

Impacts of climate change on marine fisheries

East Coast Climate Change and Fisheries Governance Workshop

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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

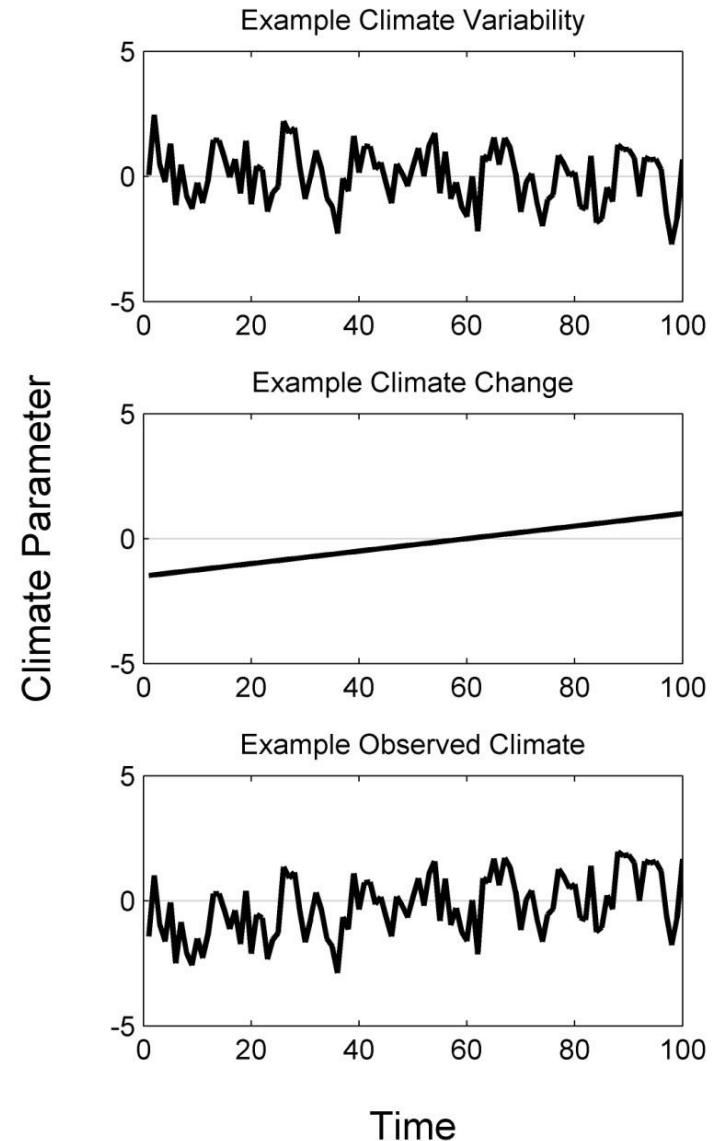
- Climate Variability and Climate Change
- Past and Future Climate States
- Impacts on Fishery Resources
- Conclusions



Many examples are from Northeast

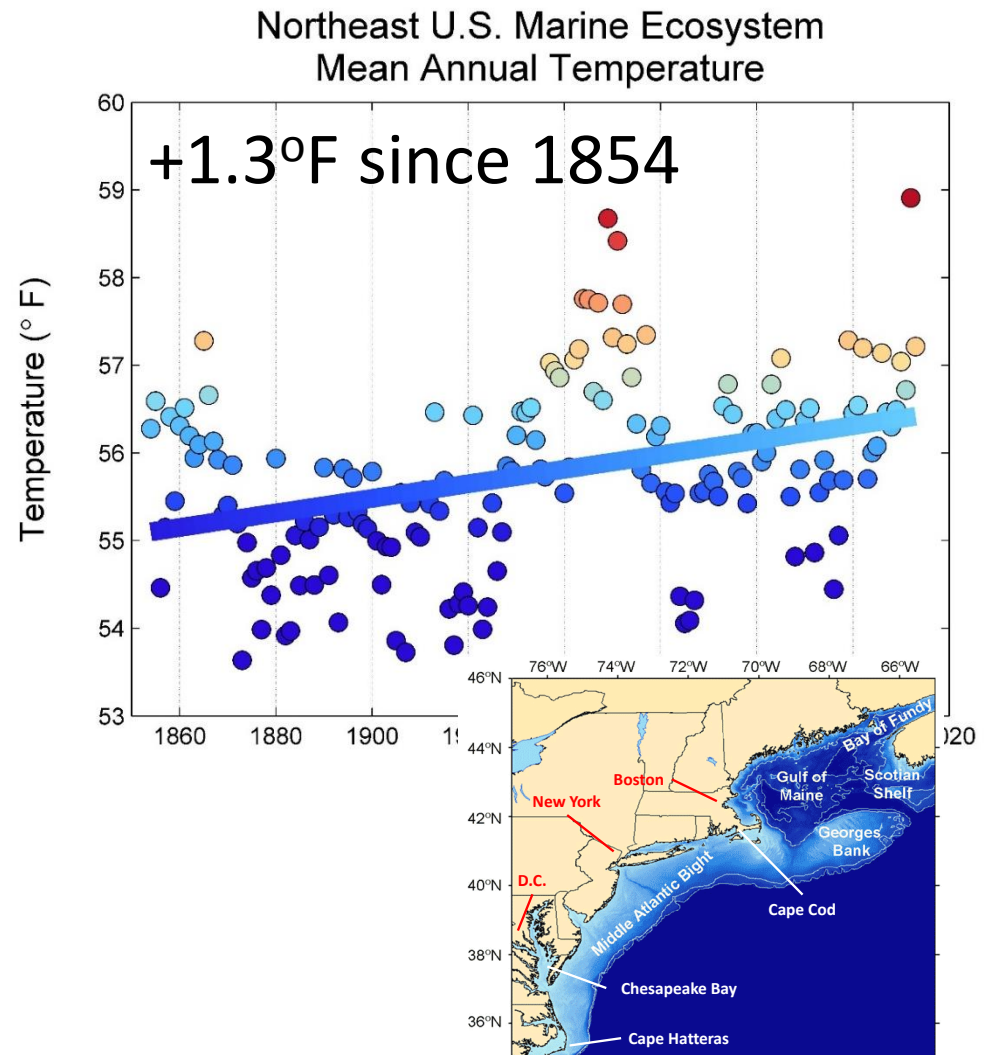
Climate Variability and Climate Change

- Important difference “climate change” vs “climate variability”
- Climate variability – natural variability within the climate system
- Climate change – long term change in the climate system



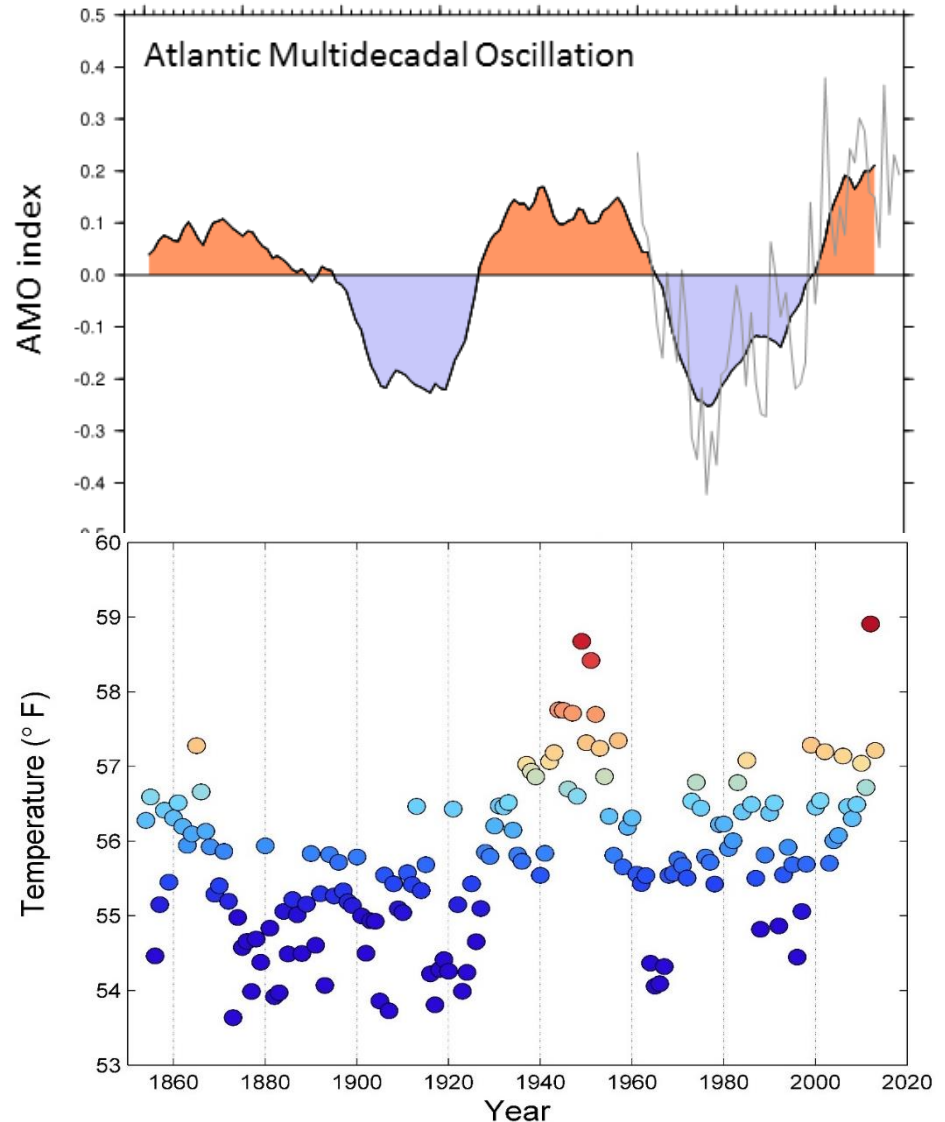
Climate Variability and Climate Change

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



Climate Variability and Climate Change

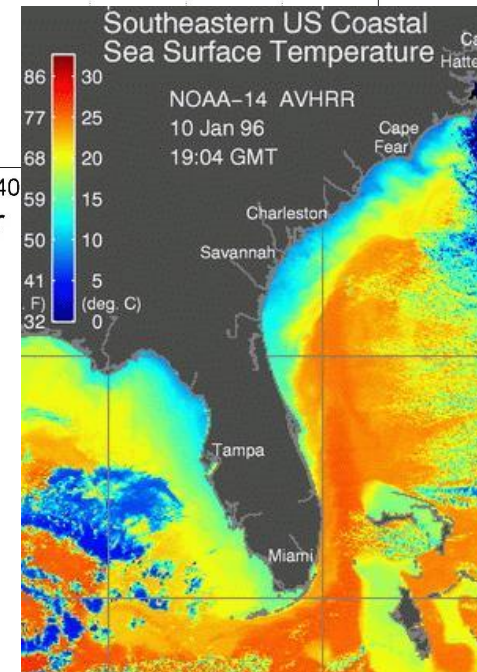
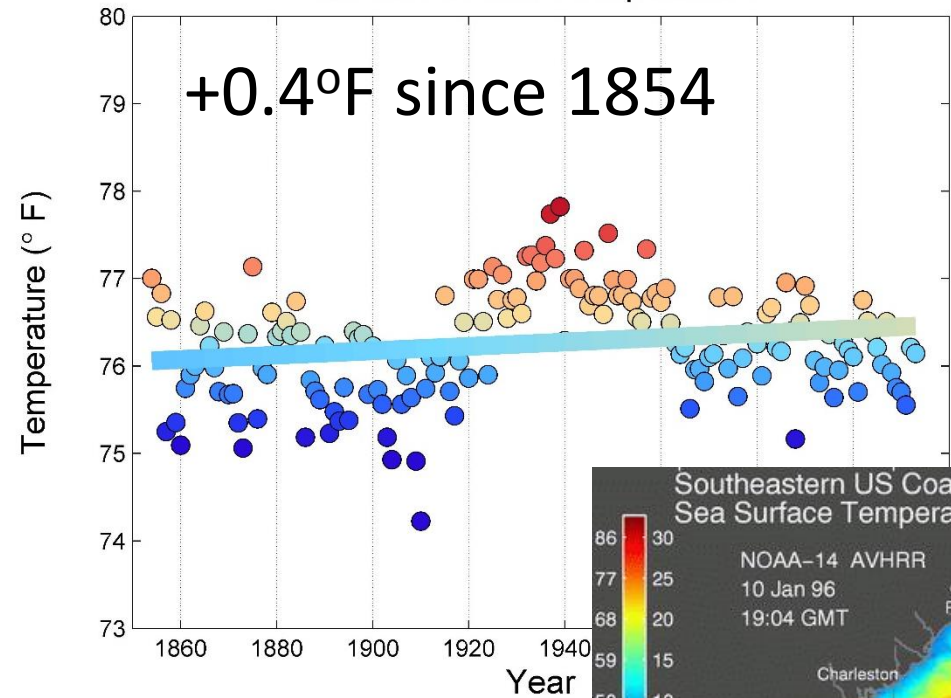
- Interannual variability
- Atlantic Multidecadal Oscillation
- North Atlantic Oscillation



