Rapid Assessment of the Governance System's Ability to Respond to Climate Change

In support of the East Coast Climate Change

and Fishery Governance Workshop

March 19-21 2014

New England Fishery Management Council

Introduction

Overview

The following rapid assessment approach and compiled document were developed to inform the agenda and discussions at the East Coast Climate Change and Fisheries Governance Workshop, March 19-21, 2014 in Washington, DC. This workshop will be hosted by the Mid-Atlantic Fishery Management Council, and was developed in partnership with the New England Fishery Management Council, South Atlantic Fishery Management Council, Atlantic States Marine Fisheries Commission and NOAA Fisheries, with coordination and facilitation support provided by the Fisheries Leadership & Sustainability Forum (Fisheries Forum).

The purpose of these rapid assessments is to describe the current state of knowledge regarding climate change impacts and concerns for managed fisheries, and in particular to help identify intersections with the workshop focus on management and governance. These initial rapid assessments were completed by council and Commission staff, and represent an investment of their time as well as an effort to share their experience and insight. The assessments are not intended to be comprehensive; rather they are a first pass at gathering information, and will serve as living documents that can be refined and updated over time to incorporate new information and perspectives.

Approach

Fisheries Forum staff, the workshop steering committee and Atlantic States Marine Fisheries Commission staff collaborated to develop a data collection template. The templates are comprised of a set of questions designed to capture information on a) observed or potential impacts on managed stocks and/or fisheries from climate change; b) management measures and communication/ coordination mechanisms in place; and c) perceptions of the ability of the governance system to address/respond to current or future climate impacts.

The initial data collection template contained two numerical ranking questions to gauge climate vulnerability and the adaptability of management measures. Assigning a numerical value to these questions was valuable to help articulate current thinking on these issues. However, given that the purpose of this assessment was not to compare fisheries, these numerical rankings have been characterized qualitatively to better highlight the insights provided by council staff in their discussion of these questions. Several terms found in the rapid assessment, such as “vulnerability” and “adaptation”, have a number of different meanings. These terms have been left undefined in the rapid assessment, and thus responses to the assessment questions may reflect different perspectives on what we mean by these terms and how we measure them.

Current and Future Use

The process of conducting the rapid assessment, and the information contained in the assessments contribute to climate change governance discussions in several ways. First, the responses contained in the rapid assessments have been a valuable input in the development and design of the workshop. The assessments are helpful for framing workshop discussions, and are provided as a reference for workshop participants. Second, the information provided by council and Commission staff in the assessments, along with broader scoping efforts by Fisheries Forum staff, was distilled into a discussion document provided to workshop participants prior to the workshop. The discussion document highlights many of the themes that emerged from looking at the assessments across all council and Commission managed species, and helps to succinctly communicate the value of these assessments in support of the workshop. Finally, these regional rapid assessment documents can be used as a platform to capture additional insights and information, and serve as a "living document" that can be used to support future discussions around climate change and its governance implications.

If you have questions or comments regarding the rapid assessment in regard to the East Coast Climate Change and Governance Workshop, please contact Katie Latanich with the Fisheries Leadership & Sustainability Forum (cal7@duke.edu). If you have questions regarding the specific information contained in the individual assessments, please contact the appropriate member of council and/or Commission staff.

East Coast Climate Change and Fisheries Governance Workshop

March 19-21, 2014 – Washington, DC

Workshop objectives

The purpose of this workshop is to convene managers and staff of the New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), South Atlantic Fishery Management Council (SAFMC), Atlantic States Marine Fisheries Commission (ASMFC), and NOAA Fisheries (NMFS) to discuss the potential governance challenges arising from the impacts of climate change on East Coast marine fisheries. Specifically, workshop participants will work collaboratively to:

- Explore the existing and potential impacts of climate change on the management and governance of East Coast marine fisheries, with an emphasis on the policy implications of shifting fishery distributions and changing productivity;
- Evaluate processes for documenting and acknowledging climate-related changes and initiating a management response;
- Identify key management questions, concerns and information needs to guide future research and coordination between management bodies;
- Examine the flexibility of the existing management framework to accommodate climate-related governance challenges; and
- Discuss potential solutions and next steps for adapting and responding to climate change impacts, and opportunities to maintain a dialogue between East Coast fishery management partners.

Table of Contents

Cod

Management authorities - *Who has the authority or obligation to manage the species?*

Along the US East Coast, Atlantic cod (*Gadus morhua)* is assessed and managed as two distinct stocks: Gulf of Maine (GOM) and Georges Bank (GB). The GOM stock includes state and federal waters, while the GB stock covers federal and international waters (Figures 1 and 2).

The GB stock is further divided into an Eastern and Western component. EGB cod is managed through the US/Canada Resource Sharing Understanding. The Eastern stock is assessed separately by the Transboundary Resource Assessment Committee (TRAC). Catches in the in EGB are negotiated between the United States and Canada based on the EGB cod assessment.

Management authorities include:
States: Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut
Federal: National Marine Fisheries Service (NMFS), New England Fisheries Management Council (NEFMC)
Other: EGB cod – NMFS, Department of Fisheries and Oceans (DFO) Canada, Transboundary Management Guidance Committee (TMGC)

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

Both GOM and GB cod stocks are moderately to very vulnerable to the negative impacts of climate change based on their life history and population status. Potential implications of negative climate change impacts are further described.

Life History

The Atlantic cod is a demersal gadoid species found on both sides of the North Atlantic. In the western North Atlantic, cod occur from Greenland to North Carolina. In U.S. waters, cod are assessed and managed as two stocks: GOM and GB. GOM cod attain sexual maturity

at a later age than GB cod due to differences in growth rates between the two stocks. The GB cod stock is the most southerly cod stock in the world. The greatest concentrations of cod off the Northeast coast of the U.S. are on rough bottoms in waters between 33 and 492 ft. (10 and 150m) and at temperatures between 32 and 50°F (0 and 10°C). Spawning occurs year-round, near the ocean bottom, with a peak in winter and spring. Peak spawning corresponds to water temperatures between 41 and 45°F (5 and 7°C). It is delayed until spring when winters are severe and peaks in winter when mild. Eggs are pelagic, buoyant, spherical, and transparent. They drift for 2 to 3 weeks before hatching. The larvae are pelagic for about three months until reaching 1.6 to 2.3 in (4 to 6 cm), at which point they descend to the seafloor. Most remain on the bottom after this descent, and there is no evidence of a subsequent diel, vertical migration. Adults tend to move in schools, usually near the bottom, but also occur in the water column.

Population Status

The inshore GOM stock appears to be relatively distinct from the offshore cod stocks on the banks of the Scotian Shelf and Georges Bank based on tagging studies. GOM cod spawning stock biomass has increased since the late 1990's from 12,236 ton (11,100 metric tons [mt]) in 1997 to 37,479 ton (34,000 mt) in 2007. However, the stock remains low relative to historic levels and is subject to a formal stock rebuilding plan. The 2010 biomass estimate, the most recent estimate available, was 8 percent of the biomass rebuilding target. Currently, the GOM cod stock is overfished and overfishing is occurring. GB cod is a transboundary stock harvested by both the U.S. and Canadian fishing fleets. The GB cod stock is overfished and overfishing is occurring.

