Exploration of climate-induced shifts in historical and future distributions of marine species on the U.S. Northeast Shelf

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Executive Summary

The overarching goal of this project is to advance ecosystem based management and ocean use planning in the Northeast and Mid-Atlantic regions through the analysis of historical and future distribution shifts of demersal marine species. As opposed to studies that examine shifts in distribution of individual species, this project takes an ecosystem approach and measures shifts in groups of species that have similar depth and temperature preferences. The project team has created new spatial data products to visualize changes in species distributions. Changes were evaluated both historically, using trawl survey data, and in the future, using cutting-edge high-resolution climate models for the U.S. Northeast Shelf. The project team produced a time series of 'movies' and static maps, illustrating temporal changes in distributions of individual species and species groups for past, contemporary, and future time periods. These results are designed to be useful to fisheries managers, spatial planners, and the wider community of stakeholders in understanding and planning for potential climate-induced changes to valuable fisheries and the ecosystem in this region.

The project was completed in two phases. During the first phase, the project team classified almost seventy species associated with the seafloor into four distinct groups, or assemblages, based on oceanographic characteristics from the spring and fall Northeast Fisheries Science Center (NEFSC) bottom trawl surveys (http://www.nefsc.noaa.gov). Because the oceanographic and habitat characteristics are so different between the Gulf of Maine (the 'n vthern' Northeast Shelf) and the Mid-Atlantic Bight and Georges Bank (the 'southern' Northeast Shelf), the species groups were examined separately in these two regions. Oceanographic data on depth and surface and bottom temperature proved to be key in distinguishing the groups in each region. Observed shifts in species distributions were compared with shifts in temperature to determine whether consistent responses to climate change were visible within the species groups.

There were distinct differences in shifts in the assemblages of species in each region. Species associated with warmer, shallower waters in the Mid-Atlantic Bight and Georges Bank exhibited a strong northward shift, tracking shifts in temperature bands along the shelf. In contrast, species in the Gulf of Maine were shifting to the southwest, possibly tracking the cooler bottom waters on the shelf and in deeper basins in this area of the Gulf. Additionally, species in the Gulf of Maine associated with cooler and deeper waters tended to shift deeper, taking advantage of the variable bottom topography in this region.

In the second phase of the project, a high-resolution climate model was used to model future species distribution shifts in the next 20-80 years. In general, species that are currently distributed in the south of the U.S. Northeast Shelf in the Mid-Atlantic Bight and Georges Bank were found to shift northward and many species currently found in the Gulf of Maine did not have access to habitat with a suitable temperature in the future. This may have important impacts on the viability of species currently inhabiting the Gulf of Maine and their ability to maintain robust populations in the future. This will also translate into impacts on the commercial fisheries in this region.

Overall, it is understood that, given climate change, there will be some species that will be 'winners' and others that will be 'losers'. What is harder to predict is how these dynamics will unfold on the U.S. Northeast Shelf, especially given the extreme warming predicted by global climate models. Understanding how species have shifted over the past decades in combination with future temperature predictions from climate models can help identify the potential impacts of climate change on vulnerable fish species. Additionally, current and potential biomass hotspots and areas of high fish biodiversity can be identified to help highlight the implications for fishermen and communities that depend on fisheries resources. Together these results provide critical information for the development of spatial management strategies in response to climate change.

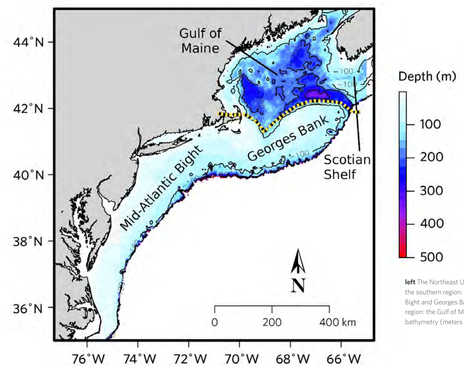
demersal
dwelling at or near the bottom of a body of water.

assemblage
a group of organisms belonging to a number of different species that co-occur in the same area and interact through trophic and spatial relationships and often share a preference for particular oceanographic characteristics.

FOR MORE INFORMATION

The products from both phases consisted of a series of static maps, distribution movies, and supporting metadata, which can be **accessed through the NEFSC Ecosystem Assessment webpage, The Nature Conservancy's Conservation Gateway, and the Northeast Ocean Data Portal:**

www.nefsc.noaa.gov/ecosys/spatial-analyses
https://www.conservationgateway.org
http://northeastoceandata.org



left The Northeast U.S. Shelf illustrating the southern region: the Mid-Atlantic Bight and Georges Bank, and northern region: the Gulf of Maine with shaded bathymetry (meters depth).

