CLIMATE CHANGE: WHAT WILL IT MEAN FOR LOUISIANA'S COASTAL FISHERIES?

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As most scientists and world leaders generally agree: the earth is warming. In January, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released *Climate Change 2001: The Scientific Basis*, its third assessment of global warming. The 1,000-page report took three years to produce and is the work of 123 lead authors, who drew on the work of 516 contributing scientists. It has been reviewed extensively by climate change experts and, after line-by-line consideration, was accepted unanimously by the intergovernmental panel.

As revealed by new records from tree rings, coral reefs, and ice cores, along with historical records, temperature increases in the Northern Hemisphere are greater than in the twentieth century than in any century during the past 1000 years. In the middle and high latitudes, snow cover has decreased by about 10 percent since the 1960s and, over the century, the annual duration of ice on lakes and rivers has shortened by about two weeks. In recent decades, scientists have noted a 40 percent decline in the thickness of Arctic Sea ice during late summer and early autumn. Rain in the middle to high latitudes of the Northern Hemisphere has increased by 0.5 to 1 percent per decade during the century and the frequency of heavy rains has increased by 2 to 4 percent over the past half-century.

This report includes new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities. The warming is linked to the emissions of six gases, but the primary culprit appears to be carbon dioxide formed by the combustion of oil, coal, and natural gas. Called "greenhouse" gases, they trap heat in the atmosphere. Since 1750, the atmospheric concentration of carbon dioxide has increased by 31 percent—from 280 to 367 parts per million. The current amount of atmospheric carbon dioxide has not been exceeded during the past 420,000 years and probably not during the past 20 million years.

The earth's atmosphere is warming faster than predicted in the assessment published by the same panel just five years

ago. "We see changes in climate, we believe humans are involved, and we're projecting future climate changes much more significant over the next hundred years than during the past hundred years," said Robert Watson of the U.N.'s IPCC. "We should start preparing ourselves for rising sea levels, changing rain patterns, and other impacts of global warming."

David Easterling of the National Oceanic and Atmospheric Administration and University of North Carolina (Chapel Hill) said, "… doing business as usual, with no major reductions in carbon dioxide emissions, we could see a world that is 5° Celsius (9°F) warmer by 2100. Depending on what climate model you look at, the range of increase is expected to be between 2.5° and 6° C (4.5° to 10.8°F) over the next century. Our best guess is 3.5° to 4°C (6° to 7°F) by the end of the century."

CLIMATE CHANGE AND SEA LEVEL HOW WILL LOUISIANA BE AFFECTED?

Unfortunately, the state is extremely vulnerable to a significant consequence of global warming: sea level rise. The thermal expansion of seawater and the melting of ice in high latitudes caused by global warming lead to higher sea levels which, under current model predictions, are expected to rise about 5 inches by 2050. With its low, flat coast, Louisiana already suffers from a high apparent sea level rise as marshes are sinking and coastal erosion is converting marsh areas into open water. True sea level rise associated with global warming will exacerbate the state's serious land loss problems.

Increased flooding of saltwater marshes can lead to water-logged soils and ion toxicity, and stresses on fresh marshes will be greater because of saltwater encroachment. All of this contributes to an increase in the open estuarine environment and loss of the more structurally complex marsh habitat. Not only will water level fluctuations affect the biological well-being and physical structure of the marsh habitat, but changes in frequency, duration and extent of flooding are likely to affect accessibility and, therefore, use by fish and shellfish. Changes in estuarine water circulation can affect both immigration and emigration and, thus, recruitment to adult fisheries. Prey-predator relationships along tidal marsh edges and flooded marsh surfaces, as well as the movement of nutrients in and out of the marsh, will also be affected.

With a greater expanse of open estuarine water where once there was marsh, surface waters will be exposed to greater levels of ultraviolet light. Although atmospheric ozone and the high concentrations of dissolved organic matter in Louisiana's coastal waters absorb parts of the ultraviolet spectrum and minimize its penetration into the water column, there may be an ultimate effect on the food supply for larval fish. The larval stages of almost all species of fish feed on immature stages of copepods. Copepod eggs are released at or near the surface and it has been demonstrated that hatching success is severely reduced by exposure to natural levels of ultraviolet light, levels the eggs would be exposed to in open, near surface waters.

CLIMATE CHANGE AND TEMPERATURE

As mentioned previously, most global climate change models predict a rise of 2.5° to 6° C in annual average global surface temperatures. A rise of 4° C in summer water temperature in Louisiana's shallow marshes and bays would exceed the reported lethal limit for white shrimp (*Penaeus setiferus*) when they are at their peak post-larval and subadult abundance in the estuaries (Condrey and Fuller 1992).

Such altered temperatures could also advance or retard estuarine spawning cycles of fishes, changing the synchrony of their early life stages with their supply of much-needed planktonic food of the appropriate size. In addition, regional temperature changes could lead to distribution shifts; in areas where we once found temperate and subtropical fish species, we could in the future see subtropical and tropical species.