Potential Implications

Studies suggest that Atlantic cod may be vulnerable to negative climate change impacts. GB cod is at the southernmost extent of the latitudinal range of global cod stocks, and thus the climate changes effects on GB cod may be of greater magnitude than GOM cod. For instance as temperatures increase, cod may have less available thermal habitat at each life stage than previously occupied, since environmental conditions may become lethal; or another consequence could be the pole-ward shift of the center of distribution in order to maintain preferred thermal habitat. These types of shifts could disrupt spawning activity and egg development, which could lead to poor/low recruitment and subsequently impact the level of the spawning stock biomass. Distribution and behavioral changes in both cod stocks could lead to loss/change in life

history pathways (i.e., loss of seasonal spawning variants) and alter stock resilience (i.e., ability to recover after change). If climate change contributes to aggregation of cod stocks, the stocks could become more vulnerable to fishing pressure, exacerbating localized depletion. Furthermore, health of individual cod fish could also be a factor if GOM and/or GB cod condition declines, making populations less resilient to abrupt shifts in environmental conditions (i.e., loss of fat/energy content).

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Ecosystem changes could result in GOM and GB cod stocks becoming more vulnerable to climate change. One factor could be a mismatch in the timing of when prey species are available and when cod aggregate to feed, leading to a reduction in fish condition and spawning potential. Ecosystem changes could also lead to reduced availability of preferred prey. Favorable conditions for predators of cod, like seals, could lead to increased rates of consumption. Competitors of cod, like haddock, may also have favorable conditions leading to high recruitment events and could result in density dependence (i.e., lack of space, food, resources for cod to grow and reproduce).

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

Low GOM and GB cod quotas constrain the multispecies groundfish fishery's ability to catch other species. One result could be that cod quotas continue to decline and further constrain the multispecies groundfish fishery.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Substantial increases in forage fish fisheries could influence the availability of these prey species to both the GOM and GB cod stocks.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Climate related concerns that have been raised in the management process include:

- Shifts in distribution: more northern latitudes for GB stock and truncation of range for GOM stock
- Continued low productivity for both stocks resulting from unfavorable environmental conditions (i.e., temperature increase) and poor stock recruitment
- Loss of stock components (i.e., GOM cod in the Eastern Gulf of Maine)

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

Social and economic consideration that are relevant to climate changes include:

- Vulnerability of coastal communities to climate change
- Level of dependency of coastal communities on cod fishing both commercially and recreationally
- Locating cod aggregations in sufficient quantity to offset the cost of harvesting
- Available opportunities to fish for other species
- The extent to which catch limits on cod constrain access to other fish stocks
- Availability and price of foreign cod in US markets (e.g., from Canada, Iceland, Norway)
- Opportunities for recreational fisheries to access GOM cod

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

The risks of the governance system not being capable of responding effectively to negative climate change impacts or within relevant timescales for the Atlantic cod stocks and the fishery include extended stock rebuilding timelines, ineffective input/output controls leading to a loss in productivity and potential fisheries yield, and in the extreme case: stock collapse.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

The Atlantic cod fishery is primarily managed by quotas that are set based on B_{MSY}. Management measures vary by component of the fishery:

Commercial fishery (GOM and GB cod)

- Sectors:
    - Input control- permits/licenses, vessel restrictions, minimum sizes, closed areas (year-round and seasonal), gear-restricted areas
    - Output controls- quotas/AMs
- Common-pool:
    - Input control-permits/licenses, vessel restrictions, minimum sizes, closed areas (year-round and seasonal), gear-restricted areas
    - Output controls-quotas/AMs, trip limits
- Other fisheries not targeting cod:
    - Output controls- sub ACLs/AMs

Recreational fishery (GOM cod):

- Input controls- minimum sizes, seasonal closure
- Output controls- bag limits

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

Management measures might both facilitate and constrain timely adaptive management. The current management system for Atlantic cod does not operate in an adaptive management framework. The system is highly complex, but it does involve the appropriate management authorities needed to make decisions to facilitate an adaptive management approach. In general, the current management system might constrain timely adaptive management (i.e., the time needed to develop and implement management actions). In addition, groundfish sectors develop sector operations plans on a sector-by-sector basis. Sectors could collectively or on their own develop strategies within their plans similar to adaptive management approaches.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

Federal and state management authorities communicate through the NEFMC process. For EGB cod, international discussions involve NOAA Fisheries, DFO, and Council members through the TMGC process.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

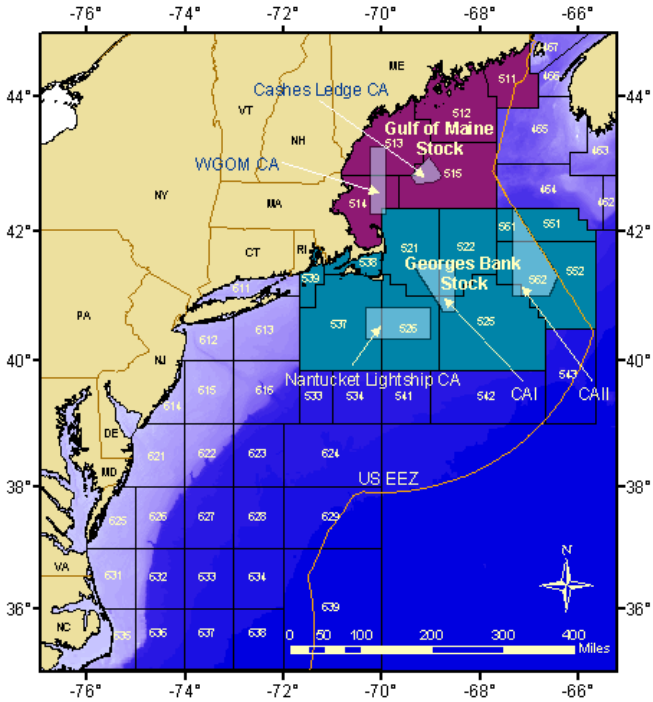

Figure 1: Map of management boundaries for the Gulf of Maine (red) and Georges Bank (green) Atlantic cod stocks by fishery statistcial areas. Source: Northeast Fisheries Science Center.

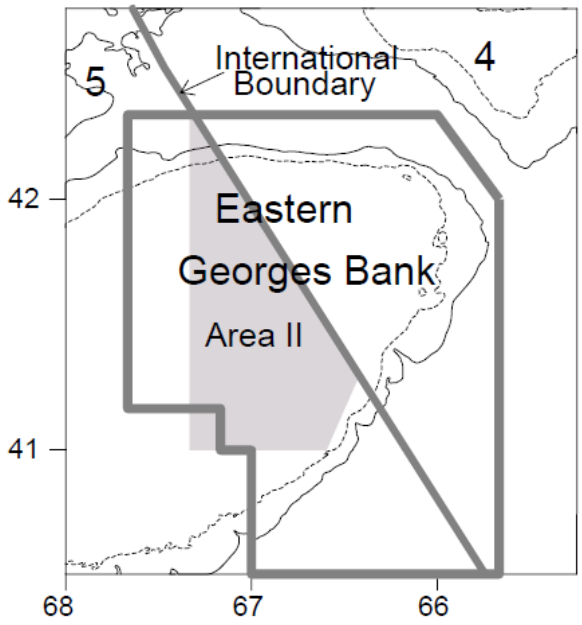

Figure 2: Map of the Eastern Geogres Bank transboundary management area between the US and Canada. Source: TRAC.