Climate Variability and Climate Change

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

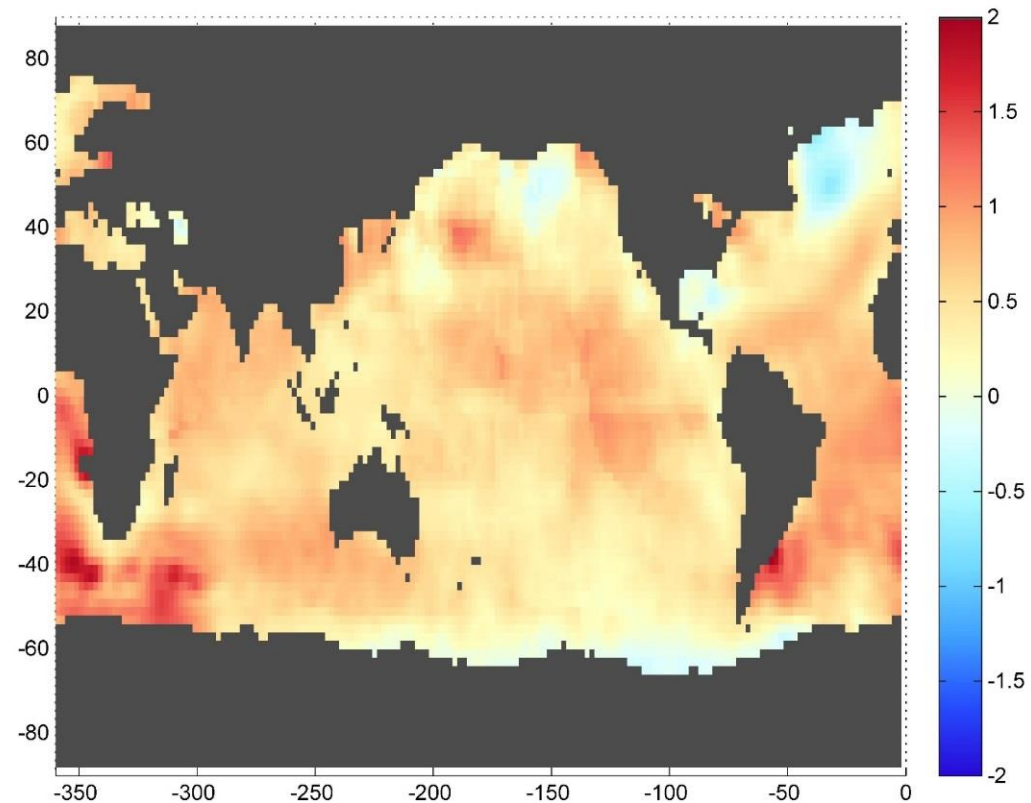
Southeast U.S. Marine Ecosystem
Mean Annual Temperature



Climate Variability and Climate Change

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

Temperature Change 1854-present

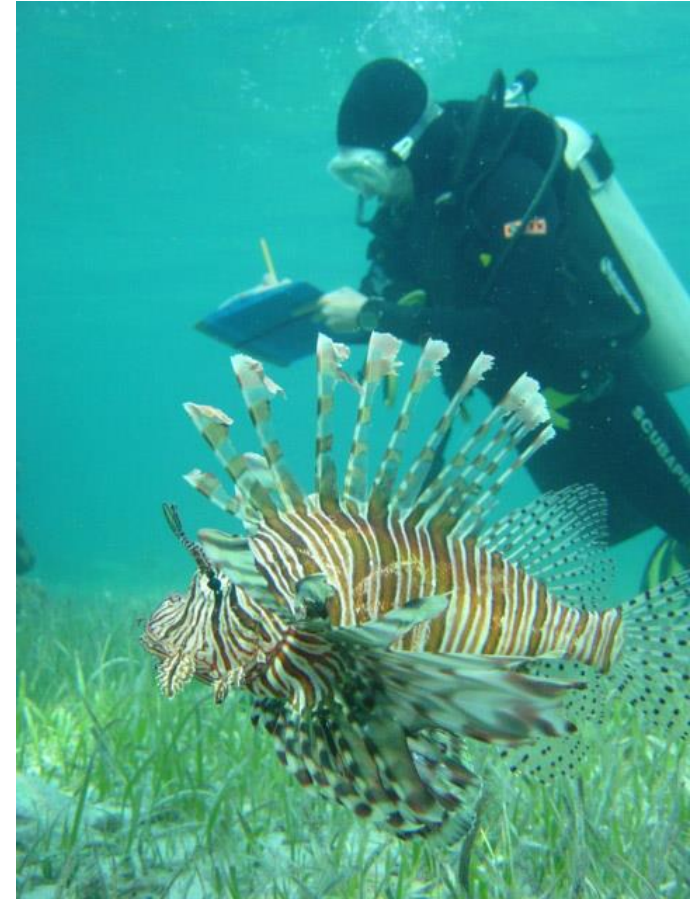


Questions?



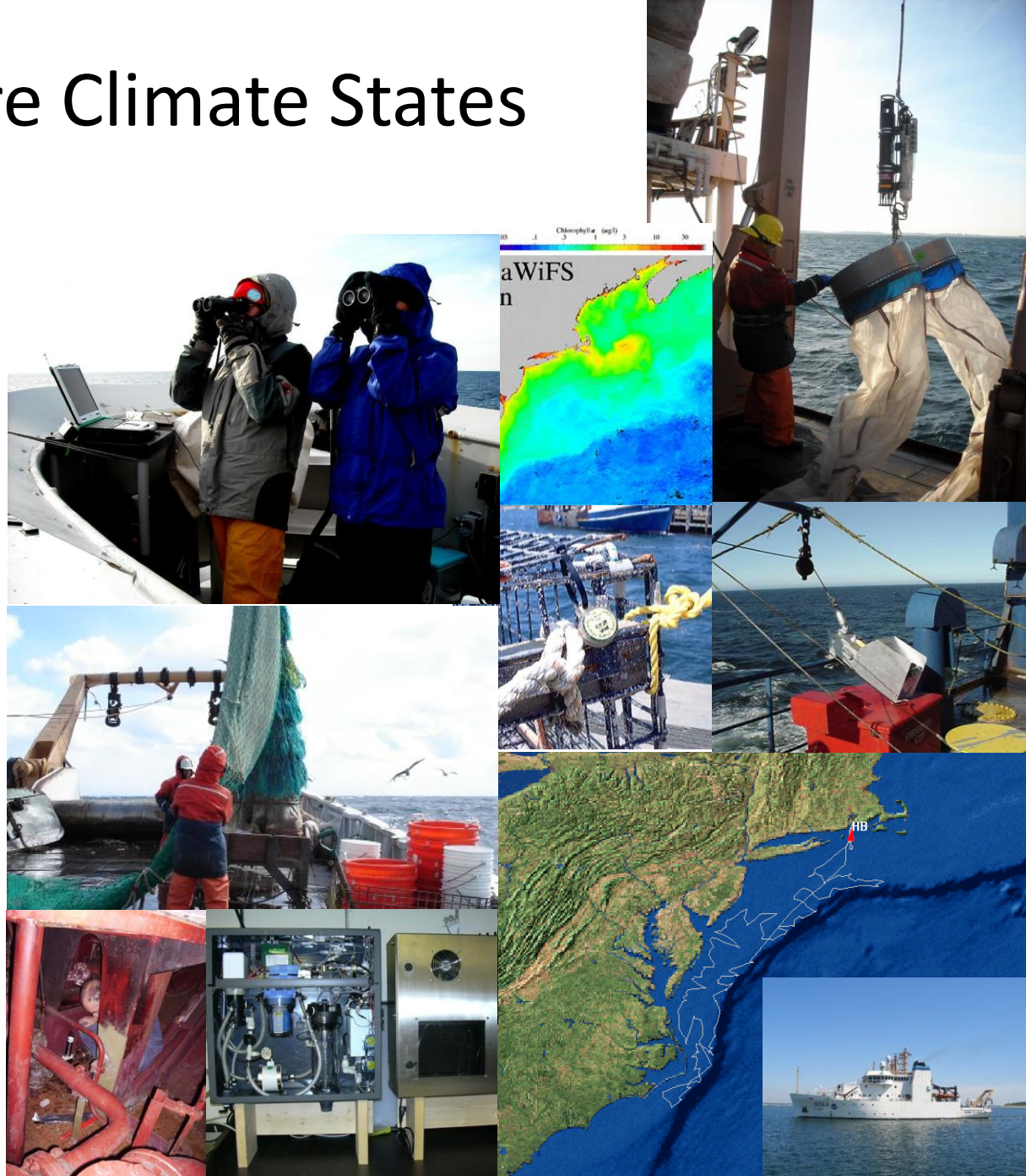
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- Climate Variability and Climate Change
- Past and Future Climate States
- Impacts on Fishery Resources
- Conclusions



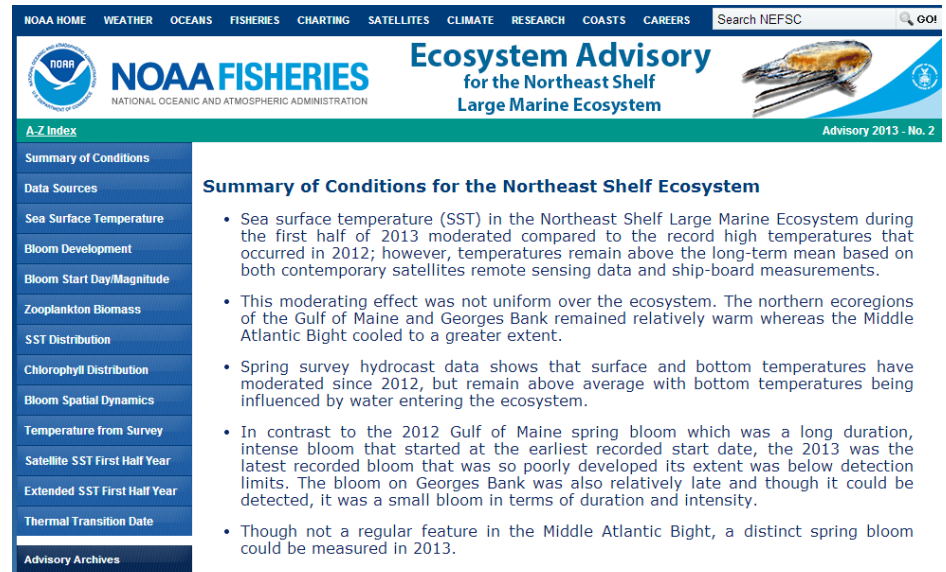
Past and Future Climate States

- 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)



The screenshot shows the NOAA Fisheries website interface. At the top, there is a navigation bar with links for NOAA HOME, WEATHER, OCEANS, FISHERIES, CHARTING, SATELLITES, CLIMATE, RESEARCH, COASTS, and CAREERS. A search bar for NEFSC is also present. The main header features the NOAA Fisheries logo and the text "Ecosystem Advisory for the Northeast Shelf Large Marine Ecosystem". Below this, there is a sidebar with a table of contents including "A-Z Index", "Summary of Conditions", "Data Sources", "Sea Surface Temperature", "Bloom Development", "Bloom Start Day/Magnitude", "Zooplankton Biomass", "SST Distribution", "Chlorophyll Distribution", "Bloom Spatial Dynamics", "Temperature from Survey", "Satellite SST First Half Year", "Extended SST First Half Year", "Thermal Transition Date", and "Advisory Archives". The main content area is titled "Summary of Conditions for the Northeast Shelf Ecosystem" and contains a bulleted list of findings from the 2013 report.

