CLIMATE CHANGE AND OCEANS: IMPACTS AND IMPLICATIONS

Testimony of
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Hearings on: "Rising Tides, Rising Temperatures; Global Warming's Impacts on the Oceans"

Chairman Markey, Ranking Minority Member Sensenbrenner, and members of the Committee: thank you for the invitation to testify today. My name is Jane Lubchenco. I am the Wayne and Gladys Valley Professor of Marine Biology and Distinguished Professor of Zoology at Oregon State University. I lead an interdisciplinary, multi-university research team called PISCO, the Partnership for Interdisciplinary Studies of Coastal Oceans, that studies the dynamics of the coastal ecosystem off Washington, Oregon and California. I had the pleasure of serving on the Pew Oceans Commission and I currently serve on the Joint Ocean Commission Initiative (JOCI) that seeks to implement the recommendations of the Pew Oceans Commission and the U.S. Commission on Ocean Policy. I also co-founded and serve as Vice Chair of Climate Central, a new nonprofit, non-advocacy organization that seeks to communicate scientific information about climate change and solutions in understandable fashion.

I am here today as a marine scientist, to share scientific information about impacts of climate change on ocean ecosystems and the implications of these changes for people and for U.S. policies and practices. I will focus on findings from the peer-reviewed scientific literature and relevant scientific assessments such as the Intergovernmental Panel on Climate Change (IPCC) the Arctic Climate Impact Assessment, and the Millennium Ecosystem Assessment, and also provide examples from my personal experiences and research.

I will use powerpoint images to illustrate some key information. I request that a copy of my powerpoint presentation be entered into the record, along with a copy of the JOCI white paper entitled "Addressing Oceans and Climate Change in Federal Legislation". Both are attached to this testimony. Thank you, Mr. Chairman.

IMPACTS

Predicted Impacts: Warmer water, rising sea level, more acidic seawater

I begin by summarizing three key impacts of climate change on oceans, all of which were predicted, based on scientific understanding of the climate system, then focus on another possible impact that has taken us by surprise. In each case, I'll describe the physical change first, then the biological and ecological consequences of the physical change. The three predicted impacts are: (1) increases in ocean temperatures, (2) increases in sea level, and (3) increases in the acidity of seawater.

(1) Warmer waters: There is unequivocal evidence that the oceans are warming. The temperature of every ocean basin around the world increased over the second half of the 20^{th} century. Taken as a whole, the ocean is now significantly warmer than it was in the middle of the 1900's.

Warmer waters have numerous consequences for life in the oceans: (a) Corals, when stressed by warmer temperatures, respond by expelling the microscopic plants they harbor – a phenomenon known as 'coral bleaching.' Although bleached corals do not always die, they often do. The incidence of bleaching events is increasing globally. Because coral reefs provide the three-dimensional habitat for millions of other species in tropical waters, their demise would have dire consequences for these rich oases of biodiversity. People who depend upon coral reef ecosystems for food, recreation and many associated livelihoods are already experiencing the consequences of disrupted and degraded coral reef ecosystems.

(b) Numerous species are shifting their geographic ranges, in response to changing ocean temperatures. In the north Atlantic, for example, herring, cod, capelin and mackerel are shifting poleward. In some cases, predators and prey shift differentially, with consequent disruptions to their ecosystems.

(c) Other species such as polar bears and other Arctic ice-dependent species face likely extinction as warmer waters melt the ice upon which they depend for food or shelter.

(2) Rising Sea Level: Sea level has risen steadily over the last century, on average about 6 inches, due to both thermal expansion and the melting of glaciers, ice caps and ice sheets on land. Sea level is expected to continue to rise, although the exact amount depends on a number of factors for which current information is insufficient for precise predictions. The consequences of rising sea level may be significant for people living on or near the shore, and significant for already-stressed coastal estuaries, salt marshes and mangrove ecosystems. On balance, however, the consequences of sea level rise are minimal for most marine species.

(3) Increasing acidity: Between 1/3 and ½ of the carbon dioxide that humans have released into the atmosphere has been taken up by oceans. When absorbed by oceans, CO2 is converted into carbonic acid, making seawater more acidic. Measurements indicate that the oceans are becoming more acidic. Experiments in the laboratory suggest that this increasing acidity is likely to be problematic for any marine species that makes a

shell or skeleton from calcium carbonate. The rate at which a new shell or skeleton is made depends on temperature and acidity. Likewise, the rate at which a shell or skeleton is dissolved depends on temperature and acidity. Hence a wide variety of life in oceans – ranging from corals to microscopic plants to snails, clams, mussels, oysters, sea stars, sea urchins, lobsters and crabs – is likely to be negatively impacted by an increasingly acid ocean.