Yellowtail Flounder

Management authorities - *Who has the authority or obligation to manage the species?*

Along the US East Coast, yellowtail flounder (*Limanda ferruginea)* is assessed and managed as three distinct stocks: Southern New England/Mid-Atlantic (SNE/MA), Cape Cod/Gulf of Maine (CC/GOM), and Georges Bank (GB). The SNE/MA and CC/GOM stocks include state and federal waters, while the GB stock covers federal and international waters (see Figures 3 and 4).

GB yellowtail flounder is managed through the US/Canada Resource Sharing Understanding. The GB stock is assessed by the TRAC. Catches are negotiated between the US and Canada based on the GB yellowtail flounder assessment.

Management authorities include:
States: ME, NH, MA, RI, CT, NY, NJ
Federal: NMFS, NEFMC
Other: GB stock- NMFS, DFO Canada, TMGC

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

All three yellowtail flounder stocks (CC/GOM, SNE/MA and GB) are moderately to very vulnerable to the negative impacts of climate change based on their life history and population status. SNE/MA may be the most vulnerable of the three stocks, due to its southerly extent. Potential implications of negative climate change impacts are further described.

Life History

The yellowtail flounder is a demersal flatfish that occurs from Labrador to Chesapeake Bay. It generally inhabits depths between 131 to 230 ft. (40 and 70 m). It is managed as three separate stocks including the CC/GOM, SNE/MA, and GB. In general, spawning occurs in the western North Atlantic from March through August at temperatures of 41 to 54 °F (5 to 12°C). CC/GOM spawning takes place along continental shelf waters northwest of Cape Cod. Yellowtail flounder spawn buoyant, spherical, pelagic eggs that lack an oil globule. Pelagic larvae are brief residents in the water column with transformation to the juvenile stage

occurring at 0.5 to 0.6 in (11.6 to 16 mm) standard length. There are high concentrations of adults around Cape Cod in both spring and autumn. The median age at maturity for females is 2.6 years off Cape Cod. The general life histories of the SNE/MA and GB yellowtail flounder are comparable to the CC/GOM yellowtail flounder. The median age at maturity for females is 1.6 years in southern New England waters. The median age at maturity for females is 1.8 years on Georges Bank. GB yellowtail flounder spawning takes place along the continental shelf waters of Georges Bank.

Population Status

The CC/GOM yellowtail flounder stock continues to be overfished and overfishing is occurring. However, fishing mortality has been declining since 2004 and was at the lowest level observed in the time series in 2009. Spawning stock biomass has increased the past few years. Based on a 2012 assessment, the SNE/MA yellowtail flounder stock is not overfished, not subject to overfishing, and is rebuilt. The assessment concluded that the stock is less productive than previously believed and, as a result, the overall biomass at recently seen low levels represents the rebuilt state of nature for the stock. GB yellowtail flounder is a transboundary stock harvested by both the U.S. and Canadian fishing fleets. The GB yellowtail flounder stock is overfished, and overfishing is occurring.

Potential Implications

Studies suggest that yellowtail flounder may be vulnerable to negative climate change impacts. SNE/MA yellowtail flounder is the southernmost of the three stocks, and thus the negative climate change effects on SNE/MA yellowtail flounder may be of greater magnitude than on CC/GOM and GB yellowtail flounder stocks. For instance as temperatures increase, SNE/MA may have less available thermal habitat at each life stage than previously occupied, since environmental conditions may become lethal; or another consequence could be the pole-ward shift of the center of distribution in order to maintain preferred thermal habitat. These types of shifts could disrupt spawning activity and egg development, which could lead to poor/low recruitment and subsequently impact the level of the spawning stock biomass. Distribution and behavioral changes in all of the yellowtail flounder stocks could lead to loss/change in life history pathways and alter stock resilience. Furthermore, health of individual yellowtail flounder could also be a factor if fish condition declines, making populations less resilient to abrupt shifts in environmental conditions (i.e., loss of

fat/energy content). These types of shifts in fish condition also may enable yellowtail flounder to become more prone to outbreaks of disease.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Ecosystem changes could result in SNE/MA, CC/GOM and GB yellowtail flounder stocks becoming more vulnerable to climate change. One factor could be a mismatch in the timing of when prey species are available and when yellowtail flounder aggregate to feed, leading to a reduction in fish condition and spawning potential. Ecosystem changes could also lead to reduced availability of preferred prey. Favorable conditions for predators of yellowtail flounder could lead to increased rates of consumption.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

Low yellowtail flounder quotas constrain the multispecies groundfish fishery, the scallop fishery, and small-mesh (i.e., whiting and squid) fisheries. One result could be that yellowtail flounder quotas continue to decline and further constrain these fisheries ability to access target stocks.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Fisheries with yellowtail flounder bycatch (e.g., scallop and small-mesh fisheries) may influence the vulnerability of this species to climate change if these catches result in further stock declines.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Climate related concerns that have been raised in the management

process include:

- Shifts in distribution: truncation of range and northward distributional shift for CC/GOM, SNE/MA, and GB stocks
- Continued low productivity for both stocks resulting from unfavorable environmental conditions (i.e., temperature increase) and poor stock recruitment
- Increased prevalence of disease

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

- Vulnerability of coastal communities to climate change
- Level of dependency of coastal communities on yellowtail flounder fishing both commercially and recreationally
- Locating yellowtail flounder aggregations in sufficient quantity to offset the cost of harvesting
- Available opportunities to fish for other species
- The extent to which catch limits on yellowtail flounder constrain access to other fish stocks
- Opportunities to access yellowtail flounder by recreational fishers

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

The risks of the governance system not being capable of responding effectively to negative climate change impacts or within relevant timescales for the yellowtail flounder stocks and the fishery include extended stock rebuilding timelines, ineffective input/output controls leading to a loss in productivity and potential fisheries yield, and in the most extreme case: stock collapse.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

The yellowtail fishery is primarily managed by quotas that are set based on B_{MSY}. Management measures vary by component of the fishery:

Commercial fishery

- Sectors:
    - Input control- permits/licenses, vessel restrictions, minimum sizes, closed areas (year-round and seasonal), gear-restricted

areas
    - Output controls- quotas/AMs
- Common-pool:
    - Input control-permits/licenses, vessel restrictions, minimum sizes, closed areas (year-round and seasonal), gear-restricted areas
    - Output controls-quotas/AMs, trip limits
- Other fisheries not targeting yellowtail flounder:
    - Output controls- sub ACLs/AMs

States- Recreational fishery (yellowtail flounder): minimums size and other controls vary by state

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

Management measures might both facilitate and constrain timely adaptive management. The current management system for yellowtail flounder does not operate in an adaptive management framework. The system is highly complex, but it does involve the appropriate management authorities needed to make decisions to facilitate an adaptive management approach. In general, the current management system might constrain timely adaptive management (i.e., the time needed to develop and implement management actions). In addition, groundfish sectors develop sector operations plans on a sector-by-sector basis. Sectors could collectively or on their own develop strategies within their plans similar to adaptive management approaches.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

Federal and state management authorities communicate through the NEFMC process. For GB yellowtail flounder, international discussions involve NOAA Fisheries, DFO, and Council members through the TMGC process.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

