Impacts of climate change on marine fisheries

East Coast Climate Change and Fisheries Governance Workshop

March 2014

Washington, D. C.

Jon Hare
NOAA Fisheries, Northeast Fisheries Science Center
Introduction

• Jon Hare, NOAA Fisheries

• Worked in Caribbean, Gulf of Mexico, Southeast U.S. and Northeast U.S.

• Currently oversee oceanography programs in Northeast

• Director, NOAA Narragansett Laboratory
Outline

• Climate Variability and Climate Change
• Past and Future Climate States
• Impacts on Fishery Resources
• Conclusions

Many examples are from Northeast
Climate Variability and Climate Change

• Important difference “climate change” vs “climate variability”

• **Climate variability** – natural variability within the climate system

• **Climate change** – long term change in the climate system
Climate Variability and Climate Change

- **Climate variability** – natural variability within the climate system
- **Climate change** – change in the climate system

http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.html
Climate Variability and Climate Change

- Interannual variability
- Atlantic Multidecadal Oscillation
- North Atlantic Oscillation
Climate Variability and Climate Change

- **Climate (Regional) variability:** Southeast warming much less than in Northeast
- **Climate change** – change in the climate system

![Temperature graph showing an increase of +0.4°F since 1854](image-url)
Climate Variability and Climate Change

- Scale of climate variability and change relatively large
  - Consistent over 100s-1000s km
  - Differences across Cape Hatteras boundary
Outline

- Climate Variability and Climate Change
- Past and Future Climate States
- Impacts on Fishery Resources
- Conclusions
Past and Future Climate States

• Past and current states are based on observations (many NMFS obs are now at risk of ending)
Past and Future Climate States

- Much of the information is from NEFSC Ecosystem Status Report and Ecosystem Advisories

- Ecosystem Assessment Program (NEFSC)
Past and Future Climate States

- Since 1960
- Warming in NE
- Constant in SE
- 2012 warmest on record in NE
- Regional differences

http://www.seascapemodeling.org/cgi-bin/mt/mt-search.cgi?blog_id=2&tag=climate&limit=20
Past and Future Climate States

- Ocean acidification is occurring
- Regional and seasonal variability
Past and Future Climate States

“Climate Change is already happening”

WHAT WE KNOW:
THE REALITY, RISKS AND RESPONSE TO CLIMATE CHANGE


- Temperature
- Acidification
- Salinity
- Wind patterns
- Precipitation
- Streamflow
- Lake ice out
- Nutrients
- Sea level rise
- And more ….
Past and Future Climate States

- Future states simulated with models

http://serc.carleton.edu/eet/envisioningclimatechange/part_2.html
Past and Future Climate States

Climate projections – Surface Temperature

- Increase 1.3°F in past
- Increase ~1-2°F in coming decades

Jamie Scott & Mike Alexander – NOAA OAR ESRL

http://www.esrl.noaa.gov/psd/ipcc/ocn/
Past and Future Climate States

Climate projections – Ocean Acidification

- Decrease 0.036 pH units since 1980
- Decrease of ~0.08 pH units in coming decades

Jamie Scott & Mike Alexander – NOAA OAR ESRL
http://www.esrl.noaa.gov/psd/ipcc/ocn/
Past and Future Climate States

Climate change is going to continue for foreseeable future

- Temperature
- Acidification
- Salinity
- Wind patterns
- Precipitation
- Streamflow
- Lake ice out
- Nutrients
- Sea level rise
- And more ....

http://www.gfdl.noaa.gov/patterns-of-greenhouse-warming-ar4
Outline

• Climate Variability and Climate Change
• Past and Future Climate States
• Impacts on Fishery Resources
• Conclusions
Impacts on Fishery Resources

Population – individuals of same species, living in the same geographical area, with capability of interbreeding

1. Abundance
2. Density
3. Dispersion
4. Distribution
5. Demographics (age, sex, etc)
6. Population Growth Rate (births, deaths)
7. Connectivity (immigration, emigration)
Impacts on Fishery Resources