Summary of Conditions for the Northeast Shelf Ecosystem

- Sea surface temperature (SST) in the Northeast Shelf Large Marine Ecosystem during the first half of 2013 moderated compared to the record high temperatures that occurred in 2012; however, temperatures remain above the long-term mean based on both contemporary satellites remote sensing data and ship-board measurements.
- This moderating effect was not uniform over the ecosystem. The northern ecoregions of the Gulf of Maine and Georges Bank remained relatively warm whereas the Middle Atlantic Bight cooled to a greater extent.
- Spring survey hydrocast data shows that surface and bottom temperatures have moderated since 2012, but remain above average with bottom temperatures being influenced by water entering the ecosystem.
- In contrast to the 2012 Gulf of Maine spring bloom which was a long duration, intense bloom that started at the earliest recorded start date, the 2013 was the latest recorded bloom that was so poorly developed its extent was below detection limits. The bloom on Georges Bank was also relatively late and though it could be detected, it was a small bloom in terms of duration and intensity.
- Though not a regular feature in the Middle Atlantic Bight, a distinct spring bloom could be measured in 2013.

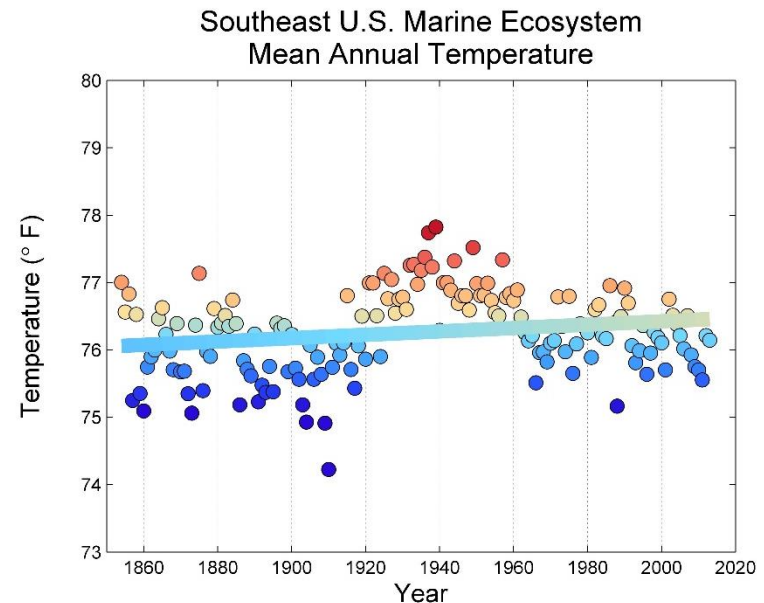
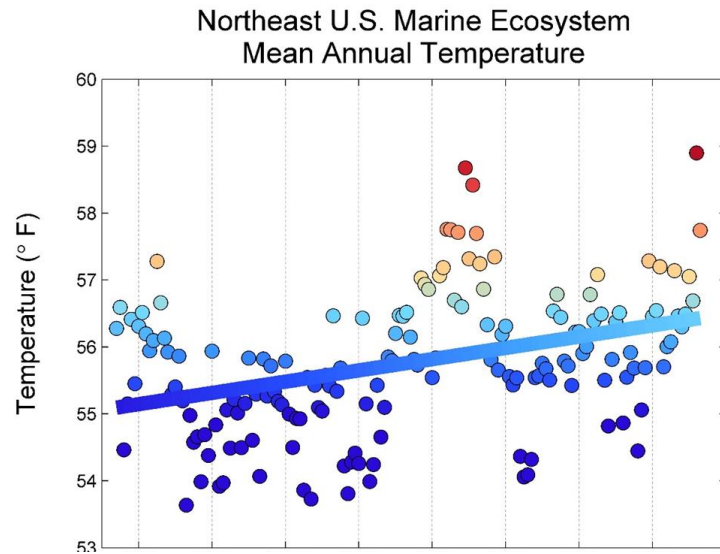
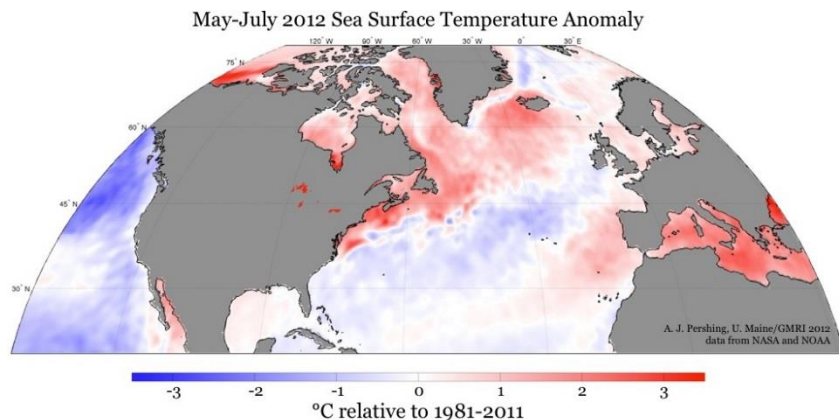


Northeast Fisheries Science Center Reference Document 12-07

Ecosystem Status Report
for the Northeast Shelf Large Marine
Ecosystem - 2011

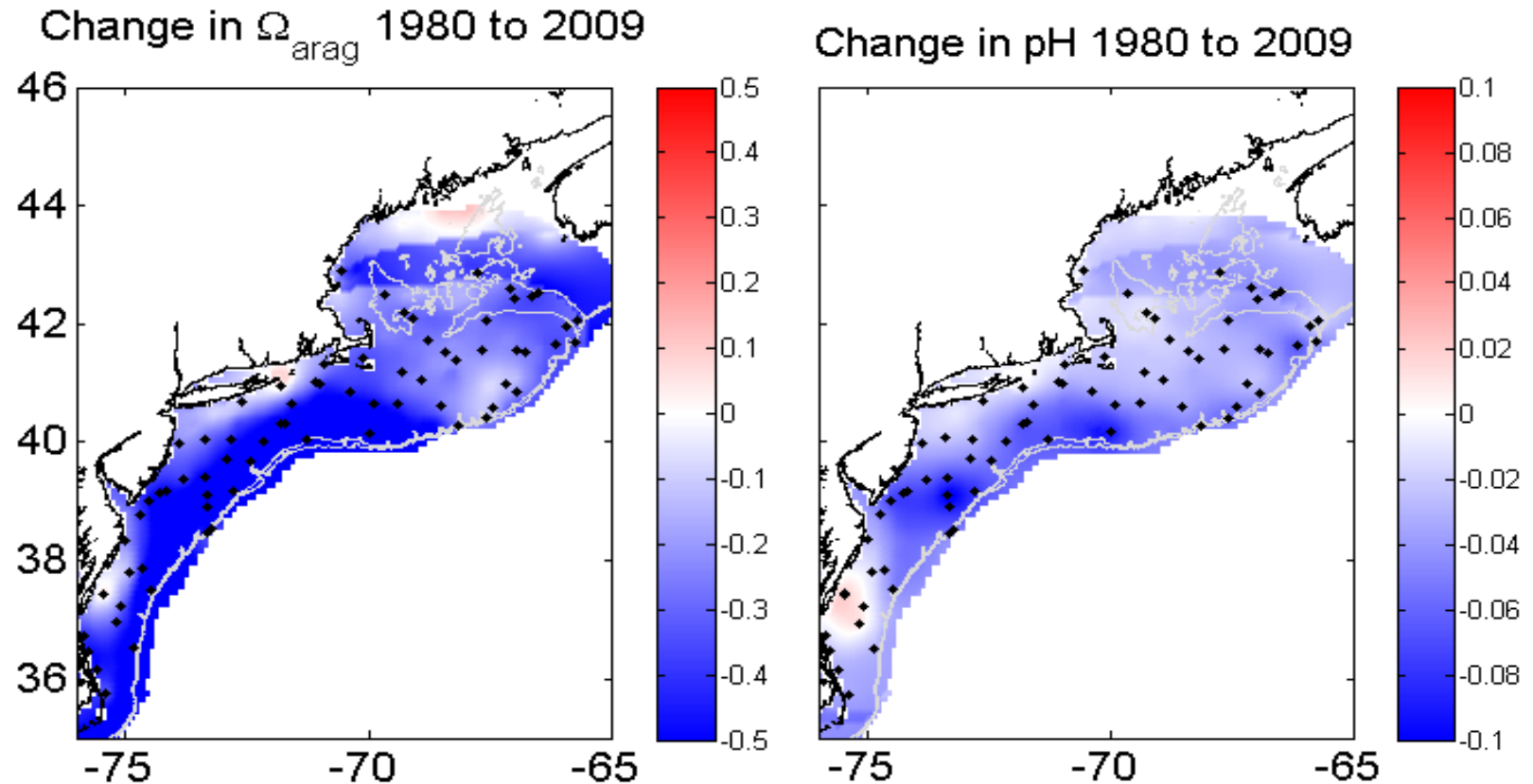
Past and Future Climate States

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



Past and Future Climate States

- Ocean acidification is occurring
- Regional and seasonal variability



Past and Future Climate States

“Climate Change is already happening”

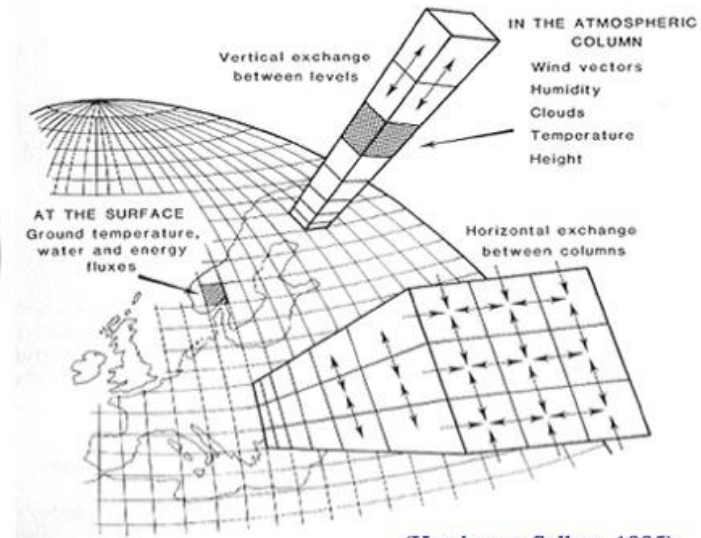
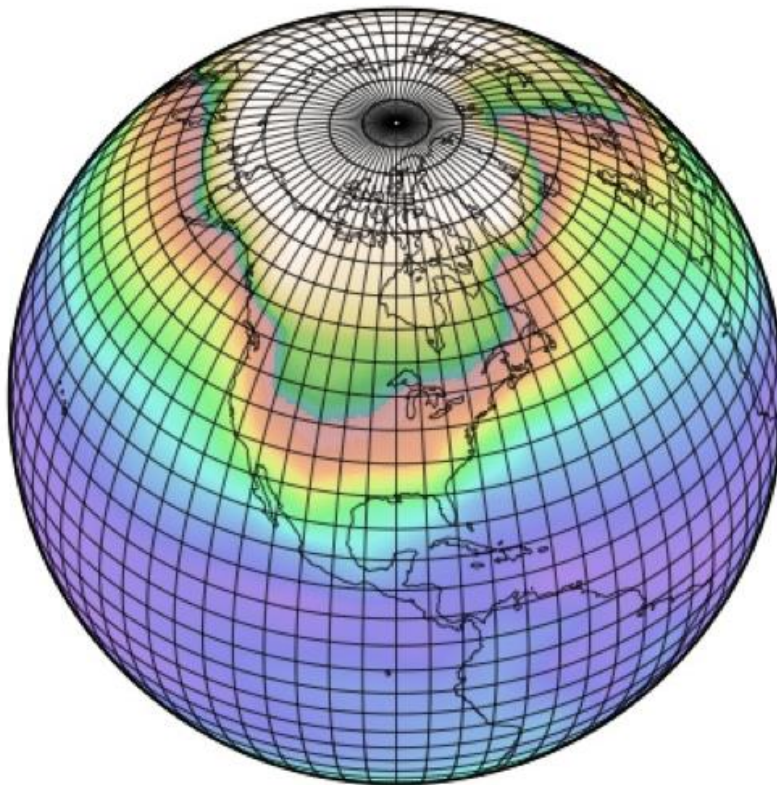
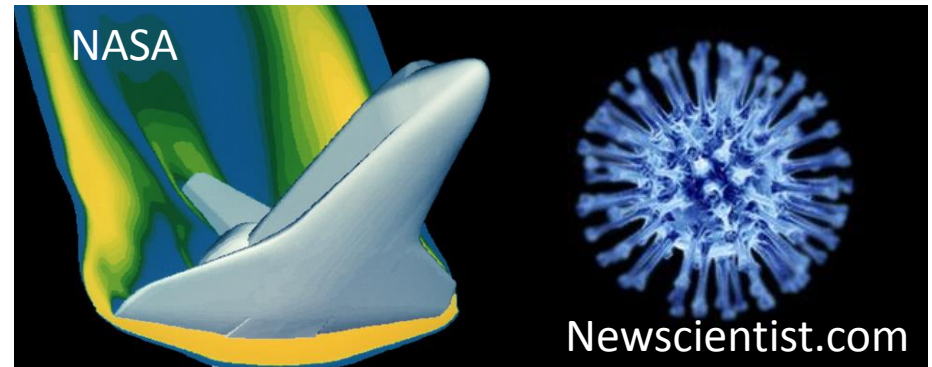