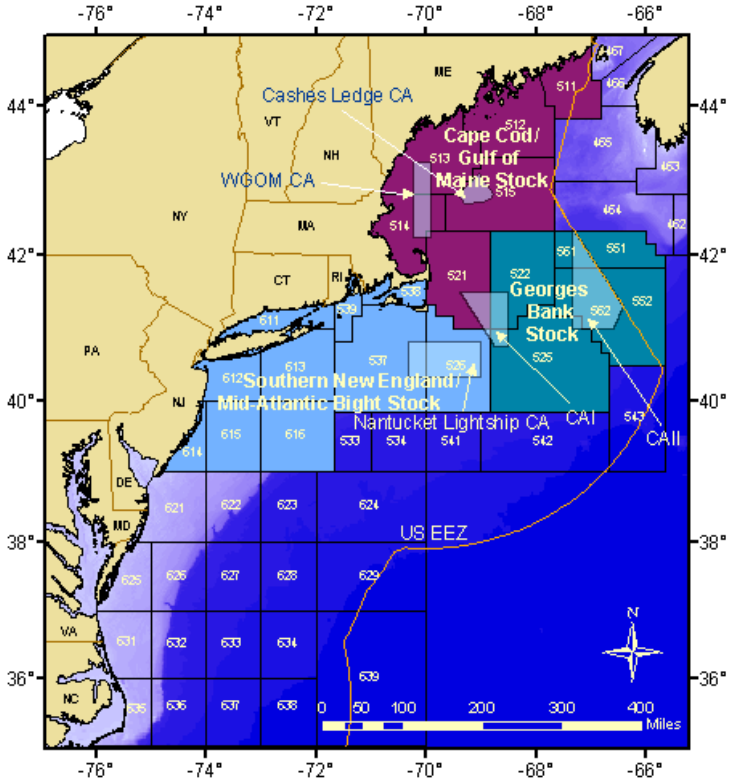

Figure 3: Map of management boundaries for the Cape Cod/Gulf of Maine (red), Southern New England/Mid-Atlantic Bight Stock (blue), and Georges Bank (green) yellowtail flounder stocks by fishery statistcial areas. Source: Northeast Fisheries Science Center.

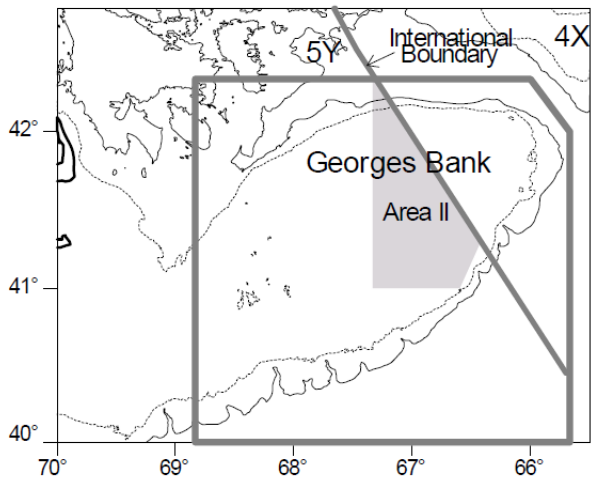

Figure 4: Map of the Eastern Geogres Bank transboundary management area between the US and Canada. Source: TRAC.

References for Atlantic cod and yellowtail flounder

Brander, K. M. 2010. Cod *Gadus morhua* and climate change: processes, productivity and prediction. *Journal of Fish Biology*, 77: 1899-1911.

Brodziak, J. and L. O'Brien. 2005. Do environmental factors affect recruits per spawner anomalies of New England groundfish? *ICES Journal of Marine Science*, 62: 1394-1407.

Bundy, A. and L. P. Fanning. 2005. Can Atlantic cod (*Gadus morhua*) recover? Exploring trophic explanations for the non-recovery of the cod stock on the eastern Scotian Shelf, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 62: 1474-1489.

Churchill, J. H., J. Runge, and C. Chen. 2011. Processes controlling retention of spring-spawned Atlantic cod (*Gadus morhua*) in the western Gulf of Maine and their relationship to an index of recruitment success. Fisheries Oceanography, 20(1): 32-46.

Drinkwater, K. F. 2005. The response of Atlantic cod (*Gadus morhua*) to future climate. *ICES Journal of Marine Science*, 62: 1327-1337.

Eero, M. et al. 2011. Multi-decadal responses of a cod (*Gadus morhua*) population to human-induced trophic changes, fishing, and climate. Ecological Applications, 21 (1): 214-226.

Frank, K. T., R. I. Perry, K. F. Drinkwater. 1990. Predicted responses of Northwest Atlantic invertebrate and fish stocks to CO_2- Induced Climate Change. *Transactions of the American Fisheries Society*, 119: 353-365.

Fogarty, M., L. Incze, K. Hayhoe, D. Mountain, and J. Manning. 2008. Potential climate change impacts on Atlantic cod (*Gadus morhua*) off the northeastern USA. *Mitigation and Adaptation Strategies for Global Change*, 13: 453-466.

Gröger, J. P. and M. J. Fogarty. 2011. Broad-scale climate influences on cod (*Gadus morhua*) recruitment on Georges Bank. *ICES Journal of Marine Science*, 68(3): 592-602.

Hollowed, A. B., Barange, M., Beamish, R., Brander, K., Cochrane, K., Drinkwater, K., Foreman, M., Hare, J., Holt, J., Ito, S-I., Kim, S., King, J., Loeng, H., MacKenzie, B., Mueter, F., Okey, T., Peck, M. A., Radchenko, V., Rice, J., Schirripa, M., Yatsu, A., and Yamanaka, Y. 2013. Projected impacts of climate change on marine fish and fisheries. *ICES Journal of Marine Science*, 70: 1023-1037.

Lough, R. G. and L. O'Brein. 2012. Life-stage recruitment models for Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) on Georges Bank. *Fisheries Bulletin*, 110: 123-140.

Kristiansen T., K. F. Drinkwater, R. G. Lough, and S. Sundby. 2011. Recruitment Variability in North Atlantic Cod and Match-Mismatch Dynamics. PLoS ONE 6(3): e17456 (1-11).

Mieszkowska, N., M. J. Genner, S. J. Hawkins, and D. W. Sims. 2009.

Chapter Three: Effects of climate change and commercial fishing on Atlantic cod *Gadus morhua*. Advances in Marine Biology, 56: 213-273.

Mills, K.E., A.J. Pershing, C.J. Brown, Y. Chen, F.-S. Chiang, D.S. Holland, S. Lehuta, J.A. Nye, J.C. Sun, A.C. Thomas, and R.A. Wahle. 2013. Fisheries management in a changing climate: Lessons from the 2012 ocean heat wave in the Northwest Atlantic. *Oceanography*, 26(2): 191 - 195.

Murawski, S. A. 1993. Climate change and marine fish distributions: forecasting from historical analogy. *Transactions of the American Fisheries Society*, 122(5): 647-658.

New England Fishery Management Council (NEFMC). 2014. Framework Adjustment 51 to the Multispecies Groundfish fishery management plan, in consultation with the National Marine Fisheries Service and the Mid-Atlantic Fishery Management Council.

Nye, J. A., J. S. Link, J. A. Hare, and W. J. Overholtz. 2009. Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. *Marine Ecology Progress Series*, 393: 111-129.

Pinsky, M. L. and M. Fogarty. 2012. Lagged social-ecological responses to climate and range shifts in fisheries. *Climatic Change*, 115: 883-891.

