2022 State of the Ecosystem

Mid-Atlantic

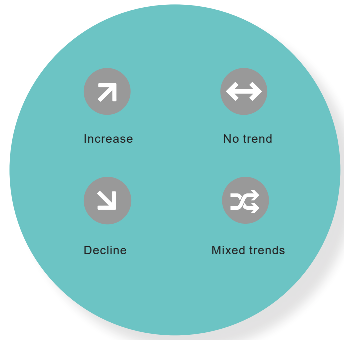
NOAA
FISHERIES

Performance Relative to Fishery Management Objectives

Trends and status of indicators related to broad ecosystem-level fishery management objectives, with implications for the Mid-Atlantic Fishery Management Council (MAFMC)

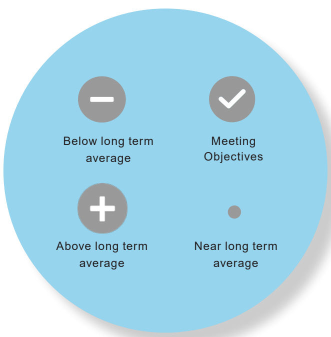
OBJECTIVE (INDICATOR)	Seafood production (total and MAFMC managed landings)	Commercial profits (indicator not updated, 2020 regional landings not yet available)	Recreational opportunities (effort and fleet diversity)
TREND	[Decline]	[Decline]	Effort [Increase]; Fleet diversity [Decline]
CURRENT STATUS	Status not updated for 2020	Status not updated for 2020	Effort [Above long term average]; Fleet diversity [Below long term average]
IMPLICATIONS	Regional commercial landings data are not yet available for 2020, but coastwide landings trends for federally managed species were mixed when compared to recent years. Recreational harvest is declining due to multiple drivers. COVID-19 seems to have exacerbated existing trends in both commercial and recreational fisheries where data are available, but impacts are not uniform across fisheries. Biomass trends within the ecosystem continue to be stable. Climate indicators continue trending toward unprecedented levels, which affects stock distributions and will generate other ecosystem changes.	Regional commercial revenue data are not yet available for 2020. Coastwide, revenue was down across many federally managed species, due to a mix of both lower prices (summer flounder, scup, black sea bass, squids, monkfish) and landings (surfclam, ocean quahogs, monkfish).	Recreational effort shows a long term increasing trend and has returned to pre-2018 levels, but fleet diversity is decreasing because of a shift away from party/charter to shore-based fishing. This shift results in a decreased range of recreational fishing opportunities. Shore-based anglers will have access to different species/sizes of fish than vessel-based anglers.

Trend



OBJECTIVE (INDICATOR)	Stability (fishery and ecosystem diversity maintained over time)	Social and cultural (community fishery engagement, reliance, and environmental justice vulnerability)	Protected species (coastwide bycatch, population numbers, mortalities)
TREND	Fishery [No trend]; Ecosystem [Mixed trends]	Status only indicator	Bycatch [Mixed trends]; Population NARW [Decline]
CURRENT STATUS	Fishery [Near long term average]; Ecosystem [Near long term average]	Environmental justice status for top commercial and recreational communities	Bycatch Harbor porpoise [Meeting Objectives]; Population NARW [Below long term average]
IMPLICATIONS	Fishery: Commercial fleet diversity metrics suggests stable capacity to respond to the current range of fishing opportunities. Recreational: Species catch diversity has been maintained by a different set of species over time. Ecosystem: Adult fish diversity indices are stable, but several climate and oceanography metrics are changing and should be monitored as warning signs for potential regime shift or ecosystem restructuring.	These indicators are used to identify top fishing communities and those with environmental justice concerns based on 2019 data. Highlighted communities may be vulnerable to changes in fishing patterns due to regulations and/or climate change. When any of these communities also experience environmental justice issues, they may have lower ability to successfully respond/adapt to change. All communities showing environmental justice concerns score high in the poverty index, while some also score high in personal disruption and population composition indices.	Mixed bycatch trends through 2019 are related to fishery management, shifts in population distribution combined with fishery shifts, and population increase for seals. Bycatch indices were not updated because of low 2020 observer coverage caused by COVID-19 restrictions. Population drivers for North Atlantic Right Whales (NARW) include combined fishery interactions/vessel strikes, distribution shifts, and copepod availability. Unusual mortality events continue for 3 large whale species.

Current Status

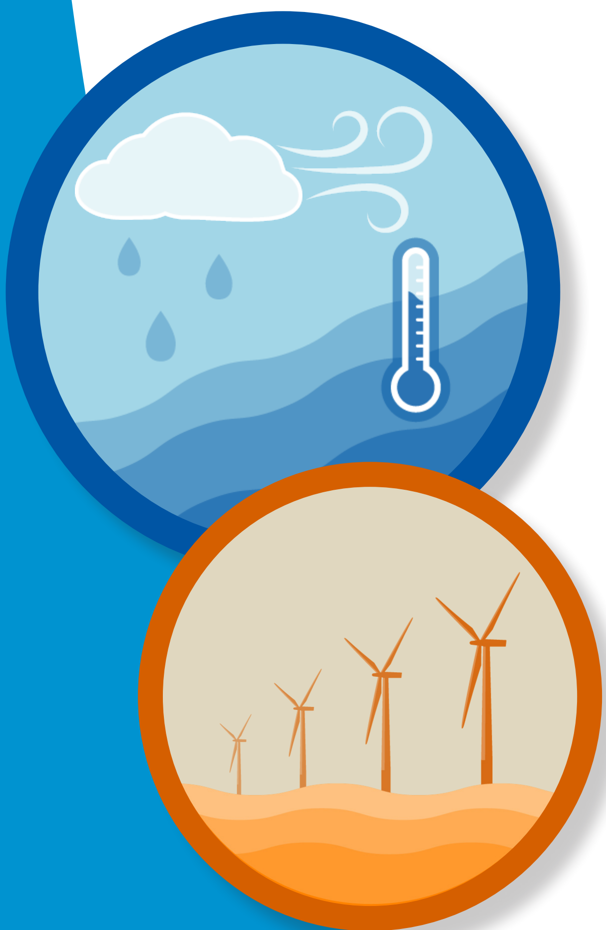


Risks to Meeting Fishery Management Objectives

Climate and Ecosystem Productivity Risks

Climate change, most notably ocean warming and changes in the Gulf Stream, continues to affect the Mid-Atlantic ecosystem:

- Frequent and intense marine heatwaves observed for the last decade continued in 2021.
- The Gulf Stream is becoming less stable, which can affect the physics, chemistry, and biology of the Northeast Shelf.
- Warm, salty, less acidic offshore water is transported onto the shelf more frequently, upwelling deepwater nutrients and reducing acidification in the outer shelf portions of the Mid-Atlantic Bight, but reducing the horizontal extent of the cold pool habitat.
- The cold pool is becoming warmer, smaller, and shorter in duration, which affects habitat for multiple federally managed species.



- Phytoplankton chlorophyll concentrations were below average throughout summer 2021 in the Mid-Atlantic Bight.
- Warming Chesapeake Bay water temperatures are having negative impacts on striped bass at all life stages. Temperature and oxygen conditions are being used to inform fishery closure decisions.
- Submerged aquatic vegetation coverage is increasing in portions of Chesapeake Bay, but declining in the lower region due to increased temperatures. These changes are impacting essential fish spawning and nursery habitats.
- Fish condition was poor for many species in 2021, and productivity is declining for multiple species.

Other Ocean Uses: Offshore Wind Risks

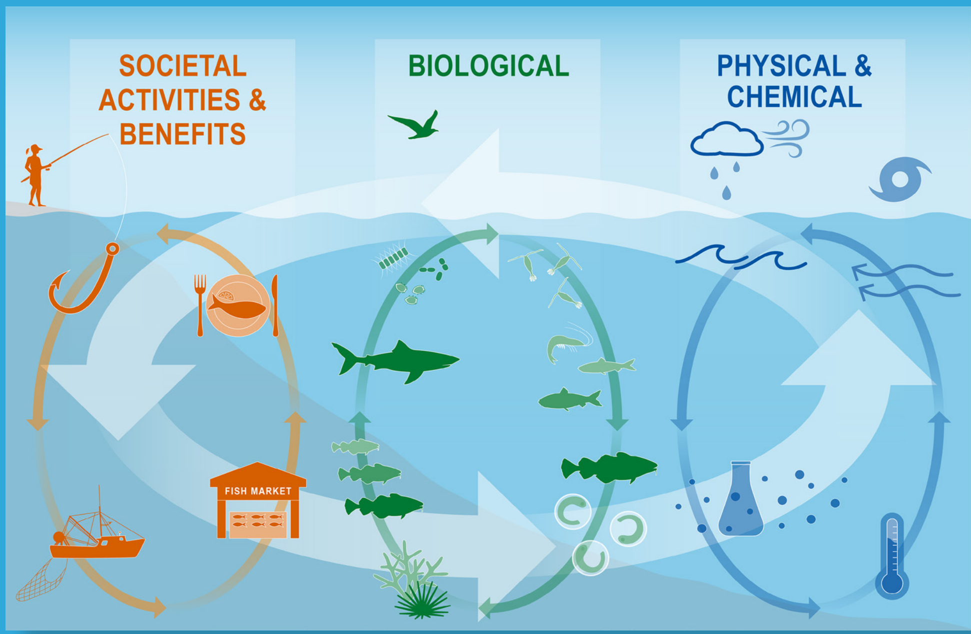
More than 20 offshore wind development projects are proposed for construction on the Northeast shelf, covering more than 1.7 million acres by 2030. An additional 6 lease areas (488,000 acres) were recently identified in the New York Bight, and more areas are anticipated off the Delmarva Peninsula. If all existing and proposed leases are developed in the Northeast:

- 1-31% of port revenue from fisheries currently comes from areas proposed for offshore wind development. Some of these port communities score medium-high to high in environmental justice concerns and gentrification vulnerability.
- Up to 20% of annual commercial landings and revenue for Mid-Atlantic species occur in lease areas and may shift to other areas.
- Development will affect species differently, negatively affecting species that prefer soft bottom habitat while potentially benefiting species that prefer hard structured habitat.
- Planned wind areas overlap with one of the only known right whale foraging habitats, and altered local oceanography could affect right whale prey availability. Development also brings increased vessel strike risk and the potential impacts of pile driving noise.
- Current plans for rapid buildout in a patchwork of areas would spread the impacts differentially throughout the region.

Characterizing Ecosystem Change

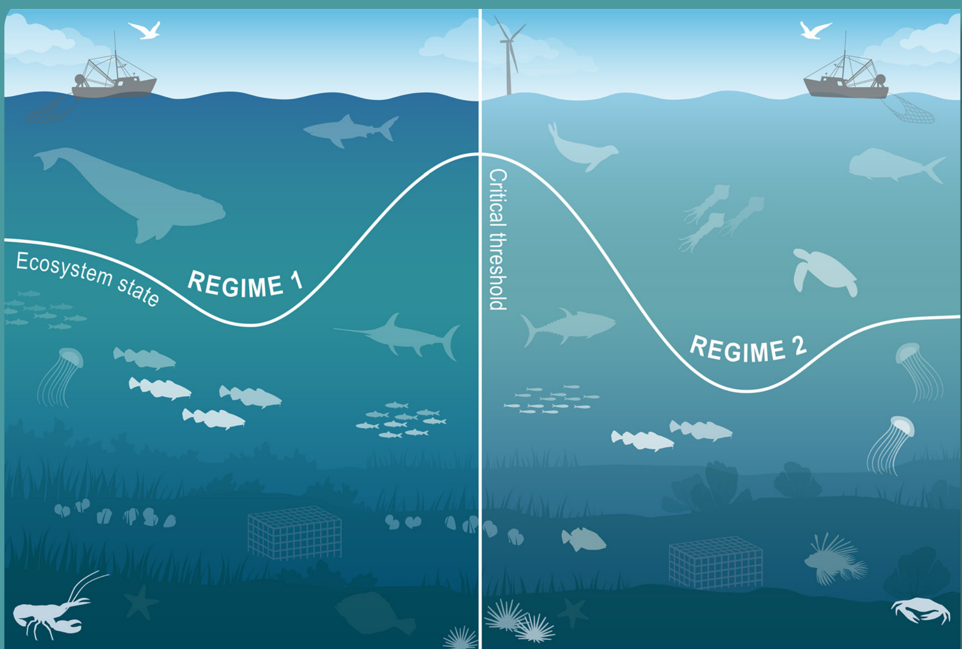
Multiple System Drivers

The Northeast shelf ecosystem is changing, which is affecting the services that the ecosystem provides. To illustrate how multiple factors are driving change in this complex ecosystem, we are using three overarching concepts: multiple system drivers, regime shifts, and ecosystem reorganization. Societal, biological, physical, and chemical factors are the **multiple system drivers** that influence marine ecosystems through a variety of different pathways.



Regime Shift

These drivers affect fishery management objectives such as seafood production and recreational opportunities, as well as other ecosystem services we derive from the ocean. Changes in the multiple drivers can lead to **regime shifts** — large, abrupt and persistent changes in the structure and function of an ecosystem. Regime shifts and changes in how multiple system drivers interact can result in **ecosystem reorganization** as species and humans respond and adapt to the new environment.



Introduction

About This Report

This report is for the Mid-Atlantic Fishery Management Council (MAFMC). The purpose of this report is to synthesize ecosystem information to allow the MAFMC to better meet fishery management objectives, and to update the MAFMC's Ecosystem Approach to Fishery Management (EAFM) risk assessment. The major messages of the report are synthesized on pages 1 and 2, and synthesis themes are illustrated on page 3. The information in this report is organized into two sections; performance measured against ecosystem-level management objectives (Table 1), and potential risks to meeting fishery management objectives (climate change and other ocean uses).

Report structure

The two main sections contain subsections for each management objective or potential risk. Within each subsection, we first review indicator trends, and the status of the most recent data year relative to a threshold (if available) or relative to the long-term average. Second, we synthesize results of other indicators and information to outline potential implications for management (i.e., connecting indicator(s) status to management and why an indicator(s) is important). For example, if there are multiple drivers related to an indicator trend, which drivers may be more or less supported by current information, and which, if any, can be affected by management action(s)? Similarly, which risk indicators warrant continued monitoring to evaluate whether regime shifts or ecosystem reorganization are likely? We emphasize that these implications are intended to represent testable hypotheses at present, rather than "answers," because the science behind these indicators and syntheses continues to develop.

A glossary of terms[1], detailed technical methods documentation[2], and indicator data[3] are available online. The details of standard figure formatting (Fig. 47a), categorization of fish and invertebrate species into feeding guilds (Table 4), and definitions of ecological production units (EPUs, including the Mid-Atlantic Bight, MAB; Fig. 47b) are provided at the end of the document.

Table 1: Ecosystem-scale fishery management objectives in the Mid-Atlantic Bight

Objective Categories	Indicators reported
Provisioning and Cultural Services	
Seafood Production	Landings; commercial total and by feeding guild; recreational harvest
Profits	Revenue decomposed to price and volume
Recreation	Angler trips; recreational fleet diversity
Stability	Diversity indices (fishery and ecosystem)
Social & Cultural	Community engagement/reliance and environmental justice status
Protected Species	Bycatch; population (adult and juvenile) numbers, mortalities
Supporting and Regulating Services	
Biomass	Biomass or abundance by feeding guild from surveys
Productivity	Condition and recruitment of managed species, primary productivity
Trophic structure	Relative biomass of feeding guilds, zooplankton
Habitat	Estuarine and offshore habitat conditions

Performance Relative to Fishery Management Objectives

In this section, we examine indicators related to broad, ecosystem-level fishery management objectives. We also provide hypotheses on the implications of these trends—*why* we are seeing them, what's driving them, and potential or observed regime shifts or changes in ecosystem structure. Identifying multiple drivers, regime shifts, and potential changes to ecosystem structure, as well as identifying the most vulnerable resources, can help managers determine whether we can do anything differently to meet objectives and how to prioritize for upcoming issues/risks.

[1] https://noaa-edab.github.io/tech-doc/glossary.html
[2] https://NOAA-EDAB.github.io/tech-doc
[3] https://github.com/NOAA-EDAB/ecodata

Special note on data availability for the 2022 report

The Catch Accounting and Monitoring System (CAMS) that will be used to provide commercial landings and discard information at the Ecological Production Unit (EPU) scale is under development. As of February 2022, our standard indicators relying on EPU scale landings data cannot be calculated for 2020 (commercial seafood production, commercial profits, ecosystem overfishing). We provide information based on coastwide commercial landings information available at this time in [1][4], and will calculate our standard indicators at EPU scales with disaggregated 2020 commercial landings data when they are available.

Seafood Production

Indicators: Landings; commercial and recreational

Total commercial landings (black) within the Mid-Atlantic are not yet available for 2020; Figure 1 includes data only through 2019. However, we do not anticipate the long-term declining trend in landings to change.

Coastwide landings at the Federal fishery management plan (FMP) level were mixed in 2020 when compared to recent years [1]. Landings of monkfish and of combined surfclam and ocean quahog declined in 2020, while landings of combined summer flounder, scup, and black sea bass increased, and landings of combined squid species increased in 2020.

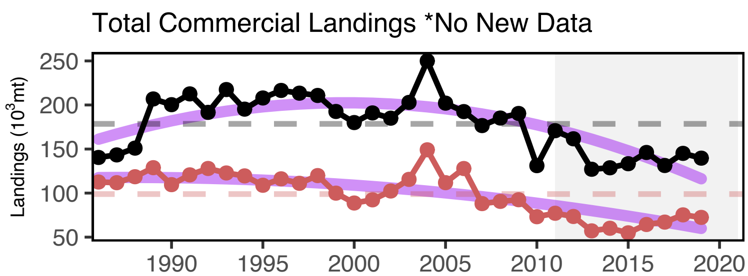


Figure 1: Total commercial seafood landings through 2019 (black) and Mid-Atlantic managed seafood landings (red).

Total recreational harvest (retained fish presumed to be eaten) is down in the MAB (Fig. 2). Although harvest has increased from a historic low in 2018, it is still below the average value for the series.

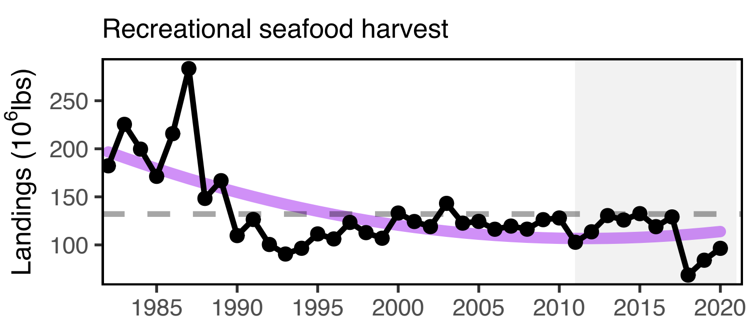


Figure 2: Total recreational seafood harvest (millions of pounds) in the Mid-Atlantic region.

Recreational shark landings show an increase in pelagic sharks over the past decade, with a sharp decrease in 2018 - 2019 persisting through 2021 (Fig 3). This is likely influenced by regulatory changes implemented in 2018 intended to rebuild shortfin mako stocks. In 2021 the International Commission for the Conservation of Atlantic Tunas

[4] https://spo.nmfs.noaa.gov/sites/default/files/TM221.pdf

(ICCAT) finalized recommendations for a two-year retention ban (ICCAT Rec.21-09), which will also affect total overall landings of pelagic sharks in coming years.

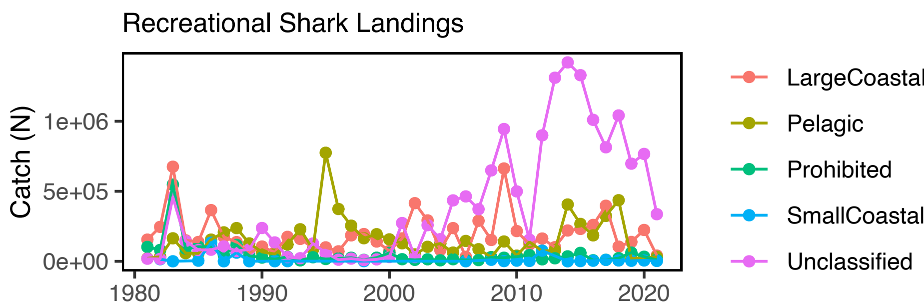


Figure 3: Recreational shark landings from Marine Recreational Information Program.

Aquaculture production is not yet included in total seafood landings, but we are working toward including it in future reports. Available aquaculture production of oysters for a subset of Mid-Atlantic states is trending upward.[5]

Implications

Declining commercial and recreational landings can be driven by many interacting factors, including combinations of ecosystem and stock production, management actions, market conditions (including COVID-19 disruptions), and environmental change. While we cannot evaluate all possible drivers at present, here we evaluate the extent to which stock status and system biomass trends may play a role.

Stock Status and Catch Limits Single species management objectives (1. maintaining biomass above minimum thresholds and 2. maintaining fishing mortality below overfishing limits) are being met for all but two MAFMC managed species, though the status of six stocks is unknown (Fig. 4).

