EFFECTS OF CLIMATE CHANGE ON FISHERIES

Written testimony by:

David O. Conover
Dean and Director
Marine Sciences Research Center
Stony Brook University
Stony Brook, NY 11794-5000

631-632-8781
dconover@notes.cc.sunysb.edu

Submitted to the:

Senate Committee on Commerce, Science, and Transportation Oceans
Atmosphere, Fisheries, and Coast Guard Subcommittee

At a hearing concerning:

Effects of climate change and ocean acidification on living marine resources

May 10, 2007
Room 253, Russell Senate Office Building

Introduction

I thank Madame Chair Cantwell, Ranking Member Snowe, and the other Members of the Subcommittee for the opportunity to describe to you the likely consequences of climate change on marine fisheries. My name is David Conover. I am the Dean and Director of the Marine Sciences Research Center of Stony Brook University, Long Island, New York. My research expertise involves the ecology and natural history of marine fishes and the impacts of harvesting and other human influences on wild fish populations. Of particular relevance to the subject of this hearing, I have devoted much of my 30-year career to studying the physiological mechanisms by which fish adapt evolutionarily to climate change. Much of this work concerns species that live along the east coast of North America from Florida to the Canadian maritimes, a region that encompasses dramatic changes in climate. We can learn a lot about what to expect from climate change by studying species that span the U.S. east coast.

You have asked me to address the consequences of climate change for fisheries, fish habitats, the distribution and abundance of species, food webs, and the gaps in our knowledge that preclude our ability to predict immediate and long term impacts. In addition, you have asked for suggestions on how resource managers should respond to these threats. I will begin by briefly outlining the major changes in the ocean ecosystems that are already underway and are expected to accelerate in the years ahead, touching briefly on ocean acidification and then devoting most of my attention to the effects of warming. Both the direct and indirect impacts of acidification and warming will be highlighted. I will then discuss several east coast examples where already there is strong evidence that climate change is harming local species and altering ecosystems in transitional zones. Finally, I'll talk about short-term solutions and research needed to provide a longer-term prognosis and options for the future.

Ocean Acidification

Knowledge of the potentially devastating impact of reduced pH on aquatic ecosystems is not new. Decades ago it became evident that acid rain was afflicting numerous freshwater ecosystems leading to declines and extinctions of numerous fish and macro-invertebrate species from certain lakes and streams that lacked a natural buffering capacity. What is new is the recognition that acidification of entire oceans is possible. It is caused not by acid rain, however, but from increased CO_2 in the atmosphere, which in turn leads to increased carbonic acid in the ocean.

Most of our knowledge of the direct effects of ocean acidification on marine organisms focuses on species known as "marine calcifiers" (e.g., corals, mollusks) that build skeletons or shells made of calcium carbonate. Many of these species will suffer impaired ability to build skeletons as pH decreases. We know less about the direct impacts of acidification on harvested species like fishes and squids. In these species, the response to acidification is likely to involve physiological diseases including acidosis of tissue and body fluids leading to impaired metabolic function. Egg and larval stages are likely to be much more susceptible than adults, suggesting that reduced reproductive success will be among the first symptoms to appear. The indirect effects of acidification on fisheries will include loss of reef habitat constructed by marine calcifiers. Many fishes depend on the physical structure provided by coral skeletons or shell-building organisms such as oyster reefs as essential habitat for one or more life stages. In addition, food web alterations will likely affect harvested species through bottom-up effects on the food chain resulting from pH-induced shifts in the plankton community. More research is needed to understand these complex interactions.

Ocean Warming

Temperature is a pervasive environmental factor with direct effects on nearly all aspects of the ecology, physiology, morphology, and behavior of poikilothermic or so-called "cold-blooded" animals. There is a vast scientific literature describing the temperature-dependence of physiological processes and thermal ecology of individuals of a given species. Less is known about population and ecosystem level responses to temperature change but we know enough to make fairly strong, general predictions about the consequences of warming at least for the species level.

All species are adapted for life over a relatively moderate range of temperatures compared with the extremes experienced form the poles to the tropics. Temperatures below the optimal range slow the rate of metabolism and, if too low, can become lethal. Temperatures above the optimal range increase metabolism and, because warmer water contains less dissolved oxygen, a thermal threshold is reached where respiratory demand exceeds the capacity for oxygen uptake, sometimes referred to as the "temperature-oxygen squeeze" (Portner and Knust 2007). Hence, temperature is one of the primary environmental factors that determine the geographic range of a species. Minimum winter temperatures often determine the high-latitude boundary (the northern boundary in the northern hemisphere) while summer maximums determine the low-latitude limit of a species. Even within the normal range of a species, the dynamics of populations often show strong correlations with temperature trends.