<http://whatwewknow.aaas.org/wp-content/uploads/2014/03/AAAS-What-We-Know.pdf>

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

Past and Future Climate States

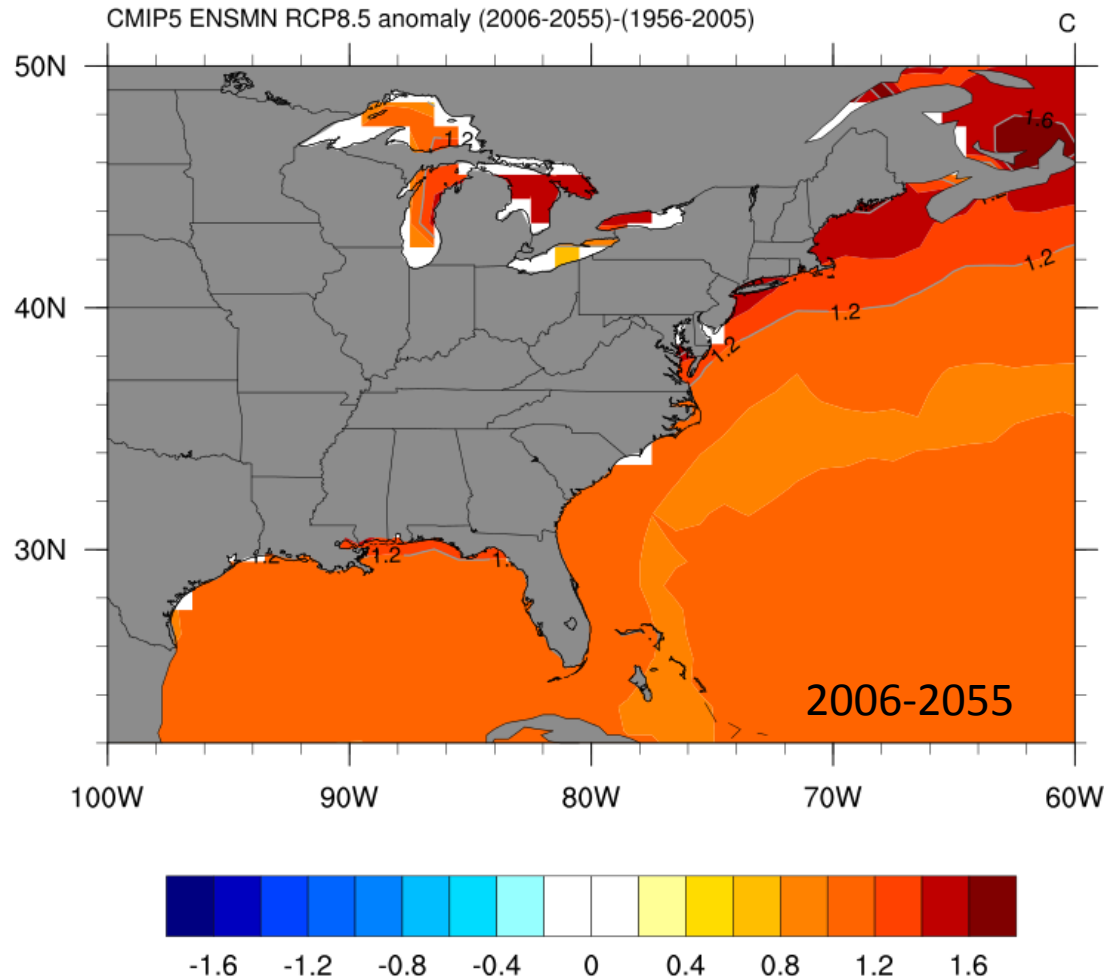
- Future states simulated with models



(Henderson-Sellers, 1985)

Past and Future Climate States

Climate projections – Surface Temperature



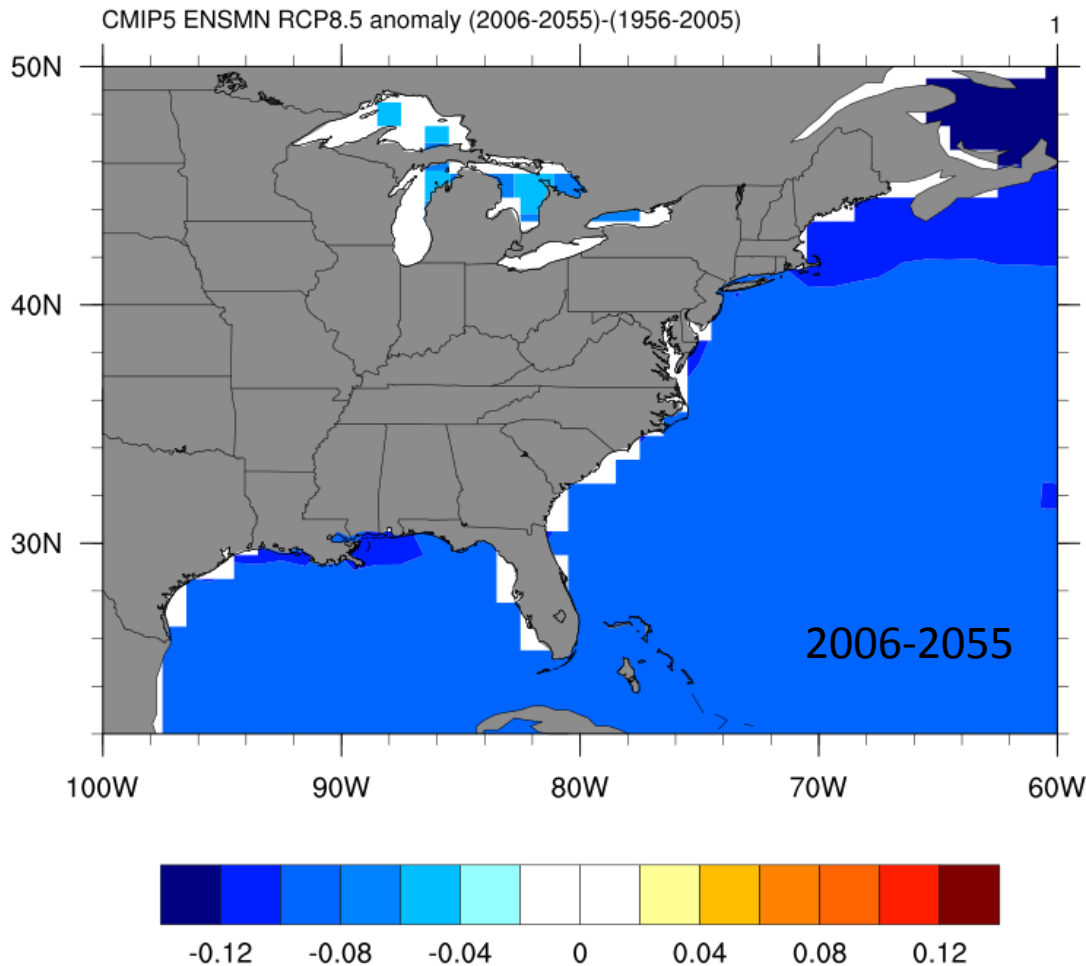
- Increase 1.3°F in past
- Increase ~1-2°F in coming decades

Jamie Scott & Mike Alexander –
NOAA OAR ESRL

<http://www.esrl.noaa.gov/psd/ipcc/ocn/>

Past and Future Climate States

Climate projections – Ocean Acidification



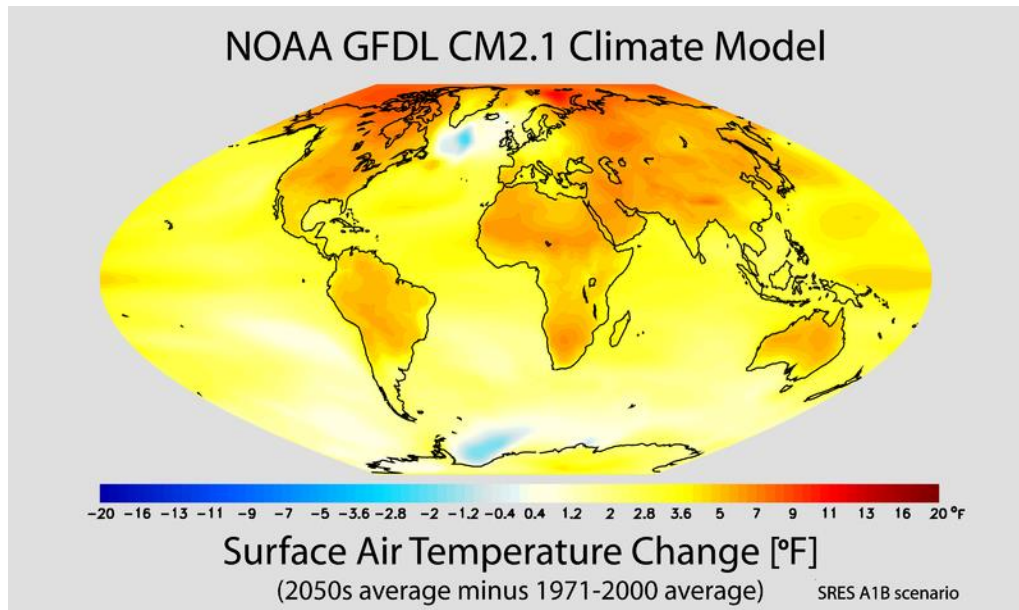
- Decrease 0.036 pH units since 1980
- Decrease of ~0.08 pH units in coming decades

