Fisheries, Aquaculture and Marine Mammals

Interrelationship, Background and Issues

Fish, Fishing and Fisheries Series

Daniel Jakobsson
Editor

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FISHERIES, AQUACULTURE AND MARINE MAMMALS: INTERRELATIONSHIP, BACKGROUND AND ISSUES

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PREFACE

This book addresses a variety of subjects related to aquaculture. Predominantly, the subject matter concerns government regulations and actions taken in the most recent Congress as they apply to all aspects of aquatic life. Aquaculture-the farming of fish, shellfish, and other aquatic animals and plants in a controlled environment-is expanding rapidly. The 111th Congress may consider legislation to modify federal activities related to aquaculture, including possible standards to guide aquaculture development in offshore federal waters. Fish and marine mammals are important resources in the open ocean and nearshore coastal areas; many federal laws and regulations guide their management as well as the management of their habitat. This book also examines the consequences of climate change for fisheries, fish habitats and the distribution and abundance of species and food webs.

This book consists of public domain documents which have been located, gathered, combined, reformatted, and enhanced with a subject index, selectively edited and bound to provide easy access.

Chapter 1 - 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.

Chapter 2 - Fish and marine mammals are important resources in open ocean and nearshore coastal areas; many federal laws and regulations guide their management as well as the management of their habitat.

Commercial and sport fishing are jointly managed by the federal government and individual states. States generally have jurisdiction within 3 miles of the coast. Beyond state jurisdiction and out to 200 miles, the federal government manages fisheries under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) through eight regional fishery management councils. Beyond 200 miles, the United States participates in international agreements relating to specific areas or species. The 111th Congress may oversee implementation of the MSFCMA as well as address individual habitat and management concerns for U.S. commercial and sport fisheries to achieve a sustainable balance between resource use and protection. Current concerns include whether additional effort should be taken to eliminate overfishing, how fishery disaster assistance should be funded, and whether to more aggressively encourage fishing vessel capacity reduction and limited access privilege programs.

Aquaculture—the farming of fish, shellfish, and other aquatic animals and plants in a controlled environment—is expanding rapidly abroad, with more modest growth in the United States. In the United States, important species cultured include catfish, salmon, shellfish, and trout. The 111th Congress may consider legislation to modify federal activities related to aquaculture, including possible standards to guide aquaculture development in offshore federal waters.

Marine mammals are protected under the Marine Mammal Protection Act (MMPA). With few exceptions, the MMPA prohibits harm or harassment ("take") of marine mammals, unless restrictive permits are obtained. It also addresses specific situations of concern, such as dolphin mortality, primarily associated with the eastern tropical Pacific tuna fishery. The 111th Congress may consider bills to reauthorize and amend the MMPA as well as measures to address specific marine mammal habitat and management concerns, such as how to deal with the effects of increasing noise in the ocean.

Chapter 3 - Fish and marine mammals are important resources in open ocean and nearshore coastal areas; many federal laws and regulations guide their management.

Commercial and sport fishing are jointly managed by the federal government and individual states. States generally have jurisdiction within 3 miles of the coast. Beyond state jurisdiction and out to 200 miles, the federal government manages fisheries under the MSFCMA through eight regional fishery management councils. Beyond 200 miles, the United States participates in international agreements relating to specific areas or species. Some of the fishery measures enacted by the 110th Congress included P.L. 110-28, providing $60.4 million for Pacific salmon disaster assistance as well as $110 million for hurricane recovery assistance to the Gulf of Mexico shrimp and fishing industries, P.L. 110-161 provided $13.395 million for alleviating economic impacts on the Massachusetts groundfish fishery, and provisions in P.L. 110-246 transferred $170 million to NMFS for distribution to commercial and recreational members of the fishing communities affected by the salmon fishery failure in California, Oregon, and Washington. Provisions in P.L. 110-114 increased the authorization for research on Columbia and Snake River salmon survival, including methods to reduce avian predation on juvenile salmon; coordinated management of two aquatic nuisance species dispersal barriers on the Chicago Sanitary and Ship Canal and authorized an Upper Mississippi River dispersal barrier project; authorized a feasibility study of a dispersal barrier on the Lake Champlain Canal; modified oyster restoration programs in Long Island Sound, Chesapeake Bay, and Delaware Bay; and modified Great Lakes fisheries restoration, allowing nonfederal participants to provide as much as 100% of their nonfederal share through in-kind contributions. P.L.110-181 directed the Secretary of Transportation to review ship disposal practices, including use of disposed vessels as artificial reefs. P.L. 110-243 directed the United States to initiate international discussions to negotiate an agreement for managing fish stocks in the Arctic Ocean.

