WRITTEN TESTIMONY OF
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Introduction

Madame Chairwoman and Members of the Committee, thank you for the opportunity to speak with you this afternoon. My name is Margaret Leinen and I am the Executive Director of Harbor Branch Oceanographic Institute and Associate Provost of Florida Atlantic University. In addition I currently serve as the President-Elect of the American Geophysical Union. You have heard much today about the ways in which the climate is changing and physical evidence of those changes. I have been asked to concentrate on changes that we are observing in ecosystems or in systems that affect us directly. I will highlight three systems: US North Atlantic fisheries, Florida-Caribbean coral reefs, and South Florida sea level rise and its impact on shoreline communities.

Changes in the ranges of US East Coast Fisheries

US Fisheries are a major industry responsible for over $5.3T in 2011 (NMFS, Annual Commercial Landings Statistics, 2011). The east coast from North Carolina to Main accounts for $1.7T of that amount. I'm going to mention briefly how this area is being affected by climate change.

A 2009 study of fishing research vessel survey data collected every spring from 1968 through 2007 showed that about half of the 36 different fish species studied, many of them commercially important, have been shifting northward over the last four decades (Nye, et al. 2009). The study, led by Dr. Janet Nye, who is an Assistant Professor at the State University of New York at Stony Brook, focused on some of our most important commercial fish species: Atlantic cod, haddock, yellowtail and winter flounder, Atlantic herring, as well as several less well known species. It covered the entire region from North Carolina to the Canadian border.

Dr. Nye and her colleagues at the Northeast Fisheries Science Center also analyzed historic ocean temperature records and long-term processes like the Atlantic Multi-decadal Oscillation and the North Atlantic Oscillation dating back to

1850 so that they could put recent temperature increases into context. Ocean temperatures in the region increased during the 40 years of survey data.

In fact, a separate study by the Northeast Fisheries Science Center showed that sea surface temperature hit a 150 year high off the US east coast from Maine to North Carolina during 2012. They were high from the sea surface to the bottom, and east to the edge of the Gulf Stream. While sea surface temperatures in this area are generally less than 48°F, they exceeded 51°F during the first half of the year. And bottom temperatures were 1-2C (2 to 4°F) warmer in the Gulf of Maine. While these changes may seem small to us since we see large daily changes in temperature, they are statistically significant for the oceans, where temperatures are much more stable.

The 36 species that were studied were chosen because they were consistently caught in high numbers during the annual spring trawl survey. This is the longest time series of standardized fishery population data.

The researchers looked at where the fish were caught and their total population weight in each year of the survey. For each fish stock, the estimated the center of abundance as well as the average depth of the stock, the area that the stock occupied, and the average temperature at which the stock was found. They took into account natural cycles of ocean temperature and changes in fishing activity.

Nye and her colleagues found that 10 of the 36 stocks had significantly expanded their range while 12 had significantly reduced it. 17 of the stocks moved the increasingly greater depths with time, 3 moved shallower. But the temperature at which each stock was found did not change over time, suggesting that the fish are moving to remain within their preferred temperature range. Some of the stocks nearly disappeared from US waters as they moved further offshore. Studies completed last year (http://www.nefsc.noaa.gov/ecosys/advisory/current/advisory.html), show that the northward shift of the fish stocks has continued.

Changes in ocean temperatures and the timing and strength of spring and fall phytoplankton blooms that provide food for the fish stocks have the potential to affect the spawning success and/or the amount of food available. In fact parts of this regions were declared a fisheries disaster during the first six months of 2012 because stocks of cod, haddock and flounder are not rebuilding in spite of the fact that fishers have been adhering to tough quotas.

These changes have implications for our fisheries, as well as the fish themselves. The changes mean that fishers who have adapted their vessels and gear for one species or group of species, may have to travel further to catch those

fish – expending more fuel. Some stocks have moved out of US waters, meaning that our fishers will have to compete with fishers from other countries for the fish that they used to have exclusive access to. Remember that this is a $1.7T industry.

Increasing extent and number of Coral bleaching events on Florida and Caribbean reefs

Coral reefs comprise some of the most beautiful and diverse ecosystems on earth. They are also important economically. US Coral reefs spur near $17B in tourism spending with 45M tourist visits annually to US reefs. They are responsible for $247M in commercial fishing (NMFS, Annual Commercial Landing Statistics, 2011). And coral reefs provide coastal protection from strong ocean currents, waves, and hurricanes. I am going to focus my remarks on Florida and US Caribbean reefs, those closest to my home.