Rose, G. A. 2004. Reconciling overfishing and climate change with stock dynamics of Atlantic cod (*Gadus morhua*) over 500 years. *Canadian Journal of Fisheries and Aquatic Sciences*, 61(9): 1553-1557.

Stige, L. C., et al. 2006. Cod and climate: effect of the North Atlantic Oscillation on recruitment in the North Atlantic. *Marine Ecology Progress Series*, 325: 227-241.

Sullivan, M. C., R. K. Cohen, and B. P. Steves. 2005. Evidence of atmosphere-ocean forcing of yellowtail flounder (*Limanda ferruginea*) recruitment in the Middle Atlantic Bight. *Fisheries Oceanography*, 14(5): 3896-399.

Swain, D. P. and R. K. Mohn. 2012. Forage fish and the factors governing recovery of Atlantic cod (*Gadus morhua*) on the eastern Scotian Shelf. *Canadian Journal of Fisheries and Aquatic Sciences*, 69: 997-1001.

Management authorities - *Who has the authority or obligation to manage the species?*

States: State-waters fisheries are managed by Individual States, in accordance with ASMFC.
Inter-state: ASMFC Interstate FMP for Atlantic Herring
Federal: NEFMC Atlantic Herring FMP

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

Herring may be somewhat vulnerable to climate change. I am not aware of anything in terms of the biology/life history of the Atlantic herring resource that would make it more or less vulnerable than other species to climate change.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Herring are an extremely important forage species for many fish, marine mammals, and seabirds in the Northeast region ecosystem. Ecosystem considerations/changes and the role of herring as a forage species could mean that the impacts of climate change on the herring resource could be more significant than on other species, and/or could result in more cumulative impacts on the ecosystem.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

If climate change affects the Atlantic herring fishery, the most significant impacts may be felt by the American lobster fishery, which relies heavily on Atlantic herring for bait. Also, if climate change negatively affects the herring fishery, this could impact fisheries for stocks that rely heavily on herring for forage (for example, potential seasonal impacts on bluefin tuna and whales in the Gulf of Maine). Changes that influence human behavior,

fishing effort, and fishing patterns could impact the Atlantic mackerel fishery, as there is significant overlap between the herring and mackerel fisheries in the southern New England/Mid-Atlantic region.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Don't think so.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Climate-related concerns have not been raised in the management process for Atlantic herring. For many years, the Atlantic herring resource has been assessed to be "rebuilt" (above the biomass target), with overfishing not occurring (fishing mortality below the threshold level). Concerns about the impact of climate change on herring stock biomass, therefore, have not been raised to fishery managers. Potential impacts of climate change, oceanographic conditions, and/or other ecosystem factors have been addressed only in the stock assessment arena thus far.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

Not at this time.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

Not sure.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

The Atlantic herring fishery has been managed by area-based quotas since 2000. A total annual catch limit (ACL) for the herring stock complex is specified annually by the Council, based on a level of acceptable biological catch (ABC) that is recommended by the SSC to

account for scientific uncertainty. The ACL is set at a level that accounts for management uncertainty and is divided into area-based sub-ACLs. The Atlantic herring fishery has been a limited access fishery since 2007. Gear restrictions include a seasonal purse seine/fixed gear only area in the inshore Gulf of Maine. Catch monitoring measures implemented in Amendment 5 (2014) include requirements for full sampling by observers on herring vessels and increased monitoring in groundfish closed areas. Catch caps for haddock and river herring (expected to be implemented in 2014) manage and minimize bycatch in the herring fishery. ASMFC manages the State waters fisheries, and the ASMFC FMP includes measures for spawning restrictions in inshore areas.

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change?

Yes, the current management structure includes a framework adjustment process, which allows the Council to develop and adopt adjustments to the current herring management program in a shorter timeframe (6-9 months, versus initiating an amendment to the Herring FMP). The current process would allow for adaptation to the extent possible, i.e., within the constraints of NEPA and other applicable law. Significant changes to management programs require amendments, which usually take longer to develop (1-2 years).

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

Atlantic herring is managed in Federal waters by NEFMC and in State waters by ASMFC. The two groups coordinate management through consistent communication and staff overlaps on technical groups. ASMFC implements complementary measures in State waters to ensure consistency between State and Federal regulations as needed. State directors serve on both the ASMFC and NEFMC and provide overlap at the decision-making level.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

Monkfish

Management authorities - *Who has the authority or obligation to manage the species?*

Federal: NEFMC and MAFMC

Climate vulnerability of species - ***Climate change can influence the biology of a species (i.e. growth, maturity,*** *reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

Monkfish may be somewhat vulnerable to climate change. Overall, the available data suggests that the relationship between monkfish and climate change is difficult to discern. Monkfish distribution data suggests that they occupy cooler temperatures and shallower depths in autumn than during spring. As a result, monkfish may move to different depths to find preferred temperatures, which was noted that 90% of monkfish were caught at bottom temperatures of 4.5-13.0°C, thus if they are affected by climate change/warming, monkfish may shift their distribution patterns northward to higher latitudes and to deeper depths (Richards, Nitschke, and Sosebee, 2008). However, as was already stated, monkfish data regarding climate warming is lacking and a closer examination on monkfish response to thermal habitat requires data to be collected over a longer period to determine trends in distribution.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Monkfish have increased their habitat range and abundance due to the warming of bottom water temperatures since the 1980s, particularly *L. piscatorius* in the North Sea (Richards, Nitschke, and Sosebee, 2008). This suggests that certain species of monkfish distribution could be affected more than others. However, as stated before, longer trend data is needed to fully understand the climate warming effects on monkfish.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

It is uncertain what the impact would be on other fisheries because there is not a full understanding of what the impact will be on monkfish.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Yes, but it is not possible to determine specific consequences. Net decreases in the availability of forage would clearly have negative impacts on the productivity of monkfish and decreases in the abundance of monkfish might lead fishermen to harvest other species more intensively if appropriate management measures were not in place.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

There have been Research Set-Asides (RSAs) and journal articles about such concerns, however there is nothing specific in the management process in regards to a course of action because of climate warming. Many monkfish studies are observing the distribution of the species regarding climate change (long term concern) and how it the species will be affected.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

There are no social or economic concerns specific to monkfish at this time. However, the concern of fishing in general and climate change is a concern. It has been noted in the National Climate Assessment (2013) that it will be difficult to quantify the effect of global climate change on commercially important species especially because many fishermen fish multiple species throughout the year. Studies regarding this are ongoing.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

Potential consequences would possibly show a decrease in monkfish landings, which would create a negative social and economic impact(s). However, this is uncertain and is a complex issue because of the many

demographics this species affects from Canada through Florida. The severity of the consequence is also unknown at this time and needs further study.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

- ACLs (annual catch limits)
- TACs (catch targets)
- AM (Accountability measures)
- DAS (days at sea)
- Trip limits – Monkfish are primarily managed through effort controls and trip limits are subject to annual catch limits; however there is no mechanism for an in-season closure of the fishery if ACLs are exceeded.

The Monkfish fishery is primarily an incidental catch fishery, which has three major gear types seen throughout the fishery – gillnet, trawls, and scallop dredges.