Aquaculture—the farming of fish, shellfish, and other aquatic animals and plants in a controlled environment—is expanding rapidly abroad, with more modest advances in the United States. In the United States, important species cultured include catfish, salmon, shellfish, and trout. The 110th Congress enacted P.L. 110-85, authorizing the Food and Drug Administration (FDA) to enhance inspection of aquaculture and seafood products and requiring FDA to report on environmental risks associated with genetically engineered seafood products, and P.L. 110-246, reauthorizing the National Aquaculture Act and enhancing various programs within the Department of Agriculture that support aquaculture.

Marine mammals are protected under the MMPA. With few exemptions, the MMPA prohibits harm or harassment ("take") of marine mammals, unless restrictive permits are obtained. It addresses specific situations of concern, such as dolphin mortality, primarily associated with the eastern tropical Pacific tuna fishery.

Chapter 4 - Open ocean aquaculture is broadly defined as the rearing of marine organisms in exposed areas beyond significant coastal influence. Open ocean aquaculture employs less control over organisms and the surrounding environment than do inshore and land-based aquaculture, which are often undertaken in enclosures, such as ponds. When aquaculture operations are located beyond coastal state jurisdiction, within the U.S. Exclusive Economic Zone (EEZ; generally 3 to 200 nautical miles from shore), they are regulated primarily by federal agencies. Thus far, only a few aquaculture research facilities have operated in the U.S. EEZ. To date, all commercial aquaculture facilities have been sited in nearshore waters under state or territorial jurisdiction.

Development of commercial aquaculture facilities in federal waters is hampered by an unclear regulatory process for the EEZ, and technical uncertainties related to working in offshore areas. Regulatory uncertainty has been identified by the Administration as the major barrier to developing open ocean aquaculture. Uncertainties often translate into barriers to commercial investment. Potential environmental and economic impacts and associated controversy have also likely contributed to slowing expansion.

Proponents of open ocean aquaculture believe it is the beginning of the "blue revolution" — a period of broad advances in culture methods and associated increases in production. Critics raise concerns about environmental protection and potential impacts on existing commercial fisheries. Potential outcomes are difficult to characterize because of the diverse nature of potential operations and the lack of aquaculture experience in open ocean areas.

The Natural Stock Conservation Act of 2007 was introduced as S. 533 on February 8, 2007. This legislation would amend the National Aquaculture Act of

1980 to prohibit the issuing of permits for marine aquaculture in the EEZ until requirements for permits are enacted into law. The National Offshore Aquaculture Act of 2007 was introduced as H.R. 2010 in the House on April 24, 2007, and as S. 1609 in the Senate on June 13, 2007, both by request of the Administration. The legislation focuses on the development of a framework for issuing permits to operate in the EEZ. At the time S. 1609 was introduced, four amendments were referred to the Committee on Commerce, Science, and Transportation concerning environmental risks, comprehensive research and development, domestic ownership, and a prohibition on finfish aquaculture off the coast of Alaska.

This report discusses four general areas: (1) operational and business-related challenges; (2) potential economic impacts; (3) potential environmental impacts; and (4) the legal and regulatory environment. It summarizes recent executive and legislative branch actions. Significant questions remain about whether an appropriate mechanism exists for any federal agency to provide an open ocean aquaculture lease with the necessary property rights to begin construction and operation. Policy makers and regulators will be challenged to weigh the needs of a developing industry against potential environmental and social impacts.

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Editors: Daniel Jakobsson

Chapter 1

EFFECTS OF CLIMATE CHANGE ON FISHERIES-CONOVER TESTIMONY

David O. Conover

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 "temperatureoxygen 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,