Written Statement By
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HEARING ON
WILDLIFE AND OCEANS IN A CHANGING CLIMATE
BEFORE THE
COMMITTEE ON NATURAL RESOURCES
SUBCOMMITTEE ON FISHERIES, WILDLIFE AND OCEANS
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Madam Chairwoman and Members of the Committee, thank you for inviting me to appear before you today. I am John Everett. I am not here to represent any particular organization, company, nor special-interest group. I have never received any funding to support my climate change work other than my NOAA salary, when I was employed there up to five years ago, in various positions over a 31 – year career. I will present the results of the work I led for the Intergovernmental Panel on Climate Change from 1988 to 2000, while an employee of NOAA. This is still the most thorough, comprehensive, and broadly reviewed work on the subjects that has been published. The reports were reviewed by hundreds of government and academic scientists as part of the IPCC process. My work included five impact analyses: Fisheries (Convening Lead Author), Polar Regions (Co-Chair), Oceans (Lead Author), and Oceans and Coastal Zones (Co-Chair/2 reports). Since leaving NOAA I have kept abreast of the literature, have talked to many individuals and groups and have maintained these subjects in the UN Atlas of the Oceans, where I am the Chief Editor and Project Manager. While I will present the results from IPCC documents I led or helped write, all opinions are mine alone, and are at the end.

Background.

I was assigned the climate change duties when I was the National Marine Fisheries Service Division Chief for Fisheries Development in the 1970s. The agency was very concerned about the impact of climate change on the United States fisheries and fishing industry. **Global cooling**. would be devastating to our fisheries and aquaculture. About 1987, the momentum shifted to fears of **global warming** and with my background, I was tasked to lead our efforts dealing with it. In 1996 I received the NOAA Administrator’s Award for “accomplishments in assessing the impacts of climate change on global oceans and fisheries.”

Taking only information from IPCC reports, essentially verbatim, I first present a summary, then more detail. The full reports are listed in the endnotes and have all the supporting text (about 60 pages) and hundreds of citations, which do not appear here.

Summary of Impacts

Fisheries

- Freshwater fisheries and aquaculture at mid to higher latitudes should benefit
- Saltwater fisheries should be about the same
- Fishery areas and species mix will shift
- Changes in abundance more likely near ecosystem boundaries
- National fisheries will suffer if fishers cannot move within and across national borders (Subsistence/small scale fishermen suffer most)
- Climate change impacts add to overfishing, lost wetlands and nurseries, pollution, UV-B, and natural variation
- Inherent instability in world fisheries will be exacerbated by a changing climate

- Globally, economic and food supply impacts should be small. In some countries, they could be large
- Overfishing is more important than climate change today; the relationship should reverse in 50-100 years (as overfishing is controlled)

Oceans

- Temperature changes will cause geographical shifts in biota and changes in biodiversity, and in polar regions the extinction of some species and proliferation of others.
- A temperature rise in high latitudes should increase the duration of the growing period and the productivity of these regions.
- Increased coral bleaching will occur as a result of a predicted 2°C increase in average global atmospheric temperature by 2050.
- The Northwest Passage and Northern Sea Route of Russia likely will be opened for routine shipping.
- Sea-level changes will occur with regional variations.
- Changes in coastal pollutants will occur with changes in precipitation and runoff.
- Changes in circulation and vertical mixing will influence nutrient availability and primary productivity, affecting the efficiency of carbon dioxide uptake by the oceans.
- The oceans' uptake and storage capacity for greenhouse gases will be affected by changes in nutrient availability resulting from other changes in precipitation, runoff, and atmospheric deposition.
- Freshwater influx from movements and melting of sea ice or ice sheets may lead to a weakening of the global thermohaline circulation, causing unpredictable instabilities in the climate system.
- Reduced yields of desirable fish species will occur if primary productivity decreases.
- Marine mineral extraction, except for petroleum hydrocarbons and the marine pharmaceutical and biotechnological industries, is insensitive to global climate change.