While scientists can use the thermal physiology of a species to predict how it might respond to the direct effects of ocean warming, there are indirect effects at the ecosystem level that complicate the overall impact considerably. In temperate regions, for example, the complex of species found at a given latitude are a mixture of those adapted to colder or warmer thermal regimes. These species are interconnected through a web of predatory, competitive, pathogenic, parasitic, and mutualistic interactions that influence the abundance of species. Invasive species also sometimes get a foothold more easily in systems undergoing disturbance. In addition, changes in temperature may influence the overall primary productivity of ecosystems in either positive or negative directions (Behrenfeld et al 2006), which may ultimately impact fisheries yields.

In general, the impact of ocean warming should be most evident at the northern and southern boundaries of the distribution of a given species. These boundaries tend to be shared among numerous species, and they tend to occur where there are sharp discontinuities in thermal gradients. Hence, there are certain regions of the world ocean that are transitional zones for numerous species. Cape Hatteras and Cape Cod are two such regions. It is within these transitional regions where we are likely to first see the strongest impacts of climate change. Most of the phenomena described above are illustrated by changes we are now seeing along the east coast of the U.S., particularly within Long Island Sound.

Impacts of warming on fisheries as exemplified by Long Island Sound

The Long Island region has represented a thermal transition zone for thousands of years. During the Pleistocene, this region was the transition from glaciated to non-glaciated terrain. Today it still represents a subtle but ecologically important transitional zone between warm water and cold-water regions.

Most temperate marine species of fishes and macro-invertebrates can be described as having either cold water or warm water affinities. Northern species like cod, winter flounder, and American lobster are classic cold-water species. For many of these species, the Long Island Sound region represents that southern terminus of their migration and/or geographic distribution. Southern species like weakfish, summer flounder, and blue crab are physiologically adapted to warm temperatures. Long Island Sound represents the northern end of their geographic occurrence. We are seeing strong evidence of shifts in the relative abundance of cold-water and warm-water species in our region that are consistent with the predictions of ocean warming.

The most well studied example is American lobster. Massive, catastrophic summer-fall mortalities of lobsters in Long Island Sound began in August 1999, and have continued to occur to a greater or lesser degree in subsequent summers. An extensive federally-sponsored research program has identified summer warming of Long Island Sound bottom waters, coupled with hypoxia, and the outbreak of disease as the most likely causes. One of these diseases called "excretory calcinosis", discovered by scientists at Stony Brook University, is a gill tissue blood disorder resulting directly from warm temperatures (Dove et al. 2004). Other lobster diseases also appear to result from the stress of high temperature and hypoxia. The result of these multiple stresses has been a 75% reduction in total landings and 85% reduction in the overall abundance of the population. These diseases now appear to be moving northward.

Another example of climate-induced effects on fisheries involves the northward expansion of a disease known as "dermo" that afflicts the oyster. It is caused by *Perkinsus marinus*, a parasite that yearly kills 50% of oysters in the Gulf of Mexico. Prior to the late 1980s, the parasite was known to occur only south of lower Chesapeake Bay. In the early 1990s, however, dermo underwent a 500 km northward range expansion extending all the way into the Gulf of Maine. Researchers at Rutgers University have demonstrated that the range expansion occurred during years when winters were unusually warm (Ford and Smolowitz 2007). The prevalence of dermo is now high from Delaware Bay to Cape Cod, with no signs of abating.

Shifts in the relative abundance of finfish in Long Island Sound also bear the signature of ocean warming. Like the lobster, winter flounder is also at the southern end of its distribution and it too is showing extremely severe declines. Commercial landings in New York are only 15% of what they were 50 years ago. According to annual resource assessment surveys conducted since 1984 by the Connecticut Department of Environmental Protection (CTDEP), winter flounder abundance in Long Island Sound is now less than 10% of what it was in 1990. We need more research to determine if winter flounder are declining due to warming temperatures. But when you look at the finfish community of Long Island Sound as a whole (CTDEP 2006), evidence of warming as the causative factor becomes much stronger. Most of the cold-water species of Long Island Sound have been declining over the past 15 years (e.g., lobster, winter flounder, Atlantic herring, cunner, longhorn sculpin, sea raven, ocean pout, winter skate, little skate) while most of the warm-water fishes have been increasing (e.g., striped bass, weakfish, summer flounder, menhaden, scup, striped sea robin, butterfish, Atlantic moonfish, hickory shad).