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

Existing management measures may both facilitate and constrain timely adaptive management. Distribution of this particular fishery could be impacted because of climate change, in which case quota will have to be changed. However, if management area boundary lines need to be changed because of climate change then that would take time and is not considered a fast adjustment.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

The monkfish fishery is a joint FMP (NEFMC and MAFMC). Both councils communicate regularly through staff coordination as well as having seats on the Monkfish Oversight Committee and AP boards.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

Flexibility among management measures that adapt to climate change will be a complex and challenging effort especially when distribution among fishing areas begin to change. Because the monkfish fishery is

mainly an incidental catch fishery at present that could possibly change due to the bottom temperatures warming and the distribution of the species begins to go further north. This may further affect diet and habitat of monkfish as well, which may intern affect other species as well. Unfortunately data on many species regarding this issue on climate change is limited, but is being looked at more closely.

References

Howard, Jennifer, Eleanora Babij, Roger Griffis, et al. 2013. Oceans and marine resources in a changing climate. *Oceanography and Marine Biology: An Annual Review* 51:71-192.

Johnson, Andrea. 2010. Influence of climate on the distribution and catch rates of monkfish, *Lophius americanus (RSA Grant). Final Report Monkfish RSA 2008/2009*.

Johnson, Andrea. 2011. Influence of climate on the distribution and catch rates of monkfish, *Lophius americanus (RSA Grant). Final Report Monkfish RSA 2009-2011*.

Richards, R. Anne, Paul C. Nitschke, and Katherine A. Sosebee. 2008. Population biology of monkfish *Lophius americanus*. *Ices Journal of Marine Science:* 65:1291-1305.

Management authorities - *Who has the authority or obligation to manage the species?*

Federal: New England Fishery Management Council

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

Red crabs likely have low vulnerability to climate change. Very little is known about the reproductive dynamics of red crab and an aging method has not yet been developed. Atlantic deep-sea red crabs live at depths of 200–1800 m from Nova Scotia to North Carolina with a separate population in the Gulf of Mexico. Concentrations that are commercially exploited by the U.S. fishery are in deep water, occurring within a narrow depth zone longitudinally (400-800 meters) but over a large north to south range (Cape Hatteras to Georges Bank). "Salinities on the upper slope where benthic red crabs occur tend to be stable and oceanic at about 35-36 ppt (Schmitz et al. 1987). The thermal regime can be more variable, ~ 4-10°C, and include the temporary warming effects of the passage of an inshore loop or gyre of the Gulf Stream along the upper slope and shelf edge." (NOAA Technical Memorandum NMFS-NE-16). Based on this information it seems that red crab can tolerate a variable thermal regime so they might be somewhat resilient to temperature changes; however, they might be vulnerable to an increase in ocean acidity because they live in a low-energy environment and are metabolically limited with respect to environmental change.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Red crab is thought to be somewhat adaptable in its food requirements, which may help it adjust to some level of climate change. "We speculate that increased nutritional flexibility exhibited by the red crab is related to its deep water habitat and that evolution of such flexibility may be required for penetration of that habitat." (Sulkin and van Heukelem, 1980).

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes*

in effort, bait supply, etc.).

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

There is very little bycatch of other species in the red crab fishery and its relatively unique geographical distribution (described in the response to the first question) minimizes interactions with other fisheries. According to the 2004 SAFE report, the only species reported to the VTR database as bycatch by the limited access red crab fleet are red crab (female crabs or crabs too small for the market), and on rare occasion, lobster and blue crab.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

It is unlikely that changes in other fisheries would have any immediate impact on the red crab fishery. The directed fishery is responsible for almost all the red crab catch, and as a result, red crab is not vulnerable to changes in fishing for others species. In 2004-2009, (according to dealer data) 12 different vessels had incidental landings of red crab. Their average catch for the 6 years was only 331 pounds per vessel.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

No specific issues related to climate change have been identified in management discussions about red crab.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

There are no particular social and economic considerations in terms of the red crab fishery that make it a greater concern than other species in terms of climate change. A maximum of three vessels have participated in the fishery in recent years and they have access to the resource throughout its range; there are no allocations based on the vessels' home ports or where they land red crab.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

The main concern with the management and possibly the governance system is the lack of fishery independent surveys to information on changes in red crab abundance and therefore if red crab abundance declines it might not be detected quickly. This is a concern because red crabs are slow growing and long-lived (the maximum age is thought to be well more than 15 years); however declines in abundance might be detected through declines in commercial catch rates.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

- A fleet-wide ACL/ACT (currently 1,775 metric tons)
- A prohibition on the landing of female red crab
- Restrictions on the total number of pots/traps on board (600) and the size of pots/traps

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

Yes, existing management measures will facilitate timely adaptive management. The current management measures allow red crab fishing operations to catch red crab throughout its range without seasonal or other operational constraints except limits on traps per vessel and a maximum trap size. There are no limits on catch per trip or state quotas for red crab.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

The NEFMC does not take special steps to communicate with other management authorities about red crab because the U.S. fishery consists of a very small number of boats based in New England that generally land red crab in New Bedford and a small amount opportunistically in Virginia. There is virtually no communication between the U.S. and Canada about red crab management although the resource off Nova Scotia is thought to be an extension of the U.S. Atlantic stock. (The size of the red crab population off Nova Scotia is small in comparison to the population off the east coast of the U.S. Annual red crab landings in Canada have been less than 100 mt since

1998 with the exception of 123.5 mt in 2001).

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

There are no other special considerations that would shed light on the ability of the governance system to respond to climate change with respect to red crab.

Scallops

Management authorities - *Who has the authority or obligation to manage the species?*

States: All states from Maine to NC have the authority to manage this species within state waters. Maine and Massachusetts have the most active fisheries as well as the most developed management systems.
Federal: NEFMC

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

There is not a lot of direct research on this subject, but scallops may have medium to high vulnerability to climate change. Because the Atlantic sea scallop resource is a shellfish it is potentially more sensitive to temperature change and ocean acidification than other species that are more mobile. The distribution for this species is relatively widespread from Canada to North Carolina, so it may be somewhat resilient in some areas. Populations in the south and inshore may be more impacted at first.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Starfish are a major predator for scallops. But if climate change causes a truncation in the range in the south and inshore, other warmer water shellfish species will likely replace them like calico scallops. Climate change could influence the prey of scallops with potentially greater impacts to the fishery and nation since scallops is a very high revenue fishery. Researchers in the region believe that large algal blooms have been a primary factor in very high recruitment events in the Mid-Atlantic, but more research is needed in this subject. In terms of habitat alternations from climate change, scallops may not be as vulnerable as other species because they seem to settle in areas based primarily on the physical substrate, and not the epifauna, which would likely be more vulnerable to climate change than the physical substrate.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

Many scallop vessels have other permits in other fisheries, but for the most part they are predominantly dependent on scallops. Therefore, they may not have as much fishing history in other fisheries, which can in some cases impact the level of access in those fisheries. The fisheries with the highest degree of overlap are probably skate, monkfish, and summer flounder. Smaller scale scallop vessels that participate in the general category fishery are more diverse and most could direct in other fisheries.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

All scallop permits are limited entry so there could not be new entrants in this fishery. However, some of the smaller permit categories are not as active (LAGC NGOM and LAGC incidental) so effort could increase in those fisheries. This seems to be the case in 2013 – total scallop landings and the number of active vessels have increased dramatically in NGOM, the same year a shrimp moratorium was put in place.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Concerns about the impacts of climate change have been raised in recent years. In 2013 the Council specifically included this subject as a research priority for the Scallop Research Set-Aside Program. The industry advisory panel and full Council first recommended this addition. The concerns are short-term, intermediate, and long-term.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

The social and economic considerations for this fishery are likely similar to other fisheries; climate change could have negative impacts on the species and fishery by reducing landings and revenue.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

There is a lot at risk with this fishery since it is such a high revenue fishery – $500-$600 million dollars annually. This has major consequences since this species plays such a large part in supporting fishing community businesses in ports along the east coast. Because there is an annual catch limit for this fishery the governance system could adapt by reducing the limit based on climate change impacts.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

This fishery is limited entry with an annual catch limit. Effort is controlled by DAS and limited number of trips with possession limits for the limited access fishery and an IFQ and possession limit for the limited access general category fishery. The limited access general category NGOM fishery has a hard-TAC and possession limit. There are numerous input controls such as gear, crew limits, and vessel baselines.