Polar Regions

- Major physical, ecological, sociological, and economic changes are expected in the Arctic, but much smaller changes are likely for the Antarctic.
- Substantial loss of sea ice is expected in the Arctic ocean. If there is more open water, there will be a feedback to the climate system of northern countries by moderating temperature and increasing precipitation.
- Polar warming probably should increase biological production, but may lead to different species composition. In the sea, marine ecosystems will move poleward. Animals dependent on ice may be disadvantaged.
- Human communities in the Arctic will be affected by the physical and ecological changes. Effects will be particularly important for indigenous peoples leading traditional lifestyles.
- There will be economic benefits and costs. Benefits include new opportunities for shipping across the Arctic Ocean, lower operational costs for the oil and gas industry, lower heating costs, and easier access for tourism. Increased costs can be expected from several sources including disruptions caused by thawing of permafrost and reduced transportation capabilities across frozen ground and water.
- Sea ice changes in the Arctic have major strategic implications for trade and defense.

The Impact of Climate Change.

The oceans and coastal zones have been far warmer and colder than is projected in the present scenarios of climate change. Marine life has been in the oceans nearly since when they were formed. During the millennia they endured and responded to CO_2 levels well beyond anything projected, and temperature changes that put tropical plants at the poles or had much of our land covered by ice more than a mile thick. The memory of these events is built into the genetic plasticity of the species on this planet. IPCC forecasts are for warming to occur faster than evolution is considered to occur, so impacts will be determined by this plasticity and the resiliency of affected organisms to find suitable habitats. In the oceans, major climate warming and cooling is a fact of life, whether it is over a few years as in an El Niño or over decades as in the Pacific Decadal Oscillation or the North Atlantic Oscillation. Currents, temperatures, salinity, and biology changes rapidly to the new state in months or a couple years. These changes far exceed the changes expected with global warming and occur much faster. The one degree F. rise since 1860 is virtually noise in this rapidly changing system. Sea level has been inexorably rising since the last glaciation lost its grip a mere 10,000 years ago. It is only some few thousand years since trees grew on Georges Bank and oysters flourished on its shores. Their remains still come up in dredges and trawls in now deep water, with the oysters looking like they were shucked yesterday. In the face of all these natural changes, and those we are here to consider, some species flourish while others diminish. These considerations were well understood in all the IPCC groups in which I participated.

The following text is taken from IPCC reports that I led. The text is left intact, with a very few edits to make complete sentences after deletion of portions irrelevant for this Hearing, such as some terrestrial impacts in the Arctic. Most background information has been deleted, but all these summary statements are fully supported in the cited references.

FISHERIES [1]

Convening Lead Author: John T. Everett, USA. **Lead Authors**: A. Krovnin, Russia; D. Lluch-Belda, Mexico; E. Okemwa, Kenya; H.A. Regier, Canada; J.-P. Troadec, France

Summary. Climate-change effects interact with those of pervasive overfishing, diminishing nursery areas, and extensive inshore and coastal pollution. Globally, marine fisheries production is expected to remain about the same; high-latitude freshwater and aquaculture production are likely to increase, assuming that natural climate variability and the structure and strength of ocean currents remain about the same. The principal impacts will be felt at the national and local levels as species mix and centers of production shift. The positive effects of climate change—such as longer growing seasons, lower natural winter mortality, and faster growth rates in higher latitudes—may be offset by negative factors such as changes in established reproductive patterns, migration routes, and ecosystem relationships.

- Globally, under the IPCC scenarios, saltwater fisheries production is hypothesized to be about the same, or significantly higher if management deficiencies are corrected. Also, globally, freshwater fisheries and aquaculture at mid- to higher latitudes could benefit from climate change. These conclusions are dependent on the assumption that natural climate variability and the structure and strength of wind fields and ocean currents will remain about the same. If either changes, there would be significant impacts on the distribution of major fish stocks, though not on global production (Medium Confidence).
- Even without major change in atmospheric and oceanic circulation, local shifts in centers of production and mixes of species in marine and fresh waters are expected as ecosystems are displaced geographically and changed internally. The relocation of populations will depend on properties being present in the changing environments to shelter all stages of the life cycle of a species (High Confidence).
- While the complex biological relationships among fisheries and other aquatic biota and physiological responses to environmental change are not well understood, positive effects such as longer growing seasons, lower natural winter mortality, and faster growth rates in higher latitudes may be offset by negative factors such as a changing climate that alters established reproductive patterns, migration routes, and ecosystem relationships (High Confidence).