Stock - a group of individuals for which population parameters can be meaningfully estimated for specific management applications

1. Abundance
2. Density
3. Dispersion
4. Distribution
5. Demographics (age, sex, etc)
6. Population Growth Rate (births, deaths)
7. Connectivity (immigration, emigration)
Impacts on Fishery Resources

- Traditional stock assessments: only external factor affecting a stock (S) is fishing (F)
- Climate effects integrated in population properties (R, G, Ma, M)

\[ S_{R,G, Ma, M} \approx f\left(\frac{1}{F}\right) \]

As F increases, S decreases
As F decreases, S increases
Impacts on Fishery Resources

• Traditional stock assessments:
  • climate effects integrated over hindcast
  • stationary over forecast
• Climate is random with no trend

\[ S_{R,G,Ma,M} \approx f\left(\frac{1}{F}\right) + \varepsilon_C \]
Impacts on Fishery Resources

• Traditional stock assessments:
  - climate effects integrated over hindcast
  - stationary over forecast

• Climate is changing & decadal scale

• Climate is random with no trend

\[ S_{R,G,Ma,M} \approx f \left( \frac{1}{F} \right) + g(C) \]
Impacts on Fishery Resources

• Changes in stock productivity (R, G, Mat, Fec)

• Changes in distribution (stock definition; catchability)

• Changes in species interactions (natural mortality, growth)
Impacts on Fishery Resources

- Changes in stock productivity
- Southern New England yellowtail
- Reduced $R$ associated with cold pool or regime shift

http://www.nap.edu/catalog.php?record_id=18488
Impacts on Fishery Resources

- Changes in distribution
- Stock boundaries / catchability
- 24 of 36 fish stocks shifted poleward / deeper (Nye et al. 2009)

http://www.int-res.com/abstracts/meps/v393/p111-129/
http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html
Impacts on Fishery Resources

• Changes in trophic interactions

• Cod changing distribution as a result of shift in prey (not necessarily climate related but ...)

• Trophic interactions are complicated

Richardson et al. in review. Can J Fish Aquat Sci
Impacts on Fishery Resources

- Not only climate change; not only fishing
- Croaker biomass dependent on both fishing and climate
Impacts on Fishery Resources

- Interactions between climate and fisheries
Impacts on Fishery Resources

- Climate change and variability are not just future issues; past, present and future
Questions?
Outline

• Climate Variability and Climate Change
• Past and Future Climate States
• Impacts on Fishery Resources
• Conclusions
Conclusions

• Reference points are not static
• Stock boundaries are not fixed
• Trophic interactions and community make-up are changing
• Multiple stressors (not all fishing, not all climate)

• EBFM!
Conclusions

NMFS is developing a Climate Science Strategy
Conclusions

Steps forward:

• Coupled fishery – climate models
• Coupled distribution – climate models
• Vulnerability assessment
• Outreach

Quantitative

• Atlantic cod
• Atlantic croaker
• River herring
• Cusk
• Others

Qualitative

e.g., this talk
Conclusions

Northeast Fisheries Climate Vulnerability Assessment (79 species)

Exposure

- Sea surface temperature*
- Air temperature*
- Salinity*
- Ocean acidification (pH)*
- Precipitation*
- Currents**
- Sea level rise**

Sensitivity

- Habitat Specificity
- Prey Specificity
- Sensitivity to Ocean Acidification
- Sensitivity to Temperature
- Stock Size/Status
- Other Stressors
- Adult Mobility
- Spawning Cycle
- Complexity in Reproductive Strategy
- Early Life History Survival and Settlement Requirements
- Population Growth Rate
- Dispersal of Early Life Stages

*modelled results (mean & variance)
**written description only

Conclusions

**Northeast Fisheries Climate Vulnerability Assessment (79 species)**

- Exposure to climate change of all species is moderately high to high
- Sensitivity higher for diadromous and shellfish; lower for groundfish and pelagics
Links & Questions?

Photo by: Chris Melrose (NEFSC)