I've summarized three major ways in which climate change is impacting life in the oceans: warmer waters, rising sea level and increasing acidity. Warming and acidification pose very serious threats to marine life and to many of the benefits that ocean ecosystems provide to people. It is important to note that although each of the three impacts was predicted, the *rate* of change for each has been faster than initially predicted. Most climate predictions have been conservative. In addition, these changes may interact with one another. A PISCO researcher, Dr. Gretchen Hofmann and her team at the University of California at Santa Barbara are finding that some species may be able to cope with changes in acidity alone or changes in temperature alone, but not the combination of the two.

A possible unexpected impact: Changes in coastal winds and circulation.

I will next describe a recently discovered perturbation of the ocean ecosystem off the west coast of the US, specifically along the coasts of Washington and Oregon. Beginning in 2002, our PISCO team has documented a new 'dead zone' that appears each summer. This dead zone is an area of the ocean where the levels of oxygen are too low to support most marine life. Fish and invertebrates suffocate if they cannot swim or scuttle away as the oxygen levels plummet.

This dead zone is unlike most of the other dead zones around the world, for example, the one in the Gulf of Mexico, that are driven by nutrient pollution coming from the land. The dead zone off the Pacific Northwest appears to be caused by changes in atmospheric and oceanic conditions, both of which are suspected of being related to climate change.

To understand how this dead zone develops, a little background information about normal upwelling dynamics is helpful. Around the world, on the western sides of continents, winds (driven by the differences in atmospheric pressure over the land and over the ocean) blow along the coast toward the equator. Because the earth is rotating, surface waters are pushed away from the coast and nutrient-rich but low-oxygen water from the dark, deeper portions of the ocean are pulled to the surface. This 'upwelling' of deep water brings nutrients to the surface and fuels the rich ecosystems typically found off these coasts. 'Coastal upwelling ecosystems' collectively represent about 1% of the surface area of oceans but they have historically provided about 20% of global fisheries, in large part due to this infusion of nutrients into sunlit, coastal waters. Other coastal upwelling ecosystems occur off the coasts of Chile and Peru, South Africa and Namibia, and Morocco.

In the Pacific North West, beginning in 2002, however, this normal pattern shifted slightly, but the slight shifts brought dire consequences. Suddenly fishermen were hauling up Dungeness crab pots only to find them full of dead crabs. Coastal residents and tourists reported mass numbers of dead fishes and crabs washed up on beaches. Recreational divers reported seeing huge schools of rockfish in unusual places. Scientists documented dead fish on the ocean floor and biological ‘erratics’: deep-dwelling fishes stranded in intertidal tide pools. Researchers with Oregon State University’s Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) team figured out the cause of these anomalies: there was not enough oxygen in some of the water for most crabs and fishes to live, so they escaped or suffocated.

Since 2002, this dead zone has reappeared each summer: we’ve documented six dead zone events in six years. In a paper published in *Science* in February, we reported that these recent events are highly unusual compared to the last 60 years (as far back as reliable dissolved oxygen measurements go.) Hypoxia (‘low oxygen’) appears to have become the ‘new normal’ for summertime off our coasts.

2006 was the worst year on record: the low-oxygen water persisted for 4 months and occupied as much as 2/3 of the water column over approximately ½ of the continental shelves of Washington and Oregon. Moreover oxygen levels plummeted to near zero in 2006: seawater was not just hypoxic, it was anoxic (no oxygen). Mass die-offs of bottom-dwelling animals were documented. Some crabs and fishes escaped, and some of those have returned to the area, but the seafloor remains significantly depleted. The long-term consequences to fisheries of the region are not known.

Teams of researchers from OSU, the University of Washington, NOAA Fisheries, the Olympic Coast National Marine Sanctuary, the Oregon Department of Fish and Wildlife and Oregon Coastal Ocean Observing System have cobbled together resources to document these events and their consequences and to piece together the following understanding. Changes in both atmospheric and oceanic conditions are implicated in causing the dead zones. We have documented both changes in ocean conditions that set the stage for dead zones and changes in the coastal winds that trigger the events. Abundant nutrients from strong upwelling trigger explosive growth of microscopic plants in the surface waters. When these plants begin to sink and die, they are decomposed by bacteria that consume oxygen. Successive cycles of upwelling and decomposition result in lower and lower levels of dissolved oxygen in the water.