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

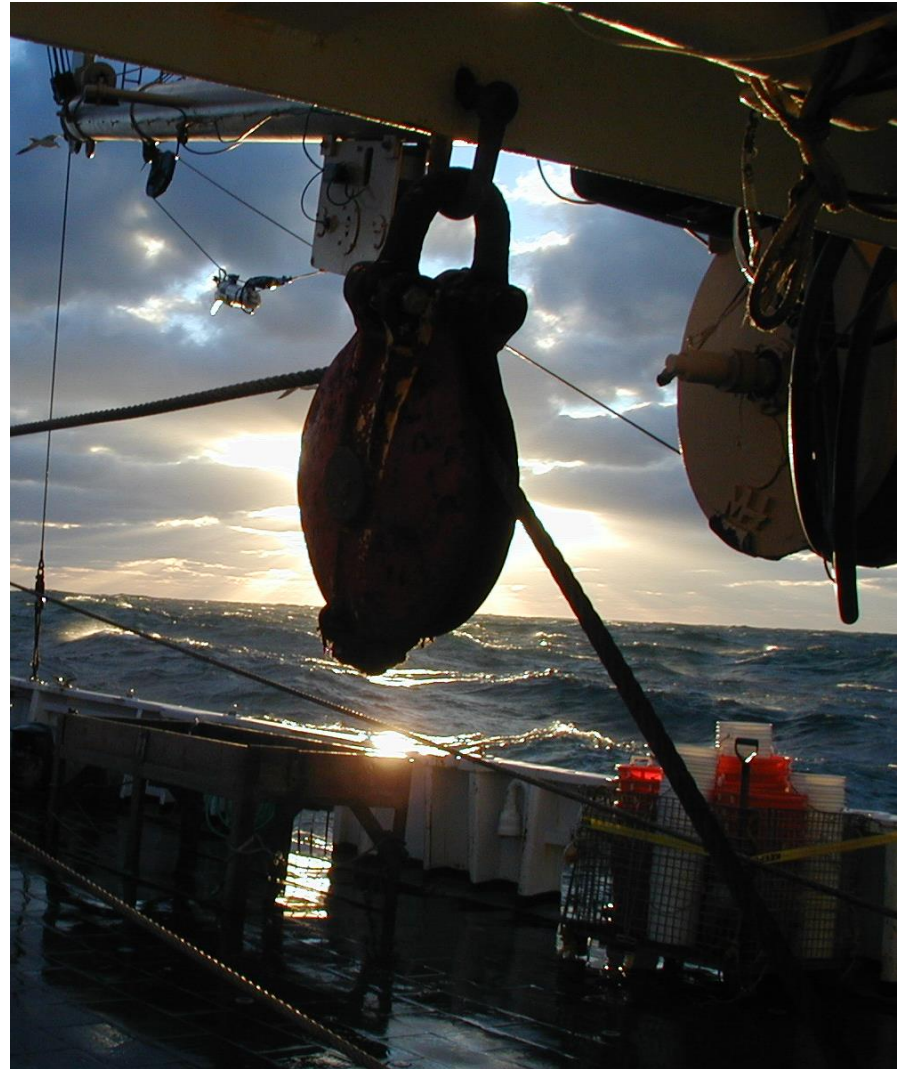


<http://www.gfdl.noaa.gov/patterns-of-greenhouse-warming-ar4>

- Temperature
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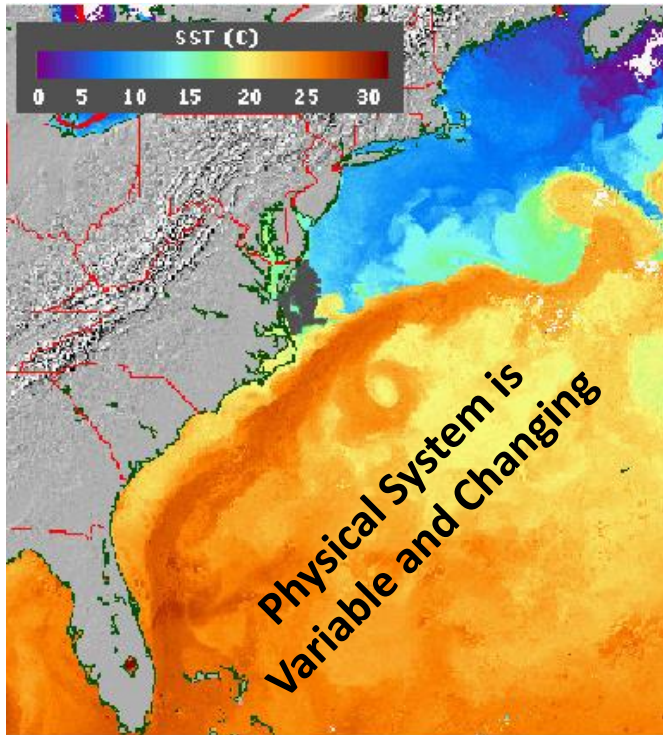
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Impacts on Fishery Resources

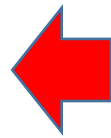
Population – individuals of same species, living in the same geographical area, with capability of interbreeding



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

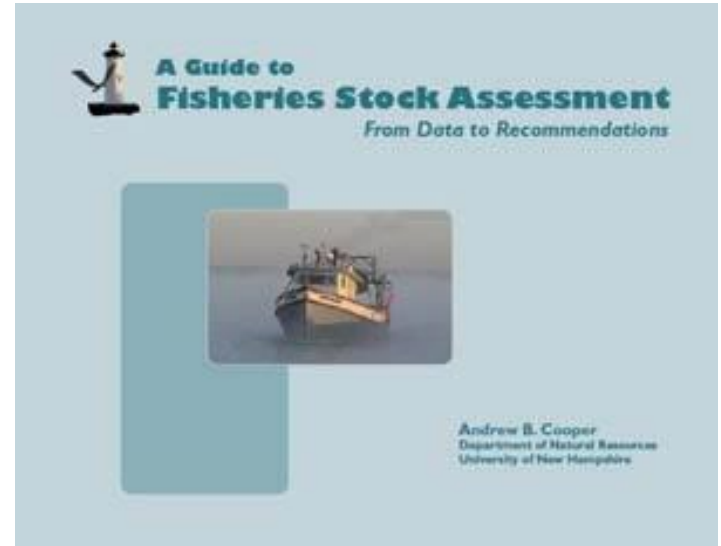


1. Abundance
2. Density
3. Dispersion
4. Distribution
5. Demographics (age, sex, etc)
6. Population Growth Rate (births, deaths)
7. Connectivity (immigration, emigration)

Changes in populations will cause changes in fisheries

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)



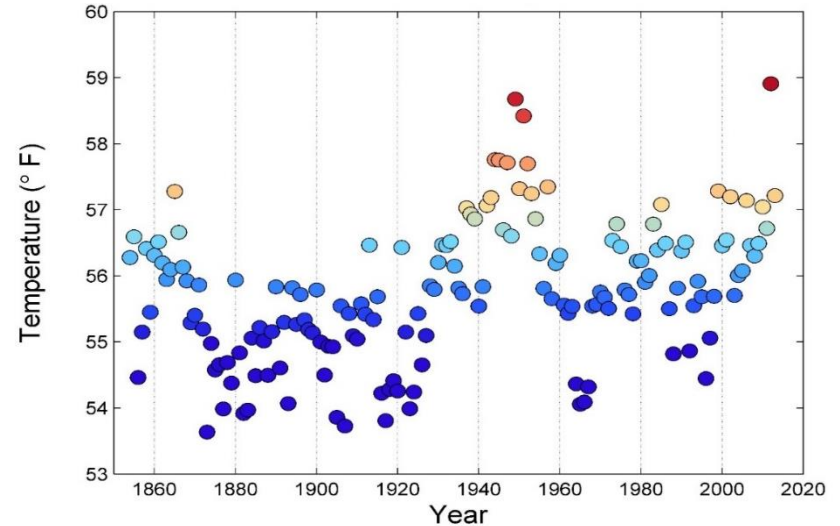
$$S_{R,G,Ma,M} \approx f\left(\frac{1}{F}\right)$$

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

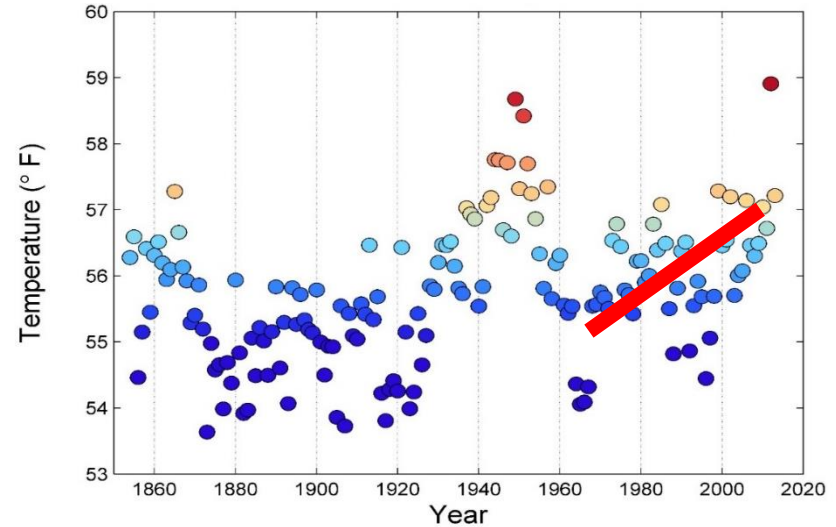


$$S_{R,G,Ma,M} \approx f\left(\frac{1}{F}\right) + \varepsilon_C$$

Impacts on Fishery Resources

- Traditional stock assessments:
 - climate effects inter-annual over hindcast
 - stationary over forecast
- Climate is random with no trend

Climate is changing & climate is variable on decadal scale



$$S_{R,G,Ma,M} \approx f\left(\frac{1}{F}\right) + g(C)$$

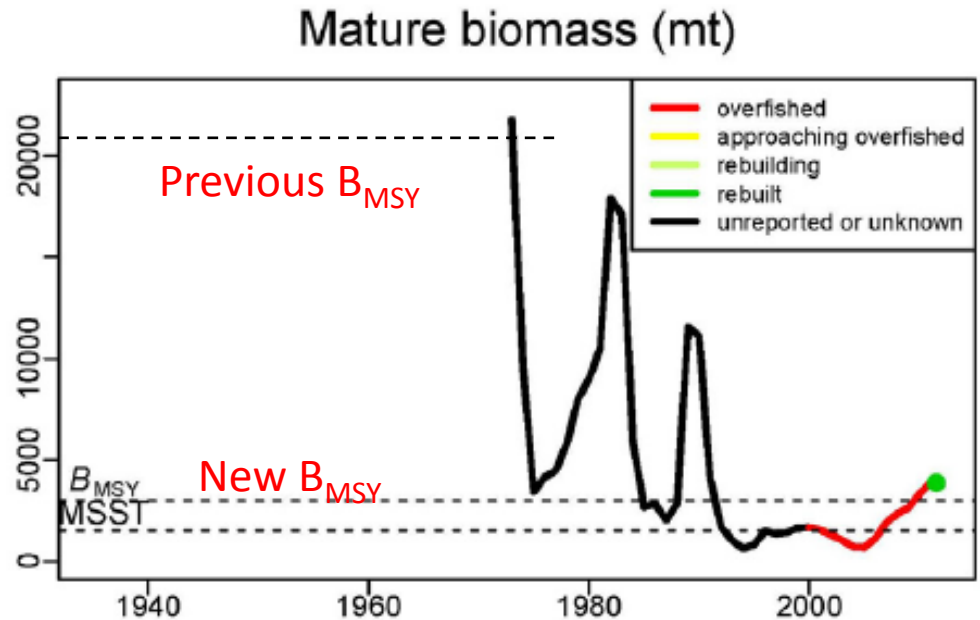
Impacts on Fishery Resources

- Changes in stock productivity (R, G, Mat, Fec)
- Changes in distribution (stock definition; catchability)
- Changes in species interactions (natural mortality, growth)