[5] https://noaa-edab.github.io/ecodata/human_dimensions_MAB#Commercial; "Oyster Aquaculture" tab

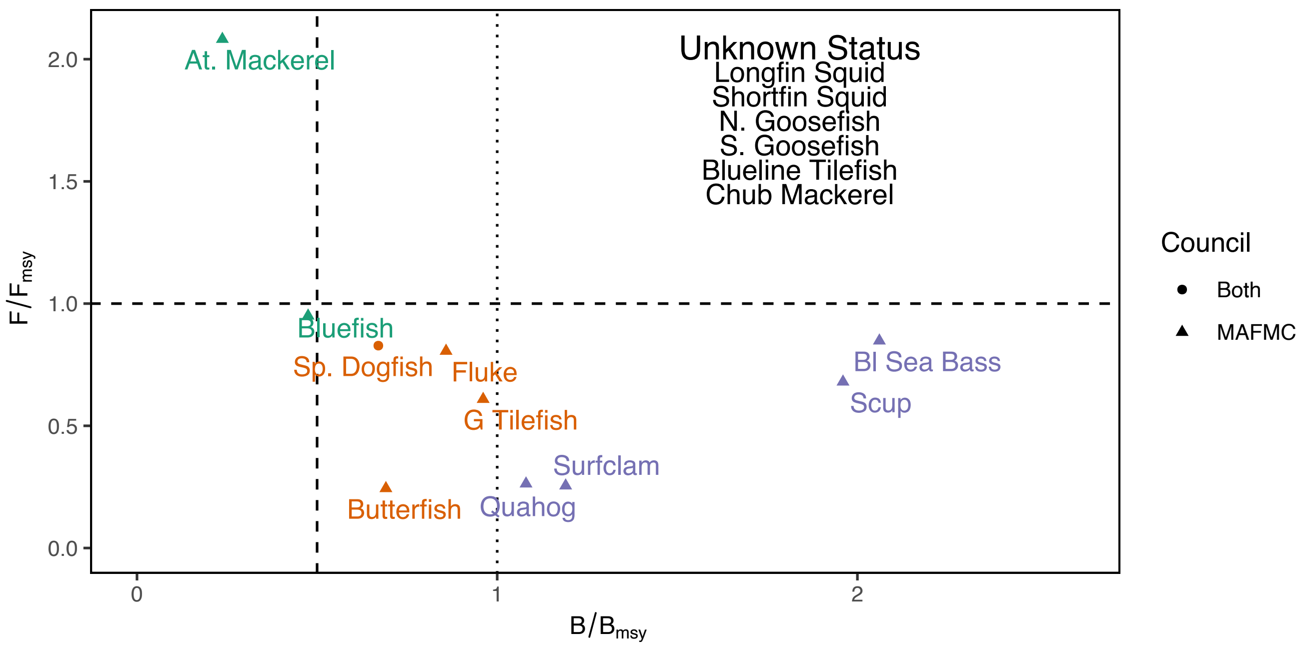


Figure 4: Summary of single species status for MAFMC and jointly federally managed stocks (Spiny dogfish and both Goosefish). The dotted verticxal line is the target bioomass reference point of Bmsy. The dashed lines are the management trehsolds of one half Bmsy (vertical) or Fmsy (horizontal). Stocks in green are below the biomass threshold (overfished), stocks in orange are above the biomass threshold but below the biomass target, and stocks in purple are above the biomass target. Only one stock, Atlantic mackerel, has fishing mortality above the limit (subject to overfishing).

Stock status affects catch limits established by the Council, which in turn may affect landings trends. Summed across all MAFMC managed species, total Acceptable Biological Catch or Annual Catch Limits (ABC or ACL) have been relatively stable 2012-2020 (Fig. 5). The recent total ABC or ACL is lower relative to 2012-2013, with much of that decrease due to declining Atlantic mackerel ABC. This is true even with the addition of blueline tilefish management in 2017 contributing an additional ABC and ACL to the total 2017-2020, due to that fishery's small relative size.

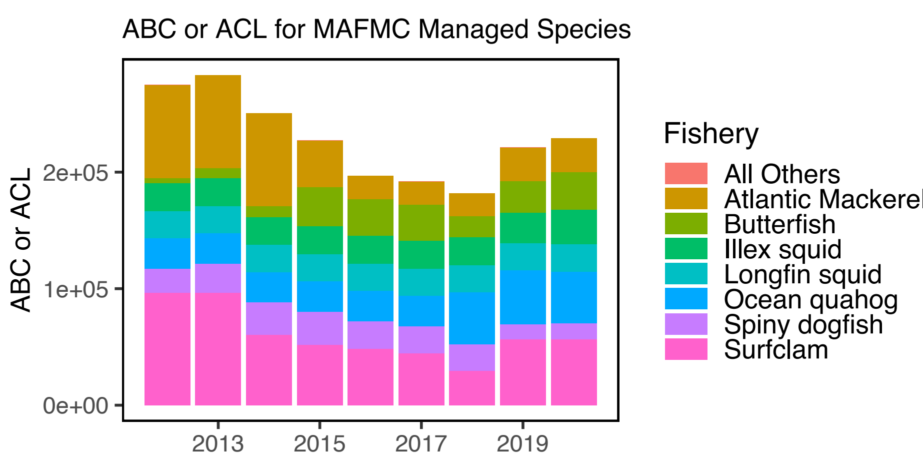


Figure 5: Sum of catch limits across all MAFMC managed fisheries.

Nevertheless, the percentage caught for each stock's ABC/ACL suggests that these catch limits are not generally constraining as most species are well below the 1/1 ratio (Fig. 6). Therefore, stock status and associated management constraints are unlikely to be driving decreased landings for the majority of species.

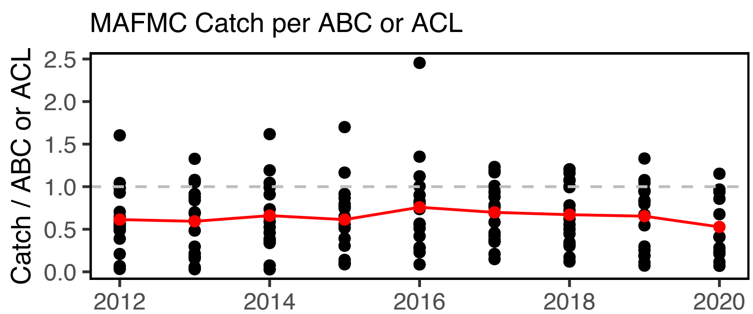


Figure 6: Catch divided by ABC/ACL for MAFMC managed fisheies. Chub mackerel removed due extremely low catch. Outliers = Recreational Black Sea Bass.

System Biomass Although aggregate biomass trends derived from scientific resource surveys are mostly stable in the MAB, spring piscivores and fall benthos show long-term increases (Fig. 7). While managed species make up varying proportions of aggregate biomass, trends in landings are not mirroring shifts in the overall trophic structure of survey-sampled fish and invertebrates. Therefore, major shifts in feeding guilds or ecosystem trophic structure are unlikely to be driving the decline in landings.

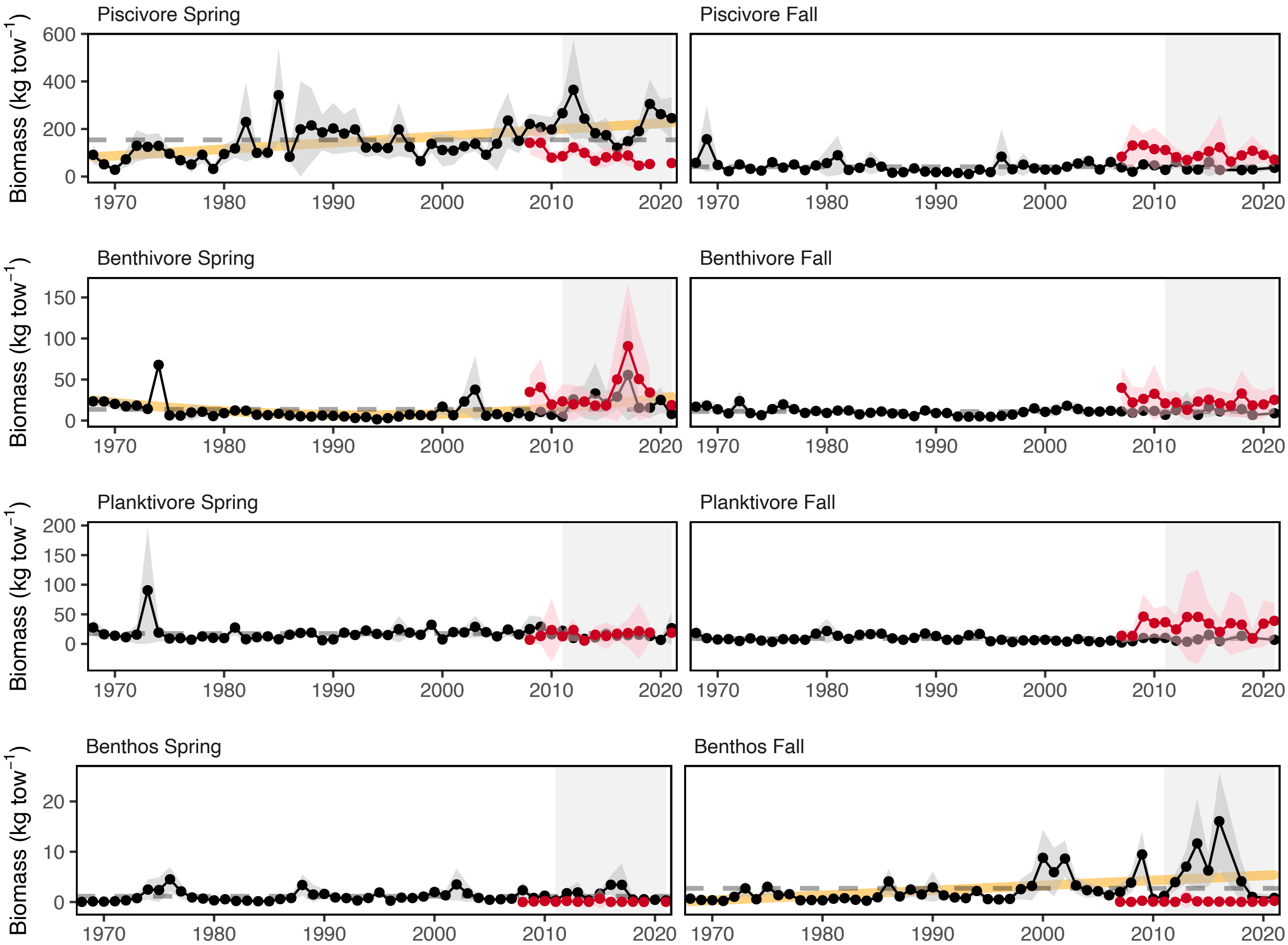


Figure 7: Spring (left) and fall (right) surveyed biomass in the Mid-Atlantic Bight. Data from the NEFSC Bottom Trawl Survey are shown in black, with the nearshore NEAMAP survey shown in red. The shaded area around each annual mean represents 2 standard deviations from the mean.

Effect on Seafood Production Stock status is mostly acceptable, and aggregate biomass trends appear stable, so the decline in commercial landings is most likely driven by market dynamics affecting the landings of surfclams and ocean quahogs, as landings have been below quotas for these species.

Climate change also seems to be shifting the distribution of surfclams and ocean quahogs, resulting in areas with overlapping distributions and increased mixed landings. Given the regulations governing mixed landings, this could become problematic in the future and is currently being evaluated by the Council.

The decline in recreational seafood landings stems from other drivers. Some of the decline, such as that for recreational shark landings, is driven by management intended to reduce fishing mortality on mako sharks. However, NOAA Fisheries' Marine Recreational Information Program survey methodology was updated in 2018, so it is unclear whether the record-low landings for species other than sharks in 2018 are driven by changes in fishing behavior or the change in the survey methodology.

Other environmental changes require monitoring as they may become important drivers of landings in the future:

- Climate is trending into uncharted territory. Globally, 2021 was the sixth warmest year on record[6] with regional marine heatwaves apparent (see Climate Risks section).

[6] https://www.climate.gov/news-features/features/2021-global-climate-summary-6th-warmest-year-record

- Stocks are shifting distribution, moving towards the northeast and into deeper waters throughout the Northeast US Large Marine Ecosystem (Fig. 8).

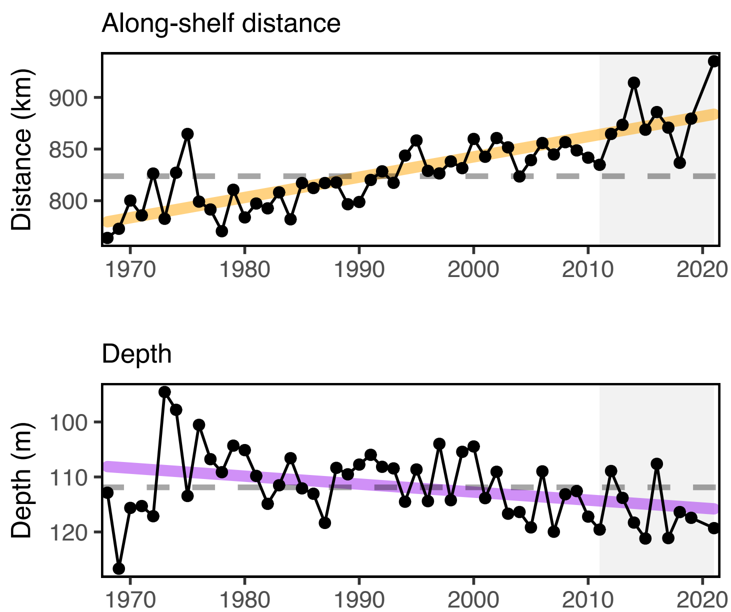


Figure 8: Aggregate species distribution metrics for species in the Northeast Large Marine Ecosystem.

- Some ecosystem composition and production changes have been observed (see Stability section).
- Some fishing communities are affected by environmental justice vulnerabilities (see Environmental Justice and Social Vulnerability section).

Commercial Profits

Indicators: revenue (a proxy for profits)

Total commercial revenues (black) within the Mid-Atlantic are not yet available for 2020; Figure 9 includes data only through 2019. However, we do not anticipate the long-term declining trend in revenue from managed species (red) to change. Coast-wide, a number of species managed by the MAFMC have seen decreases in revenue when compared to the average revenue generated between 2015 and 2019 [1]. This decline was driven by a mix of landings declines (monkfish, combined surfclam and ocean quahog) and price declines (monkfish, combined squid species, and combined summer flounder, scup, and black sea bass).

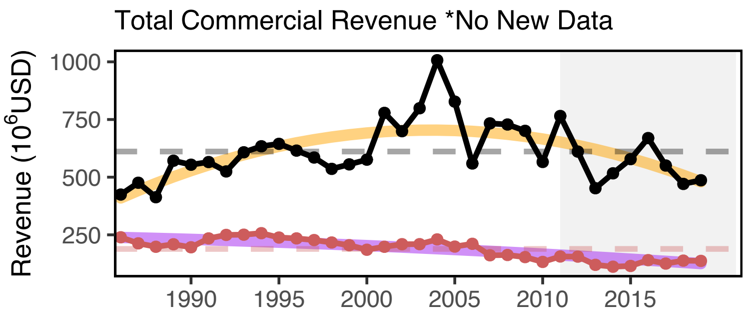


Figure 9: Revenue through 2019 for the for the Mid-Atlantic region: total (black) and from MAFMC managed species (red).

Implications

The Bennet indicator evaluating changes in landings volume and price for the Mid-Atlantic will be updated when 2020 Mid-Atlantic landings become available.

Changes in other indicators, particularly those driving landings and those related to climate change, require monitoring as they may become important drivers of revenue in the future; for example:

- Surfclams and ocean quahogs are sensitive to warming ocean temperatures and ocean acidification.
- Acidification levels in surfclam summer habitat are approaching, but not yet at, levels affecting surfclam growth (see Climate Risks section).

Recreational Opportunities

Indicators: Angler trips, fleet diversity

Recreational effort (angler trips) has increased over the long term, with 2020 effort above the long-term average (Fig. 10). However, recreational fleet diversity (i.e., effort by shoreside, private boat, and for-hire anglers) has declined over the long term (Fig. 11).

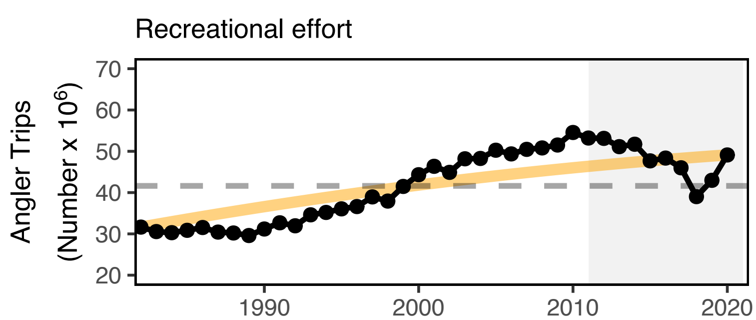


Figure 10: Recreational effort in the Mid-Atlantic.

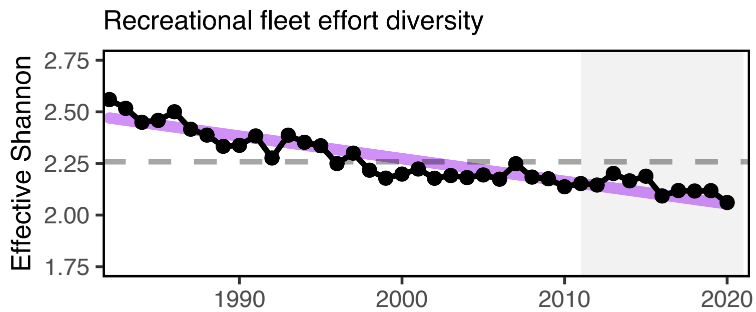


Figure 11: Recreational fleet effort diversity in the Mid-Atlantic.

Implications

Increased angler trips in 2020 relative to previous years strongly influence the long term increase in recreational effort. While the overall number of recreational opportunities in the MAB is above the long term average, the continuing decline in recreational fleet effort diversity suggests a potentially reduced range of recreational fishing options.

The downward effort diversity trend is driven by party/charter contraction (from a high of 24% of angler trips to 7% currently), and a shift toward shorebased angling. Effort in private boats remained stable between 36-37% of angler trips across the entire series.

Changes in recreational fleet diversity can be considered when managers seek options to maintain recreational opportunities. Shore anglers will have access to different species than vessel-based anglers, and when the same species is accessible both from shore and from a vessel, shore anglers typically have access to smaller individuals. Many states have developed shore-based regulations where the minimum size is lower than in other areas and sectors to maintain opportunities in the shore angling sector.

Stability

Indicators: fishery fleet and catch diversity, ecological component diversity

While there are many potential metrics of stability, we use diversity indices as a first check to evaluate overall stability in fisheries and ecosystems. In general, diversity that remains constant over time suggests a similar capacity to respond to change over time. A significant change in diversity over time does not necessarily indicate a problem or an improvement, but does indicate a need for further investigation. We examine commercial fleet and species catch diversity, and recreational species catch diversity (with fleet effort diversity discussed above), and diversity in zooplankton, and larval and adult fishes.

Fishery Diversity Diversity estimates have been developed for fleets landing managed species, and species landed by commercial vessels with Mid-Atlantic permits. A fleet is defined here as the combination of gear type (Scallop Dredge, Other Dredge, Gillnet, Hand Gear, Longline, Bottom Trawl, Midwater Trawl, Pot, Purse Seine, or Clam Dredge) and vessel length category (less than 30 ft, 30 to 50 ft, 50 to 75 ft, 75 ft and above). Commercial fishery fleet count and fleet diversity have been stable over time in the MAB, with current values near the long-term average (Fig. 12). This indicates similar commercial fleet composition and species targeting opportunities over time.

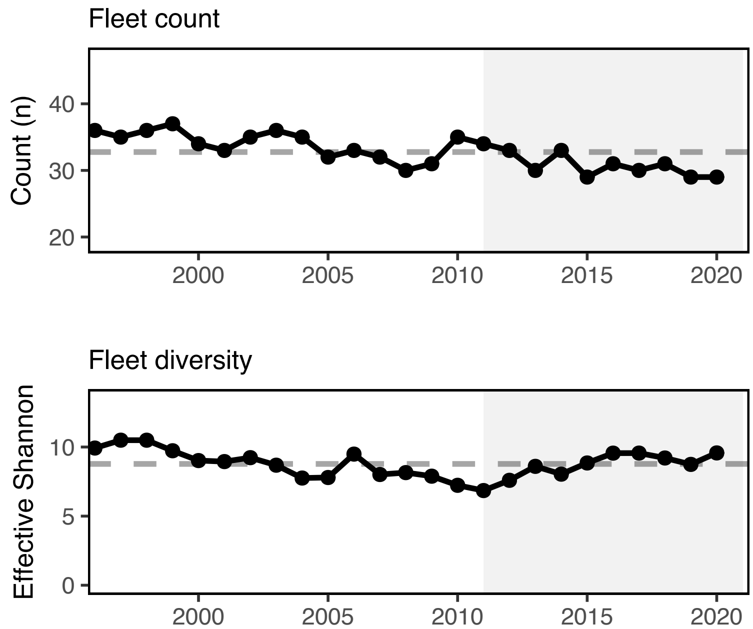


Figure 12: Commercial fleet count and diversity in the Mid-Atlantic.

Commercial fisheries are relying on fewer species relative to the mid-90s, but current species revenue diversity has been consistent since then and is currently near, but below, the long term average (Fig. 13).

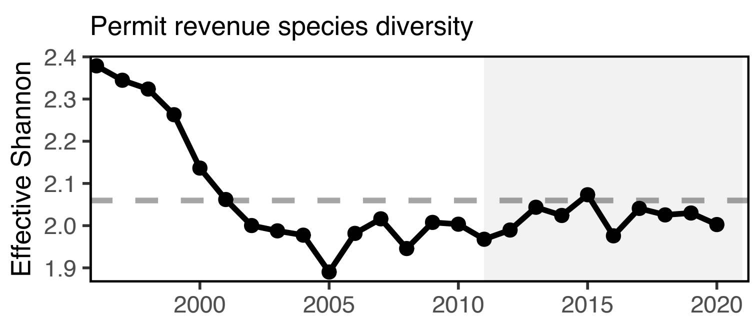


Figure 13: Species revenue diversity in the Mid-Atlantic.

