Andrew J. Pershing
Associate Professor, University of Maine School of Marine Sciences
Research Scientist, Gulf of Maine Research Institute

Testimony on
"HR 6096 the Atlantic Fisheries Statues Reauthorization Act of 2012"
U.S. House of Representatives
Committee on Natural Resources
Subcommittee on Fisheries, Wildlife, Oceans, and Insular Affairs oversight hearing
July 19, 2012
Washington DC

Chairman Fleming, Ranking Minority member Sablan, distinguished members of the Subcommittee, thank you for inviting me here to speak to you today on HR 6096, the Atlantic Fisheries Statues Reauthorization Act of 2012. My name is Andrew Pershing. I am an associate professor of oceanography at the University of Maine, and I am also a research scientist at the Gulf of Maine Research Institute. The views that I will express today are my own and do not constitute official conclusions endorsed by either institution. I received a Ph. D. in Ecology and Evolutionary Biology from Cornell University in 2001. The main goal of my research is to understand how marine ecosystems respond to changes in the physical environment. I have contributed to more than 30 peer-reviewed publications on subjects ranging from single celled algae to bus-sized right whales. Recently, much of my research has focused on understanding how a climate-driven shift in the plankton community in the Northwest Atlantic impacted fish, including herring, bluefin tuna, and Atlantic salmon.

Introduction

Since the Northwest Atlantic Fisheries Convention was enacted in 1995, fishery scientists and managers have recognized the importance of moving from single species management to ecosystem-based management. Ecosystem-based management requires managers to consider the linkages between fish stocks through predator-prey relationships and between fish and the environment. Given the large changes we are observing in the ocean environment and the changes projected for the future, there is a growing need to explicitly consider climate change when managing fish stocks.

Fishery managers are charged with the dual mission of both protecting fisheries (i.e. ensuring the fishing industry is profitable) and protecting fish (i.e. ensuring that fish populations are robust). While fishing obviously reduces the number of fish, any fisherman will tell you that the environment in the ocean matters, too. Environmental conditions such as temperature, salinity, and the abundance of plankton and other prey determine where and when a particular fish species is found and influence, quite literally, how many fish are in the sea. By altering the underlying environmental conditions, climate change is directly impacting the distribution and abundance of fish in the ocean. For fisheries management to achieve its goals of conserving both fisheries and fish, it is important expand our ability to monitor and forecast the impact of environmental changes on fish populations and to implement policies that explicitly account for the impact of climate variability and change on ocean ecosystems.

The mean temperature of our planet is now nearly 1°C warmer than at the beginning of the 20th Century, and the last ten years were the warmest ever recorded (WMO 2012). There is strong consensus in the scientific community that this warming is caused by elevated levels of greenhouse gases in the atmosphere (IPCC 2007, National Research Council 2008). A major goal of the oceanographic community is to understand how conditions in the ocean will change and how marine ecosystems will respond to these changes.

Of course, warming due to greenhouse gases is only one of the signals in the climate system. The earth's climate also exhibits natural modes of variability. These natural modes involve the redistribution of heat in the atmosphere or ocean, with warming in one location balanced by cooling in another. For example, the surface temperature of the Pacific Ocean can be characterized as being in either a "cool" state or a "warm" state (Mantua & Hare 2002). In the cool state, the Northwest Pacific is colder than average while the eastern equatorial region is warmer. During the warm phase, the temperatures reverse: warm in the northwest, cool along the equator. Temperatures in the ocean change much more slowly than those in the atmosphere, so the Pacific can remain in the same state for several years. Climate scientists named this pattern the Pacific Decadal Oscillation or PDO. Changes in the climate system like the PDO serve as natural experiments. By studying how ecosystems change in response to the shifts in the physical environment, and how these changes have impacted fish populations, we can gain insight into how they are likely to respond to future climate change.