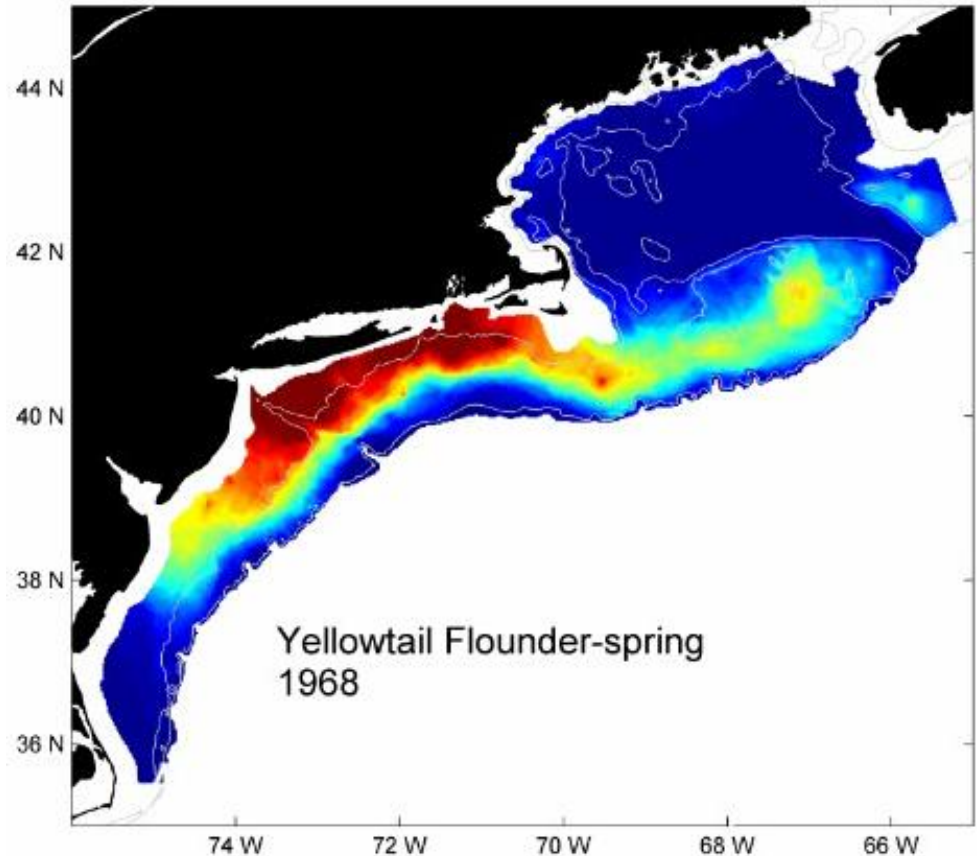
Impacts on Fishery Resources

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



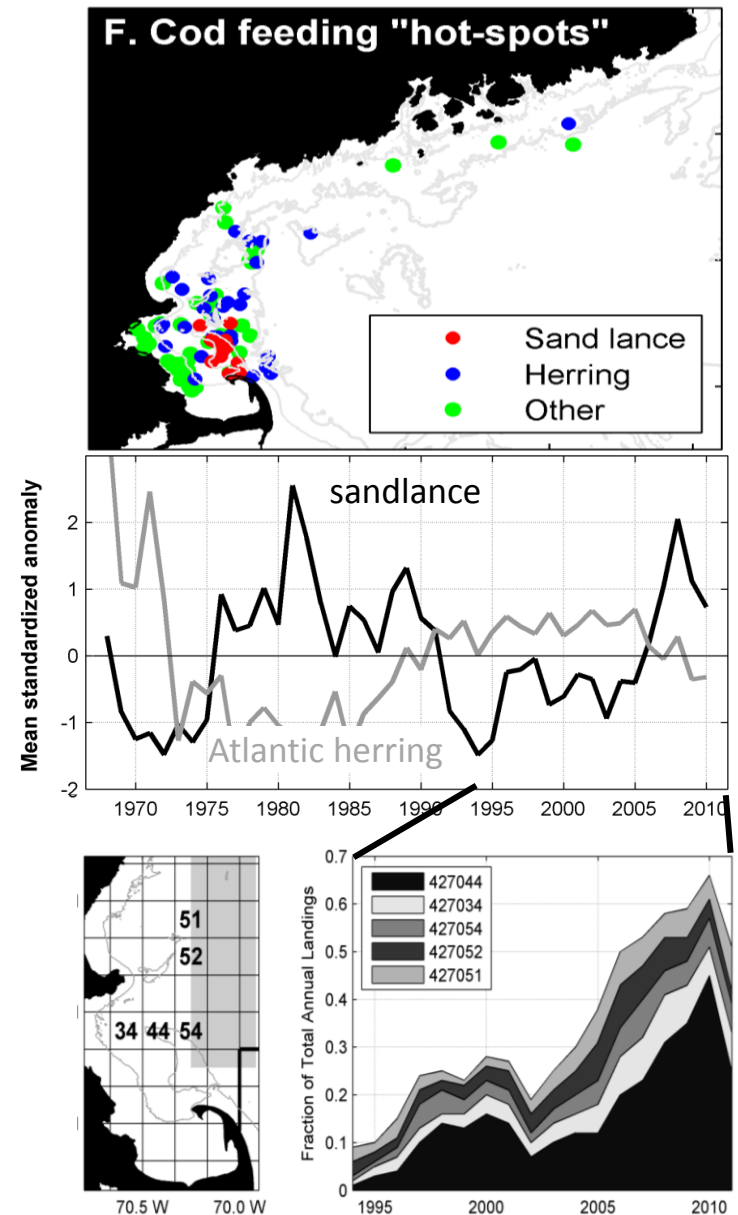
Impacts on Fishery Resources

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



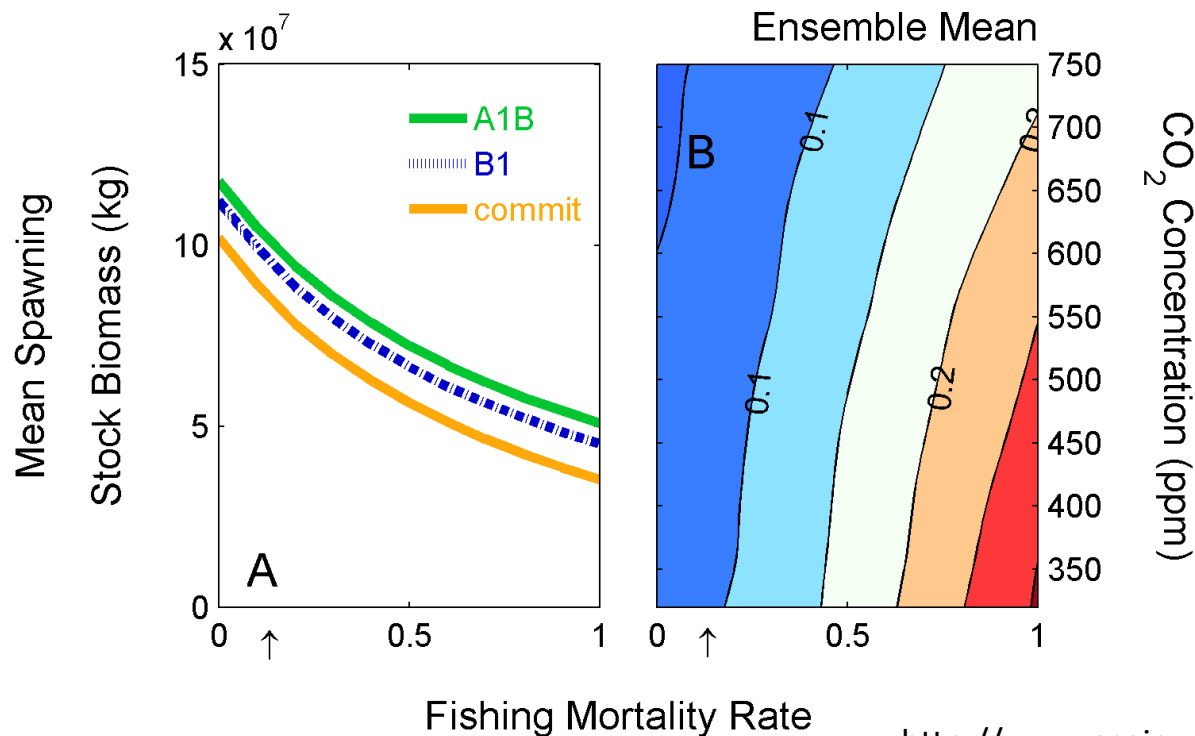
Impacts on Fishery Resources

- Changes in trophic interactions
- Cod changing distribution as a result of shift in prey (not necessarily climate related but ...)
- Trophic interactions are complicated