As noted above, recreational fleet effort diversity is declining (Fig. 11), so this metric suggests an unstable range of recreational fishing opportunities. However, recreational species catch diversity has no long term trend so is considered stable, and has been at or above the long term average in 7 of the last 10 years (Fig. 14).

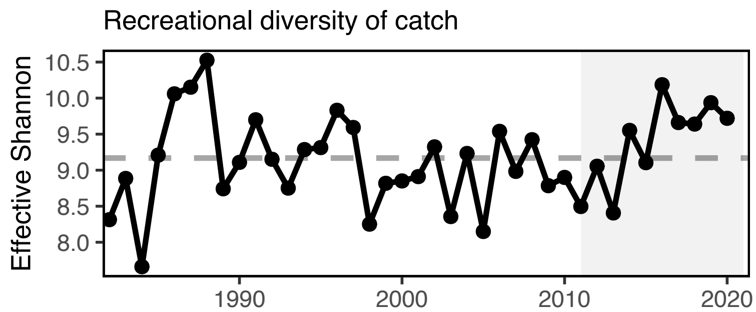


Figure 14: Diversity of recreational catch in the Mid-Atlantic.

Ecological Diversity Ecological diversity indices show mixed trends. Up to 2019, zooplankton diversity was increasing in the MAB (Fig. 15). 2020 surveys were incomplete due to COVID-19. Zooplankton and larval fish diversity indicators will be updated once 2021 survey results have been processed. Adult fish diversity is measured as the expected number of species in a standard number of individuals sampled from the NEFSC bottom trawl survey. There is no vessel correction for this metric, so indices collected aboard the research vessel Albatross IV (up to 2008) and research vessel Bigelow (2009-2021) are calculated separately. Despite this, adult fish diversity indices appear stable over time, with current values within one standard deviation from most historic estimates (Fig. 16).

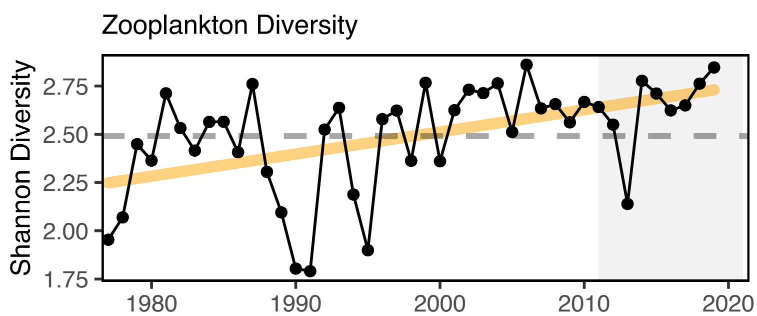


Figure 15: Zooplankton diversity in the Mid-Atlantic Bight up to 2019, based on Shannon diversity index.

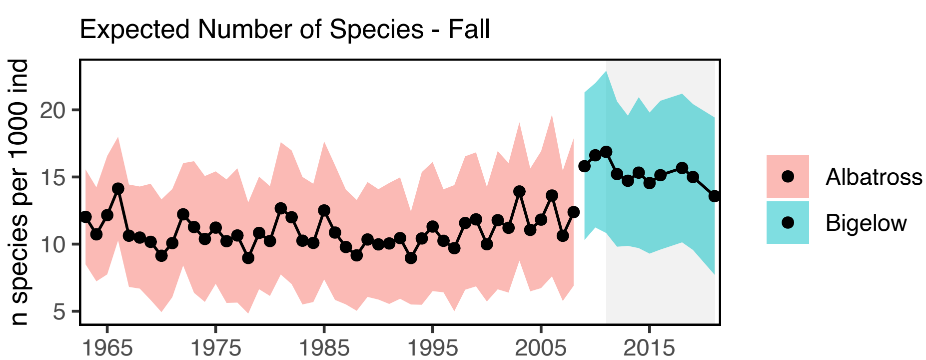


Figure 16: Adult fish diversity in the Mid-Atlantic Bight, based on expected number of species. Results from survey vessels Albatross and Bigelow are reported separately due to catchability differences.

Implications

Fleet diversity indices are used by the MAFMC to evaluate stability objectives as well as risks to fishery resilience and maintaining equity in access to fishery resources [2].

Stability in commercial fleet diversity metrics suggests stable capacity to respond to the current range of fishing opportunities.

Declining recreational fleet effort diversity, as noted above, indicates that the party/charter boat sector continues to contract, with shoreside angling becoming more important, as a percentage of recreational angler trips.

Stability in recreational species catch diversity has been maintained by a different set of species over time. A recent increase in Atlantic States Marine Fisheries Commission (ASMFC) and South Atlantic Fishery Management Council (SAFMC) managed species in recreational catch is helping to maintain diversity in the same range that MAFMC and New England Fishery Management Council (NEFMC) species supported in the 1990s.

Ecological diversity indices can provide insight into ecosystem structure. Changes in ecological diversity over time may indicate altered ecosystem structure with implications for fishery productivity and management [3].

Increasing zooplankton diversity through 2019 is driven by the declining dominance of the calanoid copepod *Centropages typicus*, with a similar composition of other zooplankton species.

Stable adult fish diversity indicates the same overall number and evenness over time, but doesn't rule out species substitutions (e.g., warm-water replacing cold-water). In addition, the change in survey vessels complicates interpretation of long term fish diversity trends.

In the MAB, existing diversity indicators suggest overall stability in the fisheries and ecosystem components examined. However, declining recreational fleet diversity suggests a potential loss in the range of recreational fishing opportunities, and increasing zooplankton diversity is due to the declining dominance of an important species, suggesting change in the zooplankton community that warrants continued monitoring to determine if managed species are affected.

Environmental Justice and Social Vulnerability

Indicators: Environmental Justice and Social Vulnerability in commercial and recreational fishing communities

Social vulnerability measures social factors that shape a community's ability to adapt to change. A subset of these can be used to assess potential environmental justice issues. Environmental Justice is defined in Executive Order 12898 as federal actions intended to address disproportionately high and adverse human health and environmental effects of federal actions on minority and low-income populations. Three of the existing NOAA Fisheries Community Social Vulnerability Indicators (CSVIs), the Poverty Index, Population Composition Index, and Personal Disruption Index, can be used for mandated Environmental Justice analysis[7].

Commercial fishery engagement measures the number of permits and dealers, and pounds and value landed in a community, while reliance expresses these numbers based on the level of fishing activity relative to the total population of a community. Recreational fishery engagement measures shore, private vessel, and for-hire fishing effort while reliance expresses these numbers based on fishing effort relative to the population of a community.

In 2021, we reported the top ten most engaged, and top ten most reliant commercial and recreational fishing communities and their associated social vulnerability. Here we apply the same selection standard for top ten fishing communities for both sectors, and focus on examining the environmental justice vulnerability in these communities.

Communities plotted in the upper right section of Fig.17 scored high for both commercial engagement and reliance, including Cape May and Barnegat Light, NJ, and Reedville, VA. Communities that ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange: Newport News, VA; Atlantic City, NJ; Hampton Bays/Shinnecock, NY; and Beaufort, Columbia and Hobucken, NC.

[7] https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-coastal-communities

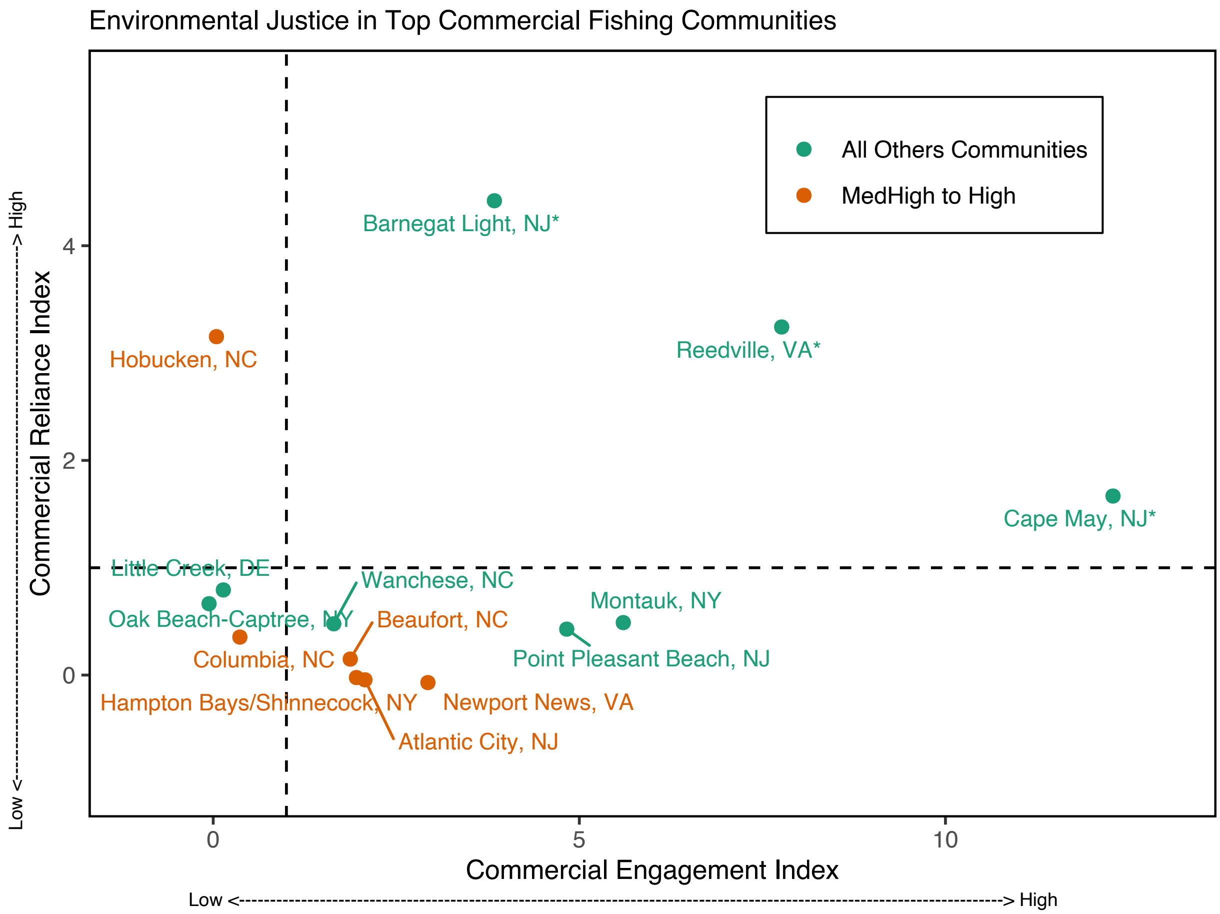


Figure 17: Commercial engagement, reliance, and environmental justice vulnerability for the top commercially engaged and reliant fishing communities in the Mid-Atlantic. Communities ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange. *Community scored high (1.00 and above) for both commercial engagement and reliance indicators.

Fig. 18 shows the detailed scores of the three environmental justice indicators for the same communities plotted in Fig.17. Communities are plotted clockwise in a descending order of commercial engagement scores from high to low, with the most highly engaged community, Cape May, NJ, listed on the top. Among the communities ranked medium-high or above for environmental justice vulnerability, Newport News, VA scored medium-high for the population composition index. Atlantic City, NJ scored high for all of the three environmental justice indicators. Hampton Bays/Shinnecock, NY scored medium-high for the population composition index. Beaufort, NC scored medium-high and very close to high for the poverty index. Columbia, NC scored high for the personal disruption index and the poverty index, and medium-high for the population composition index. Hobucken, NC scored high for the personal disruption index and the poverty index.

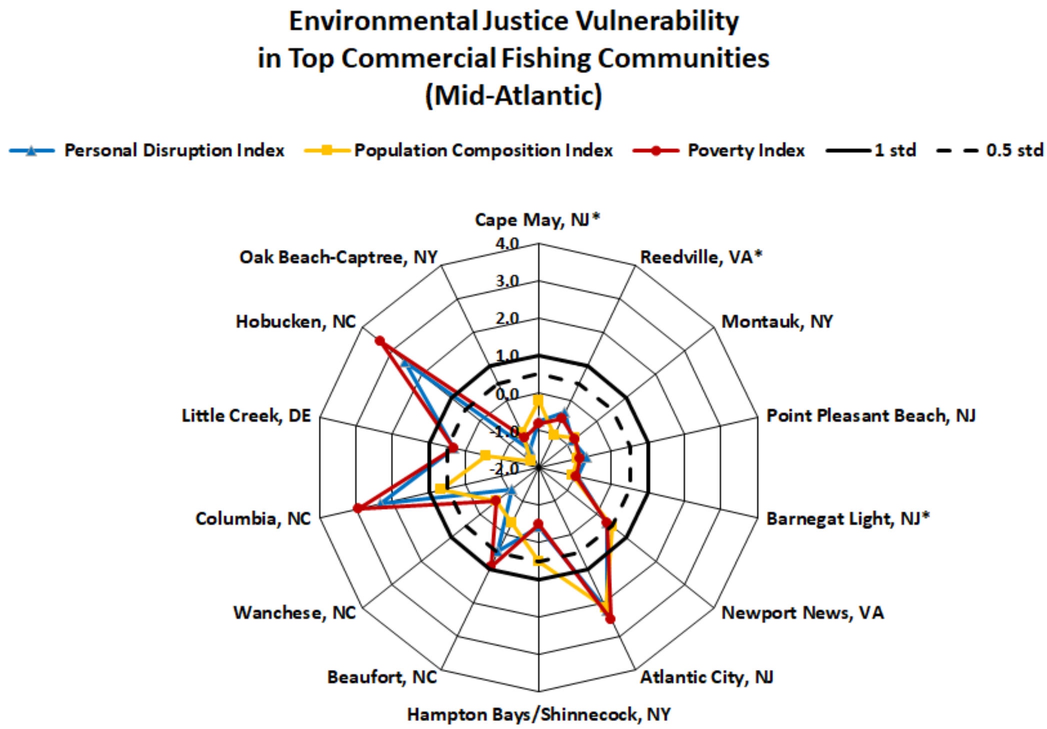


Figure 18: Environmental justice indicators (Poverty Index, population composition index, and personal disruption index) for top commercial fishing communities in Mid-Atlantic. *Community scored high (1.00 and above) for both commercial engagement and reliance indicators.

Communities plotted in the upper right section of Fig.19 scored high for both recreational engagement and reliance, including Barnegat Light, NJ and Deal Island, MD. Communities that ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange: Hatteras and Morehead City, NC.

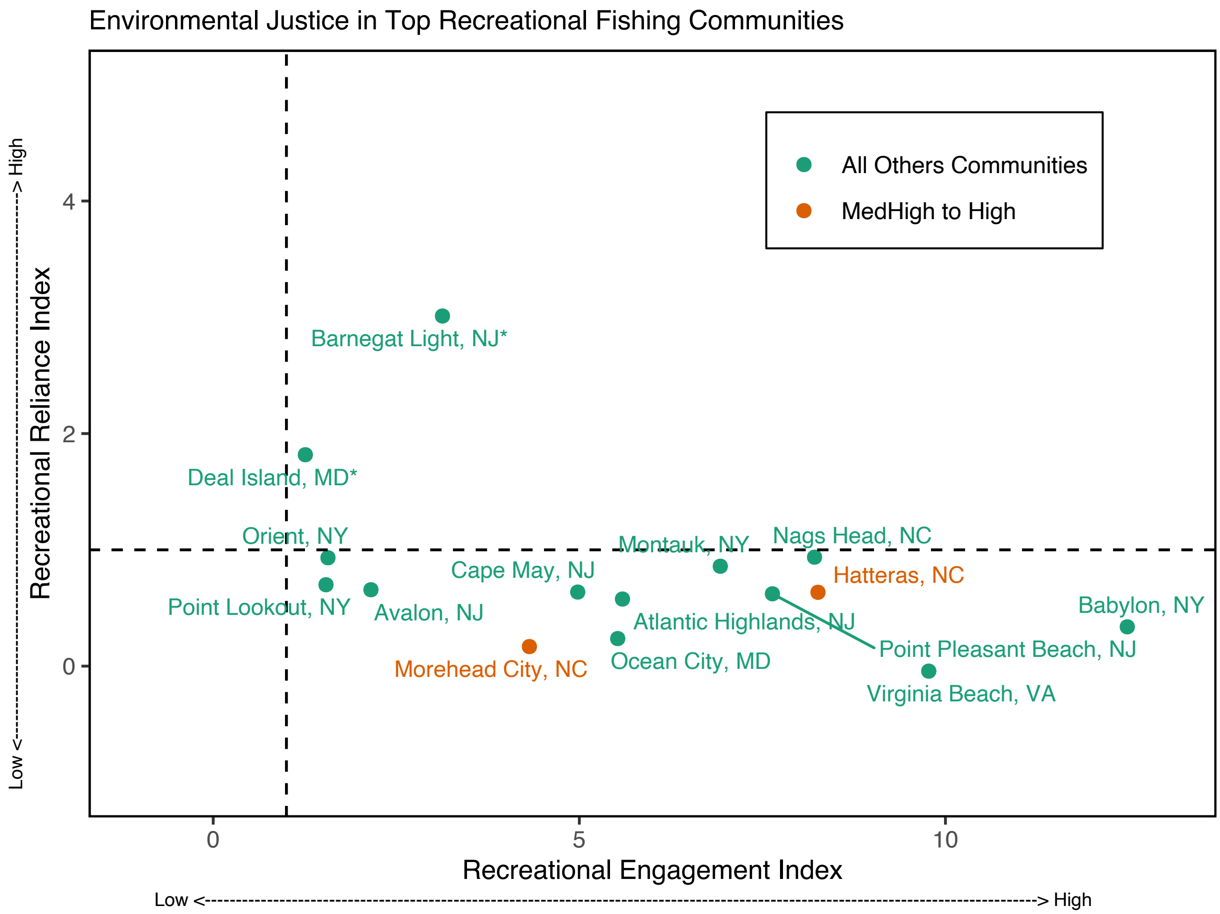


Figure 19: Recreational engagement and reliance, and environmental justice vulnerability, for the top recreationally engaged and reliant fishing communities in the Mid-Atlantic. Communities ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange. *Community scored high (1.00 and above) for both recreational engagement and reliance indicators.

Fig. 20 orders communities clockwise in a descending order of recreational engagement scores from high to low, with the most highly engaged community, Babylon, NY, listed on the top. The two communities with environmental justice concerns, Hatteras and Morehead City, NC, both scored medium-high for the poverty index.

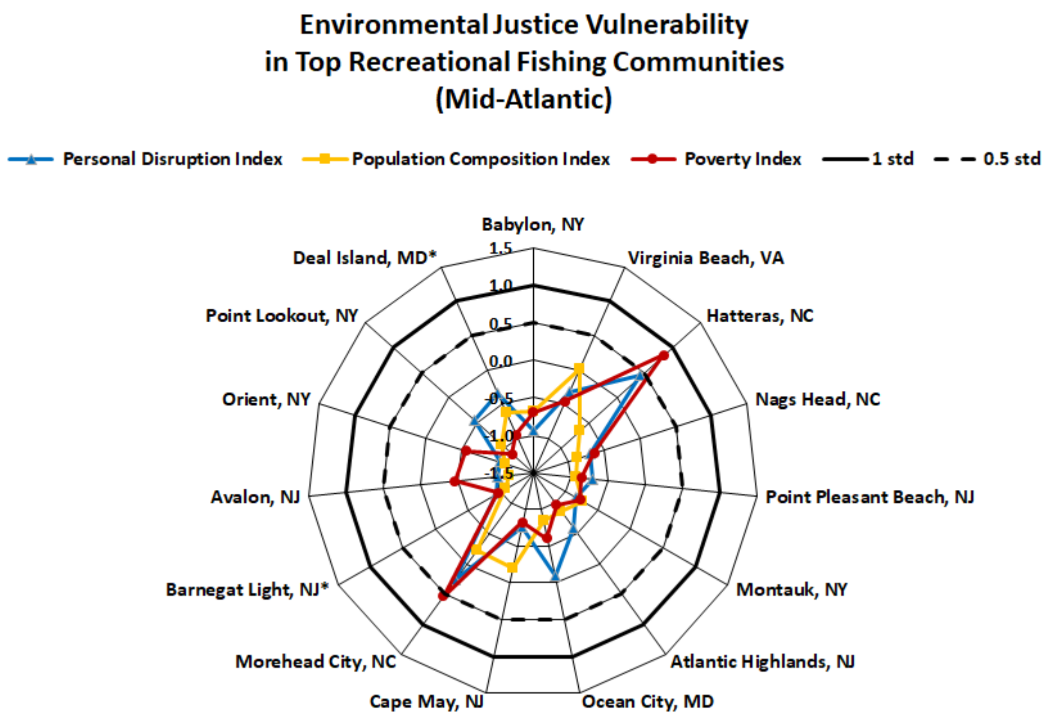


Figure 20: Environmental justice indicators (Poverty Index, population composition index, and personal disruption index) for top recreational fishing communities in Mid-Atlantic. *Community scored high (1.00 and above) for both recreational engagement and reliance indicators.

Both commercial and recreational fishing are important activities in Montauk, NY, Barnegat Light, Cape May and Point Pleasant Beach, NJ, meaning these communities may be impacted simultaneously by commercial and recreational regulatory changes. All of these communities scored lower than medium-high for all of the three environmental justice indicators, indicating that environmental justice may not be a major concern in these communities at the moment based on the indicators analyzed.