- Changes in abundance are likely to be more pronounced near major ecosystem boundaries. The rate of climate change may prove a major determinant of the abundance and distribution of new populations. Rapid change due to physical forcing will usually favor production of smaller, low-priced, opportunistic species that discharge large numbers of eggs over long periods (High Confidence). However, there are no compelling data to suggest a confluence of climate-change impacts that would affect global production in either direction, particularly because relevant fish population processes take place at regional or smaller scales for which general circulation models (GCMs) are insufficiently reliable.
- Regionally, freshwater gains or losses will depend on changes in the amount and timing of precipitation, on temperatures, and on species tolerances. For example, increased rainfall during a shorter period in winter still could lead to reduced levels in summer in river flows, lakes, wetlands, and thus in freshwater fisheries. Marine stocks that reproduce in freshwater (e.g., salmon) or require reduced estuarine salinities will be similarly affected (High Confidence).
- Where ecosystem dominances are changing, economic values can be expected to fall until long-term stability (i.e., at about present amounts of variability) is reached (Medium Confidence). National fisheries will suffer if institutional mechanisms are not in place that enable fishing interests to move within and across national boundaries (High Confidence). Subsistence and other small-scale fishermen, lacking mobility and alternatives, often are most dependent on specific fisheries and will suffer disproportionately from changes (Medium Confidence).
- Because natural variability is so great relative to global change, and the time horizon on capital replacement (e.g., ships and plants) is so short, impacts on fisheries can be easily overstated, and there will likely be relatively small economic and food supply consequences so long as no major fish stocks collapse (Medium Confidence).
- An impact ranking can be constructed. The following items will be most sensitive to environmental variables and are listed in descending order of sensitivity (Medium Confidence):
  - Freshwater fisheries in small rivers and lakes, in regions with larger temperature and precipitation change
  - Fisheries within Exclusive Economic Zones (EEZs), particularly where access-regulation mechanisms artificially reduce the mobility of fishing groups and fleets and their capacity to adjust to fluctuations in stock distribution and abundance
  - Fisheries in large rivers and lakes
  - Fisheries in estuaries, particularly where there are species without migration or spawn dispersal paths or in estuaries impacted by sea-level rise or decreased river flow
  - High-seas fisheries.
- Adaptation options with large benefits irrespective of climate change (Medium Confidence):
  - Design and implement national and international fishery-management institutions that recognize shifting species ranges, accessibility, and abundances and that balance species conservation with local needs for economic efficiency and stability
  - Support innovation by research on management systems and aquatic ecosystems
  - Expand aquaculture to increase and stabilize seafood supplies, help stabilize employment, and carefully augment wild stocks
  - In coastal areas, integrate the management of fisheries with other uses of coastal zones
  - Monitor health problems (e.g., red tides, ciguatera, cholera) that could increase under climate change and harm fish stocks and consumers.

Oceans[2]

Convening Lead Author: Venugopalan Ittekkot, Germany. **Principal Lead Authors**: Su Jilan, China; E. Miles, USA; Lead Authors: E. Desa, India; B.N. Desai, India; J.T. Everett, USA; J.J. Magnuson, USA; A. Tsyban, Russian Federation; S. Zuta, Peru

Summary. Global warming as projected by Working Group I of the IPCC will have an effect on sea-surface temperature and sea level. As a consequence, it is likely that ice cover and oceanic circulation will be affected, and the wave climate will change. The expected changes affect global biogeochemical cycles, as well as ecosystem structure and functions, on a wide variety of time and space scales; however, there is uncertainty as to whether extreme events will change in intensity and frequency. We have a high level of confidence that:

- Redistribution of temperatures could cause geographical shifts in biota as well as changes in biodiversity, and in polar regions the extinction of some species and proliferation of others. A rise in mean temperature in high latitudes should increase the duration of the growing period and the productivity of these regions if light and nutrient conditions remain constant.
- Sea-level changes will occur from thermal expansion and melting of ice, with regional variations due to dynamic effects resulting from wind and atmospheric pressure patterns, regional ocean density differences, and oceanic circulation.
- Changes in the magnitude and temporal pattern of pollutant loading in the coastal ocean will occur as a result of changes in precipitation and runoff.

We can say with a lesser degree of confidence that:
- Changes in circulation and vertical mixing will influence nutrient availability and primary productivity, thereby affecting the efficiency of carbon dioxide uptake by the oceans.
- The oceans' uptake and storage capacity for greenhouse gases will be affected further by changes in nutrient availability in the ocean resulting from other changes in precipitation, runoff, and atmospheric deposition.
- Freshwater influx from the movements and melting of sea ice or ice sheets may lead to a weakening of the global thermohaline circulation, causing unpredictable instabilities in the climate system.