Brief review of climate impacts on fisheries

At a broad level, the response of fish populations to large scale changes in their physical environment can be classified into two broad categories, range shifts and regime shifts. Range shifts involve the movement of a population from one region to another, while regime shifts involve a change in the patterns of productivity that support the fish community. Both range and regime shifts present challenges for fishery managers. I will present two examples that illustrate how these shifts impact fish and fisheries.

During the 1980s, the fishery for cod off of Newfoundland was one of the most valuable in North America. Scientists warned that fishing levels were unsustainable, but no one was prepared for how rapidly the population collapsed. A climate-driven range shift was a major factor behind the rate of decline (Rose et al. 2000). During the late 1980s, temperatures in the Labrador Sea cooled. This cooling prompted capelin, the small fish that are the preferred prey for northern cod, to shift further south, towards the Grand Banks. The cod responded by following the capelin south to warmer waters. This had the effect of concentrating the cod on the western Grand Banks, an area of very high fishing effort. The population was quickly fished to very low levels, from which it is only now beginning to recover. Of particular relevance to the Anadromous Fish Conservation Act, my colleagues and I have recently uncovered a connection between the decline in return rate of Atlantic salmon, which feed on capelin in the Labrador Sea, and the same changes in temperature and capelin that led to the shift in cod .

One of the simplest climate change predictions is that animals will shift their ranges toward the poles in response to warming. These shifts are already underway in the Northwest Atlantic. Nye et al. (2009) found that the distributions of the majority of fish caught in NMFS's annual trawl surveys have moved northward. For example, in the 1960s, a distinct southern stock of red hake existed south of Cape Cod. Today, this stock has moved into the northern stock area and is rarely found south of the Cape. Shifts that happen across stock boundaries can be particularly difficult for management (Link et al. 2011). For an area like the Gulf of Maine, stocks often cross into Canadian waters, increasing the importance of organizations like the North Atlantic Fisheries Organization.

A regime shift is an abrupt and persistent change in the structure and function of an ecosystem, and by definition, affects many components of the system (deYoung et al. 2004). The PDO mentioned above causes changes in the amount of nutrients brought to the surface along the West Coast and the equator. These changes alter the rate at which phytoplankton, single celled algae responsible for the majority of the photosynthesis in the ocean, grow. The change in phytoplankton lead to changes further up the food chain that control whether anchovies or sardines dominate and which salmon runs are successful (Hare & Mantua 2000, Chavez et al. 2003).

The Northwest Atlantic also has the potential for regime shift-like changes. The same set of physical changes that prompted the collapse of Newfoundland cod also contributed to a dramatic reorganization of the ecosystem on the Northwest Atlantic Shelf, with consequences for several US fish stocks. During the 1990s, the Gulf of Maine became considerably fresher (Smith et al. 2001, Mountain 2003). Using data collected by the National Marine Fisheries Service, I have examined how the 1990s salinity changes altered the abundance of phytoplankton, zooplankton, and fish in the Gulf of Maine (Pershing et al. 2005, Greene & Pershing 2007, Pershing et al. 2010).

The freshening in the 1990s was not enough to directly affect the physiology of the organisms in the Gulf, but it had a large impact on the density structure of the water. The density of seawater is determined by temperature and salinity, with warm or fresh water being lighter than cold or salty water. The freshening in the 1990s created stronger stratification in the water column of the Gulf of Maine (Mountain & Taylor 1998). This means that there was a greater density barrier between water at the surface and water at the bottom of the ocean. Phytoplankton were generally more abundant throughout the year, with the largest increases during the fall and winter. Tiny crustaceans called copepods are the main link between phytoplankton and fish. Most of the copepod species in the Gulf of Maine increased in the 1990s, with the largest increases also occurring during the fall and winter. The main exception to this pattern was a decline in the large copepod *Calanus finmarchicus*. *Calanus* dominates the zooplankton biomass in the North Atlantic, and it is the main prey for adult herring, larval cod, and the endangered right whale. Each of these *Calanus* predators was impacted by the plankton community changes. Individual herring were smaller during this period, larval cod survival was low