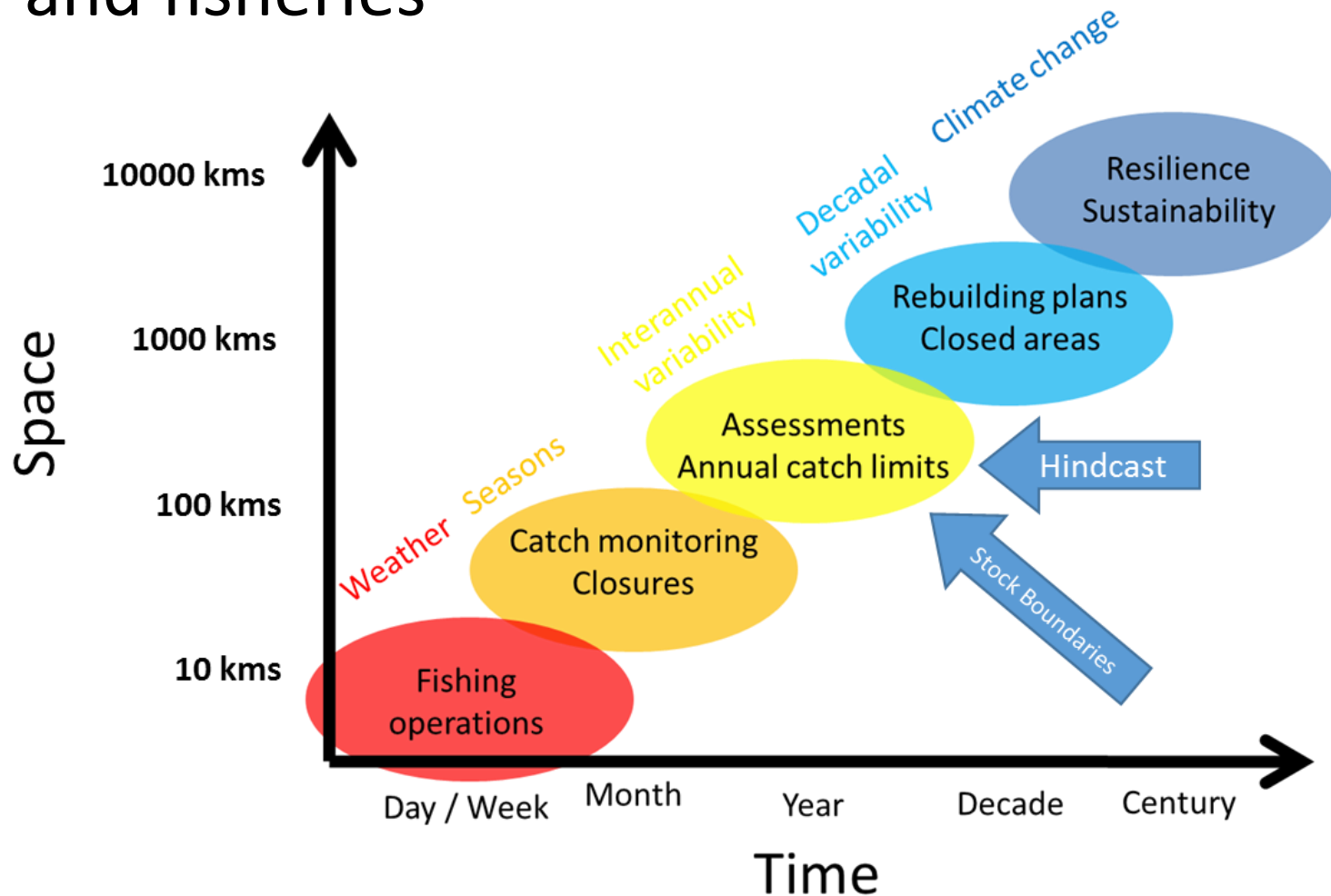
Impacts on Fishery Resources

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



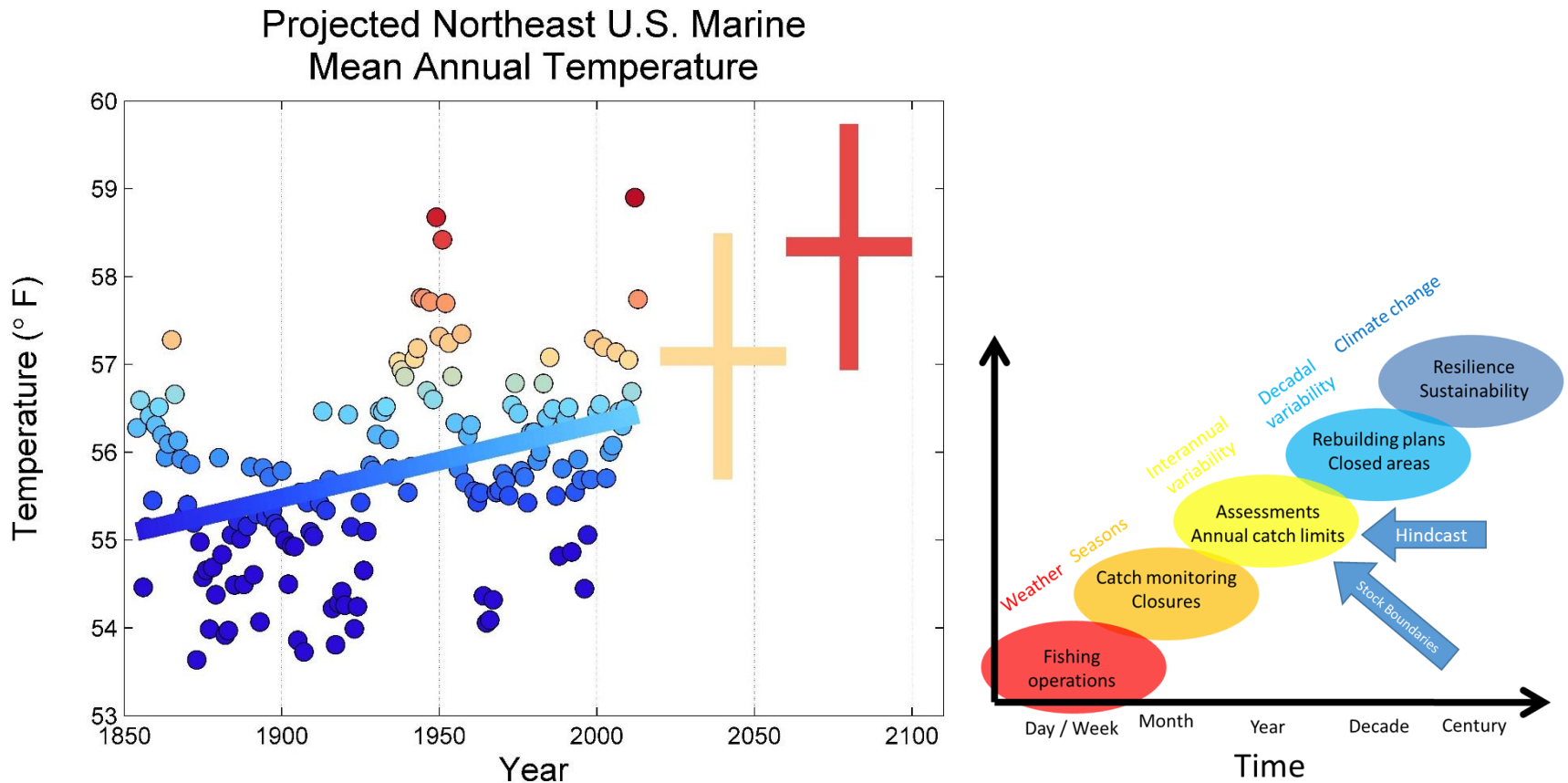
Impacts on Fishery Resources

- Interactions between climate and fisheries

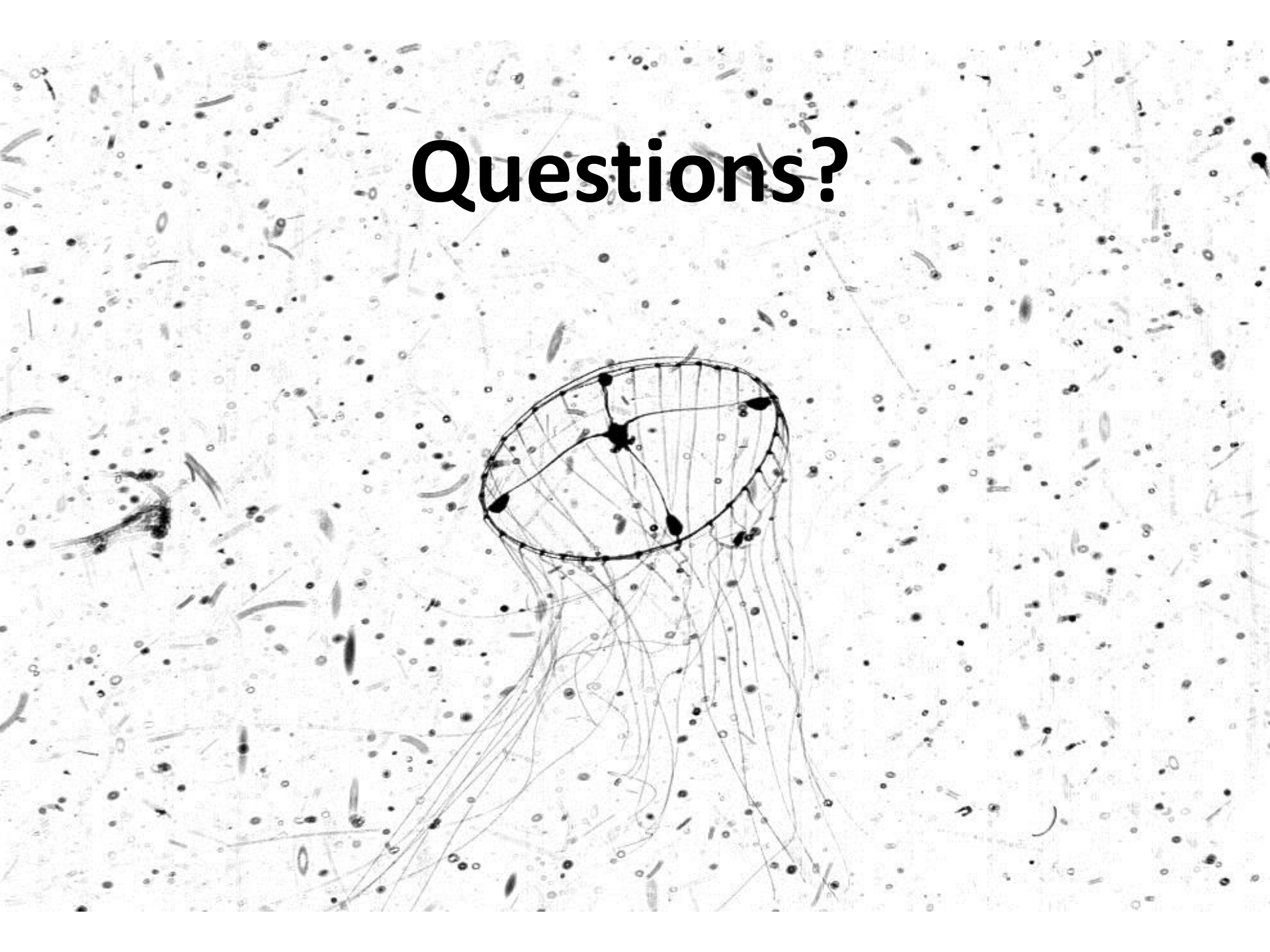


Impacts on Fishery Resources

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



Questions?



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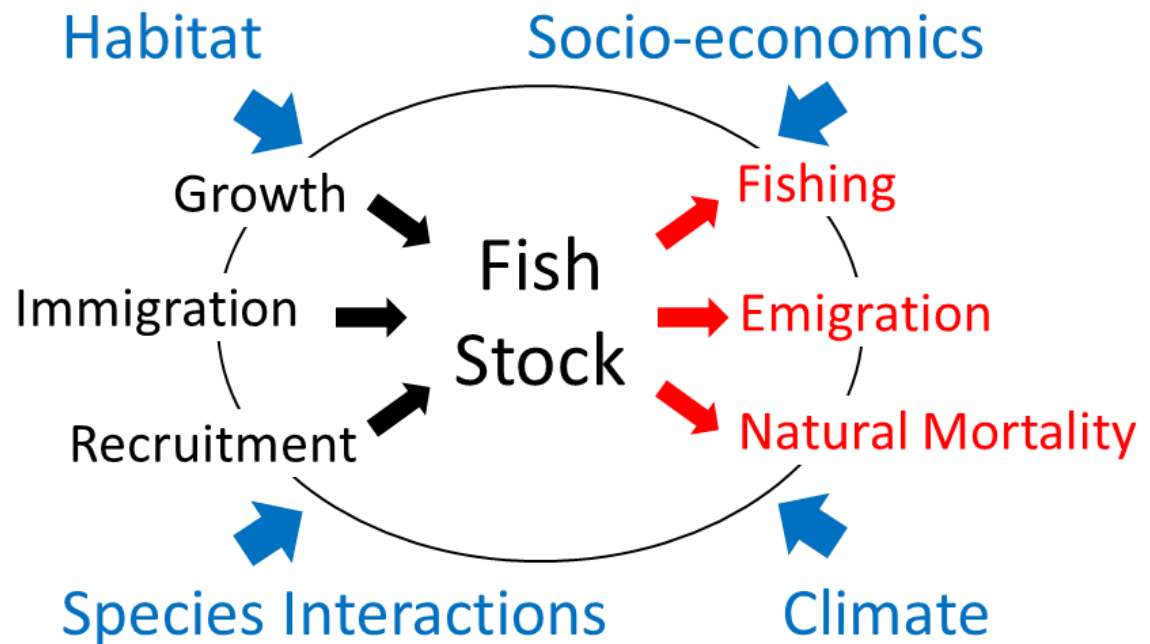