The most pervasive effects of global climate change on human uses of the oceans will be due to impacts on biotic resources; transportation and nonliving resource exploitation will be affected to a lesser degree. We can say with a high level of confidence that:
- Increased coral bleaching will occur as a result of a predicted 2°C increase in average global atmospheric temperature by 2050.
- Expanded dredging operations will be necessary to keep major ports open in the Northern Hemisphere, which will increase costs.
- The Northwest Passage and Northern Sea Route of Russia likely will be opened up for routine shipping.
- Growth in the marine instrumentation industry will occur as the need for research and monitoring of climate change increases.

We can say with a lesser degree of confidence that:
- Reduced yields of desirable fish species will occur if average primary productivity decreases.
- If the frequency of tropical storms and hurricanes increases, adverse impacts will be generated for offshore oil and gas activities and for marine transportation in the tropics.
- Marine mineral extraction, except for petroleum hydrocarbons and the marine pharmaceutical and biotechnological industries, is insensitive to global climate change.

Adaptation to the impact of climate change on oceans is limited by the nature of these changes, and the scale at which they are likely to occur:
- No adaptive responses to coral bleaching, even on a regional scale, will be available if average global temperature increases 2°C by 2050. However, reductions in land-based pollution of the marine environment, combined with reductions in habitat degradation/ destruction, would produce benefits for fisheries, aquaculture, recreation, and tourism.
- Adaptation options will be available for the offshore oil, gas, and shipping industries if the frequency of tropical storms and hurricanes increases. The options include improved design standards for offshore structures, national and international regulations for shipping, and

increased technological capabilities to provide early warning at sea. Governments also can increase attention to institutions for planning and responding to disasters and emergencies.

- Where climate change generates positive effects, market-driven needs will create their own adaptation dynamic. However, adaptation policies will be required to control externalities that are market failures. For instance, opening up both the Northwest Passage and the Russian Northern Sea Route for up to 100 days a year—while a boon to international shipping and consumers in East Asia, North America, and Western Europe—will have to be accompanied by policies designed to limit the total burden of pollutants entering the Arctic environment from ports, ship operations, and accidents.

A combination of human activities (e.g., overfishing, pollution of estuaries and the coastal ocean, and the destruction of habitat, especially wetlands and seagrasses) currently exerts a far more powerful effect on world marine fisheries than is expected from climate change.

In contrast to model projections, observations over large parts of the tropical Atlantic between 1947 and 1986 have shown an increase in the trade winds. Bakun suggests that the greenhouse effect will enhance the seasonal warming of continents—leading to a decrease in the pressure over land, an increase in the land–sea pressure difference, and increased alongshore winds. Binet has observed such effects along the coast of northwest Africa. It appears likely that the strength of both oceanic and coastal upwelling mechanisms could change under conditions of global warming, with profound impacts upon fish species and their production as well as on the climate of the immediate coastal zone.

Although ENSO is a natural part of the Earth's climate, a major question is whether the intensity or frequency of ENSO events might change as a result of global warming. Historical and paleorecords reveal that ENSO events have changed in frequency and intensity in the past on multidecadal to century timescales. It is unclear whether ENSO might change with long-term global warming.

Sea ice covers about 11% of the ocean, depending on the season. It affects albedo, salinity, and ocean-atmosphere thermal exchange. The latter determines the intensity of convection in the ocean and the timescale of deep-ocean processes affecting CO_2 uptake and storage.

Projected changes in climate should produce large reductions in the extent, thickness, and duration of sea ice. Major areas that are now ice-bound throughout the year are likely to have major periods during which waters are open and navigable. Some models even predict an ice-free Arctic. Melting of snow and glaciers will lead to increased freshwater influx, changing the chemistry of those oceanic areas affected by the runoff. There is no convincing evidence of changes in the extent of global sea ice. Studies on regional changes in the Arctic and Antarctic indicate trends of decadal length, often with plausible mechanisms proposed for periodicities of a decade or more. Longer data sets are needed to test if a genuine long-term trend is developing.

Winds and waves are the major forcing factors for vertical mixing; the degree of mixing depends on the vertical density structure. In the past 40 years, there has been an increase in the mean wave height over the whole of the North Atlantic, although it is not certain that global change is the cause of this phenomenon.