(Mountain & Kane 2010) and right whales produced fewer calves (Greene & Pershing 2004). Although individual herring were smaller than expected, the number of herring increased dramatically following the change in the plankton community. Herring spawn in the fall, and the increased phytoplankton and small copepod abundance during this time period may have supported enhanced survival of herring larvae (Greene & Pershing 2007). When the salinity anomalies ended in 2001, the plankton community returned to levels more like those in the 1980s (Pershing et al. 2005, Greene & Pershing 2007).

The 1990s regime shift was driven by enhanced stratification due to the reduced salinity. Over the next 50 years, we expect that stratification will increase in most parts of the ocean, due to increased surface warming and increased precipitation at high latitudes (Capotondi et al. 2012). Thus, the mechanism by which the 1990s salinity changes altered the Gulf of Maine ecosystem could provide a window into how this ecosystem will respond to a warmer and fresher future. The mechanism we propose begins with the influence of enhanced stratification on fall-winter phytoplankton abundance. During these seasons, phytoplankton growth is limited by the availability of light. The increased density contrast caused by the freshwater would tend to keep the phytoplankton near the surface, reducing light limitation and leading to higher phytoplankton growth. However, enhanced stratification will also tend to reduce the supply of nutrients to the surface waters, potentially limiting the total ability of the ecosystem to produce new biomass (i.e. fish). Enhanced phytoplankton production alone cannot explain the decline of *Calanus*. We are currently investigating the possibility of a positive feedback loop that could explain this pattern. In this loop, an increase in phytoplankton abundance leads to more small copepods. The enhanced copepod community supports a higher abundance of copepod predators, both invertebrate predators like chaetognaths and vertebrates such as herring. The copepod predators then reduce the abundance of *Calanus*. Fewer *Calanus* means reduced grazing pressure on the phytoplankton leading to higher phytoplankton abundance, starting the loop again. This feedback loop helps explain why the Gulf of Maine regime shift was so persistent.

Conclusions

Whether caused by natural climate variability or long-term climate change, regime and range shifts pose an array of challenges for fisheries managers. In my review of climate impacts on fish, one clear pattern emerged. Stocks that are overfished are more vulnerable to climate change, and conversely, climate change makes stocks more sensitive to overfishing (Brander 2007). Continuing to rebuild our fish stocks is a necessary step towards ensuring that US fisheries can thrive during the coming decades. However, just rebuilding biomass is not enough. One of the hallmarks of a heavily fished stock is a reduction in the older, larger members of the population. Larger fish produce more eggs, and the increased metabolic efficiency associated with large size gives these individuals an advantage during adverse conditions. Thus, big fish help buffer a population in the face of environmental variability (Berkeley et al. 2004, Ottersen et al. 2006, Planque et al. 2010). Moving beyond biomass to consider other measures of stock health should provide a more robust index of the status of a stock.

The challenges of managing in a changing climate also put a premium on accurate, timely data and on improved knowledge of the connections between fish and the environment. The ability to identify when and why a shift has occurred is a vital first step toward incorporating climate information into fisheries management. The US Integrated Ocean Observing System (IOOS) gives us an unprecedented ability to rapidly detect changes in the ocean. From my point of view as a biological oceanographer, the main limitation of current IOOS programs is the limited availability of biological data. Augmenting IOOS with additional monitoring for plankton and fish would greatly aid the task of identifying regime shifts. We also need to continue to develop new models to mechanistically link fish populations to temperature and prey abundance. Developing these models will require an integrated, interdisciplinary approach, involving collaborations between federal agencies like NOAA and the National Science Foundation and between academic and federal scientists. Organizations such as CINAR, a collaboration between NOAA and the University of Maine, Gulf of Maine Research Institute, Woods Hole Oceanographic Institution, Rutgers University, and the University of Maryland Center for Environmental Studies, were designed to do just the kind of integrative fisheries and climate science necessary to support sustainable management of fish and fisheries in a changing climate.

