cycles (fig. 13.2). Where seasonality and variability are not already taken into consideration, managers should at least assess the importance of doing so.

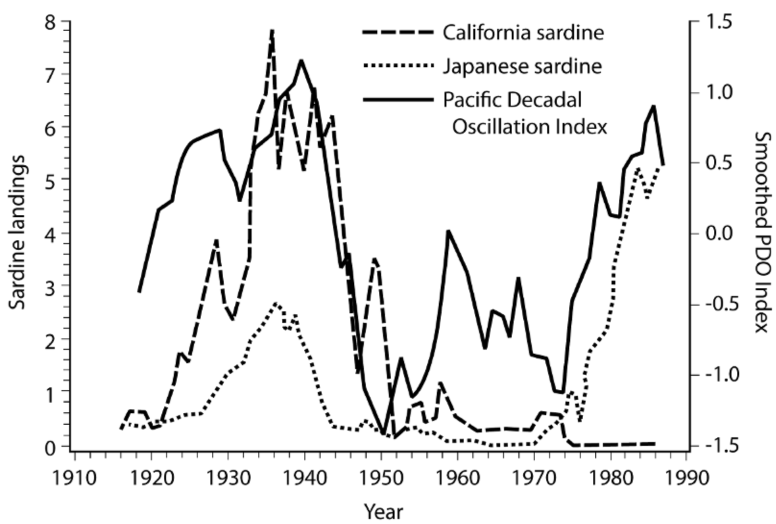

FIGURE 13.2 Sardine catch and the Pacific Decadal Oscillation. Sardine populations tend to be high when the Pacific Decadal Oscillation index is greater than 0 (warm phase) and low when it is less than 0 (cool phase). The correlation between population size and climate regime allows temperature to be factored into harvest rules. Sardine landings after FAO 2005.

Final Thoughts

Definitive coverage of issues relating to climate change and harvest are beyond the scope of this book. Rather, we hope the range of examples provides a sense of the multifaceted nature of the problem, and catalyzes thinking about equally multifaceted solutions.

Preventing the damage of overharvest has been a pressing issue for generations, and climate change only promises to compound the challenge. But there are opportunities in how we address resource extraction to create more climate-robust management schemes. Centuries of exploitation have resulted in the "shifting baseline" phenomenon whereby each generation accepts a diminished level of biodiversity or abundance as the new normal. Climate change threatens to be the ultimate shifting baseline. The challenge is to limit that shift by including climate-savvy harvest management in our strategies. Whether it is trees, fish, or some other harvested resource, planning ahead for changes will likely yield better results than waiting for dramatic changes to occur and responding in a reactionary fashion.