Finally, there is also evidence from Long Island Sound that the recent trend of warmer winters favors the growth and recruitment of invasive species over those of native species. Researchers from the University of Connecticut showed that exotic ascidian species (sea squirts) benefit more from mild winters while native species benefit more from cold winters (Stachowicz et al. 2002). Overgrowth of bottom habitat by invasive sea squirts is becoming an increasing problem in Long Island Sound.

Implications for Management

Resource managers need to recognize that local populations of species near the limits of their distributional ranges will need additional precautionary measures to protect them from extinction. Warming and acidification represent additional stresses that make populations less resilient to the effects of harvest. We may need to reduce harvest of some species in certain areas to enable them to withstand the additional stress.

Transitional regions are where the impact of climate change will first be evident. These regions are also conduits for species exchange. The transmittal of pathogens, predators, and invasive species across ecosystems will increase as species migrate into new regions across thermal and faunal boundaries such as Cape Cod, which separates the Mid-Atlantic region from the Gulf of Maine. Management practices that transplant species across ecosystems need to be viewed with caution.

Solutions, their implications, and further research

The ultimate and best solution is the reduction of greenhouse gases that cause acidification and warming. One solution advocated by some scientists and soon to be commercialized is the purposeful fertilization of open ocean habitats that are deficient in iron. The resulting pulses of phytoplankton growth sequester carbon from the atmosphere and may help reduce the buildup of atmospheric CO_2. Although this possibility deserves serious scrutiny, the ecosystem impacts of fertilization in most aquatic ecosystems almost always contain undesirable consequences for water quality, food webs, and fisheries. Hypoxia in Long Island Sound, for example, results largely from over-fertilization by nitrogen, which is the limiting nutrient in many coastal waters. Sometimes the blooms produced by enrichment turn out to be harmful algal species like “red tide” or “brown tide”. The ecological consequences of ocean fertilization on a scale sufficient to stem the build-up of green house gases needs much further research to evaluate the potential risks of unintended negative impacts.

The certainty of climate change and its potential impacts on ocean ecosystems underscore the need for a comprehensive ocean observation system. Our ability to unravel the causes and consequences of ecosystem change is directly dependent on the availability of a continuous time series of many different kinds of environmental data. Gradual trends in highly variable environmental parameters like temperature, oxygen, salinity, pH, chlorophyll, wind, circulation patterns, and others become evident only after many years. Fishery ecologists are frequently asked to explain the cause of episodic events like the die-off of lobsters in Long Island Sound, but we need an observation system that can provide “before, during, and after” data to give us the clues. Otherwise, we are like the detective at the scene of a crime with no evidence and lots of potential suspects. The technology exists to continuously measure numerous physical and biological parameters that will greatly help us understand and therefore devise strategies to cope with ecosystem alterations caused by climate change or other forces. The number and diversity of sensors currently deployed in U.S. ocean waters is woefully inadequate. Such observation systems will greatly aid resource managers in ensuring sustainable fisheries.

References

Behrenfeld, M. J., R. T. O'Malley, D. A. Siegel, C. R. McClain, J. L. Sarmiento, G. C. Feldman , J. Milligan, P. G. Falkowski, R. M. Letelier , and E. S. Boss, 2006: Climate-driven trends in contemporary ocean productivity. Nature, 444(7120), 752-755.

CTDEP, Bureau of Natural Resources, Marine Fisheries Division. 2006. *A Study of Marine Recreational Fisheries in Connecticut.* Federal Aid in Sport Fish Restoration, F-54-R-25, Annual Performance Report.

Dove ADM, LoBue C, Bowser P, Powell M. 2004. Excretory calcinosis: a new fatal disease of wild American lobsters Homarus americanus. DISEASES OF AQUATIC ORGANISMS 58 (2-3): 215-221.

Ford, S.E. and R. Smolowitz. 2007. Infection dynamics of an oyster parasite in its newly expanded range. Mar. Biol. 151:119-133.

Pörtner, H.O., Knust R. (2007) Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science 315, 95 - 97.

Stachowicz, J.J., J. R. Terwin, R.B. Whitlatch, and R.W. Osman. 2002. Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. Proc. Natl. Acad. Sci. 99:15497-15500.