Conclusions

- 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!**



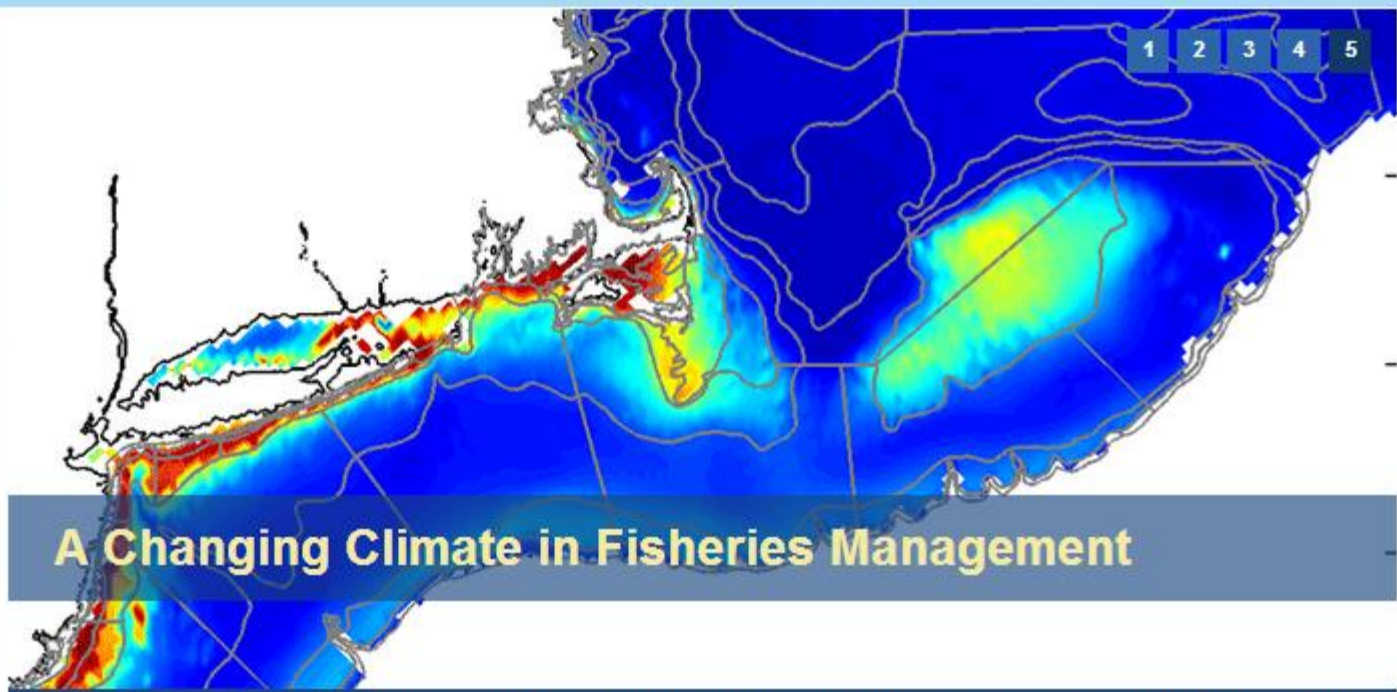
Conclusions

NMFS is developing a Climate Science Strategy



NOAA FISHERIES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

- Fisheries Home
- About Us ▶
- Programs ▶
- Regions ▶
- Science Centers ▶
- Partners ▶
- Congress ▶
- Fisheries Resources ▶
- Educators and Students ▶
- News & Multimedia ▶
- Get Involved ▶



STAY CONNECTED

Feb 14: How will we manage fish populations as they move in response to climate change? NOAA Fisheries biologist John Manderson is working on one small piece of the puzzle. [Read More . . .](#)

Conclusions

Steps forward:

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

Quantitative

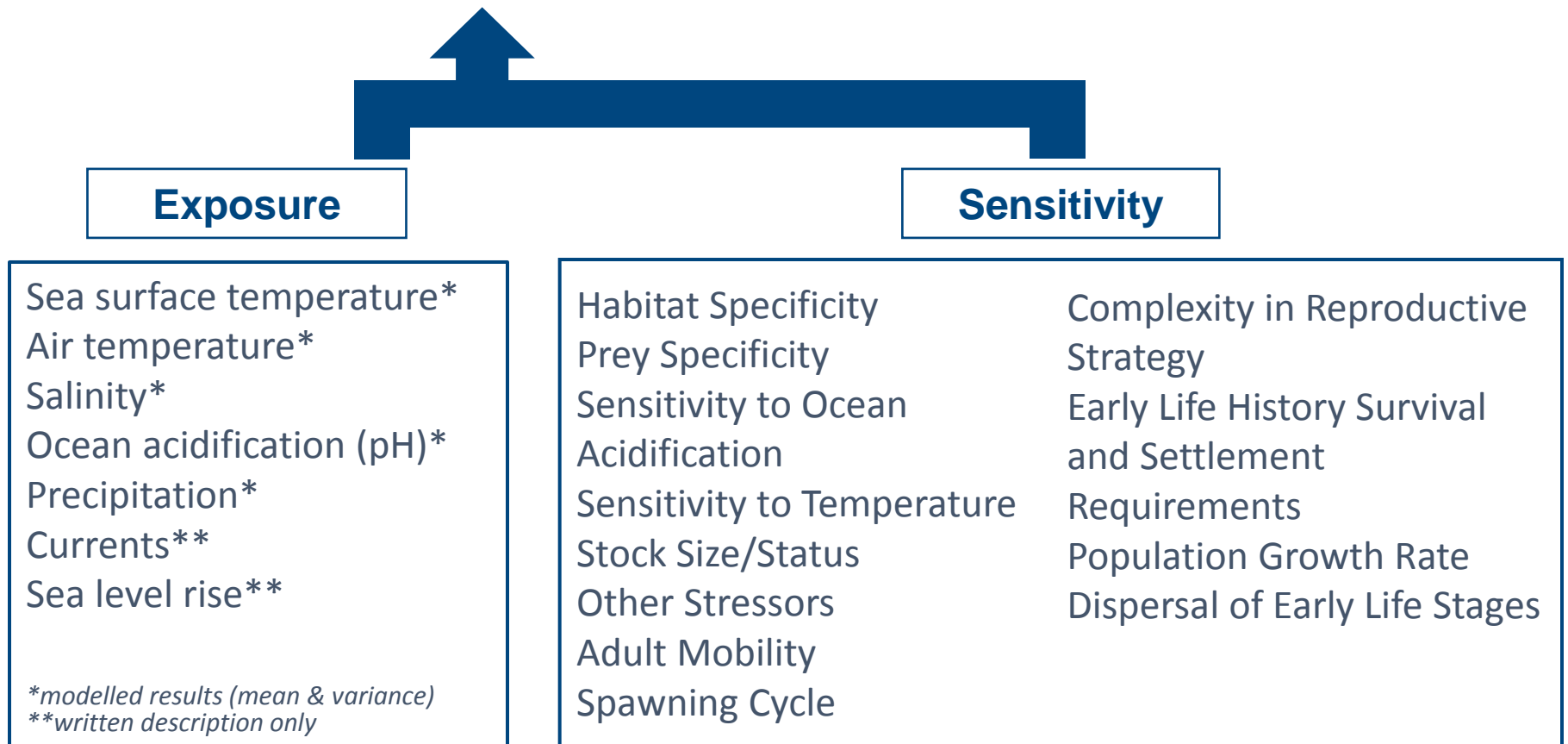
- Atlantic cod
- Atlantic croaker
- River herring
- Cusk
- Others

Qualitative

e.g., this talk

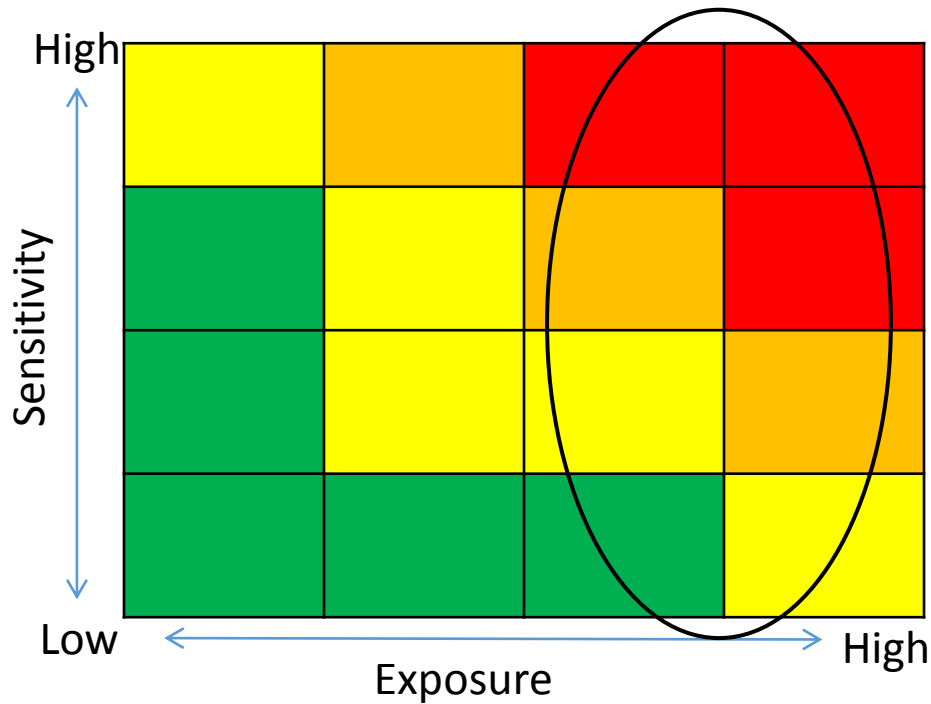
Conclusions

Northeast Fisheries Climate Vulnerability Assessment (79 species)



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?

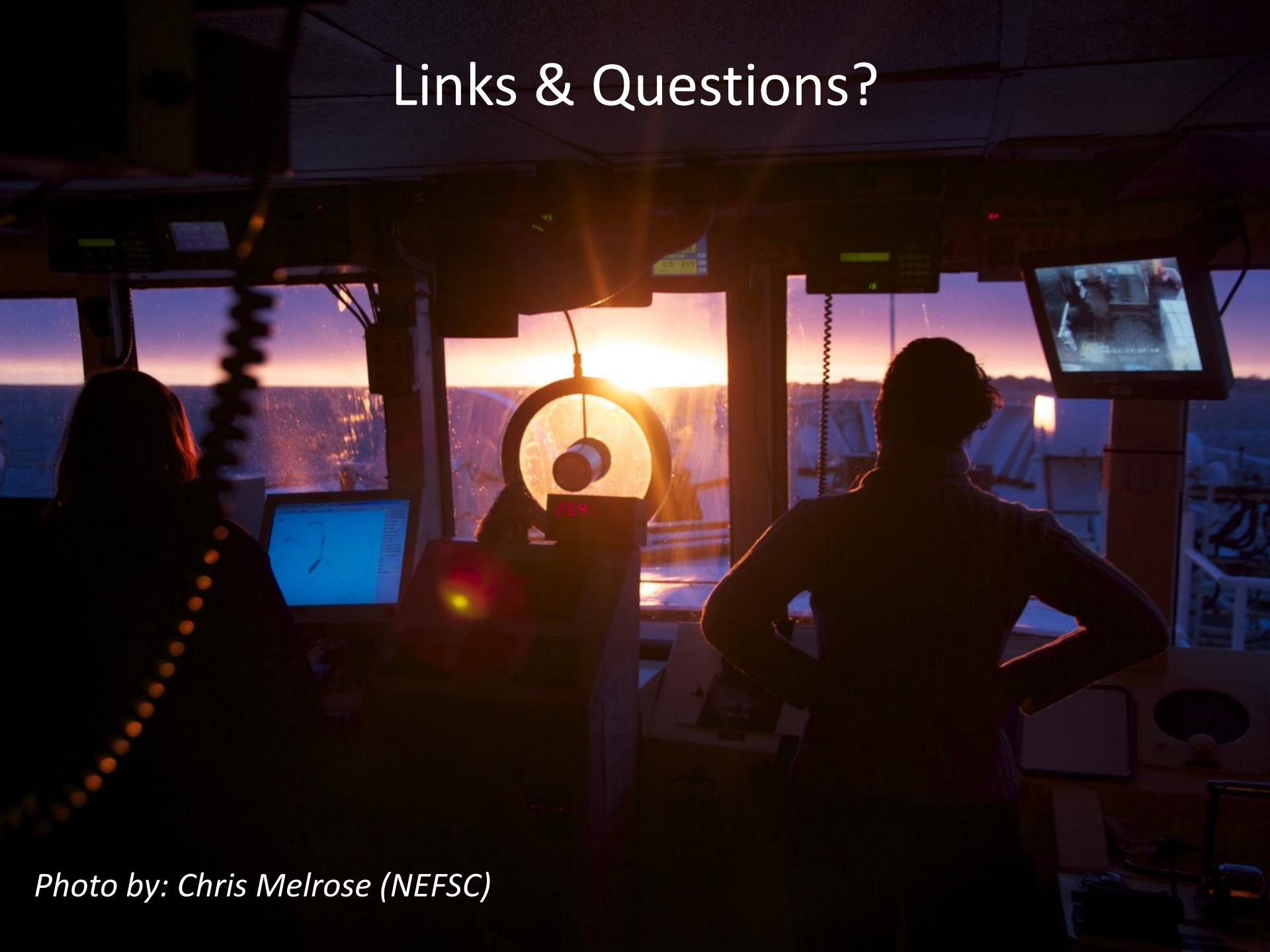


Photo by: Chris Melrose (NEFSC)