CLIMATE CHANGE AND WEATHER

Wind patterns, storm frequency and intensity, rainfall patterns, and other weather characteristics may change in response to climate warming, with resultant impacts on Louisiana's fisheries. Larval fish feeding and recruitment to estuarine nursery areas are critically affected by weather. Although regional weather patterns are one of the more unpredictable consequences of climate change, it's clear that there is a wide range of potential responses, from fisheries production and species composition to changes in local weather patterns. Ecosystem responses in a region as highly dynamic as the northern Gulf of Mexico, where continental shelf and coastal biological productivity is heavily dependent on riverine nutrients, are just now beginning to be understood. Predictions of responses to climate change are theoretical at this time.

A warmer ocean could result in stronger or more frequent hurricanes, if the additional heat is returned to the atmosphere each fall. Although the number of hurricanes each year has not increased, winds have been stronger in the storms that have occurred. Stronger storm winds cause greater inundation of coastal areas, increased penetration of seawater into coastal wetlands, more extensive coastal erosion (especially of barrier islands), and more extensive damage to coastal homes, industries, and infrastructure. Along with sea level rise and ongoing coastal erosion, these storms increase the vulnerability of coastal habitats along the northern Gulf of Mexico. These coastal habitats not only provide

places for people to live and work, but also provide economically important goods (renewable and nonrenewable natural resources) and services (e.g., storm protection and water filtration).

CLIMATE CHANGE AND THE RIVER

The Mississippi River drains 41 percent of the continental United States. Any changes in rainfall patterns within this vast drainage basin will alter the discharge and flow patterns, as well as nutrient loads, of the lower river. River-borne nutrients are responsible for most of the biological production of the northern Gulf of Mexico and any change would significantly alter fisheries production, with significant effects on the local economy and culture.

Of these river-borne nutrients, nitrogen from agricultural fertilizers has increased dramatically in the last several decades. The resulting enhancement of riverine nutrients has led to increased coastal productivity and may have also increased the aerial extent of oxygen depletion, or hypoxia, in bottom waters of the Louisiana continental shelf each year. The effects of hypoxic areas, called "dead zones," on fish and shellfish can include direct mortality from a lack of dissolved oxygen, altered migration patterns, and a reduction in the availability of benthic habitat. It is reasonable to conclude that any climate-induced changes in rainfall and subsequent erosion patterns within the Mississippi River drainage basin will result in changes in productivity patterns in the northern Gulf of Mexico with consequences for continental shelf benthic habitats and for coastal fisheries production.

CLIMATE CHANGE AND THE ECOSYSTEM

Changes in sea level may be gradual, but ecosystem changes associated with climate change will probably not be. We talk about an increase in temperature of several degrees over the next 50 years, speak in terms of general trends and averages, and this is not inaccurate. However, it ignores the realities of biological change in nature, which is typically more step-like. A three-year drought followed by a long period of flooding may yield an apparently reasonable average long-term rainfall, but the effects on the ecosystem are quite different than they would be if the same amount of rainfall were distributed in a less variable manner.

Systems tend to have some level of built-in resiliency before changing. Then they shift dramatically. Changes are often in steps rather than in uniformly gradual adjustments, a characteristic that manifests itself in regime shifts. Accurately predicting such ecosystem shifts is currently beyond our capabilities.

As indicated by the IPCC report, scientists are now in strong agreement as to the directions of climate change, and predictions of direct effects such as temperature increases are being made more confidently (with bounds). But it is the secondary effects that will cause the most important ecosystem shifts. The linkages between these direct effects and secondary effects are poorly understood and difficult to predict with our current state of ecosystem understanding. This leads to one of the more problematic aspects of global warming as it relates to fisheries—the socioeconomic consequences.

Fish populations and communities respond to a wide range of environmental factors. Demonstrating the significance of global warming for fisheries populations is, as is apparent from the discussion above, likely to be challenging and filled with uncertainty. There are other factors that have been shown to affect fish populations: overfishing, pollution, and loss or degradation of coastal habitats through more direct human impacts. History has shown that societal responses to these stresses is slow and controversial, even when fish populations are clearly being adversely affected. The effects of global warming are likely to be more protracted and more difficult to identify. Separating them from these other stresses is difficult. How the effects of global warming on fisheries can be reliably determined before the problem becomes so severe that no practical management is possible, is a perplexing question, especially with the currently limited state of our knowledge.

According to Dr. Kenneth Sherman, director of the Narragansett Laboratory in Rhode Island, 33 studies support global climate change as a dominant factor in the changing productivity levels of fisheries in the coastal nursery grounds of northeast and southeast Pacific marine ecosystems. In the northwest Pacific, large-scale changes in biodiversity and yields appear to be caused primarily by overfishing. In the northwest Atlantic, major changes are linked to overfishing, but in the northeast Atlantic, causes and effects of changes remain uncertain. Large-scale changes in the southeast Atlantic appear related principally to climate change, secondly to overfishing. Compounding this issue is the fact that changes are not usually from any single cause but usually the result of some combination of causes or factors.

There is unambiguous scientific evidence that global warming and other changes in the climate system are occurring. These changes will affect Louisiana more than most states and Louisiana needs to pay more attention to these issues. This is especially true because of Louisiana's low topographical relief and vulnerable coastal environment and because its marine production and coastal industries and economies are so dependent on a river-dominated continental shelf, disappearing marshes, and a retreating coastline.