As you may know, small symbiotic algae live inside corals and provide food and energy for the corals through photosynthesis. When these symbiotic organisms are stressed by heat they often die and are expelled leaving the corals to starve. Because these algae are responsible for the color of the corals, the corals look white or 'bleached' and these events are called 'coral bleaching'. Both the intensity and duration of heat waves influence coral stress responses and bleaching. A weeklong spike in temperature at 4°C (7°F) above the average summer maximum temperature can lead to widespread coral bleaching. Likewise just a 1°C (2°F) increase that continues for 4 weeks can result in prolific coral bleaching. Bleaching events that persist for weeks or months usually lead to extensive coral mortality.

For the past 30 years detailed surveys of coral bleaching have been accompanied by discrete sea surface temperature data. Using satellite sea surface temperature data and in situ temperature data, NOAA tracks the sea surface conditions that could lead to coral bleaching. As compared to the previous 15 years, this heat stress in the Caribbean has nearly doubled in the last decade, accompanied by severe coral bleaching events (Eakin, 2007). The Caribbean/Florida region has shown sea surface temperature increases of about 1°C (2°F) per decade (Chollett, et al., 2012) concurrent with losses of viable coral reef area of between 5.5% and 9.2% per year (Cote et al, 2005; Gardner, et al., 2001). Western Atlantic reefs have the highest percentage area affected by bleaching of any reefs worldwide.

Numerous studies have documented increases in coral disease abundance and associated coral mortality during elevated summer temperatures (e.g. Voss and Richardson 2006, Jones et al. 2004). Like coral bleaching, the duration of high temperature anomalies can impact disease abundance and severity (Bruno et al. 2007, Ruiz-Morenol et al. 2012). Thermal stress is known to both compromise

coral immunity (Harvell et al. 2009, Mydlarz et al. 2010) and increase the growth rates of certain coral pathogens (Ward et al. 2007).

Superimposed on the increasing temperature of Florida/Caribbean region have been extreme events, like those of 1997-1998 (which was also an El Nino year) and 2005 (which was not an El Nino or La Nina year). 2005 had the warmest regionally averaged Caribbean sea-surface temperatures recorded in the last 150 years. 90% of the reefs in the US Virgin Islands experienced bleaching, and many of these coral experienced secondary disease infections. Overall, coral cover in the USVI was reduced by 60% due to bleaching and disease associated mortality (Miller et al. 2009).

Climate change and associated temperature stress are not the sole drivers of coral reef health. Excess nutrients, increased sedimentation, and other human influenced factors are known to impact coral reefs. Data suggests that the synergistic effects of local stressors can reduce corals thermal tolerance limits (Carilli et al. 2009), exacerbating the potential impacts of climate change on coral health.

Sea level rise

Humans are part of the ecosystem as well and my last example focuses on climate change impacts on coastal communities from sea level rise. Again, I'll focus on the area I know best, South Florida. While this is but one area that will be affected, economic analyses indicate that 40% of the economic impact of the first foot of sea level rise in the US will be in South Florida (Tebaldi, et al., 2012).

As you all know, Florida is very flat and very low. We have a large population, almost 19 million, and it is heavily concentrated with almost 14 million people living along our coast. In South Florida Miami, the 7th largest city in the country, the Florida Keys, coastal and inland portions of Broward Country, the Florida Everglades and Fort Lauderdale are all below 2 feet in elevation.

Florida has seen 5-8 inches of sea level rise in the past 50 years. Our civic infrastructure in South Florida -- roads, storm sewers, water supplies, and power grids – is already seeing the impact of sea level rise. Although sea level has only risen these few inches in 50 years, that rise has been sufficient to prevent drainage systems from working during lunar high tides and during storms. The streets of Miami Beach are now routinely flooded at peak high tide. The addition of storm surges to these higher sea levels means that drainage systems no longer work reliably causing seawater to move into storm sewer systems and force water inland. Several flood gates are unable to discharge storm water at their full capacity during high tides. Future sea level rise of only 6 more inches – forecast as early as 2030 – would cripple half of the areas flood control infrastructure.

But the sea level rise problem in Florida is not restricted to inundation. Very porous limestone underlies most of Florida. As sea level rises, salt water intrudes into the limestone and pushes freshwater up and out of the limestone. The Biscayne limestone aquifer provides much of the freshwater to the coastal region of the southern east coast of Florida. It has been affected by saltwater intrusion and will be subject to further intrusion. Many wells for south Florida communities are close to the current boundary of saltwater intrusion. The City of Hallandale Beach is already spending $16M to upgrade their storm water system and to move the city's entire drinking water supply westward. This will only be a temporary solution as sea level continues to rise.

This south Florida coastal ecosystem, of which people are so much a part, is already seeing the impact of climate change in the rate of sea level rise, as the thermal expansion of ocean waters with their warming is a major component of the sea level rise we are already seeing.

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