Thank you for the opportunity to testify today, and I look forward to your questions.

Literature Cited

Berkeley SA, Hixon MA, Larson RJ, Love MS (2004) Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29:23-32

Brander KM (2007) Global fish production and climate change. Proceedings of the National Academy of Sciences 104:19709-19714

Capotondi A, Alexander MA, Bond NA, Curchitser EN, Scott JD (2012) Enhanced upper ocean stratification with climate change in the CMIP3 models. Journal of Geophysical Research 117

Chavez FP, Ryan J, Lluch-Cota SE, Niquen M (2003) From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. Science 299:217-221

de Young B, Harris RP, Alheit J, Beaugrand G, Mantua N, Shannon L (2004) Detecting regime shifts in the ocean: Data considerations. Progress in Oceanography 60:143-164

Greene CH, Pershing AJ (2004) Climate and the conservation biology of the North Atlantic right whale: the right whale at the wrong time? Frontiers in Ecology and the Environment 2:29-34

Greene CH, Pershing AJ (2007) Climate drives sea change. Science 315:1084-1085

Hare S, Mantua N (2000) Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-145

IPCC (2007) Climate Change 2007 - The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Vol. Cambridge University Press, Cambridge, U. K.

Link JS, Nye JA, Hare JA (2011) Guidelines for incorporating fish distribution shifts into a fisheries management context. Fish and Fisheries 12:461-469

Mantua NJ, Hare SR (2002) The Pacific Decadal Oscillation. Journal of Oceanography 58:35-44

Mountain DG (2003) Variability in the properties of Shelf Water in the Middle Atlantic Bight, 1977-1999. J Geophys Res Oceans 108:3014

Mountain DG, Kane J (2010) Major changes in the Georges Bank ecosystem, 1980s to the 1990s. Marine Ecology Progress Series 398:81-91

Mountain DG, Taylor MH (1998) Spatial coherence of interannual variability in water properties on the U. S. northeast shelf. Journal of Geophysical Research 103:3083-3092

National Research Council (2008) Understanding and Responding to Climate Change: Highlights of National Academies Reports, Vol. National Academies of the United States

Nye JA, Link JS, Hare JA, Overholtz WJ (2009) Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. Marine Ecology Progress Series 393:111-129

Ottersen G, Hjermann DØ, Stenseth NC (2006) Changes in spawning stock structure strengthen the link between climate and recruitment in a heavily fished cod (*Gadus morhua*) stock. Fish Ocean 15:230-243

Pershing AJ, Greene CH, Jossi JW, O'Brien L, Brodziak JKT, Bailey. BA (2005) Interdecadal variability in the Gulf of Maine zooplankton community with potential impacts on fish recruitment. ICES Journal of Marine Science 62:1511-1523

Pershing AJ, Head EHJ, Greene CH, Jossi JW (2010) Pattern and scale of variability among Northwest Atlantic Shelf plankton communities. Journal of Plankton Research 32:1675-1684

Planque B, Fromentin J-M, Cury P, Drinkwater KF, Jennings S, Perry RI, Kifani S (2010) How does fishing alter marine populations and ecosystems sensitivity to climate? J Mar Sys 79:403-417

Rose GA, deYoung B, Kulka DW, Goddard SV, Fletcher GL (2000) Distribution shifts and overfishing the northern cod (Gadus morhua): a view from the ocean. Canadian Journal of Fisheries and Aquatic Sciences 57:644-663

Smith PC, Houghton RW, Fairbanks RG, Mountain DG (2001) Interannual variability of boundary fluxes and water mass properties in the Gulf of Maine and on Georges Bank: 1993–97. Deep Sea Research II 48:37-70

WMO (2012) WMO Statement on the Status of the Global Climate in 2011, World Meteorological Organization