We cannot say definitively that these dead zones are caused by climate change, but we can say that they are consistent with our understanding of climate change dynamics. Moreover, there is no other obvious explanation for the appearance of dead zones off an open coast such as ours. This dead zone is a consequence of changes in oceanic and atmospheric conditions, not runoff of nutrients from the land.

This dead zone is a seasonal phenomenon. When coastal winds shift to a primarily poleward direction in October, downwelling conditions become dominant, the area is re-oxygenated and remains oxygenated until the following spring-summer when upwelling-favorable conditions develop and a new dead zone reappears. Some fish and crabs appear to venture back into the area during the wintertime, but come summer, they must again flee or die.

The consequences of the dead zone appear to be quite significant for the seafloor communities, with a number of longer-lived, large-bodied species disappearing from the system. Little is known about the impacts of repeated annual die-offs in these historically stable and rich communities.

In summary, fluctuations in the timing and intensity of coastal winds appear to be altering the dynamics of the historically rich ocean ecosystems off Washington and Oregon. These anomalies vary in intensity from year to year. These changes are unprecedented in this ecosystem relative to last 6 decades. Comparisons with other coastal upwelling ecosystems: off Chile and Peru, South Africa and Namibia, and Morocco would be useful. Further research will help determine ultimate causes and consequences.

IMPLICATIONS

The collective impacts of climate change on life in the oceans are serious and largely unappreciated. Moreover, they exacerbate a plethora of existing stresses on ocean ecosystems: overfishing, destructive fishing gear, unsustainable coastal development, nutrient and chemical pollution and introduction of non-native species. As reported in the Millennium Ecosystem Assessment and the reports from both ocean commissions, the wealth of benefits that humans derive from ocean ecosystems is already at risk due to these combined stresses, and climate changes will present even greater challenges.

Americans say they look to the ocean for healthy seafood, for abundant wildlife, for places to enjoy and be inspired, for their livelihoods, for vibrant coastal communities and in many cases for their identity. All of these benefits depend on healthy, productive and resilient ocean and coastal ecosystems. All are at risk in the face of a rapidly changing climate. If society wishes to maintain the above benefits and minimize the most serious consequences of climate change, it should

1. Reduce greenhouse gas emissions significantly
2. Avoid mitigation ‘solutions’ that trigger unintended consequences
3. Prepare to adapt human infrastructure to changes that are inevitable
4. Manage human activities to maximize likelihood that species can adapt
5. Invest in scientific monitoring and research to guide decisions, and
6. Educate citizens about options and consequences

Let me expand briefly on items 3 and 4. Most discussions about ‘adaptation’ focus on adapting human infrastructure to adjust to those impacts of climate change that are inevitable. I believe we should redefine ‘adaptation’ to also include managing human activities in a fashion that maximizes the likelihood that species can adapt to changes that are inevitable. The primary reason for expanding our thinking about ‘adaptation’ is the reality that human health, prosperity and well-being depend upon the healthy, productive and resilient ecosystems. Our future well-being depend not only on our ability to adapt, but on that of the millions of species that provide us with food, shelter, pollination services, recycling, climate regulation, flood regulation, shoreline protection, medicines, recreation, inspiration and much more.

Managing human activities to maximize the likelihood that species can adapt includes two general categories of actions: reducing other stresses and protecting biodiversity and habitats. (1) Reducing other stresses would entail reducing nutrient and chemical pollution, managing fisheries conservatively; eliminate use of destructive fishing gear, and controlling invasive species. (2) Protecting biodiversity and habitats to maximize likelihood of adaption would include establishing networks of no-take marine reserves and other protected areas and protecting coastal habitats.

All six of the items listed above have governance, management and funding implications. In my view, none of these is expendable. The recently released white paper entitled "Addressing Oceans and Climate Change in Federal Legislation" from the Joint Oceans Commission Initiative (JOCI) provides additional information about a number of these actions.

In summary, climate change is already impacting ocean ecosystems in U.S. waters and around the world. Climate-related stresses compound many previously existing stresses on ocean ecosystems. If society wishes to continue to benefit from the bounty and the beauty of the oceans, it will need to implement new and significantly more effective policies than currently exist. Ocean ecosystems are changing rapidly, sometimes in unexpected ways. Strong actions now will increase the likelihood that society will be able to benefit from and enjoy ocean resources and places for decades to come.