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

Existing management measures allow for timely adaptive management. Catch limits and other measures can be adjusted relatively rapidly to adapt to changes in the fishery. In recent years the limits have been reviewed and modified annually.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

This resource is primarily managed in federal waters by communication between the Council and NMFS. There is a state water exemption program under the federal FMP that coordinates management of the state water fisheries.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

The Scallop FMP is fortunate to have a research program within the FMP – the Scallop Research Set-Aside Program. Each year 1.25 million pounds of scallops, worth over $10 million dollars is set-aside to fund research. If potential impacts of climate change continue to be a concern for this resource and fishery, scientific research can be funded and results incorporated directly into the management system. If

research highlights changes that are necessary the governance system could respond. However, the Council process is limited to management of fisheries.

Management authorities - *Who has the authority or obligation to manage the species?*

Federal: NEFMC

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

The Northeast skate complex is thought to have medium-high vulnerability to climate change. Individual species might respond differently to climate change; without a formulaic methodology the vulnerability is somewhat subjective. Nye et al. (2009) used survey data to examine changes in spatial distribution of little, thorny, and winter skates. Little and winter skate moved further south in response to warmer temperatures. Winter skate increased area occupied with its center of biomass moving further south and into deeper water; little skate did not exhibit a statistical change in depth. Thorny skate greatly reduced area occupied but remained centered in the GOM; they did move to greater depths. Hogan et al. (2013) identified thermal habitats for the seven skate species based on catch weighted temperatures from the NEFSC trawl survey. Clearnose, little and winter skates have a broader thermal habitat compared to the other four species. Miller & Frisk (2006) found differences in growth parameters in little skate with northern individuals growing more slowly than southern individuals.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

It is difficult to say for many of the skate species as directed research has not been done, but thorny skate is of particular concern with its overfished status (since the beginning of the FMP) and currently overfishing occurring. Survey data suggest this species is becoming restricted into the GOM; if temperatures or other environmental conditions not yet identified affecting the species continue to worsen the stock may be severely impacted if conditions in the GOM area worsen.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes in effort, bait supply, etc.).*

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

There is no directed fishery for thorny skate – due to its overfished status possession is prohibited - so there would be no direct impact. If winter skate continue to broaden its distribution (and little skate shows no stat. sig. impacts) they may become available to more fisheries. The skate fishery is currently open access; fishermen could take advantage of the additional resource.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Based on available literature, thorny skate appears to have restricted distribution into the GOM and the GOM closed area. If changes are made to the WGOM closed area then increased encounters with thorny skate may occur. The discard mortality rate estimate in trawl gear is 23% but this was considered an underestimate by the authors (Mandelman et al. 2013). Fishing activity may not be the direct cause of the continued decline in thorny skate, however, it may further stress a population that is not showing any positive signs.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Yes – fishermen have raised this issue at meetings but it has not been investigated as part of a stock assessment yet. The continued decline in thorny skate survey index remains a concern, in addition to the overfished and overfishing status; the current rebuilding strategy for skates is to prohibit possession. This strategy has been used on smooth and barndoor skate, the latter has increased from zeroes in the survey to almost reach the biomass target. Directed fishing pressure is not thought to be impacting the abundance of thorny; very little thorny appear in landings based on an analysis of port sampling data (90-day finding of thorny skate listing) and possession is prohibited. The contraction into the GOM closed area also needs to be investigated.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

If sea bottom temperatures influence distribution of skates they may move away from preferred fishing grounds. Frisk et al. (2008) suggest connectivity between Scotian Shelf and GB – skates could move to areas inaccessible to US fishermen.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

Local extirpation of thorny skate and reduced TALs for the skate fisheries – all seven species contribute to the ABC for the northeast skate complex. If changes in distribution and/or abundance occur for any of the skate species (particularly little and winter skate) the ABC may decrease and impact fishing in multiple fisheries.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

ABC control rule, trip limits and possession prohibition. Permits are required but fishermen must have another permit (e.g. monkfish, multispecies permit) to fish for skates.

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change?

The management measures may both facilitate and constrain necessary adaptation. The Council will undertake management action to address the overfishing of thorny skate in 2014.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

MAFMC council members sit on Skate Committee and Council – this is not a jointly managed complex.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

More research is needed; the ability to respond is hindered by lack of knowledge of how they will respond.

Management authorities - *Who has the authority or obligation to manage the species?*

States: States manage vessels with state permits fishing in state waters, but no directed fishery exists in state waters
Federal: NEFMC

Climate vulnerability of species - *Climate change can influence the biology of a species (i.e. growth, maturity, reproduction, productivity, etc.). How vulnerable is the species to climate change, based on its biology? Please explain.*

Species in this management complex likely have low vulnerability to climate change. Silver hake and probably red hake appear to be highly responsive and adaptive to climate change. According to published research (see citations below), decreases in stock abundance and productivity in the southern stock (Mid-Atlantic/Southern New England, to the south side of Georges Bank) have been mitigated by increases in stock abundance and productivity in the northern stock (Gulf of Maine). As adults, silver hake in particular are opportunistic piscivores. The survey abundance (and probably distribution of) offshore hake appears to be influenced by the location of the Gulf Stream. Higher winter temperatures on the continental shelf may make the stock more accessible to the US fishery. Very infrequent catches of offshore hake in the Gulf of Maine may be indicative to increasing presence there if water temperatures sufficiently warm.

Ecosystem considerations - *Climate change can influence entire ecosystems. Do ecosystem considerations or changes make this species more or less vulnerable to climate change? (i.e. predator-prey interactions, competition between species, habitat, etc.). If yes, please explain.*

Maybe. Silver and red hake, particularly juveniles, are frequent prey items in the diets of other fish (such as goosefish) (and probably sea birds and marine mammals). As adults, silver hake prey on other fish. These dietary linkages suggest a fairly complex ecosystem interaction in the NW Atlantic, which would be altered by climate change. These interactions probably make small-mesh multispecies stocks more or less vulnerable to climate change, depending on what other species are favored or hindered by new environmental conditions.

Linkages to other fisheries - *Climate change can influence human behavior, such as changes in fisheries – direct fisheries, incidental fisheries, or other fisheries (i.e. changes*

in effort, bait supply, etc.).

If climate change affects the fishery for this species, what are the potential impacts to other fisheries?