Metabolic rates, enzyme kinetics, and other biological characteristics of aquatic plants and animals are highly dependent on external temperatures; for this reason alone, climate change that influences water temperature will have significant impacts on the ecology and biodiversity of aquatic systems. The capability of some species to adapt genetically to global warming will depend on existing genetic variation and the rapidity of change. Species remaining in suboptimal habitats should at least experience reductions in abundance and growth well before conditions become severe enough for extinctions to occur. The resilience of an ecosystem to climate change will be determined to a large extent by the degree to which it already has been impaired by other human activities.

Coastal ecosystems are especially vulnerable in this context. They are being subjected to habitat degradation; excessive nutrient loading, resulting in harmful algal blooms; fallout from aerosol contaminants; and emergent diseases. Human interventions also have led to losses of living marine resources and reductions in biodiversity from biomass removals at increasingly lower trophic levels. The effects on biodiversity are likely to be much less severe in the open ocean than in estuaries and wetlands, where species in shallow, restricted impoundments would be affected long before deep-oceanic species.

The chief biotic effects on individuals of an increase in mean water temperature would be increased growth and development rates. If surface temperatures were correlated positively with latitude, and temperature increased, one would expect a poleward shift of oceanic biota. While this may be the general case, there could be important regional variations due to shifts in atmospheric and oceanic circulation. The resulting changes in predator-prey abundance and poleward shifts in species' ranges and migration patterns could, in the case of marine fisheries, lead to increased survival of economically valuable species and increased yield. Such cases have been observed as a result of the large and intense 1983 El Niño.

In high latitudes, higher mean water temperature could lead to an increase in the duration of the growing period and ultimately in increased bioproductivity in these regions. On the other hand, the probability of nutrient loss resulting from reduced deep-water exchange could result in reduced productivity in the long term—again highlighting the importance of changes in temperature on patterns of circulation. Global warming could have especially strong impacts on the regions of oceanic subpolar fronts, where the temperature increase in deep water could lead to a substantial redistribution of pelagic and benthic communities, including commercially important fish species.

Most migratory organisms are expected to be able to tolerate changes, but the fate of sedentary species will be dependent on local climate changes. Some corals would be affected (as in the 1983 and 1987 bleaching events), but it is expected that other stresses (e.g., pollution, sedimentation, or nutrient influx) may remain more important factors. Intertidal plants and animals, such as mangroves and barnacles, are adapted to withstand high temperature, and unless the 1.5°C increase affects reproduction, it will have no effect. Similarly, only seagrass beds already located in thermal-stress situations (i.e., in shallow lagoons or near power plant effluents) are expected to be negatively affected by the projected temperature rise. One cannot rule out, however, the possibility of significantly greater tropical warming than 1.5°C. For example, some investigators argue that tropical warming was approximately 5°C from the last glacial maximum to today. If this value is correct, current GCMs probably underestimate tropical sensitivity.

Changes in temperature and salinity are expected to alter the survivorship of exotic organisms introduced through ballast water in ships, especially those species with pelagic larval forms. Introduction of exotic species is a form of biological pollution because, from a human perspective, they can have adverse impacts on ecosystems into which they are introduced and in some cases pose hazards to public health. A classic recent example of the spread of an introduced exotic species is that of the zebra mussel (*Dressena polymorpha*), which was transported to the Great Lakes via transatlantic shipping from the Baltic sea.. Changes in temperature could enhance the potential for the survival and proliferation of exotic species in environments that are presently unfavorable.

Changes also can be expected in the growth rates of biofouling organisms that settle on means of transport, conduits for waste, maritime equipment, navigational aids, and almost any other artificial structure in the aquatic environment. Their species distributions often are limited by thermal and salinity boundaries, which are expected to change with regional changes in temperature and precipitation. Areas that experience warming and reduced precipitation (i.e., salinity increases) likely will have increased problems with biofouling.

Predicted climate change also may have important impacts on marine mammals such as whales, dolphins, and seals, and seabirds such as cormorants, penguins, storm petrels, and albatross. However, it is presently impossible to predict the magnitude and significance of these impacts. The principal effects of climate change on marine mammals and seabirds are expected from areal shifts in centers of food production and changes in underlying primary productivity due to changes in upwelling, loss of ice-edge effects, and ocean temperatures; changes in critical habitats such as sea ice (due to climate warming) and nesting and rearing beaches (due to sea-level rise); and increases in diseases and production of oceanic biotoxins due to warming temperatures and shifts in coastal currents.