Exploring observed shifts

FALL

GULF OF MAINE

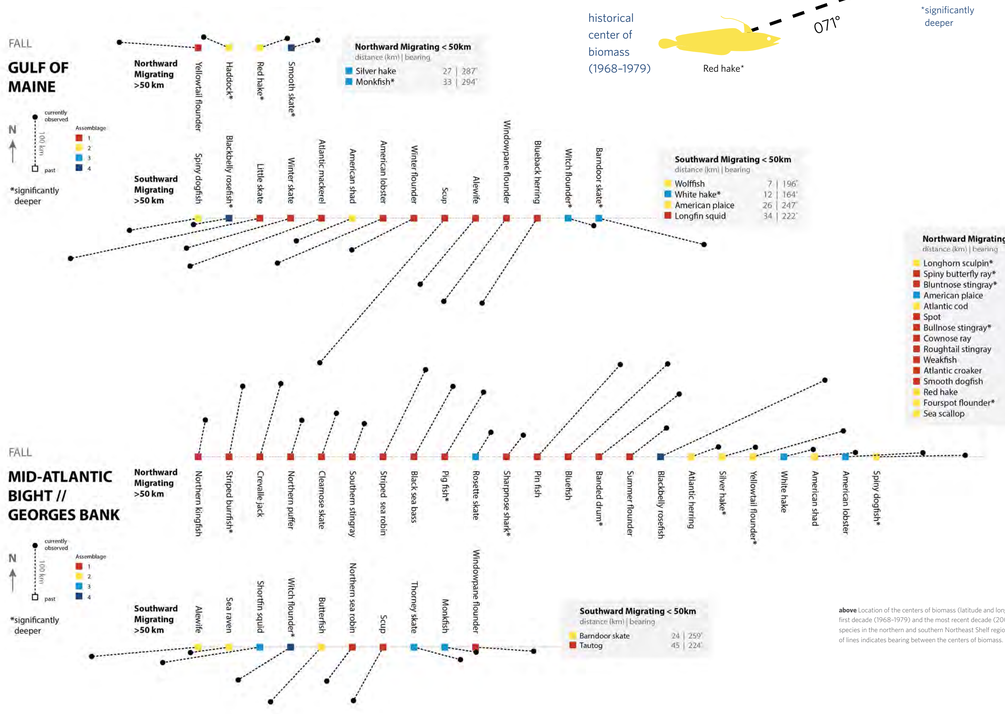
		ASSEMBLAGE		DESCRIPTION
warm shallow	1	Alewife American lobster Atlantic mackerel Blueback herring Little skate Longfin squid	Scup Windowpane flounder Winter flounder Winter skate Yellowtail flounder	Mid-trophic level Mainly demersal Primarily in shallower, coastal inshore waters/ protected bays & estuaries Some spawn in estuaries & rivers
	2	American plaice American shad Haddock	Red Hake Spiny dogfish Wolffish	Mix of mid- and higher trophic level Mix of open ocean & bottom-dwelling Found more frequently in coastal inshore waters
	3	Barndoor skate Monkfish Silver hake	White hake Witch flounder	Mainly higher trophic level Generally demersal Mid- to deep waters and occassionally/soft bottom
cold deep	4	Blackbelly rosefish Smooth skate		Mid-trophic level Found in very deep waters

FALL

MID-ATLANTIC BIGHT / GEORGES BANK

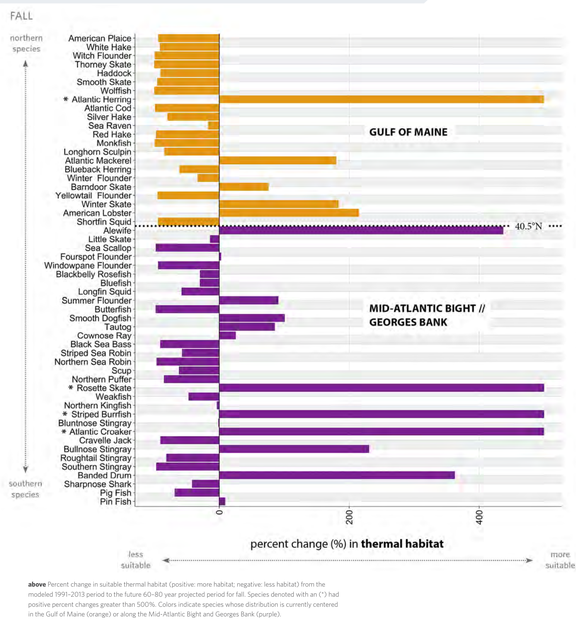
		ASSEMBLAGE		DESCRIPTION
warm shallow	1	Atlantic croaker Banded drum Black sea bass Bluefish Bluntnose stingray Bullnose stingray Clearnose skate Cownose ray Crevalle jack Northern kingfish Northern puffer Northern sea robin	Pig fish Pin fish Roughtail stingray Spiny butterfly ray Spot Striped burrfish Striped sea robin Summer flounder Tautog Weakfish Windowpane flounder	Mix of mid- and higher tropic levels Mainly demersal and reef-associated Strongly tied to coastal inshore waters, bays, estuaries, etc. and warm waters
	2	Alewife American shad Atlantic cod Atlantic herring Barndoor skate Butterfish Fourspot flounder	Longhorn sculpin Red hake Sea raven Sea scallop Silver hake Spiny dogfish Yellowtail flounder	Mix of mid- and higher trophic levels Mainly demersal/benthic Generally in coastal waters or have the ability to migrate between deeper & shallower depths
	3	American lobster American plaice Monkfish Rosette skate	Shortfin squid Thorney skate White hake	Mid- to higher trophic levels Found mostly around shelf edge over soft bottoms
cold deep	4	Blackbelly rosefish Witch flounder		Mid-trophic level Found in very deep waters

above Description of species assemblages defined for the Gulf of Maine and Mid-Atlantic Bight/Georges Bank regions from the fall bottom trawl survey.

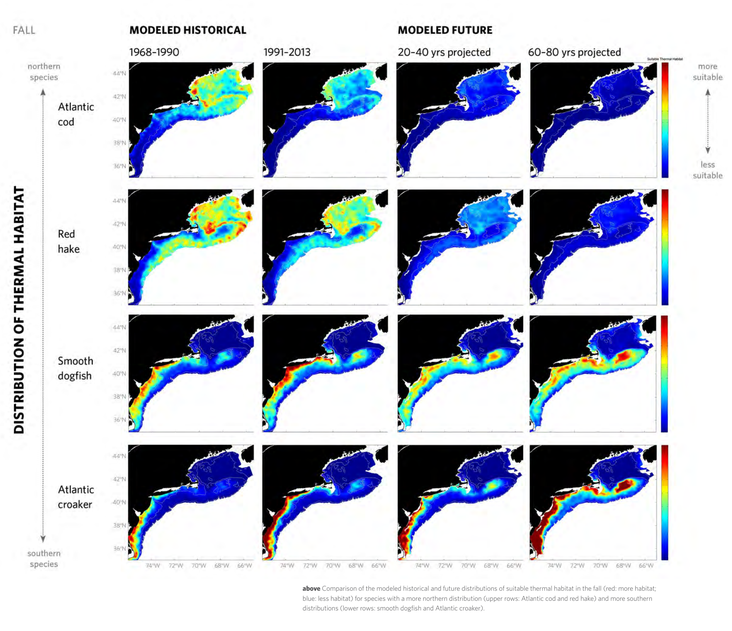


above Location of the centers of biomass (latitude and longitude) in the first decade (1968–1979) and the most recent decade (2002–2013) for species in the northern and southern Northeast Shelf regions. Direction of lines indicates bearing between the centers of biomass.

Exploring future shifts



above Percent change in suitable thermal habitat (positive: more habitat; negative: less habitat) from the modeled 1991–2013 period to the future 60–80 year projected period for fall. Species denoted with an (*) had positive percent changes greater than 500%. Colors indicate species whose distribution is currently centered in the Gulf of Maine (orange) or along the Mid-Atlantic Bight and Georges Bank (purple).



above Comparison of the modeled historical and future distributions of suitable thermal habitat in the fall (red: more habitat; blue: less habitat) for species with a more northern distribution (upper rows: Atlantic cod and red hake) and more southern distributions (lower rows: smooth dogfish and Atlantic croaker).

Project Takeaways

Historical perspective

- Using a combination of temperature and habitat variables sampled on the U.S. Northeast Shelf the project defined groups of species based on preferred temperatures and depths and explored historical distribution shifts.
- Exploring distribution shifts between the species groups on a regional basis illustrated different patterns between the Gulf of Maine, a region with variable bottom topography and complex currents, and the Mid-Atlantic Bight and Georges Bank in the south, a region with more uniform depths.
- In the Gulf of Maine, the centers of distribution of many species shifted to the southwest, possibly tracking cooler bottom temperatures in the southwestern Gulf. Species associated with cooler and deeper waters tended to shift to deeper waters.
- Along the Mid-Atlantic Bight and Georges Bank, the centers of biomass of many species shifted to the northeast, tracking shifts in temperature bands. In this region, species associated with shallow, warmer waters shifted northward at the greatest rates, generally staying in shallower waters.

Future perspective

- There will potentially be some major changes in the complex of species occupying different regions of the U.S. Northeast Shelf.
- Species currently distributed on the Mid-Atlantic Bight or Georges Bank may be future climate winners because they can shift northward or deeper.
- Species whose distribution is currently centered in the Gulf of Maine are likely to be climate losers on the Northeast Shelf because areas with suitable temperatures are may not be available.
- Along the Mid-Atlantic Bight, changes in the availability of traditionally harvested species may impose economic impacts as a result of lost access to stocks managed with species-specific quotas, and rising fuel and travel costs.
- Species that currently dominate more southerly waters along the Mid-Atlantic Bight may shift into the Gulf of Maine.
- Deep pockets in the Gulf of Maine become temperature refuges for species that currently occupy the region. Concentration of species may result in increased vulnerability to fishing activity.
- Some species in the Gulf of Maine that cannot find suitable temperatures or temperature refuges may be pushed out of the region altogether.
- Shifting species distributions will require increased collaboration among governing bodies.
- Fishing communities will need to adapt to new conditions by switching their targeted species or traveling further to maintain viable fisheries.