If exploitable stock biomass declines, fishermen will probably increasingly target alternative species that are related but are more available. This may include loligo squid and summer flounder in the southern stock area. Increases in stock biomass (presumably in the northern stock area) may offer opportunities for fishermen to target silver and red hake, rather than another species being adversely affected, such as northern shrimp.

Another impact is caused by changes in the availability of these species as bait. While the flesh is usually too soft to use as lobster trap bait, hake are preferred as bait in the tuna fishery. Increases in the biomass of silver and red hake in the northern management area could improve the use of silver and red hake as bait in the Western Gulf of Maine.

Could changes in other fisheries influence the vulnerability of this species to climate change? If yes, please explain.

Yes. Increases in abundance of predators on hakes, particularly juveniles, could reduce the productivity of hake stocks.

Known climate-related concerns – *Have any climate related concerns been raised in the management process (i.e. scientists, fisherman, managers, other stakeholders, etc.)? List any specific issues (i.e. productivity, distribution, acidification). Are they short-term, intermediate, or long-term concerns?*

Yes – the trophic relationships were recognized as an important factor in the most recent benchmark assessment (SAW 51). Predation rates and mortality due to predation were estimated and found to be very significant, as much as 10 times commercial catch. Assessments using these data (used to estimate a third mortality source, i.e. M2) did not perform well, however.

Social and economic concerns - *Are there any social or economic considerations that are relevant to climate change? If yes, please explain.*

Yes – This fishery has experienced considerable changes over the last 50

years. Hake fisheries in NJ and Ipswich Bay were considerably more productive and vibrant than they once were. It's not entirely clear, however, that these fishery changes were related to climate change, foreign fishing, or other factors. Port infrastructure, processors, and fishermen have had to adapt to new circumstances, often relying on other species for landings.

What's at risk? *Can you describe potential consequences of a governance system that is not capable of responding effectively to climate change impacts or within relevant timescales?*

The risk is probably the same as in any other fishery that has inflexible management specifications, allocations, and limits. In some circumstances, the fishery may not be able to achieve optimum yield because not enough fish were allocated and the stock cannot be harvested at a sustainable level. Possession limits, for example may be set too low, causing discarding. On the other hand, allocations and limits that are too high may be ineffective in capping catch at a sustainable level, leading to decreasing CPUE and increasing fishing cost, let alone overfishing.

Since the NEFSC conducts periodic assessments and the Council adjusts management measures on a periodic basis through specifications packages and framework adjustments, this risk may be low for the small-mesh multispecies fishery. On the other hand, measures that restrict the fishery to keep groundfish catch at or below acceptable levels may (and could already) provide insufficient opportunity to fish on increasing stock biomass in the northern stock area.

Existing management measures - *What management measures are primarily used in the management of this species? Please list.*

Three species are managed by small-mesh multispecies fishery regulations under the NE Multispecies FMP: silver hake (*Merluccius bilinearis*), red hake (*Urophycis chuss*), and offshore hake (*Merluccius albidus*). Silver hake and red hake are assessed and managed as two stocks, a northern stock and a southern stock, separated by Georges Bank. Any vessel may obtain an open access permit and fish with small-mesh trawls in an exempted area (see below) that allows it.

The small-mesh multispecies fishery is managed by an ABC control rule that limits catch and landings, and accountability measures that apply when the fishery exceeds these limits. Individual ABC specifications apply to each silver hake and red hake stock area and are adjusted

every three years following an update or benchmark assessment. These assessments rely primarily on spring and fall annual survey data and the Council has the ability to make more frequent adjustments if recommended by the Plan Development Team.

Offshore hake are considered to be a component of the southern silver hake ABC, based on historic averages. Some trips target or partially target offshore hake when they are available in the fishing area on the Continental Shelf edge. Often offshore hake are landed and marketed as silver hake due to similarity in appearance and price.

Silver and red hake possession limits for each stock area are set partially as a disincentive for large (i.e. 'factory') vessels to land large volumes of fish, flooding the limited US market and depressing prices paid to traditional small-mesh fishermen. The possession limits also keep trip duration short because hakes are soft bodied and do not fare well on extended trips. The possession limits also help to restrict the total annual catch, since the number of participants is limited by market forces and fishing knowledge.

Most relevant issues arising from climate change are the exempted fishing areas. Fishing using small-mesh is restricted to five specific areas in the Gulf of Maine and one area (Cultivator Shoals Area) on Georges Bank. All fishing is restricted to specific seasons to minimize catches of regulated large-mesh groundfish (e.g. cod, haddock, pollock, yellowtail flounder). Three of the Gulf of Maine exempted areas also require vessels to use a raised footrope trawl, also intended to minimize catches of regulated large-mesh groundfish. Small-mesh fishing in the southern management area is exempted from the large-mesh groundfish gear regulations.

Do these measures allow for timely adaptation that might be necessary given the species vulnerability to climate change? Explain.

> Existing management measures may both facilitate and constrain timely adaptive management. The ABC specifications can accommodate changes in biomass and stock productivity caused by climate change. They are updated frequently enough to accommodate the effects of climate change. Permitted vessels are currently allowed to fish in either of the two management areas, although local knowledge of the fishing grounds and available markets often hinder changing fishing practices. The management measures are categorized as mixed, because while the abundance and distribution of hakes is responsive to climate change, the

distribution of large-mesh groundfish may not be as adaptive, preventing changes in the timing and location of exemption areas where small-mesh vessels may fish. The Council is also contemplating a limited access restriction on new entrants that may or may not apply to specific management zones.

Communication and coordination - *How do management authorities communicate with one another about the management of the species? (i.e. Joint FMPs, designated seats, MOUs, staff coordination, etc.)*

The FMP is managed solely by the New England Fishery Management Council (NEFMC) in consultation with the National Marine Fishery Service. One Mid-Atlantic Fishery Management Council (MAFMC) sits on the Whiting Oversight Committee and the Council has a MAFMC liaison that attends NEFMC plenary meetings. One CT state biologist sits on the Whiting Plan Development Team. The Council has an industry advisory panel with members from NY that target hakes and squid in the southern management area. Public hearings are held when needed throughout the fishing area, including NJ.

Anything else? *Are there other categories or considerations that would shed light on the ability of the governance system to respond to climate change?*

The Council is considering limited access to restrict access to all or parts of the small-mesh fishery. The Council is also beginning to develop an EBFM plan that may be affected by or incorporate consideration of climate change factors.

References

Murawski, S.A. 1993. Climate Change and Marine Fish Distributions: Forecasting from Historical Analogy. Trans Am Fish Soc. 122(5):647-658. (http://www.tandfonline.com/doi/abs/10.1577/1548-8659(1993)122%3C0647%3ACCAMFD%3E2.3.CO%3B2#.UvKzs0IlTVY)

NMFS. Undated online publication. Two Takes on Climate Change in the Ocean.(http://www.nmfs.noaa.gov/stories/2013/09/9_30_13two_takes_on_climate_change_in_ocean.html)

Northeast Fisheries Science Center. 2011. 51st Northeast Regional Stock Assessment Workshop (51st SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 11-02; 856 p. (http://www.nefsc.noaa.gov/publications/crd/crd1102/index.html).

Nye, Janet A. T.M. Joyce, Y. Kwon, and J.S. Link. 2011. Silver hake tracks changes in Northwest Atlantic circulation. Nature Communications 2:412.

Nye, Janet A., J.S. Link, J.A. Hare, and W.J. Overholtz. 2009. Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf.