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INTRODUCTION

I thank Chairman Markey, Ranking Member Sensenbrenner, and other members of the Select Committee for the opportunity to talk with you today about global climate change and its impact on the ocean. My name is Vikki Spruill and I am the president and CEO of Ocean Conservancy, becoming just the fifth person, and the only woman, ever to hold that title. Prior to my appointment at Ocean Conservancy, I was president and founder of SeaWeb, a non-profit organization that uses strategic communications techniques to advance ocean conservation. I also led a team there that in eleven years designed and executed countless important and innovative programs to promote ocean conservation and improve ocean governance. You have asked me to provide testimony on the effects that climate change is already having on our oceans, their impacts on marine ecosystems and the people dependent upon them, as well as highlighting the policies necessary to stop the decline of our oceans and what some solutions might be to enhance resilience to climate change. My testimony will focus on the impacts of global climate change on the ocean, emphasizing coral reefs and arctic ecosystems

THE VALUE OF OCEAN

We have named our planet Earth, and we call the soil beneath our feet earth. We live on earth, we grow most of our food in earth, and our homes come from great forests anchored in earth. Yet 71 percent of Earth's surface is not earth, but water – the ocean. Of the planet's living space, 99 percent is ocean. Life evolved for most of its history in water. The greatest diversity and quantity of life is found in the ocean. We came from water and we are made mostly of water. We are ocean.

Our bodies are an ocean environment. Taste your tears – they are salty like the ocean. Measure the pH of your blood – it is similar to that of ocean. Take a breath – of the uncountable oxygen molecules in your lungs nearly half were produced by microscopic plants living in the ocean. Take a drink of fresh water – roughly 90 percent of the precipitation falling on land is water evaporated from the ocean, each molecule having cycled through the ocean numerous times over the millennia.

We cannot live without ocean. With each breath we release carbon dioxide (CO_2). One day, all the carbon in your body will return to the atmosphere as CO_2 and then be absorbed, once again, by the ocean where it will be taken up by phytoplankton, and then drift to the bottom of the sea, to join 99.9 percent of all the CO_2 ever assimilated by life. While we are fond of summarizing our brief stay on Earth with the phrase "dust to dust", "ocean to ocean" is more apt.

Most of us relate to the ocean through the brief encounters we've had during our lives – a day at the beach, a fishing trip, watching whales, a cruise to distant ports. But, what most of us have encountered are merely the edge and the surface of the ocean. We understand the life that lives beneath its shiny, opaque surface only from brief glimpses—a whale surfacing, a flying fish escaping its watery bonds for a few seconds, or a fillet on a plate. Many have been enthralled by the beauty of tropical fish in an aquarium or the unbelievably diverse and dynamic seascape of a coral reef, but few know those wonders first-hand. If you have been lucky enough to snorkel over a vibrant coral reef or dive through a swaying kelp forest, then you have surely been enraptured by the thrill, the beauty, and the other-worldliness of life *in* the ocean.

That the ocean is finite—that its influence ends where it ends, at the edge and the surface—are but illusions. Our lives are intertwined with ocean. We are dependent on the ocean, though most of us are oblivious to the fact. Whether we live in Massachusetts, California, or Wisconsin, we are all linked to the ocean through vast physical cycles, the biosphere, and economics. We are all affected by the rhythms of the ocean, and the lives of millions are inexorably tied to those rhythms.

We think of climate as atmospheric – as the extremes of weather we experience from day to day – wind and storm, rain and snow, heat and cold, blue sky and clouds. Without the ocean, however, our weather would be far harsher and much less stable. The ocean is a great buffer, protecting us from extremes of heat and drought, as coastal dwellers are well aware. Seattle, Washington and Bismarck, North Dakota are at nearly the same latitude. The temperature extremes in landlocked Bismarck, however, span 159 degrees (-45 to 114°F), but in Seattle just 100 degrees (0 – 100°F).

The ocean stores vast amounts of heat and distributes it across the globe; far more than does the atmosphere. There is more heat in the first ten feet of ocean than in the entire atmosphere. In the Northern Hemisphere, the Gulf Stream and Kurshio Current – the Western Boundary Currents – distribute heat from the tropics northward affecting not only the ocean climate, but also our climate on land. Without the Gulf Stream, Europe would be a much colder and less productive place. The ocean absorbs so much energy from the Sun that it is largely responsible for the circulation of air and water within the atmosphere—heating the air here, cooling it there, and causing it to move by variation in pressure.

In 2005, millions in the US and Caribbean experienced first-hand, and tragically, how the ocean's heat engine can drive violent storms ashore – Katrina, Rita, Dennis, Emily and Wilma. Over 2000 lives were lost and $128 billion in damage occurred in that devastating 2005 hurricane season. The dynamics of the ocean and atmosphere are so tightly linked, and so easily overlooked, we must remind ourselves that we ignore the ocean's role in climate at our own peril.

The ocean is vast, but it is difficult to grasp such vastness. We measure the size of the ocean in terms of the area of its surface, but that is the equivalent of measuring the capacity of the Astrodome by the area of its roof. Though the surface of the ocean is certainly impressive, it is the ocean's *volume* that truly taxes the imagination — making up 99 percent of all living space on the planet. The abyss *averages* some 13,000 feet deep and the deepest point is over a full mile deeper than Everest is tall.

The ocean was, for most of human history, considered mostly barren – like Australia, an expansive desert surrounded by a thin green ribbon of life. Now we know that life teems around thermal vents in the abyss, over deep seamounts, and even in that watery 'void' between bottom and surface. Of course, we are most familiar with the grand diversity of life at the margins – on coral reefs, among mangroves, in the channels of salt marshes, within kelp forests, and in the tide pools where many of us first witnessed the likes of hermit and shore crabs, mussels and oysters, sea stars, cucumbers, anemones and urchins, and maybe an octopus staring back at us.

The ocean is home to an unbelievable diversity of life. What we do not know about ocean life far outstrips that which we do know. Humans have described perhaps 2 million species on the planet of an estimated 5-100 million (species!) thought to exist. Although, only one in ten of the described species are marine, one estimate suggests that there are 10 million undescribed species in the deep ocean alone yet to be discovered.

Coral reefs are nicknamed the "rain forests of the sea" for their amazing biodiversity, productivity, and structural and functional complexity. Coral reefs occupy just 0.2 percent of the area of the ocean, yet roughly 25 percent of all known marine fish species inhabit coral reefs. Something like ten thousand coral reef species have been described and estimates say three million may remain.

We rely on these millions of marine species, even the ones we have yet to discover, for important ecological services. The vast quantities of phytoplankton assimilate as much CO_2 as all plant life on land. Converting that CO_2 to carbon compounds fuels our ocean food webs, which in turn feed millions of humans. All of the carbon that ends up at the bottom of the ocean would, without phytoplankton, remain in the atmosphere to accentuate the global warming that we are now experiencing. Without phytoplankton we would have to rely on a diminishing quantity of terrestrial plant life to produce all the oxygen we need. Lastly, phytoplankton are the food of zooplankton that are the food of larger species, ranging in size from anchovies to the largest creature on the planet, the blue whale.

In the United States, the contribution of the commercial and recreational seafood industries exceeds $50 billion per year. Around the world, in 2005, over 85 million tons of seafood was taken from the seas, and another 19 million tons was produced by aquaculture. For many peoples, in this country and elsewhere, seafood is a staple; in some cases, *the* staple source of protein. Fish supply 16 percent of the world's protein, and 40 percent of the world's population (more than 2.5 billion people) gets at least 20 percent of its protein from fish. Worldwide, over 40 million people catch or raise fish for a living. In the tropics, there are an estimated 30 million small-scale fishers who depend almost exclusively upon the productivity and biodiversity of coral reefs.

We are coastal people. Over half of the U.S. population now lives in coastal counties. Florida has seen a 1000 percent increase in population since 1940, and a large percentage of those new residents use and rely on the ocean for recreation. The President's Commission on Ocean Policy reported that coastal communities generated over 10 percent of GDP; three quarters of those jobs are in the ocean tourism and recreation sectors alone. By comparison, agriculture employs two-thirds as many people and contributes just 40 percent as much value to the economy. A 1999 ecological valuation study[1] put the contribution of the ocean to the world welfare at a striking $21 trillion per year, 60 percent of which comes from coastal and shelf areas.

Often we emphasize industries, like energy, that exploit the resources we require for life, as those most important to the economy. It is the recreation industry, however, that contributes more to our economy that any other ocean industry. Coastal tourism creates over $160 billion in revenue annually worldwide.[2] Cruise passenger embarkations totaled 9 million in 2006 at U.S. ports alone; with $18 billion spent on goods and services by cruise lines, their passengers, and crews.[3] The direct and indirect economic impact of the cruise industry generated $36 billion in the U.S., creating just under 350,000 jobs nationwide while doling out $15 billion in wages and salaries.

Our way of life is dependent on the burning of fossil fuels. Like the metabolism of carbon compounds in our bodies, the burning of ancient carbon compounds – fossil fuels – releases large quantities of CO_2 into the atmosphere. As we are all well aware, it has been the massive release of CO_2, sequestered in the skies over the last 150 years, that has upset the balance of CO_2 in our atmosphere and led to the global warming, which brings us together today.

Often the exponential growth of the world's population is tagged as the driver of global warming, but the increase in energy consumption has been driven more by a rise in our consumption than by population growth. Consumerism, and its creep around the world, is at the heart of our problem. It is an irony, perhaps, that the extraction of oil and gas from our continental shelves

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[1] Costanza, R. 1999. The ecological, economic, and social importance of the oceans. *Ecological Economics* 31: 199-213.

[2] Nellemann, C et al. (eds). 2008. In Dead Water – Merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds, United Nations Environment Programme, GRID-Arendal, Norway

[3] http://www.cruising.org/press/research/U.S.CLIA.Economic.Study.2006.pdf

that boosts our economy today, contributes to global climate change that threatens our way of life tomorrow. There are nearly four thousand oil and gas platforms offshore around the United States, mostly in the Gulf of Mexico. Those platforms provide roughly 30 percent of the oil and 25 percent of the natural gas that we use. In an ironic counterbalance to the extraction of oil and gas, the ocean holds the promise of relatively clean, sustainable, and efficient energy production from wind, wave, tidal, and current generators.

We harvest kelp for animal feed, fertilizer, and use in beauty products. We mine the ocean for sand, gravel, dead coral, and certain metals. For millennia we have dried seawater to produce the dietary staple, salt. Biochemicals from living marine organisms have become a big business, finding use in pharmaceuticals, foods, and beauty products.

Ocean vistas, roaring surf, and kaleidoscopic coral reefs bring us peace and offer a chance to reflect on the value of wildness and nature to our health, and to our spirit. We cherish the beauty and mystery of ocean, without necessarily knowing why. Millions pay dearly and risk everything to live at its mercurial edge. Our lives are enriched by the opportunity to visit the ocean, play on its shores, or dip below its surface. The ocean provides food, materials and energy, and is an integral part of our economy. Life on this planet cannot exist without the ecological services it provides. And, yet we have failed to protect this vital resource, whether by ignorance or indifference. In doing so we have jeopardized our future. For much too long, we have treated the ocean as a dumping ground for our waste, and acted as if its bounty were limitless. We have learned painful lessons about the true costs of collapsed fisheries, dead zones, red tides, destroyed habitats, and endangered wildlife. The ocean is not limitless and it cannot absorb all that we throw its way. We have compromised its ability to resist stress and to recover from injury. We have done what many once thought impossible; we have diminished the health of our vast and generous ocean. Today, with the potentially devastating impacts of climate change just emerging and predicted to get vastly worse, our weakened ocean is in peril. To save it, we must act with conviction now.

THREATS TO THE OCEAN

For most, the standard of ocean health is the best that they can recall from their own lifetimes—regardless of how short of historical standards their personal standards fall. This concept is what scientists call “shifting baseline syndrome.” In reality, 'shifting baselines' is shorthand for how, over time, successive generations narrow their perspectives from the last, gradually lowering their standards of what a healthy ocean looks like.

Our shifting baselines have contributed significantly to declining ocean health. Lack of historical perspective leads us to misdiagnose or miscalculate ocean health, and seduces us into further excess exploitation of already depleted resources. So longstanding and so profound is human exploitation of the oceans that scientists agree that there is no clear historical baseline by which to measure healthy ecosystems.

Today, many marine ecosystems have changed so dramatically that they would be unrecognizable to our grandparents. The world's ocean continues to face an onslaught of stresses, many caused by people: overfishing, pollution, marine debris, poor water quality, and coastal development. Non-climate stresses increase vulnerability of ocean ecosystems to climate change by reducing resilience and adaptive capacity to react to the physical effects of climate change. The threats to the ocean are considerable – overfishing, pollution, poor water quality, marine debris, and coastal development all have huge impacts on marine communities and ecosystems and their effects have been well documented. Climate change will exacerbate the effect of current stresses on the ocean, and the scientific community at-large is concerned that the effects of climate change, acting together with existing threats, will accelerate the rate at which we lose biodiversity.[4] We cannot fully understand or predict the impact that climate change will have on the ocean without first understanding the context – the ocean has long been assaulted by multiple, cumulative human impacts that make its ecosystems and human society more vulnerable to climate change.

The ocean drives earth's climate and is one of the first, and often unnoticed, casualties of increased emissions of greenhouse gases. The major threats facing the ocean from climate change include increased temperature, sea level rise, decreased ocean salinity, acidification, shifting ocean currents and wind patterns, and amplified extreme events such as droughts, floods, heat waves, and the intensity of hurricanes.

Ocean Warming

Carbon dioxide and other greenhouse gases have markedly increased since 1850 as a result of human activity.[5] The 35 percent increase in CO_2 over this period is primarily due to fossil fuel use and changes in land-use patterns. Human-driven increases in greenhouse gases have resulted in significant increases in atmospheric and oceanic temperatures and a significant warming trend over the past 30 years. Even if carbon emissions are substantially reduced, CO_2 levels in the oceans will continue to increase for decades. Atmospheric CO_2 levels are accelerating at rates greater than predicted because of increased carbon dioxide emissions and declining carbon dioxide sinks.[6]

Over 80 percent of the excess heat produced by the greenhouse effect has been absorbed by the ocean, as evidenced by a rise in global ocean temperatures of 0.1 degrees Celsius in the upper 700 meters between 1961 and 2003.[7] This is a small number because the ocean is so

[4] Parmesan, C., H. Galbraith. 2004. Observed impacts of global climate change in the U.S. Pew Center on Global Climate Change, Arlington, Virginia, USA.

[5] IPCC 2007. Fourth Assessment Report: Climate Change 2007. Contributions from Working Groups I (The Physical Science Basis), II (Impacts, Adaptation and Vulnerability), and III (Mitigation of Climate Change) and the Synthesis Report to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA (http://www.ipcc.ch, accessed November 19, 2007)

[6] Canadell and 9 others. In press. Contributions to accelerating atmospheric CO2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Science.

[7] IPCC 2007

huge, but the importance to ocean organisms is significant. More alarming is a widening tropical belt and the poleward movement of large-scale climate systems (e.g., jet streams and storm tracks), which could have profound effects on ocean circulation and all ocean ecosystems.[8]

Right now we are seeing some of the greatest atmospheric warming impacts in the Arctic. In fact, we are seeing warming at twice the rate of the rest of the planet. Scientists from the National Snow and Ice Data Center (NSIDC) and the National Center for Atmospheric Research (NCAR) found that Arctic sea ice is melting faster than models have projected.[9] Ice loss may accelerate if sea ice thins - an alarming concern given that older and thicker perennial ice has already been declining.[10] Scientists are concerned that a striking drop in ice in 2007 could indicate we may have reached a tipping point where sea ice loss will occur very rapidly with summer ice lost as early as the end of 2012.[11] In addition to the loss of sea ice, coastlines are losing permafrost, which provides rigidity and support to coastlines. The combined loss of permafrost and ice is causing increased erosion from late winter storms that ordinarily occur once the sea ice has set in.

Sea-Level Rise

The most recent Intergovernmental Panel on Climate Change (IPCC) report projected that global sea level will rise by 18 to 59 cm (7 to 23 inches) during this century, assuming a negligible contribution from the Greenland and Antarctic ice sheets. However, some scientists believe that with warming of two to three degrees Celsius significant melting of the Greenland and Antarctic ice sheets could occur, triggering a rise in sea level of 6 meters (approximately 20 feet).[12] Such a rise in temperature is possible within this century if current greenhouse gas emission levels continue over the next 10 years.

Ocean Acidification

The oceans play an important role in the planet's carbon cycle by absorbing large volumes of carbon dioxide and recycling it in various processes. Rising levels of CO_2 in the atmosphere have led to increased absorption of CO_2 in the ocean where it reduces the available level of carbonate required by many shell-building organisms. Increased CO_2 absorption has already made ocean surface waters less alkaline (i.e., increased the acidity) by 30 percent (or, lowered its pH by about 0.1 units) since preindustrial times.[13]

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[8] Seidel et al. in press. Widening of the tropical belt in a changing climate. *Nature*.

[9] Stroeve et al. 2007. Arctic sea ice decline: Faster than forecast. *Geophysical Research Letters* 34:L09501

[10] Serreze et al. 2007. Perspectives on the Arctic's shrinking sea-ice cover. *Science* 315:1533-1536

[11] Jay Zwally, unpublished data

[12] Hansen et al. 2006. Global temperature change. *Proceedings of the National Academy of Sciences of the United States of America* 103:14288-14293;
Hansen, J., and 46 others. 2007. Dangerous human-made interference with climate: A GISS model study, *Atmospheric Chemistry and Physics* 7:2287-2312

[13] IPCC 2007

While these numbers may seem small, the pH scale is ‘exponential’ – each unit of pH represents a 10-fold difference in acidity or alkalinity. Pure water is neutral with a pH of 7.0. Sea water with a pH around 8.0 is alkaline in nature. IPCC models project that global surface pH will decrease between another 40-120% (0.14 and 0.35 units) over the 21st century.[14] These estimates may be conservative. Other studies have estimated that increased CO_2 uptake by the oceans may increase pH by 100-220% (0.3 to 0.5 units).[15]

Based on modeling and archaeological records, oceanic absorption of anthropogenic carbon dioxide by the end of this century will cause the amount of CO_2 in the ocean to exceed that of any time in the last 300 million years.

Ocean Currents

The ocean drives climate. Atmospheric circulation is driven by the energy released when evaporated water condenses into clouds – which in turn drives ocean circulation by winds and changes in sea-surface temperatures. Ocean currents transport heat, most often poleward. Temperature exchange and ocean current are also dependent on differences in temperatures of the vertical water layers. Changes of temperature in this complex system could change our ocean currents and wind patterns, ultimately affecting marine ecosystem productivity, oceanic carbon dioxide uptake, and oxygen concentrations.

In the most recent IPCC review, one of these major climate-shaping currents, the North Atlantic meridional overturning circulation (MOC), which is thought to have a large effect on climate in the North Atlantic and Northern Europe, is very likely to weaken in the 21st century. A weakening of this effect could lead to a large, abrupt shift in the MOC, which, while unlikely, is possible. However, the global warming trend will likely swamp the potential cooling effect of a weaker MOC, and result in a net warming of the Atlantic region.

Extreme Events

Strengthening of the water cycle (interaction between atmosphere and ocean) could also mean increased rainfall in the tropics and high latitudes with drier conditions in the subtropics and increased frequency of extreme droughts and floods. Scientists predict that the influence of the ocean will contribute to more extreme maximum temperatures, heat waves, and heavy precipitation in greater frequency. And, as the Ocean continues to warm, the duration and intensity of hurricanes is predicted to increase.[16] There is empirical evidence of increased hurricane intensity in the North Atlantic since about 1970 that is correlated with increased sea-surface temperatures, and it is probable that hurricanes on the average will become even more intense in the future.

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[14] IPCC 2007

[15] Feely et al. 2004. Impact of anthropogenic CO2 on the CaCO3 system in the Oceans. *Science* 305:362-366

[16] IPCC 2007

Accelerated Climate Change

The latest research shows more rapid increases in CO_2, losses of summer Arctic sea ice that could lead to the complete melting of summer ice as early as 2013, breakup of Antarctic ice shelves, ocean acidification, coral bleaching, and even greater sea level rise than were predicted just a short time ago. Research published in November 2007 documented a surprising acceleration in atmospheric CO_2, driven by economic growth and the deterioration of carbon absorption on land and in the ocean. It appears that the vast Southern Ocean may be becoming saturated with CO_2 and unable to absorb as much as it once did. Another study from the same time shows that rising acidity is happening faster in the Southern Ocean where it could negatively affect the plankton that are critical to removing CO_2 from the atmosphere, further compromising the seawater's already reduced ability to absorb CO_2. Scientists recently thought it would take a century or more for the Arctic ice cap to disappear, but the timeframe is now estimated in decades. One researcher has even projected its loss in less than 10 years.

IMPACTS

Given the myriad and diverse threats facing ocean ecosystems and their marine life summarized above, it should come as no surprise that these systems and their inhabitants are strained to the breaking point, show tremendous and increasing signs of stress, and are starting to unravel and collapse. More than a century ago, the U.S. Commission of Fish and Fisheries recognized major impacts to nearshore resources associated with human habitation.[17] More than a decade ago, the National Research Council found that the diversity of life in the ocean was being dramatically altered by the rapidly increasing and potentially irreversible effects of activities associated with expanding human populations. [18] By then, it was clear that fishing, pollution, physical alteration of habitat, invasive species, and global climate change were among the most critical of these stresses and that they had already impacted ocean life from the intertidal zone to the deep sea. Many more recent scientific studies and two national ocean commission reports attest to the fact that human impacts to ocean resources continue to increase and proliferate.[19]

Even in the absence of climate change, the onslaught of other human-caused stresses would threaten ocean ecosystems and their living components. The shifting baseline syndrome previously discussed has partially masked some of these impacts to ocean ecosystems and their inhabitants. However, they are now feeling the combined impacts of climate change on top of these other stresses. Climate change may pile on the straws that break the backs of ocean

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[17] United States Commission of Fish and Fisheries. 1880. Report of the Commissioner of Fish and Fisheries for 1878. Wash. DC. Gov't Printing Office

[18] National Research Council (NRC). 1995. Understanding Marine Biodiversity: A Research Agenda for the Nation. Wash. DC. Nat'l Acad. of Sci.

[19] Pew Oceans Commission. 1993. America's Living Oceans, Charting a Course for Sea Change. A Report to the Nation. Pew Trusts; U.S. Commission on Ocean Policy. 2004. An Ocean Blueprint for the 21st Century Final Report of the U.S. Commission on Ocean Policy

ecosystems. The added burden of climate change on top of other escalating threats is creating a perfect storm of impacts that threatens the future of ocean ecosystems and life stretching from the polar regions to the tropics. To date, some of the impacts to coral reef and Arctic habitats have been especially profound, but stresses are being felt in other ecosystems, too. The most recent assessment by the IPCC indicates that many long-term changes in climate have been documented across the oceans and affect its nearshore and offshore inhabitants. These changes include increased Arctic temperatures and less ice cover, increased ocean acidity, decreased ocean salinity, shifting current patterns, amplified extreme events (e.g., droughts, precipitation, heat waves) and changes in marine biodiversity and population size, movement and phenology (i.e., the timing of events in an animal's yearly cycle, such as the time of the year during which seals would give birth).

Coral Reefs

Coral reefs provide an excellent focal point for exploring the impacts of climate change and some of the potential solutions for addressing them. As previously discussed, coral reef ecosystems, like tropical rain forests, harbor tremendous biological diversity and provide great value to humans when properly conserved. But reefs are also fragile. In addition to their great value, coral reefs provide a good lens through which to view climate change impacts due to their accessibility, and because they are among our most charismatic and well-documented ecosystems. Many of the proposed solutions for addressing coral reef impacts are also applicable to other ecosystem types.

Nearly a decade ago, the U.S. Coral Reef Task Force concluded that the world's coral reef ecosystems were in serious jeopardy, threatened by an increasing array of overexploitation, pollution, habitat destruction, invasive species, disease, bleaching, and global climate change.[20] The rapid decline of these ancient, complex, and biologically-diverse ecosystems has significant social, economic, and environmental impacts here in the U.S. and around the world. A comprehensive review of Caribbean coral reef research studies concluded that, as of 2000, live coral cover had already declined by an average of 80 percent across this region's valuable and vulnerable reefs.[21] Elkhorn and staghorn corals, two of the region's most important reef-building corals, were harder hit and are now listed as threatened under the U.S. Endangered Species Act. Another comprehensive study of coral sites across Australia's Great Barrier Reef showed similar decades-long declines in coral cover.[22] A series of collaborative "State of the World's

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[20] United States Coral Reef Task Force (USCRTF). 2000. The National Action Plan to Conserve Coral Reefs. Wash. DC. Environmental Protection Agency (EPA)

[21] Gardner TA, ICôté IM, Gill JA, Grant A, Watkinson AR. 2003. Long-term region-wide declines in Caribbean corals. *Science* 301: 958-60

[22] Hughes, TP et al. 2003. Climate Change, Human Impacts, and the Resilience of Coral Reefs. *Science* ,15 August, 2003

Coral Reefs Reports" in recent years has documented similar long-term coral reef decline across even broader areas.[23]

No single stress is solely responsible. There is strong scientific agreement that fishing and pollution, especially eutrophication (enrichment from excess nutrients) and sedimentation, are among the key drivers of reef decline in many areas, that they act synergistically, and that climate change threatens reefs on an even larger scale.[24] Climate change impacts are likely already being felt on the world's reefs. Bleaching events in which corals expel their symbiotic algae, turn white, and may die or become diseased, are linked to elevated sea surface temperatures and appear to be becoming more frequent, severe, and repetitive as sea water temperatures increase. The summers of 1998 and 2005 were among the most damaging for coral reefs in history. In 1998, about 16 percent of the world's coral reefs were lost due to severe coral bleaching in the Indian and Western Pacific oceans. If we were talking about forests this would be the equivalent of all but 1% of the all the forests in North America burning in one year. In 2005, unusually warm waters caused even more severe bleaching in the Caribbean with average mortality rates over 50 percent in some places, including the U.S. Virgin Islands.[25]

Coral reefs are more than just corals. They are myriad interwoven and interdependent habitats and associated species. The extraordinary degree of interdependence and specialization among reef species, and the intense predator-prey, grazer-producer, and competitive interactions found within and among reef dwellers rival any on earth and may be in part responsible for the remarkable diversity found on reefs. These close relationships are critical to structuring reef communities, controlling energy and nutrient flows on reefs, and the tight recycling of materials characteristic of reef systems. Consequently, fishing and other extractive activities often remove critical living components of coral reefs, destabilize reef ecosystems, and reduce the resilience of coral reefs to withstand impaired water quality, climate change and other stresses.[26] A recent study by the United Nations Environment Programme predicts that 80 to 100 percent of the world's coral reefs may experience annual bleaching events by the year 2080.[27]

Ocean acidification, on top of warming, has the potential to completely wipe out coral reefs as we know them within this century, if we do not take the necessary steps to reduce carbon dioxide levels immediately. Moreover, it is likely that the increased acid levels already being felt by reefs in some locations could be inhibiting coral growth rates. In the face of other stresses, this could tip the balance in favor of halting or reversing reef growth.

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[23] Wilkinson et al 1998, 2000, 2002, 2004. Status of the Coral Reefs of the World 2000, 2002, 2004. GCRMN and AIMS. Townsville, Australia

[24] Schuttenberg and Hoegh-Guldberg, 2007. A World with Corals: What Will It Take? *Science,* 5 October 2007. Washington, DC

[25] Wilkinson C, Souter D. 2008. Status of Caribbean coral reefs after bleaching and hurricanes in 2005. Townsville: Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre

[26] Sobel and Dahlgren 2004. Marine Reserves, A guide to science, design, and use. Island Press, Washington, DC

[27] UNEP 2008, In Dead Water

Ocean Warming

Rising ocean temperatures, shrinking polar ice caps, and sea level rise will result in a cascade of ecological effects. Water temperature is an important determinant of physiological function of ocean organisms, and is, ultimately, an important feature of distribution and ranges of species and habitats. Changes in ocean temperature will cause major shifts in the distribution of organisms and a reorganization of the interactions that determine ecosystem function and the provision of ecosystem services. These impacts will, ultimately, affect human populations.