Implications

These plots provide a snapshot of the presence of environmental justice issues in the most highly engaged and most highly reliant commercial and recreational fishing communities in the Mid-Atlantic. These communities may be vulnerable to changes in fishing patterns due to regulations and/or climate change. When any of these communities are also experiencing social vulnerability including environmental justice issues, they may have lower ability to successfully respond to change.

Protected Species

Protected species include marine mammals protected under the Marine Mammal Protection Act, endangered and threatened species protected under the Endangered Species Act, and migratory birds protected under the Migratory Bird Treaty Act. In the Northeast U.S., endangered/threatened species include Atlantic salmon, Atlantic and shortnose sturgeon, all sea turtle species, and five baleen whales. Fishery management objectives for protected species generally focus on reducing threats and on habitat conservation/restoration. Here we report on the status of these actions as well as indicating the potential for future interactions driven by observed and predicted ecosystem changes in the Northeast U.S. Protected species objectives include managing bycatch to remain below potential biological removal (PBR) thresholds, recovering endangered populations, and monitoring unusual mortality events (UMEs).

Indicators: bycatch, population (adult and juvenile) numbers, mortalities

As of 2019, rolling 5 year average bycatch indices for both harbor porpoise and gray seal bycatch were below current PBR thresholds, thus meeting management objectives. However, the 2019 bycatch estimate for gray seals was the highest in the time series and above PBR for that year (see 2021 report[8]). Bycatch indices were not updated because of low 2020 observer coverage caused by COVID-19 restrictions.

The North Atlantic right whale population was on a recovery trajectory until 2010, but has since declined (Fig. 21). Reduced survival rates of adult females and diverging abundance trends between sexes have also been observed. It is estimated that there are fewer than 100 adult females remaining in the population.

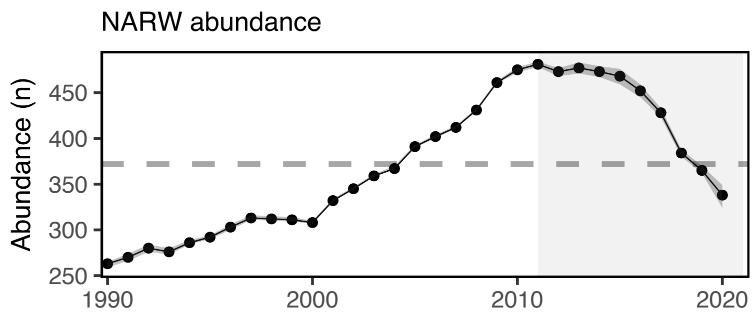


Figure 21: Estimated North Atlanic right whale abundance on the Northeast Shelf.

North Atlantic right whale calf counts have generally declined after 2009 to the point of having zero new calves observed in 2018 (Fig. 22). However, seven new calves were born in 2019, 10 were born in 2020, and preliminary 2021 observations of 18 calves have been recorded as of January 2022.

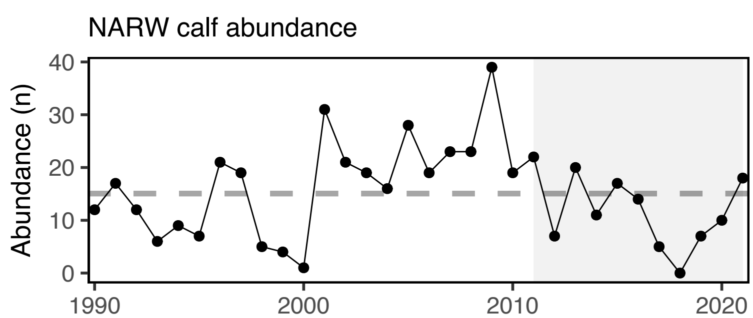


Figure 22: Number of North Atlantic right whale calf births, 1990 - 2021.

This year, the Unusual Mortality Event (UME) for North Atlantic right whales continued. Since 2017, the total UME right whale mortalities includes 34 dead stranded whales, 13 in the US and 21 in Canada. When alive but seriously injured whales (16) are taken into account, 50 individual whales are included in the UME. During 2020, two mortalities were documented, however, recent research suggests that many mortalities go unobserved and the true number of mortalities are about three times the count of the observed mortalities [4]. The primary cause of death is "human interaction" from entanglements or vessel strikes[9].

Two additional UMEs continued from previous years for humpback whales and minke whales; suspected causes include human interactions and/or infectious disease. A UME for both gray and harbor seals was declared from

[8] https://repository.library.noaa.gov/view/noaa/29525
[9] https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2022-north-atlantic-right-whale-unusual-mortality-event

2018-2020 due to a high number of mortalities thought to be caused by phocine distemper virus, but is pending closure as of January 2022[10].

Implications

Bycatch management measures have been implemented to maintain bycatch below PBR thresholds. The downward trend in harbor porpoise bycatch could also be due to a decrease in harbor porpoise abundance in US waters, reducing their overlap with fisheries, and a decrease in gillnet effort. The increasing trend in gray seal bycatch may be related to an increase in the gray seal population (U.S. pup counts).

The number of gray seals in U.S. waters has risen dramatically in the last three decades. Based on a survey conducted in 2016, the size of the gray seal population in the U.S. during the breeding season was approximately 27,000 animals, while in Canada the population was estimated to be roughly 425,000. The population in Canada is increasing at roughly 4% per year, and contributing to rates of increase in the U.S., where the number of pupping sites has increased from one in 1988 to nine in 2019. Mean rates of increase in the number of pups born at various times since 1988 at four of the more data-rich pupping sites (Muskeget, Monomoy, Seal, and Green Islands) ranged from no change on Green Island to high rates of increase on the other three islands, with a maximum increase of 26.3% (95%CI: 21.6 - 31.4%; [5], and see the 2021 New England report[11]). These high rates of increase provide further support for the hypothesis that seals from Canada are continually supplementing the breeding population in U.S. waters.

Strong evidence exists to suggest that interactions between right whales and both the fixed gear fisheries in the U.S. and Canada and vessel strikes in the U.S. are contributing substantially to the decline of the species [6]. Further, right whale distribution has changed since 2010. New research suggests that recent climate driven changes in ocean circulation have resulted in right whale distribution changes driven by increased warm water influx through the Northeast Channel, which has reduced the primary right whale prey (*Calanus finmarchicus*) in the central and eastern portions of the Gulf of Maine [6–8]. Additional potential stressors include offshore wind development, which overlaps with important habitat areas used year-round by right whales, including mother and calf migration corridors and foraging habitat [9,10]. This area is also the only known right whale winter foraging habitat. Additional information can be found in the offshore wind risks section.

The UMEs are under investigation and are likely the result of multiple drivers. For all three large whale UMEs, human interaction appears to have contributed to increased mortalities, although investigations are not complete. An investigation into the cause of the seal UME so far suggests phocine distemper virus as a potential cause.

A climate vulnerability assessment is currently underway for Atlantic and Gulf of Mexico marine mammal populations and will be reported on in future versions of this report.

Risks to meeting fishery management objectives

Climate and Ecosystem Productivity

Large scale climate related changes in the ecosystem can lead to changes in important habitats and ecological interactions, potentially resulting in regime shifts and ecosystem reorganization.

Climate Change Indicators: ocean temperature, heatwaves, currents, acidification

Ocean and estuarine temperature and salinity Ocean temperatures continue to warm at both the surface (Fig. 23) and bottom (Fig. 24) throughout the Northeast Shelf including the Mid-Atlantic. Seasonal sea surface temperatures in 2021 were above average throughout the year, with some seasons rivaling or exceeding the record warm temperatures observed in 2012.

[10] https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events
[11] https://repository.library.noaa.gov/view/noaa/29524

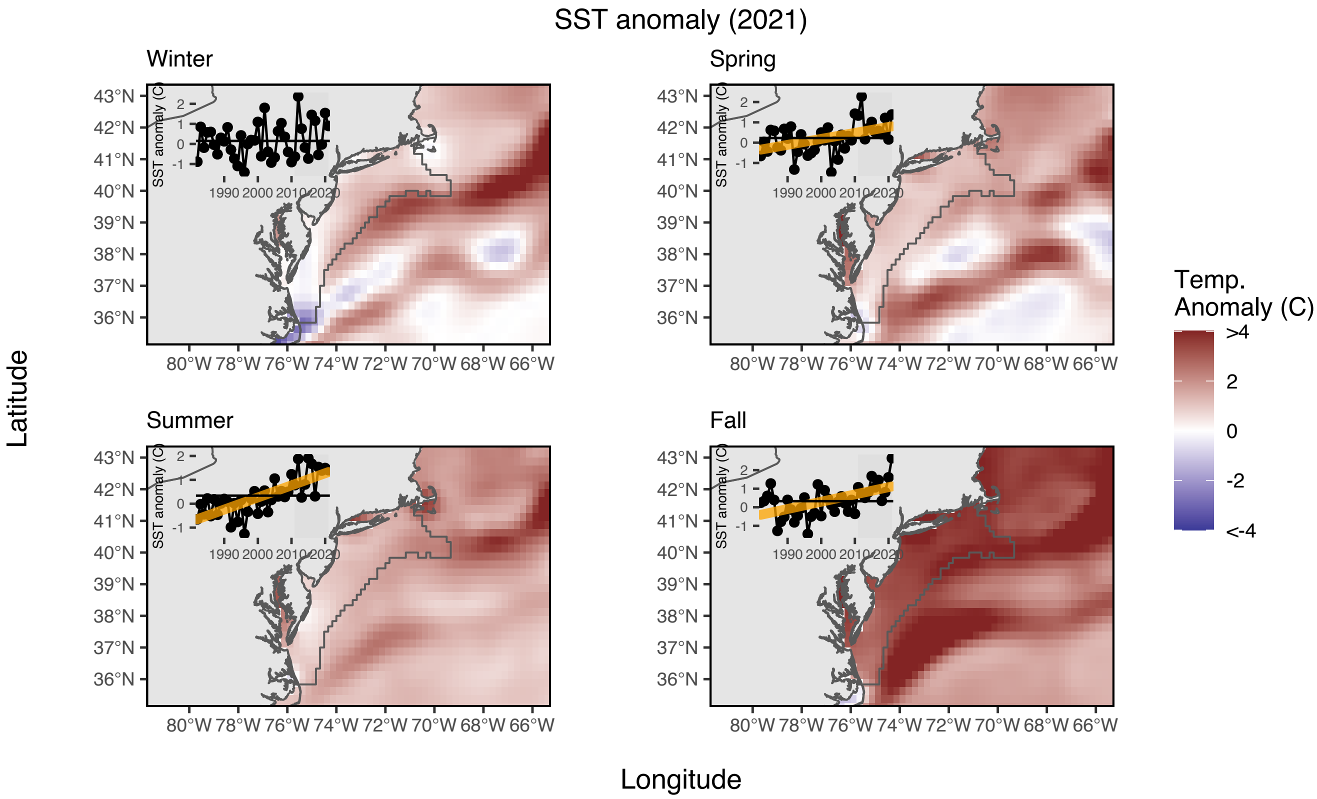


Figure 23: MAB (grey outline) seasonal sea surface temperature (SST) time series overlaid onto 2021 seasonal spatial anomalies. Seasons are defined as: Jan-Mar for winter, Apr-Jun for spring, Jul-Sep for summer, and Oct-Dec for fall.

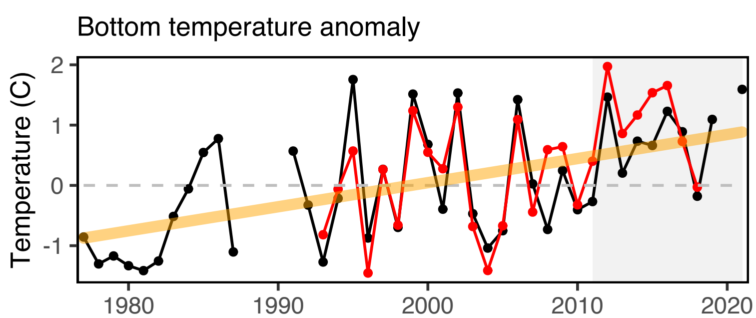


Figure 24: Annual bottom temperature in the MAB (black = in situ observations, red = observations from modeled reanalysis for comparison).

The Chesapeake Bay experienced a warmer-than-average winter and fall in 2021, and average conditions in the spring and summer, relative to the baseline period 2008-2020 (Fig. 25) as measured by satellites[12] (note that Chesapeake Bay seasonal definitions and baseline periods are different from the sea surface temperature anomalies reported in Fig.23 for the full Mid-Atlantic region). Similar 2021 seasonal temperature patterns were observed by bouys[13] (Fig. 25), which also indicated above-average salinity in the Chesapeake Bay throughout the summer, with a decrease in salinity from late July to early August (Fig. 25). Salinity fell below average in September and remained at lower levels throughout fall 2021.

[12]https://coastwatch.noaa.gov/cw/index.html
[13]https://buoybay.noaa.gov/

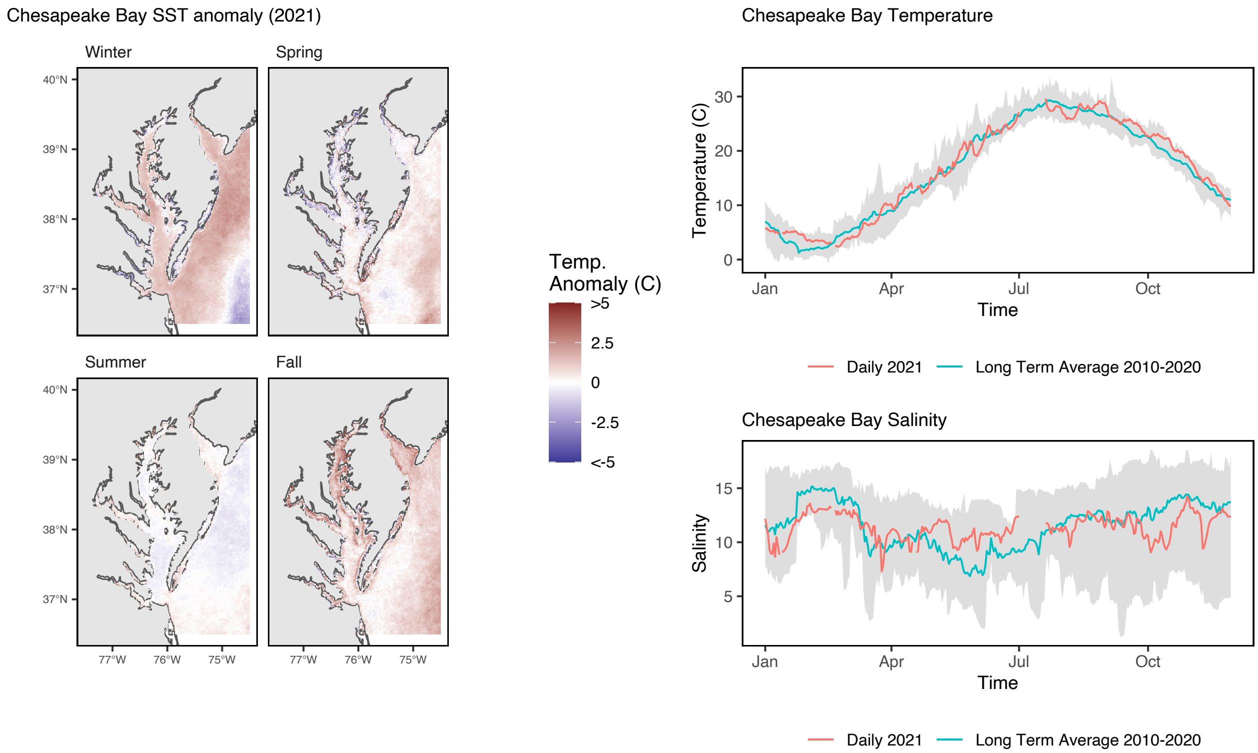


Figure 25: Left panel: 2021 sea surface temperature anomalies for the Chesapeake Bay. Data are from NOAA's multi-satellite SST products and produced by NOAA's Coastwatch Program. Seasons are defined to match the annual life cycles of many biological resources in Chesapeake Bay: Dec-Feb for winter, Mar-May for spring, Jun-Aug for summer, and Sep-Nov for fall. Right panel: NOAA Chesapeake Bay Interpretive Buoy System Gooses Reef bouy sea water temperature (top) and salinity (bottom); Red = 2021, Blue = Long term average 2010-2020.

Marine heatwaves A marine heatwave is a warming event that lasts for five or more days with sea surface temperatures warmer than 90% of previously observed (1982-2011) temperatures for that date [11]. Marine heatwaves measure not just high temperature, but how long the ecosystem is subjected to the high temperature. They are driven by both atmospheric and oceanographic factors and can have dramatic impacts on marine ecosystems. The region is experiencing more frequent marine heatwaves over the last decade, including 2021, compared to the historical period.

In 2021, the Mid-Atlantic Bight experienced seven distinct marine heatwaves with the strongest event beginning on September 13 and lasting 53 days (Fig. 26). Relative to prior years, this marine heatwave ranked 9^{th} on record in terms of maximum intensity and 4^{th} on record in terms of cumulative intensity.

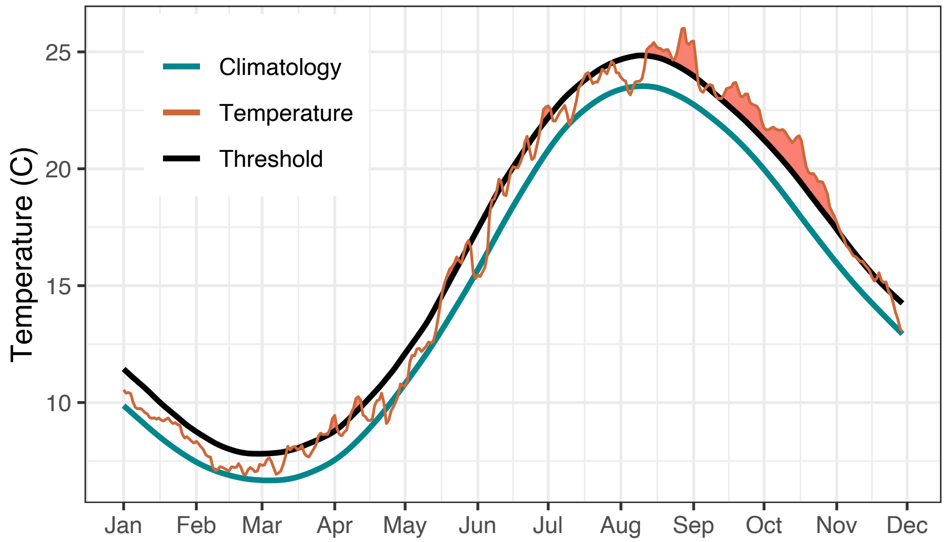


Figure 26: Marine heatwave events (red shading above black line) in the Mid-Atlantic occuring in 2021.

Ocean currents and features Variability of the Gulf Stream is one of the major drivers of changes in the oceanographic conditions of the Slope Sea and subsequently the Northeast U.S. continental shelf [12]. Changes in the Gulf Stream and Slope Sea can affect large-scale climate phenomena as well as local ecosystems and coastal communities. During the last decade, the Gulf Stream has become less stable and shifted northward [13,14] (Fig. 27). A more northern Gulf Stream position is associated with warmer ocean temperature on the northeast shelf [15], a higher proportion of Warm Slope Water in the Northeast Channel, and increased sea surface height along the U.S. east coast [16].

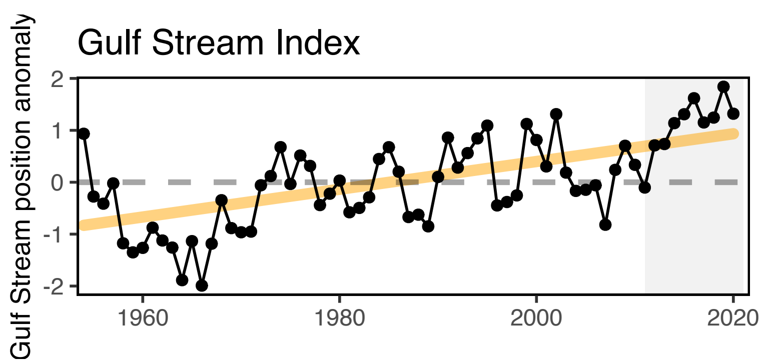


Figure 27: Index representing changes in the location of the Gulf Stream north wall. Positive values represent a more northerly Gulf Stream position.

Since 2008, the Gulf Stream has moved closer to the Grand Banks, reducing the supply of cold, fresh, and oxygen-rich Labrador Current waters to the Northwest Atlantic Shelf [17]. Nearly every year since 2010, warm slope water made up more than 75% of the annual slope water proportions entering the Gulf of Maine. In 2017 and 2019, almost no cooler Labrador Slope water entered the Gulf of Maine through the Northeast Channel (Fig. 28). The changing proportions of source water affect the temperature, salinity, and nutrient inputs to the Gulf of Maine ecosystem. In 2021, warm slope water continued to dominate (86.1%) inputs to the Gulf of Maine. The 2022 position of the north wall of the Gulf Stream is forecasted to be similar to 2021 [18], extending this pattern.