Ice plays an important role in the development and sustenance of temperate to polar ecosystems because it creates conditions conducive to ice-edge primary production, which provides the primary food source in polar ecosystems; it supports the activity of organisms that ensure energy transfer from primary producers (algae and phytoplankton) to higher trophic levels (fish, marine birds, and mammals); and, as a consequence, it maintains and supports abundant biological communities.

One of the possible beneficial consequences of global warming might be a reduction in the extent and stability of marine ice, which would directly affect the productivity of polar ecosystems. For example, the absence of ice over the continental shelf of the Arctic Ocean would produce a sharp rise in the productivity of this region, provided that a sufficient supply of nutrients is maintained. Changes in water temperature and wind regimes as a result of global warming also could affect the distribution and characteristics of polynyas (ice-free areas), which are vital to polar marine ecosystems. In addition, changes in the extent and duration of ice, combined with changes in characteristics of currents—for example, the circumpolar current in southern latitudes—may affect the distribution, abundance, and harvesting of krill. Krill are an important link in the ocean fauna in the Southern Ocean. It is important to understand how, when, and where productivity in the Southern Ocean will change with global warming.

A number of marine organisms depend explicitly on ice cover. For example, the extent of the polar bear's habitat is determined by the maximum seasonal surface area of marine ice in a given year. The disappearance of ice would threaten the very survival of the polar bear, as well as certain marine seals. Similarly, a reduction in ice cover would reduce food supplies for seals and walruses and increase their vulnerability to natural predators and human hunters and poachers. Other animals, such as the otter, could benefit by moving into new territories with reduced ice. Some species of marine mammals will be able to take advantage of increases in prey abundance and spatial/temporal shifts in prey distribution toward or within their primary habitats, whereas some populations of birds and seals will be adversely affected by climatic changes if food sources decline or are displaced away from regions suitable for breeding or rearing of young.

Animals that migrate great distances, as do most of the great whales and seabirds, are subject to possible disruptions in the distribution and timing of their food sources during migration. For example, it remains unclear how the contraction of ice cover would affect the migration routes of animals (such as whales) that follow the ice front. At least some migrating species may respond rapidly to new situations.

While the impacts of these ecological changes are likely to be significant, they cannot be reliably forecast or evaluated. Climate change may have both positive and negative impacts, even on the same species. Positive effects such as extended feeding areas and seasons in higher latitudes, more-productive high latitudes, and lower winter mortality may be offset by negative factors that alter established reproductive patterns, breeding habitat, disease vectors, migration routes, and ecosystem relationships.

Polar Regions: Arctic/Antarctica[3]

Convening Lead Authors: J.T. Everett (USA) and B. Blair Fitzharris (New Zealand)
Lead Author: Barrie Maxwell (Canada)

Summary. Direct effects could include: ecosystem shifts, sea and river ice loss, and permafrost thaw. Indirect effects could include positive feedback to the climate system. There will be new challenges and opportunities for shipping, the oil industry, fishing, mining and tourism, infrastructure, and movement of populations, resulting in more interactions and changes in trade and strategic balance. There will be winners and losers. As examples, a reduced and thinning ice cover will disadvantage polar bears, while sea otters will have new habitats; communities on new shipping routes will grow while those built on permafrost will have difficulties. Native communities will face profound changes impacting on traditional lifestyles.

- Major physical, ecological, sociological, and economic changes are expected in the Arctic, but much smaller changes are likely for the Antarctic, over the period of this assessment.
- Substantial loss of sea ice is expected in the Arctic ocean. If there is more open water, there will be a feedback to the climate system of northern countries by moderating temperature and increasing precipitation. If warming occurs, there will be considerable thawing of permafrost leading to changes in drainage, increased slumping and altered landscapes over large areas.
- Polar warming probably should increase biological production, but may lead to different species composition. In the sea, marine ecosystems will move poleward. Animals dependent on ice may be disadvantaged.
- Human communities in the Arctic will be affected by these physical and ecological changes. Effects will be particularly important for indigenous peoples leading traditional lifestyles.
- There will be economic benefits and costs. Benefits include new opportunities for shipping across the Arctic Ocean, lower operational costs for the oil and gas industry, lower heating costs, and easier access for tourism. Increased costs can be expected from several sources including disruptions caused by thawing of permafrost and reduced transportation capabilities across frozen ground and water.
- Sea ice changes in the Arctic have major strategic implications for trade and defense.

Marine Ecological Systems. If warming should occur, there will be an increase in growth and development rates of non-mammals. In general, productivity should rise. Risks include the loss of sea ice cover upon which several marine mammals depend for food and protection. Also, Arctic shipping, oil exploration and transport, and economic development could bring risks to many species.