Arctic Impacts

Climate change effects in Polar Regions will cause major physical, ecological, sociological, and economic impacts, especially in the Arctic. The rate of Arctic warming is of grave concern because it is home to the world's few remaining pristine ecosystems and to societies and cultures with close ties to their surroundings.

Ice-associated marine algae and amphipods provide the base of a productive and unique food web that includes Arctic cod, sea birds, ice seals, walrus, whales, polar bears, and Arctic foxes. Loss of sea ice may lead to the local loss or even extinction of species unable to adapt. The loss of sea ice is already projected to severely impact polar bears.[28] Scientists predict that two-thirds of the world's polar bear population will be lost by mid-century, given current rates of warming. Loss of sea ice in the Bering, Chukchi, and Beaufort Seas will impact other ice-dependent ocean wildlife (e.g., ringed seals, spotted seals, ribbon seals, bearded seals, walruses). Ringed seals have a close association with sea ice for resting, pupping, mating, molting, and feeding.

Another concern for ocean species living at the poles is how they will adapt to warming temperatures. Species are already moving poleward in response to warming, but for those species already living as far north as possible, there is no place to go but extinct.[29] This phenomenon is already being documented from species living at the tops of mountains.

Melting ice has opened up the Arctic to industrial exploitation that in turn contributes to climate change. With the retreat of sea ice, and seasonal ice-free waters, there is great potential for greater disturbance in the Arctic Ocean from increased vessel traffic and potential fisheries interactions as well as offshore development – all of which will ultimately increase emissions and warming while threatening ecosystems also being stressed by rapid changes in temperature and ice cover. More than 78 million acres in the Chukchi, Beaufort, and Bering Seas will be made available for oil and gas development in the proposed oil lease sales by the US Federal Government. This area overlaps with habitat that is biologically important for Arctic ocean species, including critically endangered North Pacific right whales, bowhead whales, ice

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[28] US Geological Survey, 2007. USGS Science to inform U.S. Fish and Wildlife Service decision-making on polar bears: Executive Summary. (http://www.usgs.gov/newsroom/special/polar_bears/docs/executive_summary.pdf, accessed Nov 19, 2007)

[29] Parmesan 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* 37: 637-669

seals, walrus and polar bear. As the ice retreats, new shipping routes will become available, such as the Northwest Passage and the Northern Sea Route, significantly increasing the volume of vessel traffic in the Arctic. Projections suggest that by 2050, the Northern Sea Route will have 125 days per year with less than 75% sea-ice cover. Increased shipping, fishing vessels, and cruise ships bring an increased chance of interactions between vessels and whales and the chance of oil spills. The US Mineral Management Service's Environmental Impact Statement on the Chukchi Sea leases estimates the chances of one or more large spills greater than 1,000 barrels of oil at between 33 and 51 percent, and states that in 'open-water to broken-ice conditions,' only 10 to 20 percent of the spilled oil would be recovered." This represents a massive threat to Chukchi ecosystems and wildlife.

One of the greatest concerns we face with global climate change in the Arctic is the impact on indigenous Arctic communities whose coastal communities rely heavily on ice-dependent resources. Of the nearly four million people living in the Arctic today, about 10% are of indigenous descent. There are over 50 different groups of indigenous peoples throughout the Arctic – each with its own distinct culture yet united by shared dependence on the health of Arctic resources and their vulnerability to global warming. Many of these cultures, for millennia, have depended on and have adapted to the environment. One of the most widespread observations independently documented across the Arctic is that residents cannot predict the weather like they used to; residents recognize that the Arctic is inherently variable, but they have been able to use knowledge passed on from generation to generation to survive in one of the harshest environments on our planet. Because Arctic residents have maintained a vibrant connection with the environment in everyday life they are able to detect unusual characteristics and patterns in wind, weather, and sea ice conditions.[30] These changes in environmental conditions, documented by scientists and described by indigenous people, are influencing ocean wildlife, as described above. Arctic peoples have subsisted on ocean resources for thousands of years and do so, even today, but the future of subsistence is uncertain. Traditional subsistence use of ocean resources is fundamental to cultural identity, social interactions, and a primary means to obtain food. While considering the impacts of climate change to ocean wildlife, we also need to think about the communities that will be severely impacted, and ensure that other stresses on marine resources such as vessel traffic and offshore development are minimized to ensure that these cultures and societies can continue to exist.

Rising Sea Level

Rising sea level is already impacting the most low-lying coastal areas with the loss of coastal wetlands and mangroves as well as increased coastal damage from flooding.[31] If unchecked, sea level rise could severely impact human populations, wetlands, and coastal ocean species and will exacerbate inundation, storm surge, erosion, and other coastal hazards.

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[30] ACIA 2005. Arctic Climate Impact Assessment. Cambridge University Press, 1042pp
[31] IPCC 2007

An international report examined global cities whose asset value would be the most threatened by sea-level rise in the next sixty years and U.S. cities ranked high – half of the top 10 cities were in the U.S. In terms of the population that would be exposed and at risk to sea-level rise, Mumbai, India topped the list, but Miami, New York, and New Orleans were in the top 10.[32]

An increase in sea level is a threat to seals, sea lions and sea turtles that haul out on land to rest and for reproductive purposes. Low-lying sand and pebble beaches will no longer be available for these important yearly cycle events. Many islands contained within the Northwest Hawaiian Islands are low-lying and very vulnerable to increased sea level. Scientists simulated potential habitat loss and determined that with a maximum sea level increase of 88 centimeters (35 inches) the loss varies from island to island, but with an increase of 129 centimeters (51 inches) from spring tides all land would be periodically inundated.[33] They predicted that endangered Hawaiian monk seals, threatened green turtles, and endangered Laysan finch would face the greatest threats from lost habitat due to seal level rise – based on their ecological, geographical and population characteristics. The estimates used in this study are conservative relative to the reality of current levels of ice melt observed in Greenland and Antarctica. Given a maximal rise of 600 centimeter (20 feet) in sea level, much of this habitat would be lost within one of our greatest national treasures, the Papahānaumokuākea National Marine Monument.

Shifting Ranges

A snap-shot of the ocean tomorrow may not resemble the ocean that we have come to know and love today. The evidence that climate change is responsible for shifting ranges and distribution of species is mounting.[34] Our picture of ocean ecosystems may be dramatically transformed due to species altering their range in response to changing environmental features such as temperature, ice cover, circulation, and salinity.[35] As population sizes change and species shift their geographic distributions, biological communities and food webs change, with consequences for biodiversity, ecosystem function, and dependent economies. It is important to note that many of these changes may not be simultaneous. Those species that are physically able to change location may do so sooner, resulting in reorganized ecosystems with different functional relationships.

Poleward range shifts have been well documented, for individual species as well as for communities.[36] Distributions of fishes in the North Sea responded to increased temperatures, with about 2/3 of them shifting in mean latitude and/or depth over 25 years of observations.

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[32] Nicholls, RJ et al. 2008. "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", OECD Environment Working Papers, No. 1, OECD Publishing

[33] Baker et al. 2006. Potential effects of sea level rise on the terrestrial habitats of endangered and endemic megafauna in the Northwestern Hawaiian Islands. *Endangered Species Research* 4:1-10

[34] Petersen et al. 2008. Regime shift in a coastal marine ecosystem. *Ecological Applications* 18:497-510., IPCC 2007, Parmesan 2006, Grebmeier et al. 2006

[35] Harley et al. 2006. The impacts of climate change in coastal marine systems. *Ecology Letters* 9:228-241

[36] Grebmeier et al. 2006. A Major Ecosystem Shift Observed in the Northern Bering Sea. *Science* 311:1461-1464; Parmesan 2006

Similar documentation has been made for zooplankton in the North Sea. These changes are not occurring only in distant waters, but in our own backyard, where lucrative $2 billion dollar fisheries occur. In the Bering Sea, changes in the biological community have occurred simultaneous with shifting atmospheric and hydrographic characteristics. Changes in ocean and air temperatures and reductions in sea ice have coincided with a reduction in benthic species and communities. These changes in prey base have negatively affected higher trophic species such as seabirds and ocean wildlife populations, such as Steller sea lions.[37]

Human Impacts

Coastal communities and ocean-based societies and economies will suffer substantial losses in coming decades compromising or eliminating historic human use of coasts and the ocean. Rising sea level is currently affecting low-lying nations, such as the Pacific island of Tuvalu, where tidewater floods homes and streets. Scientists determined that sea level rise has been 1.2 mm per year, and the country is currently examining relocation options along with fears about the loss of their culture.[38] These impacts on low-lying island nations foreshadow what low-lying U.S. cities might see in the not-so-distant future. Arctic villages along the Chukchi and Beaufort Seas are facing relocation due to coastal erosion, loss of permafrost, sea level rise, and the increased frequency and intensity of storms.

There is an estimated 284,300 km^2 of coral reefs in the world,[39] which have been estimated to be worth US$100,000 to $600,000 per km^2 annually.[40] That is a total value of 28.4 to 171 billion dollars per year. By this valuation, the 3,770 km^2 of coral reefs in the United States are worth 377 million to 2.3 billion dollars per year.

Roughly half of all federally managed commercial and subsistence fisheries in the U.S. are dependent on healthy coral reefs ecosystems. Those fisheries have an estimated direct value of over $100 million per year.

Human health is predicted to decline due to increased risk of mortality and injury because of climate change related causes.[41] Some of the increased deaths may be due to infectious diseases because of heavy precipitation events; food and water shortages and water and food borne diseases in areas affected by drought; death and food and water borne diseases because of intense tropical cyclone activity; and drowning in floods because of increased incidence of extreme high seas. Many of the effects of climate change on society will be worst for those people residing in economically poorer nations with limited adaptive capacity.

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[37] Atkinson et al. 2008. Anthropogenic causes of the western Steller sea lion *Eumetopias jubatus* population decline and their threat to recovery. *Mammal Review* 38:1-18.

[38] Hunter 2002. A note on Relative Sea Level Change at Funafuti, Tuvalu. Antarctic Cooperative Research Centre, University of Tasmania. Technical Report; Patel 2006. A sinking feeling. *Nature* 440:73-736

[39] The World Atlas of Coral Reefs, prepared by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)

[40] UNEP-WCMC (2006) In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs. UNEP-WCMC, Cambridge, UK 33 pp

[41] IPCC 2007

SOLUTIONS

Unless we change course, the ocean and humankind are at the mercy of global climate change. Global warming and increased CO_2 concentrations are already having noticeable and severe impacts on the ocean, and we humans are feeling the effects. If we thought we had time to plan, we were mistaken. Recent research along many lines has shown that the pace of ocean-climate change is accelerating. Even under the most optimistic scenarios, atmospheric CO_2 concentrations will rise significantly over the coming decades.

There are just two options for addressing climate change. First and foremost, mitigation—we must significantly reduce greenhouse gas emissions now. Second, adaptation—we have no choice but to find ways cope with the impacts of climate change. The first addresses the root of the problem and the second will lessen or minimize climate change effects on ecosystems and human society.

Mitigation

The future of our planet and quality of life for our children and grandchildren depend on the world developing and implementing a plan that will commit all nations to significant reduction in greenhouse gas emissions. Members of Congress, many states, and countries around the world understand the urgency of taking action, and are willing to take the lead in making the changes that will be necessary to turn global climate change around. The U.S. government has failed to commit to effective action or provide the leadership needed. The United States is the largest single emitter of greenhouse gases and we must take responsibility for our role in degrading the ocean—the life-support system of the planet. Other nations contribute significantly, and China may soon surpass us, but that does not absolve us from acting responsibly. Without visionary and brave leadership from Congress and the next Administration, the planet will continue on its path toward a point of no return. We believe that the courage exists within us and that we will act decisively and quickly to avert the worst of what is coming should we continue down this road, but we cannot avoid coping with the changes global warming and ocean acidification is bringing.

Can we do anything to avoid or at least reduce the worse impacts of climate change? The answer is a simple – yes, but only if we reduce greenhouse gas emissions significant and immediately. Carbon dioxide is the most important, but not the only cause of global warming. We must control other gases, such as methane, and the production of black carbon, which we are just learning may contribute nearly as much to global warming as CO_2. We must rapidly slow and eventually reverse the dangerous increase in greenhouse gas emissions of the last 50 years. The consequences of inaction are dire.

Adaptation

Even if we cap CO_2 emissions at today's level, or, even better, reduce them to 1990's level, we will not escape climate change impacts – warming will continue for decades as a result of the excess CO_2 now in the atmosphere. Although we have no choice but to cut emissions to slow the increase in global warming, we will still be forced to cope with climate-related changes.

Indeed, those changes are already being experienced by many coastal communities around the world. If you are an artisanal fisher in the Seychelles, where most of the corals around the inner islands bleached and died in 1998, then you do not doubt that climate change is happening. If you lived in the Lower Ninth Ward of New Orleans and suffered Hurricane Katrina, you do not doubt it. And, if you are an Iñupiat living in Kivalina at the edge of the Chukchi Sea—a descendant of people who have lived there for over 10 thousand years now watching your home fall into the sea—then you certainly have no doubt.

Nature itself will attempt to adapt to climate change and its effects, but because of the unprecedented magnitude and speed of change, that adaptation will be incomplete in many cases. Managers and scientists are challenged with assisting natural marine systems as they try to adapt to climate change, and society will have to adapt to the impacts of climate change on our marine industries, coastal built environments, and economies.

It is true that the only real solution to climate change lies in mitigation – eliminating the disease – but we cannot ignore the need for adaptation to lessen the damage and pain as we seek to cure the patient.

Resilience

Our ability to foster adaptation of marine ecosystems is limited by the difficulty of direct intervention in the marine environment. We should undertake the restoration of damaged marine habitats where feasible, but the approach is expensive and is not likely to be able to deal economically with the extent and area of the many habitat types that will need to be restored. In the face of the global scale and wide scope of climate change impacts, our primary tool will be to protect, maintain and restore the natural resilience of marine ecosystems and species. Biological and ecological systems have complex regulatory processes that act to maintain structure and function in response to natural environmental variability and stresses, somewhat as the human body maintains its integrity and function through the regulation of temperature, water, and nutrients and the repair of damage.

Such a system's capacity to absorb and/or recover from a harm done by an environmental stress, whether natural or human, is referred to as resilience. Marine biological and ecological systems that have been damaged through periods of abuse may suffer reduced resilience, much as someone with certain diseases might be more susceptible to, and take longer to recover from cancer. Excessive fishing and whaling, pollution, nutrient runoff, and habitat destruction have reduced ocean ecosystems' resilience to stress such as that associated with climate change.

The primary adaptation tool for marine ecosystems is to ensure that their natural resilience is not compromised. The degree of resilience shown by different coral reefs, for example, varies depending on how stressful the environment is. Nonetheless, natural resilience can be exceeded by stresses more extreme than are normally experienced on a reef. Depending on the ecosystem, habitat, or species, this will mean that our response will focus on 1) protecting and maintaining intact resilience, or 2) restoring lost resilience.

Remote ecosystems such as the Arctic Ocean or the Northwestern Hawaiian Islands are likely to be nearly intact and resilient. While the Northwestern Hawaiian Islands are almost fully protected, they may still require some attention to rebuilding resilience with efforts to reverse the effects of lobsters being overfished and bottomfish being reduced by decades of commercial fishing, as well as the restoration of endangered monk seals. On the other hand, the Arctic Ocean has been removed from most human insults by its harsh environment and the ice, and we presume that its ecosystems are fully functional and resilient. However, the rapid loss of the ice cap is opening the Arctic Ocean to impacts to which the rest of the oceans have long been exposed – overfishing and destructive fishing practices, spills and disturbance associated with oil and gas exploration, and shipping accidents leading to fuel and cargo spills, for example.

In the Arctic, adaptation to climate change will entail protecting and maintaining ecosystem resilience in the face of new uses. An opportunity exists to build ecosystem-based management systems from the ground up *before* we do serious damage to its environment. In contrast, coral reefs have been subjected to multiple impacts from human activities for a very long time. The capacity of coral reefs to resist the effects of ocean warming and acidification is going to depend on the restoration of their natural resilience, which will not have a chance to happen if the stresses that have caused the degradation continue.

Coral reefs are not likely to be the only ecosystems to suffer reduced resilience. A recent global mapping study of multiple ecosystem types (e.g. mangroves, seagrasses, salt marshes, kelp forests and rocky reefs) and 17 different anthropogenic stresses, found that less than 4 percent of the ocean is impacted "very lightly",[42] while 43 percent of the ocean is "moderately" to "heavily impacted" by multiple stresses.

Maintaining and restoring ecosystem resilience depends on the control, reduction and elimination of stresses other than climate change. Without the negative impacts of other human influences and activities, ecosystems, habitats and species will better be able to resist ocean warming, decreased productivity, shifts in ocean currents, and/or acidification. Removing the stresses on a degraded ecosystem with compromised resilience, will not guarantee recovery – the degree and type of recovery will depend in part on characteristics of the ecosystem. But, without removing the stresses there is little or no chance of recovery.

Significantly reducing the impacts of human activities on ocean environments will require greater dedication to environmental management that aims to minimize the impact of human activity at the expense of short-term benefit to individuals, industries and economies. We are faced with severely altered ecosystems, collapsed resources, dead zones, species nearing extinction, and devastation of coastal communities because we have for decades managed for immediate profit rather than ecological sustainability.

Maintaining and restoring resilience relies on different strategies. Priority should be given to characteristics and processes that are critical to resilience. The capacity of an ecosystem to

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[42] Halpern, B.S. et al. 2008. Mapping the global impact of human threats to marine ecosystems. *Science* 319: 948-952.

maintain function when stressed is a factor, among others, of biodiversity. The loss of even a few species from a diminished ecosystem could have a large effect on the system's function. Conversely, the loss of many species from a rich ecosystem may have little effect because other species can occupy vacant ecosystem roles. Areas that have lost ecologically functional groups of organisms, such as predators, herbivores, or keystone species, will be more susceptible to degradation and less able to recover without intervention.

Local environmental conditions may also affect resilience to warming. Corals that are bathed by cold upwelling waters, or subject to strong currents, may be less susceptible to bleaching because warm water is less likely to persist around them. Protecting many such reefs will reduce the chance that catastrophic, local impacts will eliminate a habitat or species – in other words, putting your eggs in many baskets is a wise strategy in the face of climate change. The recovery of affected areas will be influenced by their connectivity to other areas, especially those less affected. For instance, connectivity of ecosystems through the dispersal of eggs and larvae, and the movements of juveniles or adults, will be important in repopulating depleted areas. Ecologically connected networks of habitat patches will be key to preserving ecosystems under climate change stress.

As we learned from the Atlantic hurricanes of 2005 and the Indonesian tsunami in 2004, the condition and structural integrity of coastal habitats is critical to protecting human built environments. Healthy, intact coastal habitats such as coral reefs, mangroves, salt marshes, and dune systems provide highly effective buffers to the effects of storms. Without those buffers there is greater chance of potentially catastrophic ecological, social, and economic damage to coastal habitats and built environments. Once compromised, coast buffer habitats can take a long time to recover and may require human intervention to do so. The recovery, maintenance, and protection of coastal buffer habitats are crucial for coastal communities experiencing increased storm intensity and sea-level rise.

We lag behind in developing strategies to ensure that coastal communities adapt to climate change. We should modify coastal development planning to take into account the risks associated with climate change and how they interact with buffer habitats. We should consider relocating built environments and infrastructure at risk of loss. We should reformulate polices that create economic incentives that encourage risky coastal development to discourage such behavior and reward incorporating resilience into development plans. The impacts of climate change on coastal communities will be some of the most costly effects of climate change, but proactive, informed and timely intervention can do a lot to reduce those impacts.

Management Reform

We must reform the way that we manage the marine environment if the ocean is going to have a chance to withstand the onslaught of climate change. New approaches to management include: 1) ecosystem-based management, 2) adaptive management, and 3) application of the precautionary principle.

Ecosystem-based management, in which the primary goal is preserving ecological function and with it the ecological services that we depend on, must replace the out-dated single-species, single-issue approach.

Scientific uncertainty and lack of knowledge will require a greater reliance on adaptive management – applying a scientific approach to management and adjusting strategies in response to observed changes. To a large extent, we will have to learn how to adapt to climate change as we go.

Typically, we do not undertake management to control use or exploitation until a problem appears, but often by that time considerable harm has been done and resilience has been compromised. Faced with uncertainty and risk of climate change, a precautionary approach is needed – allowing only limited use and exploitation until it can be shown that ecosystem function and integrity will not be substantially harmed.

A precautionary approach is especially relevant in the Arctic where we have the opportunity to implement innovative management strategies and methods before substantial use and exploitation begins. The Arctic offers a grand laboratory for the study of methods and approaches to large-scale ecosystem-based, adaptive, and precautionary management.