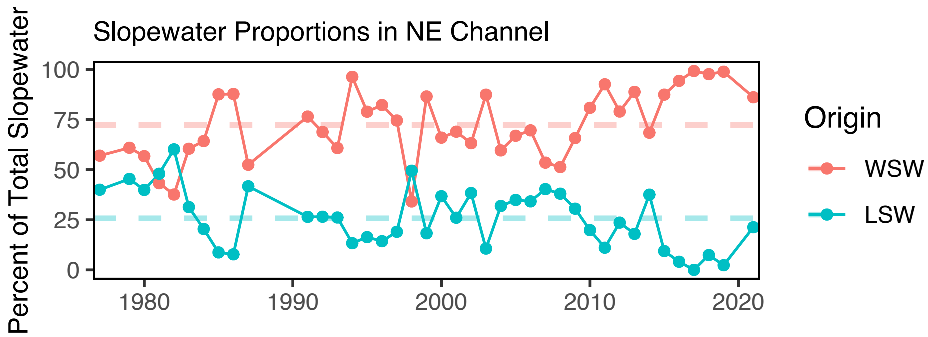


Figure 28: Proportion of Warm Slope Water (WSW) and Labrador Slope Water (LSLW) entering the Gulf of Maine through the Northeast Channel.

The increased instability of the Gulf Stream position and warming of the Slope Sea may also be connected to the regime shift increase in the number of warm core rings formed annually in the Northwest Atlantic [12,19] (Fig. 29). Timing of ring formation may also be changing. In 2021, a remarkable number of rings were observed simultaneously near the shelf break in June. When warm core ring water moves onto the continental shelf, it can alter the habitat and disrupt seasonal movements of fish [20].

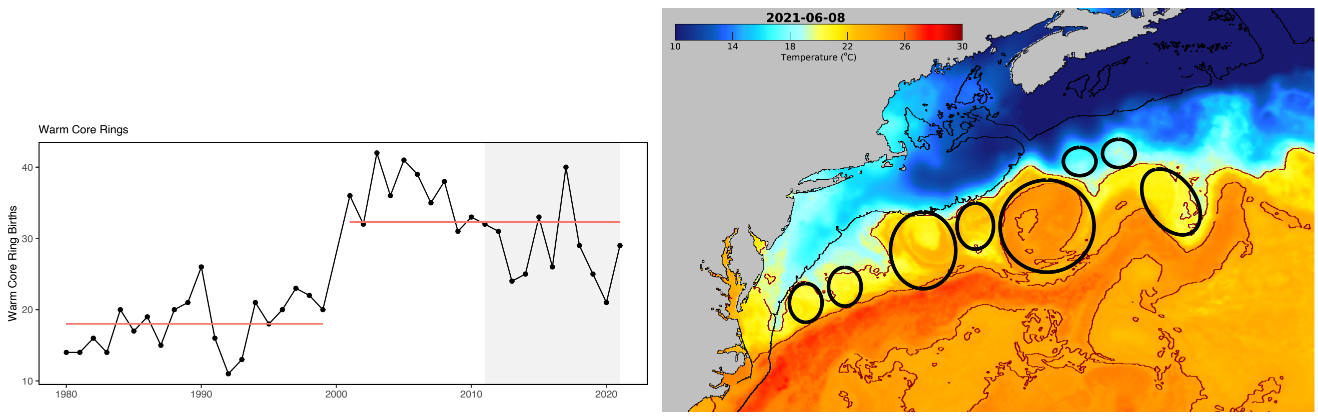


Figure 29: Warm core ring formation on the Northeast U.S. Shelf: Annual number of rings (left) and June 2021 rings (right), where the black line is the 200 m isobath (the shelf break) and the red lines are the 20 and 24 degree isotherms.

When warm core rings and eddies interact with the continental slope they can transport warm, salty water to the continental shelf [21], and this is now happening more frequently [20,22]. These interactions can be significant contributors to marine heatwaves in the Mid-Atlantic Bight [21,23] as well as the movement of shelf-break species inshore [20,24,25].

Changes in ocean temperature and circulation alter habitat features such as the seasonal cold pool, a 20–60 m thick band of cold, relatively uniform near-bottom water that persists from spring to fall over the mid and outer shelf of the MAB and southern flank of Georges Bank [26,27]. The cold pool plays an essential role in the structuring of the MAB ecosystem. It is a reservoir of nutrients that feeds phytoplankton productivity, is essential fish spawning and nursery habitat, and affects fish distribution and behavior [26,28]. The average temperature of the cold pool is getting warmer over time [29,30], the area is getting smaller [31], and the duration is getting shorter (Fig. 30).

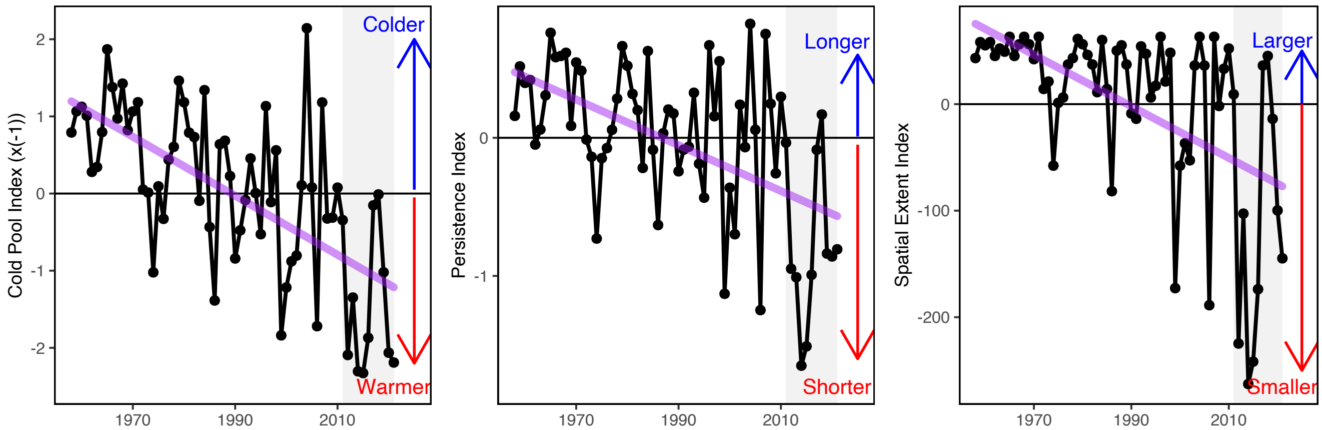


Figure 30: Seasonal cold pool indices: mean temperature within the cold pool, cold pool persistence, and spatial extent.

Ocean Acidification Ocean acidification (OA) has caused measured declines in global ocean pH. On the Northeast Shelf, summer bottom pH (2007-2021) varied spatially and temporally, ranging from 7.69-8.07 (Fig. 31, left panel). The lowest pH values were recorded in western Long Island Sound, and nearshore to mid-shelf waters off the coast of New Jersey. In summer 2021, water column pH from the glider-based profiles ranged from 7.67-8.22 (Fig. 31, right panel). The lowest pH occurred in bottom waters, reaching minimum values in shallow waters typically inhabited by Atlantic surfclams (27-56 m) in the southern flank of the Hudson Canyon (mean pH = 7.80).

This seasonal pH minimum in the Mid-Atlantic is associated with cold pool subsurface and bottom water, which is cut off from mixing with surface water by strong stratification. Fall mixing and slope water intrusions act to increase the pH in outer shelf waters [32].

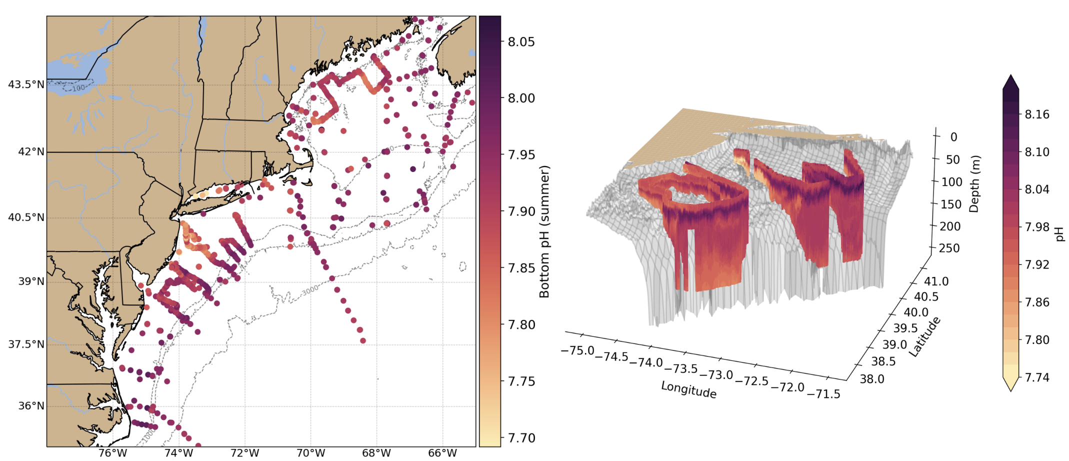


Figure 31: Left: Summer bottom pH collated from all quality-controlled vessel- and glider-based measurements from 2007-2021. Right: Glider-based pH profiles collected during summer 2021 in the Mid-Atlantic.

Ecosystem Productivity Indicators: phytoplankton, zooplankton, forage fish, fish condition

Phytoplankton Phytoplankton support the food web as the primary food source for zooplankton and filter feeders such as shellfish. Numerous environmental and oceanographic factors interact to drive the abundance, composition, spatial distribution, and productivity of phytoplankton. In 2021, MAB phytoplankton biomass (surface chlorophyll) was above average in winter, but below average during the spring and summer months. Below average phytoplankton biomass could be due to reduced nutrient flow to the surface and/or increased grazing pressure. A short fall bloom was detected in November. Primary productivity (the rate of photosynthesis) was average to below average throughout 2021 (Fig. 32).

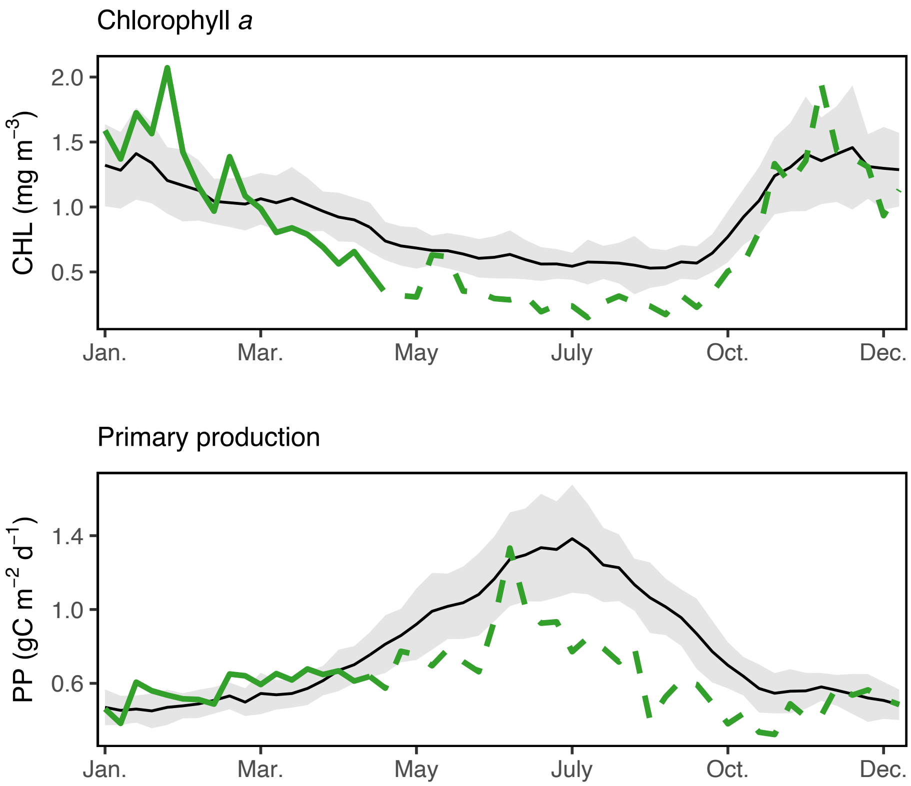


Figure 32: Weekly chlorophyll concentrations and primary productivity in the Mid-Atlantic are shown by the colored line for 2021 (dashed portion indicates preliminary data from a near real-time satellite source). The long-term mean is shown in black and shading indicates +/- 1 standard deviation.

The seasonal cycle of phytoplankton size distribution shows that the spring and fall bloom periods are dominated by larger-celled microplankton, while smaller-celled nanoplankton dominate during the warmer summer months. The proportion of the smallest phytoplankton, picoplankton (0.2-2 microns), is relatively constant throughout the year. In 2021, microplankton proportions were above average during the winter and fall bloom periods, but below average for the summer months (Fig. 33).

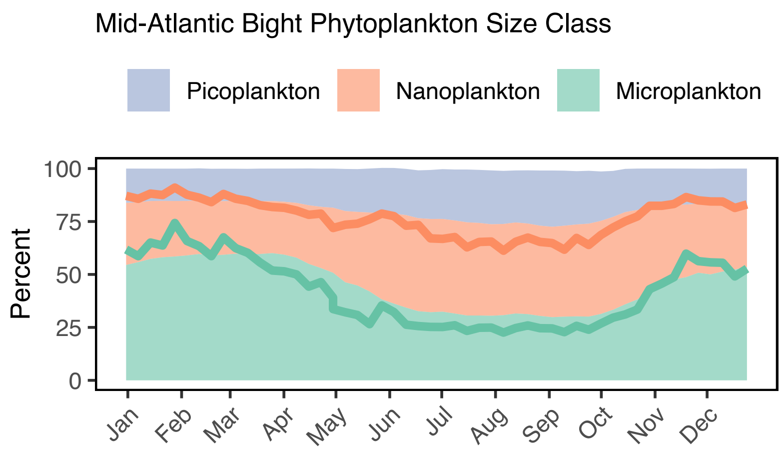


Figure 33: The annual climatology (1998-2020) percent composition of the phytoplankton size classes in the Mid-Atlantic based on satellite observations in the shaded portions. The 2021 proportions for the microplankton (>20 microns, green) and nanoplankton (2-20 microns, orange) are shown in the bold lines.

Zooplankton While zooplankton indicators could not be updated for this report due to 2020 survey disruptions and lags in sample processing, data up to 2019 showed long-term increasing trends of gelatinous zooplankton and krill on the northeast shelf (see 2021 report[14]). Preliminary 2021 observations found the total volume of plankton caught in the bongo net was significantly greater than the previous years due to increased gelatinous zooplankton, predominantly salps (*Thalia democratica*). Unusually high concentrations of salps were found throughout the Northeast shelf and in the Slope Sea during other summer 2021 scientific surveys, which may be associated with water mass intrusions at the shelf break [33,34]. Salps are filter feeders feeding on phytoplankton and other small particles and may have contributed to the below average phytoplankton biomass in summer 2021 (Fig. 32).

Forage Fish Energy Content Nutritional value (energy content) of juvenile and adult forage fish as prey is related to environmental conditions, fish growth, and reproductive cycles. Forage energy density measurements from NEFSC trawl surveys 2017-2021 are building toward a time series to evaluate trends (Fig. 34). Limited data from the spring 2020 survey, and complete spring 2021 survey measurements were consistent with previous reports: the energy density of Atlantic herring was almost half the value (5.69 +/- 0.07 kJ/g wet weight) reported in earlier studies (10.6-9.4 kJ/ g wet weight). Silver hake, longfin squid (*Loligo* in figure) and shortfin squid (*Illex* in figure) were also lower than previous estimates [35,36]. Energy density of alewife, butterfish, sand lance, and Atlantic mackerel varies seasonally, with seasonal estimates both higher and lower than estimates from previous decades.

[14] https://repository.library.noaa.gov/view/noaa/29525

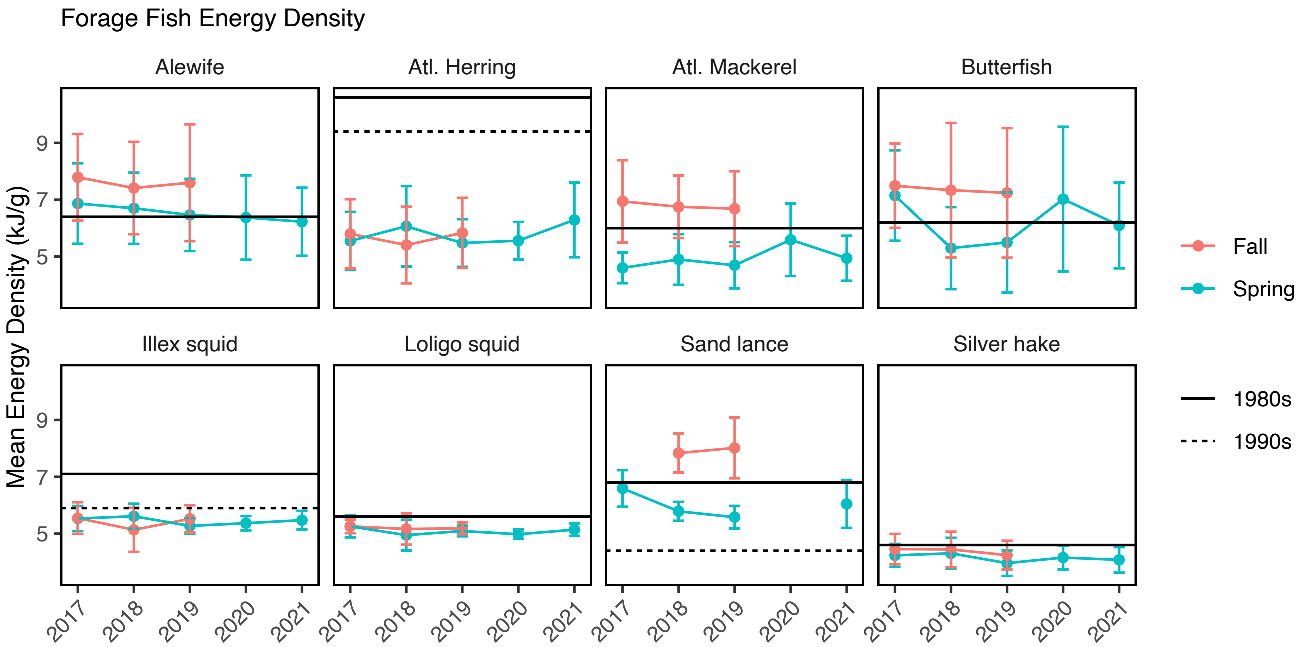


Figure 34: Forage fish energy density mean and standard deviation by season and year, compared with 1980s (solid line; Steimle and Terranove 1985) and 1990s (dashed line; Lawson et al. 1998) values.

Fish Condition The health and well being of individual fish can be related to body shape condition indices (i.e., weight at a given length) such as relative condition index, which is the ratio of observed weight to predicted weight based on length [37]. Heavier and fatter fish at a given length have higher relative condition which is expected to improve growth, reproductive output, and survival. A pattern of generally good condition was observed across many MAB species prior to 2000, followed by a period of generally poor condition from 2001-2010, with a mix of good and poor condition 2011-2019. However, most species in the MAB had below average or poor condition again in 2021 (Fig. 35). Preliminary results of synthetic analyses show that changes in temperature, zooplankton, fishing pressure, and population size influence the condition of different fish species.

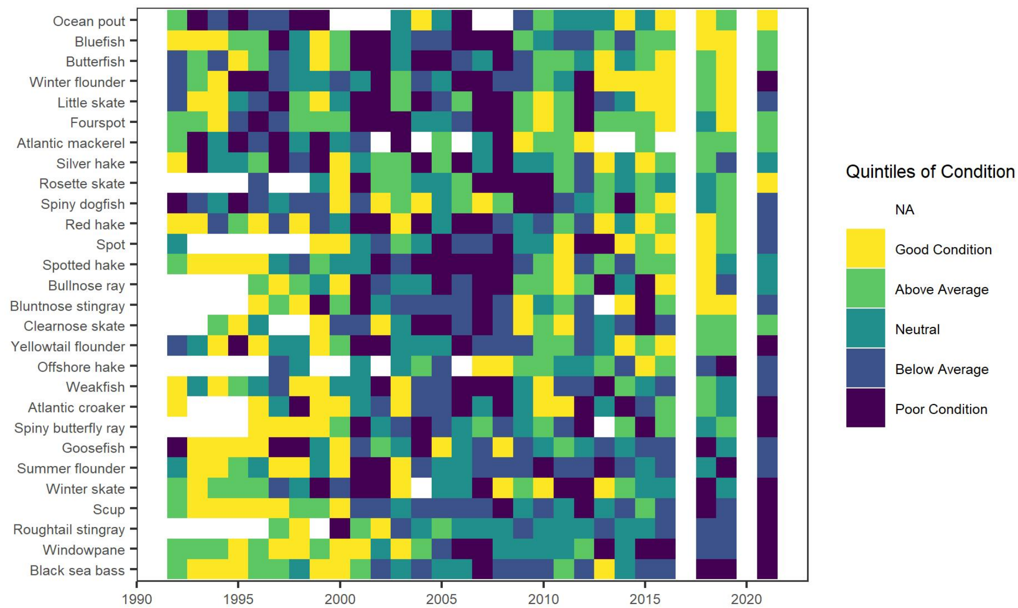


Figure 35: Condition factor for fish species in the MAB based on fall NEFSC bottom trawl survey data. MAB data are missing for 2017 due to survey delays, and no survey was conducted in 2020.

Fish Productivity We describe patterns of aggregate fish productivity in the Mid-Atlantic with the small fish per large fish anomaly indicator, derived from NEFSC bottom trawl survey data (Fig. 36). The indicator shows that productivity has been declining in this region since 2010.