- **Ice.** If there is warming, the Arctic could experience a thinner and reduced ice cover, including that in Arctic lakes and streams. In contrast, the vast Antarctic is so cold that any warming within the IPCC scenarios should have little impact except in the Dry Valleys and on the Antarctic Peninsula. In fact, ice could accumulate through greater snowfall, slowing sea level rise.
- **Permafrost**. Permafrost underlies as much as 25% of the global land surface. Considerable amounts will disappear, causing major changes in ecosystem structure and in human impacts.
- **Fisheries**. Warming could lead to a rise in production, unless changes in water properties would disrupt the spawning grounds of fish in high latitudes. There could be a substantial redistribution of important fish species. Fisheries on the margin of profitability could prosper or decline. Fishing seasons will lengthen, but most stocks are already fully exploited.
- **Navigation and Transport**. If sea-ice coverage is reduced, coastal and river navigation will increase. Opportunities for water transport, tourism, and trade will increase. The Arctic Ocean could become a major trade route. Seasonal transport across once frozen land and rivers may become difficult or costly. Offshore oil production should benefit from less ice.

- **Arctic Settlements**. If the climate ameliorates, conditions will favor the northward spreading of agriculture, forestry, and mining, with an expansion of population and settlements. More infrastructure such as marine, road, rail, and air links would be required. Changes in the distribution and abundance of sea and land animals will impact on traditional lifestyles of native communities.

WORLD OCEANS AND Coastal Zones[4]

Co-Chairs: John. Everett USA; Alla Tsyban (Russia); Jim Titus (USA)

World Oceans And Coastal Zones: Ecological Effects[5]

Co-Chairs: John. Everett USA; Alla Tsyban (Russia); Martha Perdomo (Venezuela))

These two report's findings were incorporated into subsequent reports and are included above, with the possible exception that these made a stronger case for the impacts of sea level rise. Since the projected amount of rise has now been rolled back in the latest scientific assessment due to a lack of acceleration in sea level rise, these findings are no longer relevant. Some of their adaptation recommendations are included below.

Research Needs

Information is most valuable if there are institutions and management mechanisms to use it. Research on improved mechanisms is needed so that fisheries can operate more efficiently with global warming as well as in the naturally varying climate of today. There is relatively little research underway on such mechanisms. Knowledge of the reproductive strategies of many species and links between recruitment and environment is poor.

The following items are needed specifically because of climate change. Other types of research, which are prerequisites for dealing with such concerns but which support the day-to-day needs of fisheries managers or relate more to understanding how ecosystems function, are not included.

- Determine how fish adapt to natural extreme environmental changes, how fishing affects their ability to survive unfavorable conditions, and how reproduction strategies and environments are linked. Link fishery ecology and regional climate models to enable broader projections of climate-change impacts and improve fishery management strategies.
- Implement regional and multinational systems to detect and monitor climate change and its impacts—building on and integrating existing research programs. Fish can be indicators of climate change and ecological status and trends. Assemble baseline data now so comparisons can be made later.
- Develop ecological models to assess multiple impacts of human activities.
- Determine the fisheries most likely to be impacted, and develop adaptation strategies.
- Assess the potential leaching of toxic chemicals, viruses, and bacteria due to sea-level rise and how they might affect both fish and the seafood supply.
- Determine institutional changes needed to deal with a changing climate. Such changes are likely the same ones needed for mastering overfishing and coping with the variability and uncertainty of present conditions. Improved institutions would probably reduce stock variability more than climate change would increase it.
- Study the historical ability of societies to adapt their activities when their resources are impacted by climate changes.
- Research activities to better understand processes in the oceans, in particular the role of the oceans in the natural variability of the climate system at seasonal, interannual, and decadal to century timescales.
- Long-term monitoring and mapping of: water-level changes, ice coverage, and thermal expansion of the oceans; sea-surface temperature and surface air temperature; extratropical storms and tropical cyclones; changes in upwelling regimes along the coasts of California,

Peru, and West Africa; UV-B radiation, particularly in polar regions, and its impact on aquatic ecosystems; regional effects on distribution of species and their sensitivity to environmental factors; changes in ocean biogeochemical cycles.
- Socioeconomic research activities to document human responses to global change

Adaptation Options
- Establish management institutions that recognize shifting distributions, abundances and accessibility, and that balance conservation with economic efficiency and stability
- Support innovation by research on management systems and aquatic ecosystems
- Expand aquaculture to increase and stabilize seafood supplies and employment, and carefully, to augment wild stocks
- Integrate fisheries and CZ management
- Monitor health problems (e.g., red tides, ciguatera, cholera)
- Coastal planners and owners of coastal properties and infrastructure should carefully consider projected relative sea level changes when evaluating new or reconstruction projects.
- Coastal planners and environmental decision-makers should consider that a healthy environment is a prerequisite for coral reefs, mangroves and sea grasses to keep pace with a rising sea and to continue their coastal protection benefits

Understanding Climate Change in Order to Assess Impacts – My View

My specialty that is relevant to this hearing is in impacts assessment, not the **science** of climate change. However, to determine impacts correctly, one must understand the nature of change and its likelihood to continue. In the IPCC structure, the science has been led by the UK and US scientists, and they used modeling as their primary tool, with some paleoclimate analysis coming later. The Impacts Assessments were led by the Russians, who had an intense distrust of modeling. They viewed paleoclimatology as the most valid tool: if you want to know what will happen when CO2 rises or the temperature changes, look at the history of the earth. As an American, working with the Russian teams, I was often caught in the middle of both camps. I learned to listen to both views, and continue to do so. In particular, we learned to distrust any science literature or impacts assessment that did not consider all data available, whether modeling, the instrumented record back into the 1800s and/or the paleo and historical temperature reconstructions. **If the data are truncated, there is likely an agenda**.

In this light I view with grave concern the two latest IPCC Summary for Policy Makers which use truncated data in text and graphics to misrepresent the amount of warming, causing undue alarm. For example, from the most recent SPM, “The Working Group I Fourth Assessment concluded that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. ….” This is a red flag. It begs the question of why the restriction “since the mid-20th century”. What is wrong with the full data set back into the 1800s? Is it restricted to “mid-20th century” because it is too difficult to explain the prior decades of falling temperatures in the face of rising CO2? This demonstration (and there are many others) is typical of what has led many disagreeing scientists to not be invited to IPCC anymore, and others to lose interest. Over 20 years the core IPCC-participating scientists have become more homogeneous. The consensus has become stronger as dissenting scientists have moved to become the “other consensus”, usually called climate skeptics.

The source of the warming or cooling is of little importance to an impacts assessment, except where it provides a clue as to future trends. Most people agree that there has been a warming of 1 degree Fahrenheit in the instrumental record of 150 years. Those in the "IPCC-oriented consensus" believe it is due to mankind's increased CO2 and other gas emissions; therefore temperatures are likely to rise as more humans inhabit the earth and economies grow. This is important information to a specialist in assessments. Also important, though, is staying in touch with other views. Scientists in the "other consensus" believe that, even if the 1 degree change is accurate (and is not just "noise"), the CO2 rise can, at most, explain a piece of the temperature rise. Many believe that increased water vapor, solar variations in radiation and magnetic flux, our relative position in the solar system, the tilt of our planet's axis, the clearing of our atmosphere of pollutants which allows more sunlight to reach the ground, or our position in the Milky Way galaxy that affects the amount of radiation reaching our atmosphere and affecting cloud formation, are also important and are not (and cannot be yet) adequately considered in the computer models used by the IPCC consensus. Many believe CO2 may not be the culprit.

Concluding Remarks

Personally, I do not know whether the earth is going to continue to warm, or that having reached a peak in 1998, we are at the start of a cooling cycle that will last several decades or more. Whichever it is, our actions should be prudent. Our fishing industry, maritime industry and other users of the ocean environment compete in a world market and are vulnerable in many ways to possible governmental actions to reduce CO2 emissions. We already import most of our seafood and many of the nations with which we compete do not need further advantages. Our research should focus on those ecosystem linkages we need to understand in order to wisely manage our fisheries, and this includes the ability to incorporate natural climate variability along with long term changes. Institutionally, we should work with our neighbors to pre-determine what should happen when one of our major fish stocks ignores the international boundary. Lastly, I would like to draw the Committee's attention to the testimony of Dr. Steven Murawski, of NMFS, at a hearing on Projected and Past Effects of Climate Change: a Focus on Marine and Terrestrial Ecosystems before the Senate Committee on Commerce, Science and Transportation, Subcommittee on Global Climate Change and Impacts, on April 26, 2006. I think it is well done, although I would quibble with some minor points..

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