Societal Adaptation

Not only marine ecosystems and species will have to adapt to climate change. Humankind will have to adapt. Populations of exploited species are already beginning to shift in response to warming. Fishers will have to adapt to shifting stock sizes and ranges, and eventually replace them in their catches with other species. Some preferred and valuable species will decline in abundance and eventually disappear from certain areas, with potentially severe consequences for coastal communities dependent on fishing. New species will invade, requiring fishermen to use new gear and develop new fishing methods if they are going to maintain their livelihoods. Managers will be required to account for these factors in order to manage resources effectively. Fishers, the fishing industry, and fishing-dependent communities will require technological, governmental, and economic assistance to adapt. Much as human stresses have reduced ecosystem resilience, climate change will reduce the social and economic resilience of coastal communities.

Our resource exploitation and management strategies ecosystems operate within a dynamic range that doesn't change drastically, which may have been appropriate at one time, but not in an age of continual climate change. Fishermen off Cape Cod today expect that cod will be there year after year. They do not expect that because of ocean warming stocks will gradually shift northward, to be replaced by others from the south. The rates of range shift will vary, and shifts will alter interactions among species, the combined effect of which may be chaos. Fishers will have to fundamentally alter their strategies to adapt to the changing composition of fish species available to them, or to move with the fish. Similarly, related industries—processors, distributors, and retailers—will not be able to count on stable supplies, forcing them to adapt markets, distribution, and menus.

The need for all the players to adapt rapidly and continually to the changing ocean environment will be true wherever we depend upon resources that are living. It will be true for fishers, kelp harvesters, bioprospecters, dive operators, aquarists, and aquaculturists.

Ecological systems do not always change gradually in response to incremental environmental changes. They sometimes exhibit disproportionate and unpredictable shifts in response to small changes in conditions. A fish species may decline in abundance gradually as the ocean warms, but then suddenly disappear because it meets some unanticipated threshold in it's interaction with another species. Management strategies will have to cope with multiple, rapid, and unpredictable changes in ocean environments and the resources upon which we depend.

Resources for Adaptation

Making adjustments in our thinking and management strategies to adapt to climate change will require substantial investments in education and research. Our knowledge of ocean systems is comparatively limited. Even now, we struggle to understand the relationships between ocean processes and our use of resources, and to set management strategies based on that understanding. In the context of accelerating climate change, this gap puts a premium on improving our understanding of marine ecosystems and how they react to human stresses.

In an era in which the lay of the sea will change beneath our keels, there is an imperative to increase funding and support for marine research. We are entering uncharted waters, beyond the collective experience of scientists and managers and outside our scientific knowledge base. This puts an even greater imperative on increasing the resources that we invest in understanding ocean dynamics, ecosystem processes, resource dynamics, and socioeconomic dependencies. Our ability to adapt to climate change depends on our ability to understand what is happening to the ocean, to predict as much as we can of what will come next, and to craft effective adaptation strategies.

Policy Development

While there are things the Administration can do now to address the impacts of climate change, coping with the profound challenges of building resilience in our ocean ecosystems will require legislation changes our climate governance structure. While most major bills in Congress relating to climate change focus on mitigation through the reduction of global warming pollutants, there have also been proposals in both the House and Senate to develop strategies for improving ocean adaptation and resilience, and to direct funding to such activities. The energy bill passed by the House (HR 3221) contained strong provisions for developing a national ocean adaptation strategy and for assisting states in carrying out similar activities. In addition, the major vehicle in the Senate for climate change mitigation directs funding from the auction of carbon allowances to wildlife and ocean adaptation efforts.

These proposals represent strong steps in the right direction. Consistent with the principles set forth by Chairman Markey on Earth Day, April 22nd, 2008, we urge Congress to build on these proposals, and include in broader climate change legislation provisions to help our oceans and coastal communities adapt to the impacts from climate change.

National Strategic Plan – Legislation should call for the development of a national strategic plan to respond to and alleviate the impacts of global warming and ocean acidification in the United States. This strategy must use the best available science, should include a plan for implementing the strategy across multiple federal agencies, and include a plan for carrying out research, education, monitoring, assessment, as well as for specific adaptation activities. It should also include a mechanism to ensure that any federal decision- that may exacerbate the impacts of climate change on our environment take into account the added negative effects of climate change.

National Climate Office – Second, legislation should create a National Climate Office to guide the development of the national strategy, and to coordinate and facilitate federal adaptation efforts and strategies. The legislation should codify both the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce, and the White House Committee on Ocean Policy, which was established by Executive Order 13366 on December 17, 2004. While NOAA is the principle agency with respect to researching climate change impacts on the oceans, and for overseeing management of our ocean resources, multiple federal agencies have decision-making authority that can profoundly affect our ocean and coastal ecosystems, compounded by the effects of climate change. A centralized body is needed to oversee implementation of the national strategy with respect to oceans and coasts, and to coordinate all federal decision-making related to the health of our oceans. Providing a legislative mandate for NOAA, which was established by Executive Order in 1970 and has struggled under an obsolete management structure and unclear mission, would greatly improve its ability to carry out ocean adaptation measures, particularly if charged with carrying out ecosystem-based ocean management, taking into account the effects of climate change.

Adaptation Funding – Finally, climate change legislation must direct a substantial portion of the proceeds from the auction of carbon allowances to fund the development and implementation of national adaptation strategies, and should provide grants for states for similar activities. For years, we have significantly under-invested in the protection and restoration of our ocean and coastal resources, particularly given the vital role they play in our nation's economy, and the increasing threats posed by pollution, overfishing, and habitat destruction. Now as the oceans and coasts face the additional threats posed by climate change, a dedicated funding source to improve their resiliency is critically needed.

CONCLUSIONS

We stand at a crossroads, atop a mountain, but there is no ambiguity about which road goes straight toward the cliff and which toward home. We must make the right choice if we want to survive and prosper. The emission of greenhouse gases has to be slowed and ultimately stopped, and we have to act swiftly. We in the United States and in other developed countries enjoy an unprecedented quality of life, which is the envy of the rest of the world. But, that standard of living is expensive in the currency of carbon and it is not sustainable, especially with the rest of the world rapidly trying to emulate us. It is not sustainable if we do not take care of the ocean and the biosphere. We have a moral obligation to change our relationship with the planet. If we make those changes intelligently across all sectors of society and the economy, and if we undertake a 'mission-to-Mars' like development of new technology, then the changes have the chance to be more productive than painful. We may be able to cope and adapt to the changes that we see within our lifetimes without too much difficulty, but if we do not act now our children will suffer from out indecision and their children and grandchildren may lead much less rewarding lives, experience a significantly poorer standard of living, and face a world that is fundamentally more dangerous and uncertain. I have great faith in our ability to rise to this challenge, much as we have before when faced with global challenges to our way of life.

Nonetheless, our nation, its environment, economy, and people will be harmed by climate change. We face a twin challenge to mitigate its impacts and adapt to those which we cannot mitigate. We need strategies for responding to climate change impacts that will minimize the damage and cost of those impacts. We must get much better at anticipating what climate change is going to throw at us, and when and where those curve balls are going to appear. Adaptation to climate change will require significant investments in research, education, industry, and government, but it is within our capacity as a global society.

We have never faced a challenge of this magnitude before, but if we are willing to act now in collaboration with the World, we can succeed.

Thank you for the opportunity to provide the Select Committee on Energy Independence and Global Warming information regarding the importance of the ocean and how is being affected by climate change. If I can be of further assistance, please do not hesitate to ask.