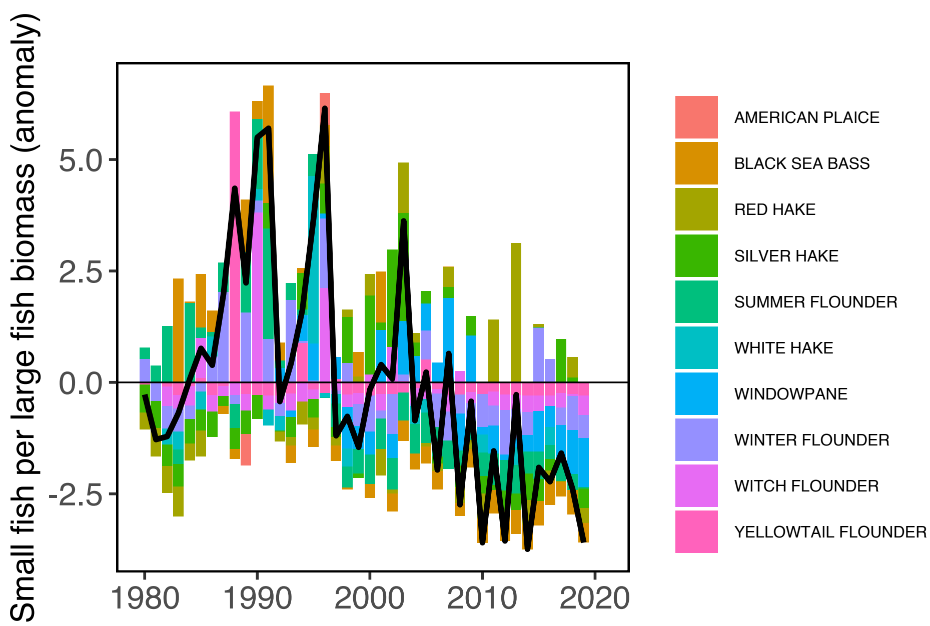


Figure 36: Small fish per large fish biomass anomaly in the Mid-Atlantic Bight. The summed anomaly across species is shown by the black line.

Ecosystem Structure Indicators: distribution shifts, diversity, predators

As noted in the Landings Implications section above, stocks are shifting distribution throughout the region. In aggregate, fish stocks are moving northeast along the shelf and into deeper waters.

Zooplankton diversity was increasing in the MAB as of 2019, while adult fish diversity indices appear stable over time, with current values within one standard deviation from most historic estimates (see Diversity Indicators section, above).

New indicators for shark populations, combined with information on gray seals (see Protected Species Implications section, above), suggests predator populations range from stable (sharks, Fig. 37) to increasing (seals) in the MAB. Stable predator populations suggest stable predation pressure on managed species, but increasing predator populations may reflect increasing predation pressure.

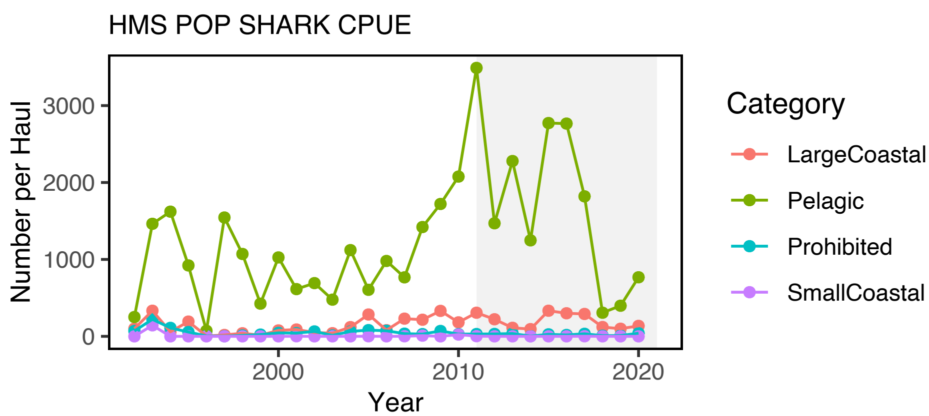


Figure 37: Estimated number of sharks per unit effort from Highly Migratory Species Pelagic Observer Program data.

Stock status is mixed for Atlantic Highly Migratory Species (HMS) stocks (including sharks, swordfish, billfish, and tunas) occurring in the Mid-Atlantic region. While there are several HMS species considered to be overfished or that have unknown stock status, the population status for some managed Atlantic sharks and tunas is at or above the biomass target (Fig. 38), suggesting the potential for robust predator populations among these managed species.

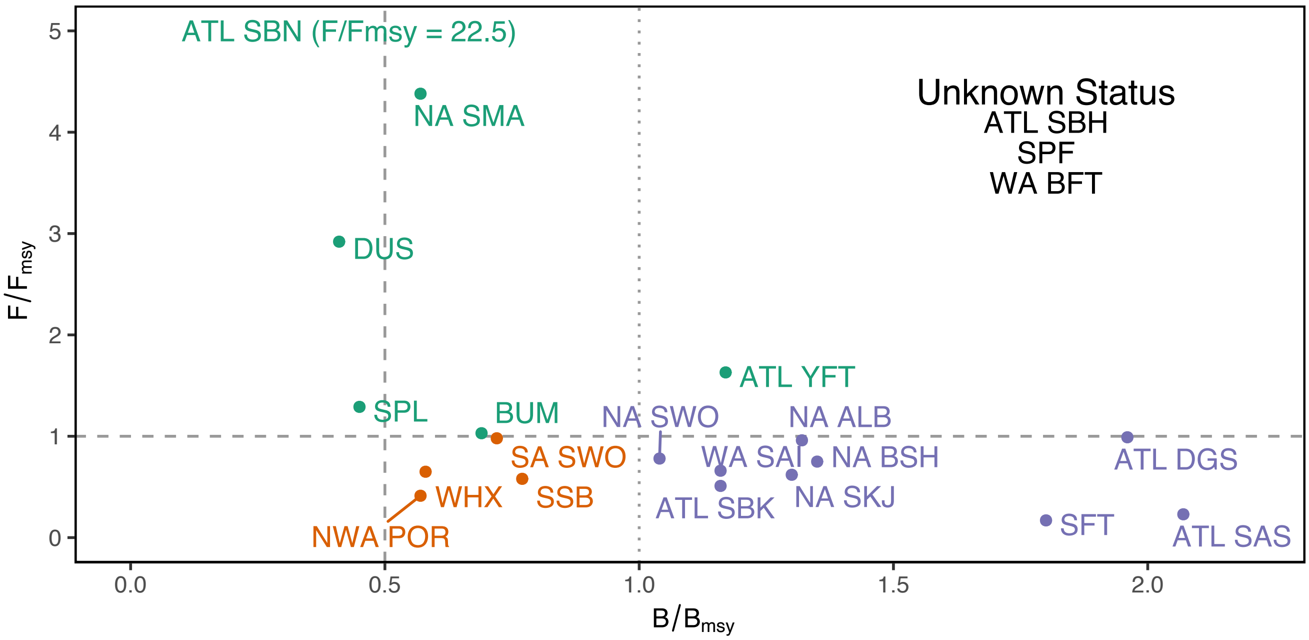


Figure 38: Summary of single species status for HMS stocks; key to species names at https://noaa-edab.github.io/tech-doc/atlantic-highly-migratory-species-stock-status.html.

As noted in the Protected Species section, gray seal populations are increasing. Harbor and gray seals occupying New England waters are generalist predators that consume more than 30 different prey species. An evaluation of hard parts found in seal stomachs showed that harbor and gray seals predominantly exploit abundant demersal fish species (i.e., red, white, and silver hake). Other relatively abundant prey species found in hard-part remains include sand lance, yellowtail flounder, four-spotted flounder, Gulf Stream flounder, haddock, herring, redfish, and squids.

A recent stable isotope study utilizing gray seal scat samples obtained from Massachusetts habitats showed individual gray seals can specialize on particular prey. It also found that gray seals vary their diet seasonally, focusing on demersal inshore species prior to the spring molt, and offshore species such as sand lance after molting. DNA studies on gray seal diet in Gulf of Maine and Massachusetts waters found spiny dogfish and Jonah crab present in gray seal scat samples. Skate and crab remains were also found in gray seal stomach remains. In contrast to direct feeding, it is uncertain if the presence of skates and crabs is due to secondary consumption or scavenging.

Habitat Risk Indicators: habitat assessments, submerged aquatic vegetation, estuarine habitat quality, fishing gear impacts

Habitat Assessments The Northeast Regional Marine Fish Habitat Assessment (NRHA) is a collaborative effort to describe and characterize estuarine, coastal, and offshore fish habitat distribution, abundance, and quality in the Northeast. This includes mapping inshore and offshore habitat types used by focal fish species, summarizing impacts of habitat climate vulnerability on these species, modeling predicted future species distributions, and developing a publicly accessible decision support tool to visualize these results. This is a three-year project led by the New England and Mid-Atlantic Fishery Management Councils in collaboration with many partners including NOAA Fisheries, and will be completed in July 2022[15].

As part of the NRHA work, climate vulnerability information from NOAA's Habitat Climate Vulnerability Assessment [38] and the Northeast Fish and Shellfish Climate Vulnerability Assessment [39][16] is synthesized for approximately 70 species in the northeast region. For example, black sea bass, scup, and summer founder have

[15] https://www.mafmc.org/nrha
[16] https://www.fisheries.noaa.gov/new-england-mid-atlantic/climate/northeast-vulnerability-assessment

been linked to several highly vulnerable nearshore habitats from salt marsh, submerged aquatic vegetation, and shallow estuarine and marine reefs. Details on highly vulnerable habitats with linkages to a variety of species, including which life stages have different levels of dependence on a particular habitat, are available in a detailed table[17].

Submerged Aquatic Vegetation Submerged aquatic vegetation (SAV) is designated as a Habitat Area of Particular Concern (HAPC) for summer flounder and is important habitat for many fish species, particularly during vulnerable juvenile stages. Increased SAV coverage (including wild celery, water stargrass, and hydrilla) in the tidal fresh areas of the Chesapeake Bay (Fig. 39) has been attributed to restoration efforts. This ecosystem engineering has improved water quality, promoting further expansions of SAV meadows. However, in the higher salinity region near the mouth of the Chesapeake Bay (Fig. 39), increased water temperatures, especially during the summer, have led to a decline in eelgrass coverage.

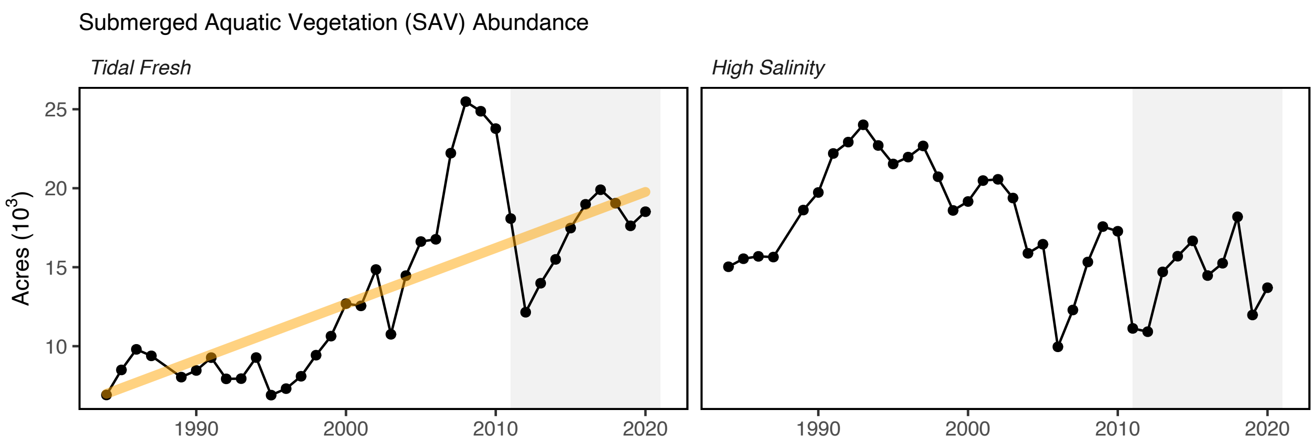


Figure 39: Submerged Aquatic Vegetation (SAV) coverage in tidal fresh and high salinity regions of the Chesapeake Bay.

Estuarine Habitat Quality (Chesapeake Bay) Many important MAFMC managed species (e.g., summer flounder, scup, black sea bass, and bluefish) use estuarine habitats as nurseries or are considered estuarine and nearshore coastal-dependent, and interact with other important estuarine-dependent species (e.g., striped bass and menhaden). An integrated measure of multiple water quality criteria shows a significantly increasing proportion of Chesapeake Bay waters meeting or exceeding EPA water quality standards over time ([40]; Fig. 40). This pattern was statistically linked to total nitrogen reduction, indicating responsiveness of water quality status to management actions implemented to reduce nutrients. Water quality trends and status may be used to inform aquaculture siting decisions in Chesapeake Bay.

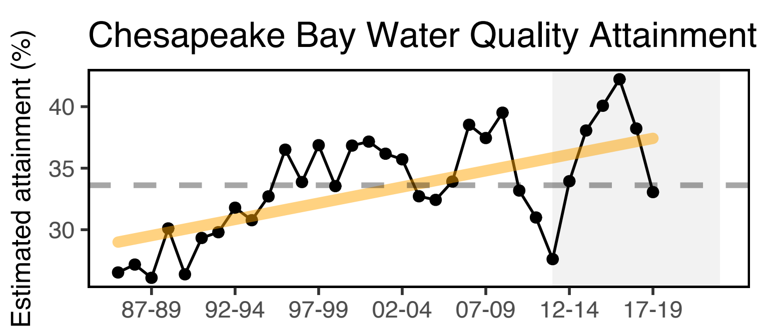


Figure 40: Water quality attainment in Chesapeake Bay following rolling three year assessment periods.

[17] https://noaa-edab.github.io/ecodata/Hab_table

Fishing Gear Impacts Estimates of the impacts of fishing gear on habitat are available through the habitat section of the Northeast Ocean Data Portal[18]. The data portal hosts selected outputs from the Northeast Fishing Effects Model which combines seafloor data (sediment type, energy regime) with fishing effort data to generate percent habitat disturbance estimates in space and time. More detailed information can be found in the Synthetic Indicator Catalog.[19]

Implications

Links between climate change and managed species Estuarine, nearshore, and offshore habitats support many life stages of state and federally managed species, and are highly vulnerable to climate change. Below we highlight how recently observed habitat changes affect several key managed species in Chesapeake Bay and in both nearshore and offshore waters of the MAB. Overall, multiple drivers interact differently for each species, producing a range of population impacts.

Striped Bass Increasing water temperatures in Chesapeake Bay have negative impacts on striped bass at all life stages, although impovements in water quality mitigate some impacts. Declining recruitment since 2000 is associated with higher winter and spring water temperatures and lower freshwater flows, which compress the reproductive season, cause production of zooplankton prey earlier in the season before striped bass larvae are feeding, and reduce concentration of zooplankton prey in larval habitat.

In 2021, average summer water temperatures combined with better dissolved oxygen conditions likely improved habitat quality for larger juvenile and adult striped bass in the summer. The expansion of submerged aquatic vegetation meadows in the tidal fresh region of the Chesapeake Bay (Fig. 39) is likely benefiting species like striped bass who use this as spawning and nursery habitat in the spring. However, similar to 2020, the warm winter in 2021 may have reduced larval survival, despite the average spring temperatures and high spring flows, which represent favorable conditions for striped bass recruitment success.

Understanding habitat conditions can enhance recreational fishery management. Maryland Department of Natural Resources is incorporating habitat conditions into striped bass catch-and-release management, including 1) a two-week summer closure directed at reducing catch-and-release mortality[20] as a substitute for harvest season reductions, and 2) the Striped Bass Fishing Advisory[21], which lets anglers know the relative level of risk of released fish dying due to high temperatures.

Blue Crabs Warmer winter temperatures may benefit Chesapeake Bay blue crabs, an important commercial and forage species. Above-average fall and winter temperatures in 2021 may have reduced overwintering mortality [41–43] and contributed to increased productivity of blue crabs going into 2022. Longer growth seasons are associated with increased production of blue crabs and oysters in Chesapeake Bay. Blue crabs are moving northward with warming temperatures and have been documented in the Gulf of Maine [44], with implications for both their management and for the inshore ecosystems.

Eastern Oyster Oyster reefs provide habitat for several managed fish species including juvenile black sea bass and summer flounder. Increased Chesapeake Bay salinity has been linked to high juvenile oyster abundance [45]. In 2021, high oyster spat set was predicted based on high summer salinity[22], and was observed in Maryland during fall 2021. Virginia oyster recruitment was at record levels 2019-2020 and was above average in 2021.

Summer Flounder and Black Sea Bass The reduced amount of Chesapeake Bay water volume with low oxygen (hypoxic volume) in June and July 2021 suggests better environmental conditions during a critical period of juvenile production for key species such as black sea bass and summer flounder. The increase in hypoxic volume in the fall, however, may have been particularly harmful as it coincided with above-average water temperatures. Additionally, eelgrass in the higher salinity areas near the mouth of the Chesapeake Bay (Fig. 39) is critical nursery habitat for summer flounder, and recent declines seen in SAV coverage could negatively impact recruitment survival.

[18] https://www.northeastoceandata.org/data-explorer/
[19] https://noaa-edab.github.io/catalog/northeast-fishing-effects-model.html
[20] https://dnr.maryland.gov/fisheries/Documents/StripedBass_regulations2022.pdf
[21] https://dnr.maryland.gov/fisheries/Pages/SB_forecast.aspx
[22] https://content.buoybay.noaa.gov/sites/default/files/NCBOSeasonalSummary2021Summer.pdf

Surfclam Ocean acidification also has different implications, depending on the species and life stage. Recent lab studies have found that surf clams exhibited metabolic depression in a pH range of 7.46-7.28 [46]. Computer models are in development to help determine the long term implications of growth on surf clam populations. Aggregated data from 2007-2021 show that summer bottom ocean pH (7.69-8.07, Fig. 31) has not yet reached the metabolic depression threshold observed for surfclams in lab studies so far.

Northern Shortfin Squid Since 2017, extraordinarily high availability of northern shortfin squid have been observed in the Mid-Atlantic, resulting in high fishery catch per unit effort (CPUE) and early fishery closures. High instances of squid catch near the shelf break are significantly related to low bottom temperatures (< 10 degrees C), high salinity (>35.6 psu), increased chlorophyll frontal activity as well as the presence and orientation of warm core rings. Warm core rings are an important contributor to squid availability, likely influencing habitat conditions across different life stages. In particular, fishing effort was concentrated on the eastern edge of warm core rings, which are associated with upwelling and enhanced productivity.

Heatwave impacts While marine heatwaves lasting over days may disturb the marine environment, long lasting events such as the warming in 2012 (Fig. 41) can have significant impacts to the ecosystem [23]. The 2012 heatwave affected the lobster fishery most notably, but other species also shifted their geographic distributions and seasonal cycles [47]. The 2012 heatwave was caused by a shift in the atmospheric Jet Stream, whereas the 2017 marine heatwave in the Mid-Atlantic was associated with a strong positive salinity anomaly and is likely related to cross-shelf flow driven by the presence of a warm core ring adjacent to the shelfbreak south of New England [23]. During the 2017 event, warm water fish typically found in the Gulf Stream were caught in shallow waters near Block Island, RI [20]. Ocean temperatures in 2021 rivaled or exceeded the record temperatures in 2012 in some seasons, but the impacts to fisheries have yet to be determined.

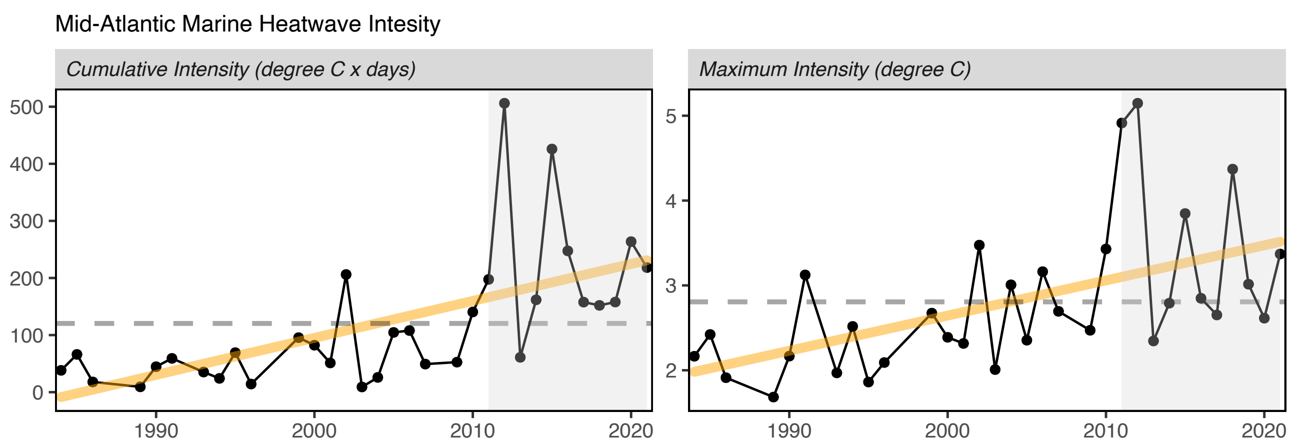


Figure 41: Marine heatwave cumulative intesity (left) and maximum intensity (right) in the Mid-Atlantic Bight.

Cold pool impacts Changes in the cold pool habitat can affect species distribution, recruitment, and migration timing for multiple federally managed species. Southern New England-Mid Atlantic yellowtail flounder recruitment and settlement are related to the strength of the cold pool [29]. The settlement of pre-recruits during the cold pool event represents a bottleneck in yellowtail life history, during which a local and temporary increase in bottom temperature negatively impacts the survival of the settlers. Including the effect of cold pool variations on yellowtail recruitment reduced retrospective patterns and improved the skill of short-term forecasts in a stock assessment model [29,30]. The cold pool also provides habitat for the ocean quahog [31,48]. Growth rates of ocean quahogs in the MAB (southern portion of their range) have increased over the last 200 years whereas little to no change has been documented in the northern portion of their range in southern New England, likely a response to a warming and shrinking cold pool [49].

Distribution shift impacts Trends for a suite of 48 commercially or ecologically important fish species along the entire Northeast Shelf continue to show movement towards the northeast and generally into deeper water (Fig. 8). We hope to expand this analysis beyond fish. Marine mammal distribution maps are available online[23]; updated maps and trends are currently being developed.

Shifting species distributions alter both species interactions and fishery interactions. In particular, shifting species distributions can alter expected management outcomes from spatial allocations and bycatch measures based on historical fish and protected species distributions.

Ecosystem productivity change impacts Climate and associated changes in the physical environment affect ecosystem productivity, with warming waters increasing the rate of photosynthesis at the base of the food web. However, increased summer production in the MAB may not translate to increased fish biomass because smaller phytoplankton dominate in this season.

While krill and large gelatinous zooplankton are increasing over time, smaller zooplankton are periodically shifting abundance between the larger, more nutritious *Calanus finmarchicus* and smaller bodied copepods with no apparent overall trend. The nutritional content of larger bodied forage fish and squid changes seasonally in response to ecosystem conditions, with apparent declines in energy density for Atlantic herring and *Illex* squid relative to the 1980s, but similar energy density for other forage species. Some of these factors are now being linked to the relative condition of managed fish.

The apparent decline in productivity across multiple managed species in the MAB, along with low fish condition for many species in 2021, also suggest changing ecosystem productivity at multiple levels. During the 1990s and early 2000s high relative abundance of smaller bodied copepods and a lower relative abundance of *Calanus finmarchicus* was associated with regime shifts to lower fish recruitment [50]. The unprecedented climate signals along with the trends toward lower productivity across multiple managed species indicate a need to continually evaluate whether management reference points remain appropriate, and to evaluate if ecosystem regime shifts have occurred or reorganization is in progress.

Other Ocean Uses: Offshore Wind

Indicators: development timeline, revenue in lease areas, coastal community vulnerability

As of February 2022, 24 offshore wind development projects are proposed for construction over the next decade in the Northeast (timelines and project data are based on Tables E-2, E-4, and E-4-2 of South Fork Wind Farm Final Environmental Impact Statement). Offshore wind areas are anticipated to cover more than 1.7 million acres by 2030 in the Greater Atlantic region (Fig. 42). Beyond 2030 values include acreage for the NY Wind Energy Areas (WEA) and Gulf of Maine Area of Interest for floating research array.

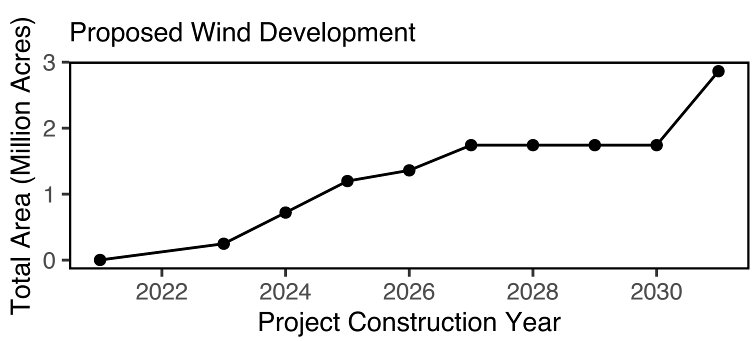
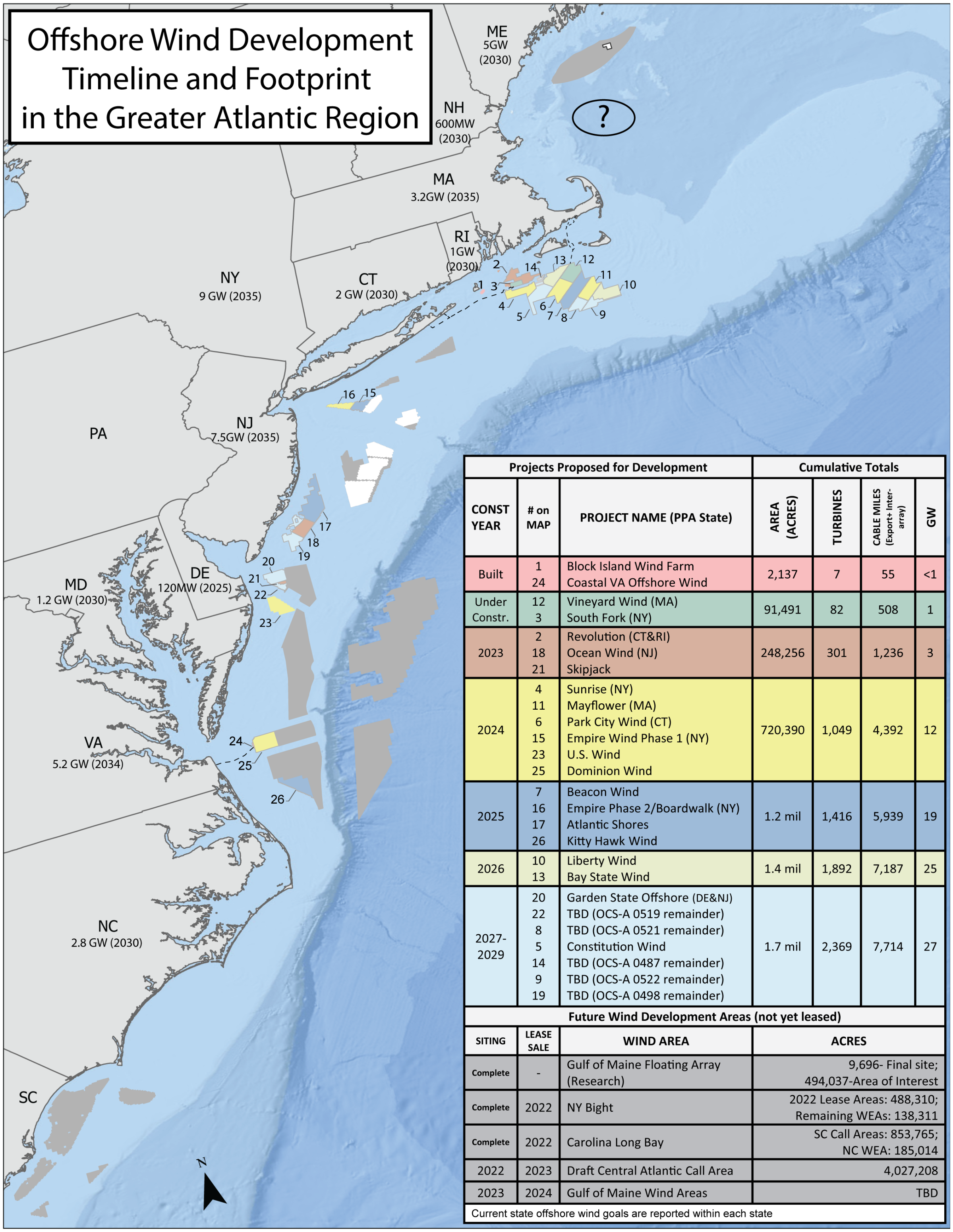


Figure 42: Proposed wind development on the northeast shelf.

[23] https://www.nefsc.noaa.gov/AMAPPSviewer/



Projects Proposed for Development			Cumulative Totals			
CONST YEAR	# on MAP	PROJECT NAME (PPA State)	AREA (ACRES)	TURBINES	CABLE MILES (Export+ Inter-array)	GW
Built	1 24	Block Island Wind Farm Coastal VA Offshore Wind	2,137	7	55	<1
Under Constr.	12 3	Vineyard Wind (MA) South Fork (NY)	91,491	82	508	1
2023	2 18 21	Revolution (CT&RI) Ocean Wind (NJ) Skipjack	248,256	301	1,236	3
2024	4 11 6 15 23 25	Sunrise (NY) Mayflower (MA) Park City Wind (CT) Empire Wind Phase 1 (NY) U.S. Wind Dominion Wind	720,390	1,049	4,392	12
2025	7 16 17 26	Beacon Wind Empire Phase 2/Boardwalk (NY) Atlantic Shores Kitty Hawk Wind	1.2 mil	1,416	5,939	19
2026	10 13	Liberty Wind Bay State Wind	1.4 mil	1,892	7,187	25
2027-2029	20 22 8 5 14 9 19	Garden State Offshore (DE&NJ) TBD (OCS-A 0519 remainder) TBD (OCS-A 0521 remainder) Constitution Wind TBD (OCS-A 0487 remainder) TBD (OCS-A 0522 remainder) TBD (OCS-A 0498 remainder)	1.7 mil	2,369	7,714	27

Future Wind Development Areas (not yet leased)			
SITING	LEASE SALE	WIND AREA	ACRES
Complete	-	Gulf of Maine Floating Array (Research)	9,696- Final site; 494,037-Area of Interest
Complete	2022	NY Bight	2022 Lease Areas: 488,310; Remaining WEAs: 138,311
Complete	2022	Carolina Long Bay	SC Call Areas: 853,765; NC WEA: 185,014
2022	2023	Draft Central Atlantic Call Area	4,027,208
2023	2024	Gulf of Maine Wind Areas	TBD

Wind area boundaries, construction data and timelines are frequently updated.This map contains the most recent published information **as of 2/2/22**
Sources: South Fork Wind Farm FEIS, BOEM GIS data, BOEM Leasing Path Forward 2021-2025

Figure 43: All Northeast Project areas by year construction ends (each project has 2 year construction period).

Just over 2,500 foundations and more than 7,000 miles of inter-array and offshore export cables are proposed to date.

The colored chart in Fig. 43 also presents the offshore wind development timeline in the Greater Atlantic region with the estimated year that foundations would be constructed (matches the color of the wind areas). These timelines and data estimates are expected to shift but represent the most recent information available as of February 2022. Based on current timelines, the areas affected would be spread out such that it is unlikely that any one particular area would experience full development at one time. Future wind development areas are also presented. Additional lease areas, totalling over 488,000 acres in the NY Bight are available for BOEM's 2022 lease sale. It's anticipated that the NY Bight leases will fulfill outstanding offshore wind energy production goals for NY and NJ. VA and NC have outstanding goals that cannot be fulfilled within the existing lease areas, and it is expected that these will be fulfilled with future development off the Delmarva Peninsula.

Based on federal vessel logbook data, average commercial fishery revenue from trips in the current offshore wind lease areas and the New York Bight leasing areas identified in the proposed sale notice represented 2-20% of the total annual revenue for the most affected fisheries in federal waters from 2008-2019 (Fig. 44).

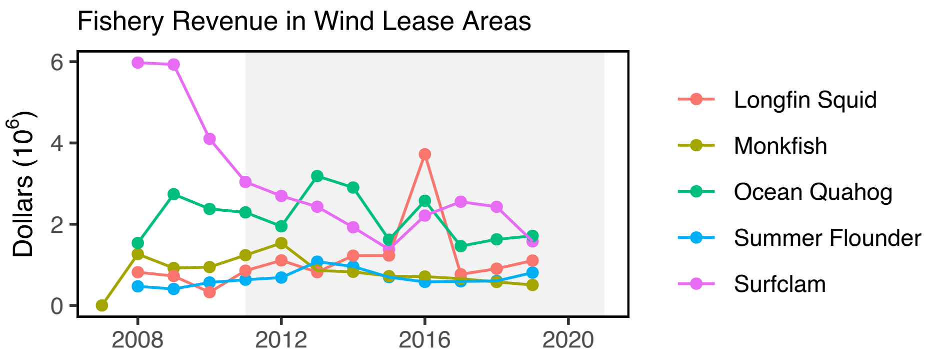


Figure 44: Wind energy revenue in the Mid-Atlantic.

The surfclam fishery could be the most affected fishery, with a maximum of 20% of annual fishery revenue occurring within potential wind lease areas during this period, followed by chub mackerel (15%), ocean quahog (13%), and Atlantic mackerel (10%). The *Illex* squid and bluefish fisheries were the least affected, at 1-2% maximum annual revenue affected, respectively. A maximum of 9% of the annual scup revenues were affected by these areas, with similar effects for the longfin squid (8%), blueline tilefish and black sea bass (7%), and monkfish and golden tilefish (6%) fisheries. The proposed New York Bight lease areas represented up to 5% of total annual fishery revenue from any MAFMC fishery during 2008-2019, with the surfclam fishery most affected. Similar patterns are observed when examining the proportion of annual fishery landings within current and proposed lease areas (see Table 2).

Table 2: Top ten species Landings and Revenue from Wind Energy Areas.

GARFO and ASMFC Managed Species	Maximum Percent Total Annual Regional Species Landings	Minimum Percent Total Annual Regional Species Landings	Maximum Percent Total Annual Regional Species Revenue	Minimum Percent Total Annual Regional Species Revenue
Atlantic surfclam	21 %	6 %	20 %	6 %
American eel	13 %	2 %	18 %	0 %
Atlantic menhaden	17 %	3 %	17 %	3 %
Atlantic chub mackerel	15 %	0 %	16 %	0 %
Yellowtail flounder	14 %	0 %	15 %	0 %
Offshore hake	14 %	0 %	14 %	0 %
Ocean quahog	14 %	5 %	13 %	5 %
Atlantic sea scallops	12 %	1 %	10 %	1 %
Skate wings	10 %	5 %	10 %	5 %
Atlantic mackerel	9 %	0 %	10 %	0 %

Proposed wind development areas interact with the region's federal scientific surveys. Scientific surveys are impacted by offshore wind in four ways: 1. Exclusion of NOAA Fisheries' sampling platforms from the wind development area due to operational and safety limitations; 2.Impacts on the random-stratified statistical design that is the basis for scientific assessments, advice, and analyses; 3.Alteration of benthic and pelagic habitats, and airspace in and around the wind energy development, requiring new designs and methods to sample new habitats; and, 4.Reduced sampling productivity through navigation impacts of wind energy infrastructure on aerial and vessel survey operations. Increase vessel transit between stations may decrease data collections that are already limited by annual days-at-sea day allocations. The total survey area overlap ranges from 1-14% for all Greater Atlantic federal surveys. Individual survey strata have significant interaction with wind, including the sea scallop survey (up to 96% of individual strata) and the bottom trawl survey (BTS, up to 60% strata overlap). Additionally, up to 50% of the southern New England North Atlantic right whale survey's area overlaps with proposed project areas. A region-wide survey mitigation program is underway (Table 3)

Table 3: Survey mitigation planning.

Survey	1.Evaluate designs & Impacts	2.Design New Methods	3.Calibrate New/Existing Surveys	4.Bridge Solutions	5.Conduct New Surveys	6.Comms & Data
Fall BTS	Started	Inital	No	No	No	Initial
Spring BTS	Started	Initial	No	No	No	Initial
EcoMon	No	No	No	No	No	No
Scallop	Started	Initial	No	No	No	No
Shellfish(Clams)	No	No	No	No	No	No
Right Whale (Air)	Inital	Initial	Initial	No	No	No
Marine Mammal/Turtle (Ship/Air)	No	No	No	No	No	No
Altantic Shark (Bottom Long-Line	No	No	No	No	No	No
GOM Bottom Long-Line	No	No	No	No	No	No
GOM Shrimp Survey	No	No	No	No	No	No
Atlantic Shark COASTPAN	No	No	No	No	No	No

Equity and environmental justice (EJ) are priority concerns with offshore wind development and fisheries impacts in the Northeast. Fig. 45 links historic port revenue (2008-2019) from within all wind lease areas as a proportion of the port's total revenue based on vessel trip reports as described in the revenue and landings of species in the wind indicator above. The range (minimum and maximum) of total percent revenue from within wind energy areas is presented in the graph and ports are sorted from greatest to least revenue from within wind areas.

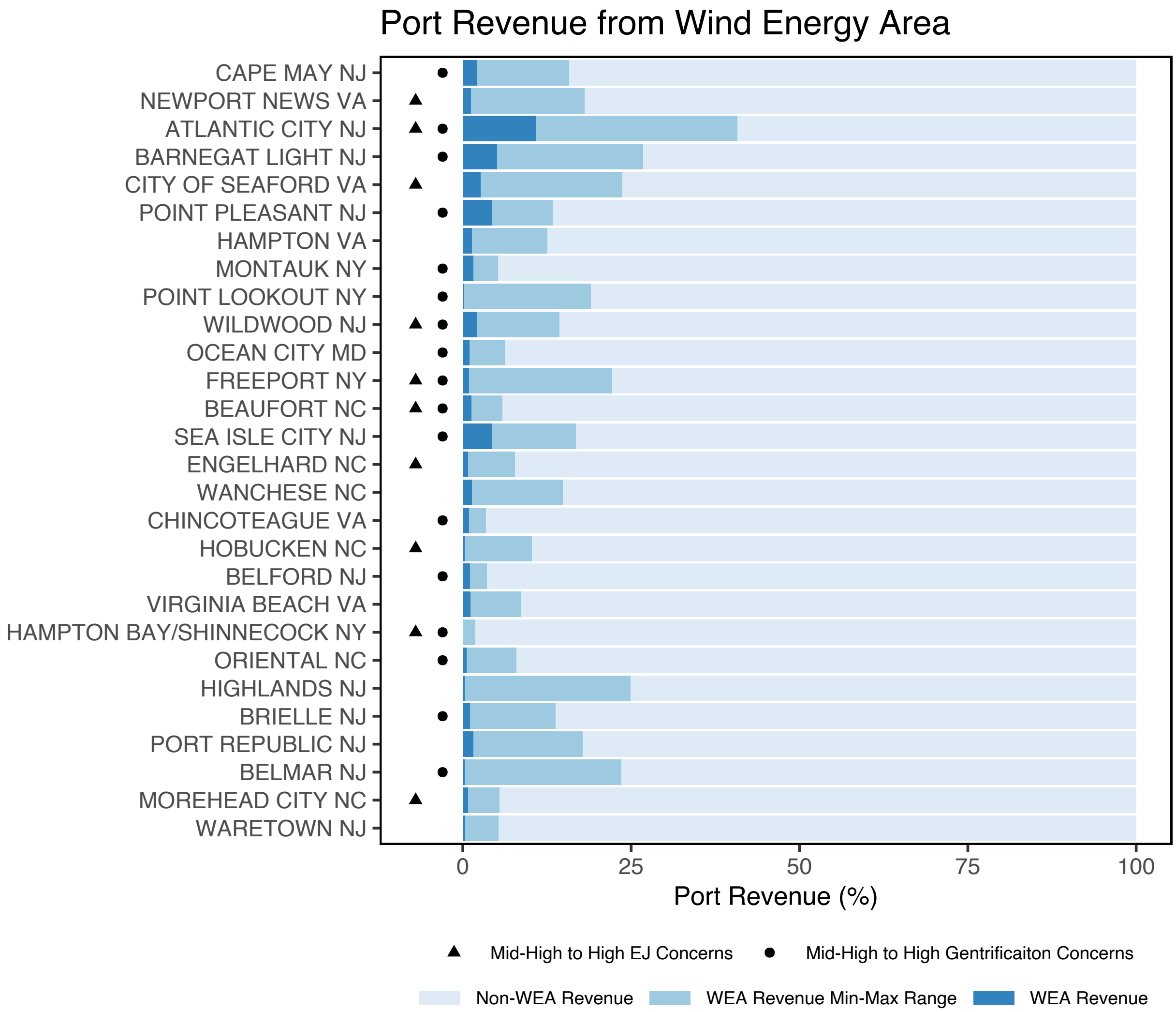


Figure 45: Percent of port revenue from Wind Energy Areas (WEA) in descending order from most to least port revenue from WEA. EJ = Environmental Justice.

For example, Atlantic City, NJ had a minimum of 11% and maximum of 30% overlap of wind energy revenue to the total port revenue between 2008-2019. Those communities that score Med-High or higher in at least one of the vulnerability indicators that address environmental justice concerns (i.e., Poverty, Population Composition, Personal Disruption; see indicator definitions) are noted with a triangle. Gentrification pressure is also highlighted here, with those communities that score Med-High or higher in one or more gentrification pressure indicators (i.e., Housing Disruption, Retiree Migration, Urban Sprawl) represented with a circle (Fig. 45). BOEM reports that cumulative offshore wind development (if all proposed projects are developed) could have moderate impacts on low-income members of environmental justice communities who work in the commercial fishing and for-hire fishing industry due to disruptions to fish populations, restrictions on navigation and increased vessel traffic, as well as existing vulnerabilities of low-income workers to economic impacts [51].

Top fishing communities high in environmental justice concerns (i.e., Atlantic City, NJ, Newport News, VA, Hobucken and Beaufort, NC) should be considered in decision making to reduce the social and economic impacts and aid in the resilience and adaptive capacity of underserved communities. It also highlights communities where we need to provide further resources to reach underserved and underrepresented groups and create opportunities for and directly involve these groups in the decision-making process.

Implications

Current plans for rapid buildout of offshore wind in a patchwork of areas spreads the impacts differentially throughout the region (Fig. 43).

Up to 20% of total average revenue for major Mid-Atlantic commercial species in lease areas could be forgone or reduced and associated effort displaced if all sites are developed. Displaced fishing effort can alter historic fishing area, timing, and method patterns, which can in turn change habitat, species (managed and protected), and fleet interactions. Several factors, including fishery regulations, fishery availability, and user conflicts affect where, when, and how fishing effort may be displaced.

Planned development overlaps right whale mother and calf migration corridors and a significant foraging habitat that is used throughout the year [9] (Fig 46). Turbine presence and extraction of energy from the system could alter local oceanography [52] and may affect right whale prey availability. Proposed wind development areas also bring increased vessel strike risk from construction and operation vessels. In addition, there are a number of potential impacts to whales from pile driving and operational noise such as displacement, increased levels of communication masking, and elevated stress hormones.

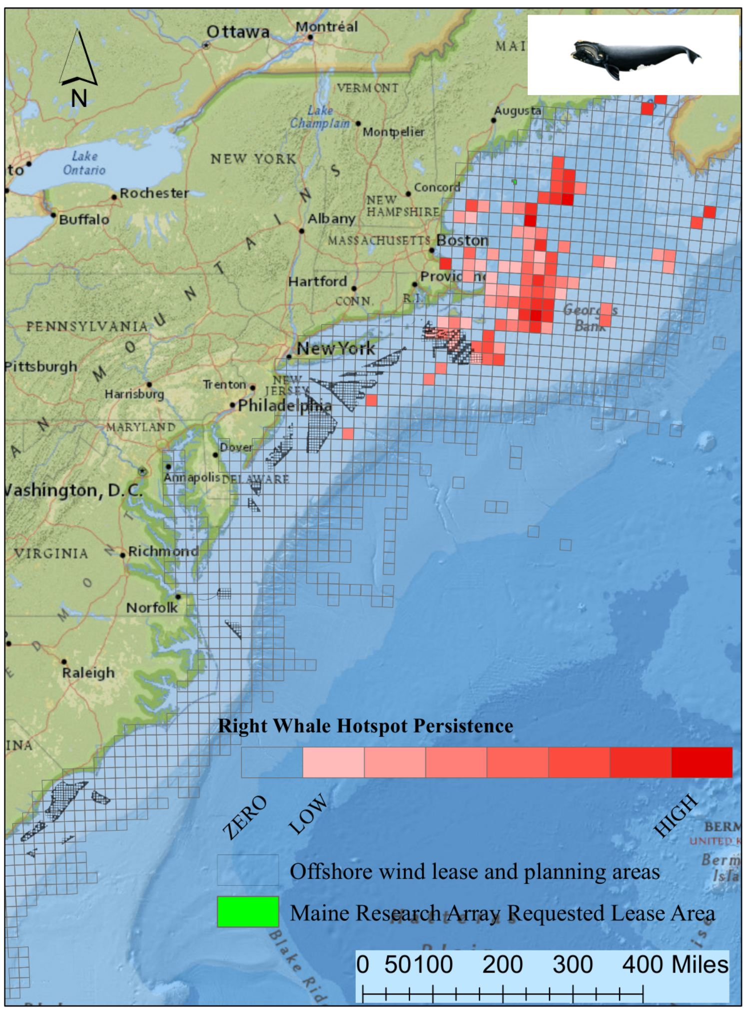


Figure 46: Northern Right Whale persistent hotspots and Wind Energy Areas.

Scientific data collection surveys for ocean and ecosystem conditions, fish, and protected species will be altered, potentially increasing uncertainty for management decision making.

The increase of offshore wind development can have both positive (e.g., employment opportunities) and negative (e.g., space-use conflicts) effects. Continued increase in coastal development and gentrification pressure has resulted in loss of fishing infrastructure space within ports. Understanding these existing pressures can allow for avoiding and mitigating negative impacts to our shore support industry and communities dependent on fishing. Some of the communities with the highest revenue overlap with offshore wind that are also vulnerable to gentrification pressure are Point Pleasant and Atlantic City, NJ, Ocean City, MD, and Beaufort, NC.

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Document Orientation

The figure format is illustrated in Fig 47a. Trend lines are shown when slope is significantly different from 0 at the $p < 0.05$ level. An orange line signifies an overall positive trend, and purple signifies a negative trend. To minimize bias introduced by small sample size, no trend is fit for < 30 year time series. Dashed lines represent mean values of time series unless the indicator is an anomaly, in which case the dashed line is equal to 0. Shaded regions indicate the past ten years. If there are no new data for 2021, the shaded region will still cover this time period. The spatial scale of indicators is either coastwide, Mid-Atlantic states (New York, New Jersey, Delaware, Maryland, Virginia, North Carolina), or at the Mid-Atlantic Bight (MAB) Ecosystem Production Unit (EPU, Fig. 47b) level.

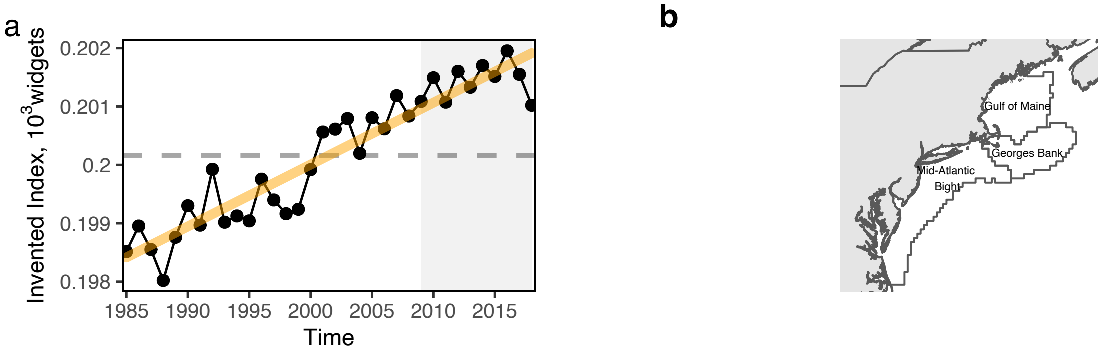

Figure 47: Document orientation. a. Key to figures. b.The Northeast Large Marine Ecosystem.

Fish and invertebrates are aggregated into similar feeding categories (Table 4) to evaluate ecosystem level trends in predators and prey.

Table 4: Feeding guilds and management bodies.

Guild	**MAFMC**	**Joint**	**NEFMC**	**State or Other**
Apex Predator	NA	NA	NA	bluefin tuna, shark uncl, swordfish, yellowfin tuna
Piscivore	bluefish, longfin squid, northern shortfin squid, summer flounder	goosefish, spiny dogfish	acadian redfish, atlantic cod, atlantic halibut, clearnose skate, little skate, offshore hake, pollock, red hake, silver hake, smooth skate, thorny skate, white hake, winter skate	fourspot flounder, john dory, sea raven, striped bass, weakfish, windowpane
Planktivore	atlantic mackerel, butterfish	NA	atlantic herring	alewife, american shad, blackbelly rosefish, blueback herring, cusk, longhorn sculpin, lumpfish, menhaden, northern sand lance, northern searobin, sculpin uncl
Benthivore	black sea bass, scup, tilefish	NA	american plaice, barndoor skate, crab,red deepsea, haddock, ocean pout, rosette skate, winter flounder, witch flounder, yellowtail flounder	american lobster, atlantic wolffish, blue crab, cancer crab uncl, chain dogfish, cunner, jonah crab, lady crab, smooth dogfish, spider crab uncl, squid cuttlefish and octopod uncl, striped searobin, tautog
Benthos	atlantic surfclam, ocean quahog	NA	sea scallop	blue mussel, channeled whelk, sea cucumber, sea urchin and sand dollar uncl, sea urchins, snails(conchs)

References

1. Thunberg EM. Northeast Region Fisheries Impacts from COVID-19. US Seafood Industry and For-Hire Sector Impacts from COVID-19: 2020 in Perspective NOAA Tech Memo NMFS-SPO-221. 2021. pp. 53–64. Available: https://spo.nmfs.noaa.gov/sites/default/files/TM221.pdf

2. Gaichas SK, DePiper GS, Seagraves RJ, Muffley BW, Sabo M, Colburn LL, et al. Implementing Ecosystem Approaches to Fishery Management: Risk Assessment in the US Mid-Atlantic. Frontiers in Marine Science. 2018;5. doi:10.3389/fmars.2018.00442

3. Friedland KD, Langan JA, Large SI, Selden RL, Link JS, Watson RA, et al. Changes in higher trophic level productivity, diversity and niche space in a rapidly warming continental shelf ecosystem. Science of The Total Environment. 2020;704: 135270. doi:10.1016/j.scitotenv.2019.135270

4. Pace RM, Williams R, Kraus SD, Knowlton AR, Pettis HM. Cryptic mortality of North Atlantic right whales. Conservation Science and Practice. 2021;n/a: e346. doi:https://doi.org/10.1111/csp2.346

5. Wood SA, Murray KT, Josephson E, Gilbert J. Rates of increase in gray seal (Halichoerus grypus atlantica) pupping at recolonized sites in the United States, 1988–2019. Swanson B, editor. Journal of Mammalogy. 2020;101: 121–128. doi:10.1093/jmammal/gyz184

6. Hayes S, Gardner S, Garrison LP, Henry A, Leandro L. North Atlantic Right Whales-Evaluating Their Recovery Challenges in 2018. NOAA Tech Memo NMFS NEFSC 247. 2018.

7. Record N, Runge J, Pendleton D, Balch W, Davies K, Pershing A, et al. Rapid Climate-Driven Circulation Changes Threaten Conservation of Endangered North Atlantic Right Whales. Oceanography. 2019;32. doi:10.5670/oceanog.2019.201

8. Sorochan KA, Plourde S, Morse R, Pepin P, Runge J, Thompson C, et al. North Atlantic right whale (Eubalaena glacialis) and its food: (II) interannual variations in biomass of Calanus spp. On western North Atlantic shelves. Journal of Plankton Research. 2019;41: 687–708. doi:10.1093/plankt/fbz044

9. Quintana-Rizzo E, Leiter S, Cole TVN, Hagbloom MN, Knowlton AR, Nagelkirk P, et al. Residency, demographics, and movement patterns of North Atlantic right whales Eubalaena glacialis in an offshore wind energy development area in southern New England, USA. Endangered Species Research. 2021;45: 251–268. doi:10.3354/esr01137

10. Schick RS, Halpin PN, Read AJ, Slay CK, Kraus SD, Mate BR, et al. Striking the right balance in right whale conservation. Canadian Journal of Fisheries and Aquatic Sciences. 2009;66: 1399–1403. doi:10.1139/F09-115

11. Hobday AJ, Alexander LV, Perkins SE, Smale DA, Straub SC, Oliver ECJ, et al. A hierarchical approach to defining marine heatwaves. Progress in Oceanography. 2016;141: 227–238. doi:10.1016/j.pocean.2015.12.014

12. Gangopadhyay A, Gawarkiewicz G, Silva ENS, Silver AM, Monim M, Clark J. A Census of the Warm-Core Rings of the Gulf Stream: 1980–2017. Journal of Geophysical Research: Oceans. 2020;125: e2019JC016033. doi:10.1029/2019JC016033

13. Andres M. On the recent destabilization of the Gulf Stream path downstream of Cape Hatteras. Geophysical Research Letters. 2016;43: 9836–9842. doi:10.1002/2016GL069966

14. Caesar L, Rahmstorf S, Robinson A, Feulner G, Saba V. Observed fingerprint of a weakening Atlantic Ocean overturning circulation. Nature. 2018;556: 191–196. doi:10.1038/s41586-018-0006-5

15. Zhang R, Vallis GK. The Role of Bottom Vortex Stretching on the Path of the North Atlantic Western Boundary Current and on the Northern Recirculation Gyre. Journal of Physical Oceanography. 2007;37: 2053–2080. doi:10.1175/JPO3102.1

16. Goddard PB, Yin J, Griffies SM, Zhang S. An extreme event of sea-level rise along the Northeast coast of North America in 2009–2010. Nature Communications. 2015;6. doi:10.1038/ncomms7346

17. Gonçalves Neto A, Langan JA, Palter JB. Changes in the Gulf Stream preceded rapid warming of the Northwest Atlantic Shelf. Communications Earth & Environment. 2021;2: 1–10. doi:10.1038/s43247-021-00143-5

18. Silver A, Gangopadhyay A, Gawarkiewicz G, Taylor A, Sanchez-Franks A. Forecasting the Gulf Stream Path Using Buoyancy and Wind Forcing Over the North Atlantic. Journal of Geophysical Research: Oceans. 2021;126: e2021JC017614. doi:10.1029/2021JC017614

19. Gangopadhyay A, Gawarkiewicz G, Silva ENS, Monim M, Clark J. An Observed Regime Shift in the Formation of Warm Core Rings from the Gulf Stream. Scientific Reports. 2019;9: 1–9. doi:10.1038/s41598-019-48661-9

20. Gawarkiewicz G, Todd R, Zhang W, Partida J, Gangopadhyay A, Monim M-U-H, et al. The Changing Nature of Shelf-Break Exchange Revealed by the OOI Pioneer Array. Oceanography. 2018;31: 60–70. doi:10.5670/oceanog.2018.110

21. Chen K, Gawarkiewicz G, Yang J. Mesoscale and Submesoscale Shelf-Ocean Exchanges Initialize an Advective Marine Heatwave. Journal of Geophysical Research: Oceans. 2022;127: e2021JC017927. doi:https://doi.org/10.1029/2021JC017927

22. Gawarkiewicz G, Fratantoni P, Bahr F, Ellertson A. Increasing Frequency of Mid-depth Salinity Maximum Intrusions in the Middle Atlantic Bight. Journal of Geophysical Research: Oceans. In Review;

23. Gawarkiewicz G, Chen K, Forsyth J, Bahr F, Mercer AM, Ellertson A, et al. Characteristics of an Advective Marine Heatwave in the Middle Atlantic Bight in Early 2017. Frontiers in Marine Science. 2019;6. Available: https://www.frontiersin.org/article/10.3389/fmars.2019.00712

24. Potter IF, Galuardi B, Howell WH. Horizontal movement of ocean sunfish, Mola mola, in the northwest Atlantic. Marine Biology. 2011;158: 531–540. doi:10.1007/s00227-010-1578-2

25. Worm B, Lotze HK, Myers RA. Predator diversity hotspots in the blue ocean. Proceedings of the National Academy of Sciences. 2003;100: 9884–9888. doi:10.1073/pnas.1333941100

26. Lentz SJ. Seasonal warming of the Middle Atlantic Bight Cold Pool. Journal of Geophysical Research: Oceans. 2017;122: 941–954. doi:10.1002/2016JC012201

27. Chen Z, Curchitser E, Chant R, Kang D. Seasonal Variability of the Cold Pool Over the Mid-Atlantic Bight Continental Shelf. Journal of Geophysical Research: Oceans. 2018;123: 8203–8226. doi:10.1029/2018JC014148

28. Miles T, Murphy S, Kohut J, Borsetti S, Munroe D. Offshore Wind Energy and the Mid-Atlantic Cold Pool: A Review of Potential Interactions. Marine Technology Society Journal. 2021;55: 72–87. doi:10.4031/MTSJ.55.4.8

29. Miller TJ, Hare JA, Alade LA. A state-space approach to incorporating environmental effects on recruitment in an age-structured assessment model with an application to southern New England yellowtail flounder. Canadian Journal of Fisheries and Aquatic Sciences. 2016;73: 1261–1270. doi:10.1139/cjfas-2015-0339

30. Pontavice H du, Miller TJ, Stock BC, Chen Z, Saba VS. Incorporating environmental effects from ocean models improves a marine fish stock assessment. ICES Journal of Marine Science. In Review;

31. Friedland KD, Miles T, Goode AG, Powell EN, Brady DC. The Middle Atlantic Bight Cold Pool is warming and shrinking: Indices from in situ autumn seafloor temperatures. Fisheries Oceanography. 2022;31: 217–223. doi:10.1111/fog.12573

32. Wright-Fairbanks EK, Miles TN, Cai W-J, Chen B, Saba GK. Autonomous Observation of Seasonal Carbonate Chemistry Dynamics in the Mid-Atlantic Bight. Journal of Geophysical Research: Oceans. 2020;125: e2020JC016505. doi:https://doi.org/10.1029/2020JC016505

33. Madin LP, Kremer P, Wiebe PH, Purcell JE, Horgan EH, Nemazie DA. Periodic swarms of the salp Salpa aspera in the Slope Water off the NE United States: Biovolume, vertical migration, grazing, and vertical flux. Deep Sea Research Part I: Oceanographic Research Papers. 2006;53: 804–819. doi:10.1016/j.dsr.2005.12.018

34. Deibel D, Paffenhofer G-A. Predictability of patches of neritic salps and doliolids (Tunicata, Thaliacea). Journal of Plankton Research. 2009;31: 1571–1579. doi:10.1093/plankt/fbp091

35. Steimle F, Terranova R. Energy Equivalents of Marine Organisms from the Continental Shelf of the Temperate Northwest Atlantic. Journal of Northwest Atlantic Fishery Science. 1985;6. doi:10.2960/J.v6.a11

36. Lawson JW, Magalhães AM, Miller EH. Important prey species of marine vertebrate predators in the northwest Atlantic: Proximate composition and energy density. Marine Ecology Progress Series. 1998;164: 13–20. Available: https://www.jstor.org/stable/24825521

37. Le Cren ED. The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (Perca fluviatilis). Journal of Animal Ecology. 1951;20: 201–219. doi:10.2307/1540

38. Farr ER, Johnson MR, Nelson MW, Hare JA, Morrison WE, Lettrich MD, et al. An assessment of marine, estuarine, and riverine habitat vulnerability to climate change in the Northeast U.S. PLOS ONE. 2021;16: e0260654. doi:10.1371/journal.pone.0260654

39. Hare JA, Morrison WE, Nelson MW, Stachura MM, Teeters EJ, Griffis RB, et al. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLOS ONE. 2016;11: e0146756. doi:10.1371/journal.pone.0146756

40. Zhang Q, Murphy RR, Tian R, Forsyth MK, Trentacoste EM, Keisman J, et al. Chesapeake Bay's water quality condition has been recovering: Insights from a multimetric indicator assessment of thirty years of tidal monitoring data. Science of The Total Environment. 2018;637-638: 1617–1625. doi:10.1016/j.scitotenv.2018.05.025

41. Bauer LJ, Miller TJ. Temperature-, Salinity-, and Size-Dependent Winter Mortality of Juvenile Blue Crabs (Callinectes sapidus). Estuaries and Coasts. 2010;33: 668–677. Available: https://www.jstor.org/stable/40663676

42. Hines AH, Johnson EG, Darnell MZ, Rittschof D, Miller TJ, Bauer LJ, et al. Predicting Effects of Climate Change on Blue Crabs in Chesapeake Bay. Biology and Management of Exploited Crab Populations under Climate Change. Alaska Sea Grant, University of Alaska Fairbanks; 2011. pp. 109–127. doi:10.4027/bmecpcc.2010.22

43. Rome MS, Young-Williams AC, Davis GR, Hines AH. Linking temperature and salinity tolerance to winter mortality of Chesapeake Bay blue crabs (Callinectes sapidus). Journal of Experimental Marine Biology and Ecology. 2005;319: 129–145. doi:10.1016/j.jembe.2004.06.014

44. Johnson DS. The Savory Swimmer Swims North: A Northern Range Extension of the Blue Crab Callinectes Sapidus? Journal of Crustacean Biology. 2015;35: 105–110. doi:10.1163/1937240X-00002293

45. Kimmel DG, Tarnowski M, Newell RIE. The Relationship between Interannual Climate Variability and Juvenile Eastern Oyster Abundance at a Regional Scale in Chesapeake Bay. North American Journal of Fisheries Management. 2014;34: 1–15. doi:10.1080/02755947.2013.830999

46. Pousse E, Poach ME, Redman DH, Sennefelder G, White LE, Lindsay JM, et al. Energetic response of Atlantic surfclam Spisula solidissima to ocean acidification. Marine Pollution Bulletin. 2020;161: 111740. doi:10.1016/j.marpolbul.2020.111740

47. Mills K, Pershing A, Brown C, Chen Y, Chiang F-S, Holland D, et al. Fisheries Management in a Changing Climate: Lessons From the 2012 Ocean Heat Wave in the Northwest Atlantic. Oceanography. 2013;26. doi:10.5670/oceanog.2013.27

48. Powell EN, Ewing AM, Kuykendall KM. Ocean quahogs (Arctica islandica) and Atlantic surfclams (Spisula solidissima) on the Mid-Atlantic Bight continental shelf and Georges Bank: The death assemblage as a recorder of climate change and the reorganization of the continental shelf benthos. Palaeogeography, Palaeoclimatology, Palaeoecology. 2020;537: 109205. doi:10.1016/j.palaeo.2019.05.027

49. Pace SM, Powell EN, Mann R. Two-hundred year record of increasing growth rates for ocean quahogs (Arctica islandica) from the northwestern Atlantic Ocean. Journal of Experimental Marine Biology and Ecology. 2018;503: 8–22. doi:10.1016/j.jembe.2018.01.010

50. Perretti C, Fogarty M, Friedland K, Hare J, Lucey S, McBride R, et al. Regime shifts in fish recruitment on the Northeast US Continental Shelf. Marine Ecology Progress Series. 2017;574: 1–11. doi:10.3354/meps12183

51. BOEM. Vineyard Wind 1 Offshore Wind Energy Project Supplement to the Draft Environmental Impact Statement. OCS EIS/EA, BOEM 2020-025 [Internet]. 2020. Available: https://www.boem.gov/sites/default/files/documents/renewable-energy/Vineyard-Wind-1-Supplement-to-EIS.pdf

52. Christiansen N, Daewel U, Djath B, Schrum C. Emergence of Large-Scale Hydrodynamic Structures Due to Atmospheric Offshore Wind Farm Wakes. Frontiers in Marine Science. 2022;9. Available: https://www.frontiersin.org/article/10.3389/fmars.2022.818501