Mid-Atlantic Fishery Management Council
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Michael P. Luisi, Chairman | P. Weston Townsend, Vice Chairman
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MEMORANDUM

Date: March 22, 2023

To: Council

From: Brandon Muffley, Council staff

Subject: Mid-Atlantic State of the Ecosystem Report – Meeting Materials

On Wednesday, April 5, 2023, Dr. Sarah Gaichas (NEFSC) will present the 2023 Mid-Atlantic State of the Ecosystem (SOE) report. The Council will review the findings and ecosystem considerations contained in the report and provide any feedback on the future report development and the utility of the information for management. Dr. Gaichas will also provide an update on the SSC's Ecosystem Work Group activities and their approaches to potentially integrate SOE and other climate information into the science and management process.

Materials listed below are provided for Council consideration of this agenda item.

Materials behind the tab:

- 2023 Mid-Atlantic State of the Ecosystem report
- Cover letter and State of the Ecosystem response memo
- March 2023 SSC Ecosystem Work Group update report

2023 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)	TREND	CURRENT STATUS	IMPLICATIONS
Seafood production (total and MAFMC managed landings)	Decline	Below long term average	Commercial landings are at the lowest point observed, driven by recent declines in species not managed by the Mid-Atlantic Council. Recreational harvest is declining due to multiple drivers. COVID-19 likely exacerbated existing trends, but impacts are not uniform across fisheries. Biomass trends within the ecosystem continue to be stable. Climate indicators continue to exceed historical bounds, which affects stock distributions and will generate other ecosystem changes.
Commercial profits	Decline	Below long term average	Regional commercial revenue is the lowest that has been observed, driven in part by managed clam species. Falling prices are almost universal and due to market dynamics including COVID-19 impacts. Monitor climate risks to surfclams and ocean quahogs.
Recreational opportunities (effort and fleet diversity)	EFFORT: No trend FLEET DIVERSITY: Decline	EFFORT: Near long term average FLEET DIVERSITY: Below long term average	Recreational effort shows no long term trend and is near average, 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.
Stability (fishery and ecosystem diversity maintained over time)	FISHERY: No trend ECOSYSTEM: Mixed trends	FISHERY: Near long term average ECOSYSTEM: Near long term average	Commercial: Fleet diversity metrics suggest 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 and continues to be above the long-term mean. 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.
Social and cultural (community fishery engagement, reliance, and environmental justice vulnerability)	**Status only indicator**	**Environmental justice status for top commercial and recreational communities**	These indicators are used to identify top fishing communities and those with environmental justice concerns based on 2020 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. The top Mid Atlantic recreational communities changed between 2019 and 2020.
Protected species (coastwide bycatch, population numbers, mortalities)	BYCATCH: Mixed trends POPULATION NARW: Decline	BYCATCH: Meeting objectives POPULATION NARW: Below long term average	Mixed bycatch trends through 2021 are related to fishery management, shifts in population distribution combined with fishery shifts, and population increase for seals. Recent bycatch data is uncertain. 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.

Risks to Meeting Fishery Management Objectives

Climate and Ecosystem Productivity Risks

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

- 2022 was among the warmest years on record in the North Atlantic, with both long term surface and bottom warming observed in the Mid-Atlantic.
- The Gulf Stream is becoming less stable and moving further north, which can affect the physics, chemistry, and biology of the Northeast Shelf.
- The cold pool is becoming warmer, smaller, and shorter in duration, which affects habitat for multiple federally managed species.
- Ocean acidification in western Long Island Sound, nearshore to mid-shelf waters of the Mid-Atlantic Bight off the coast of New Jersey, and in waters > 1000 meters may impact organisms.
- Above average early winter and late fall phytoplankton blooms were observed in the Mid-Atlantic, but larger phytoplankton concentrations were below average in early fall.
- The value of Chesapeake Bay habitat for fishes is changing. Several finfish species, including summer flounder, show relative decline in Chesapeake Bay habitat usage. There is evidence that suitable habitat for juvenile summer flounder has declined between 47% and 64% since 1996.
- Shifts in species distribution are being observed across many managed fish and marine mammal species, complicating regional management by changing fishing patterns and risks.
- Fish condition was mixed in 2022, and fish productivity is declining for many managed species.

Other Ocean Uses: Offshore Wind Risks

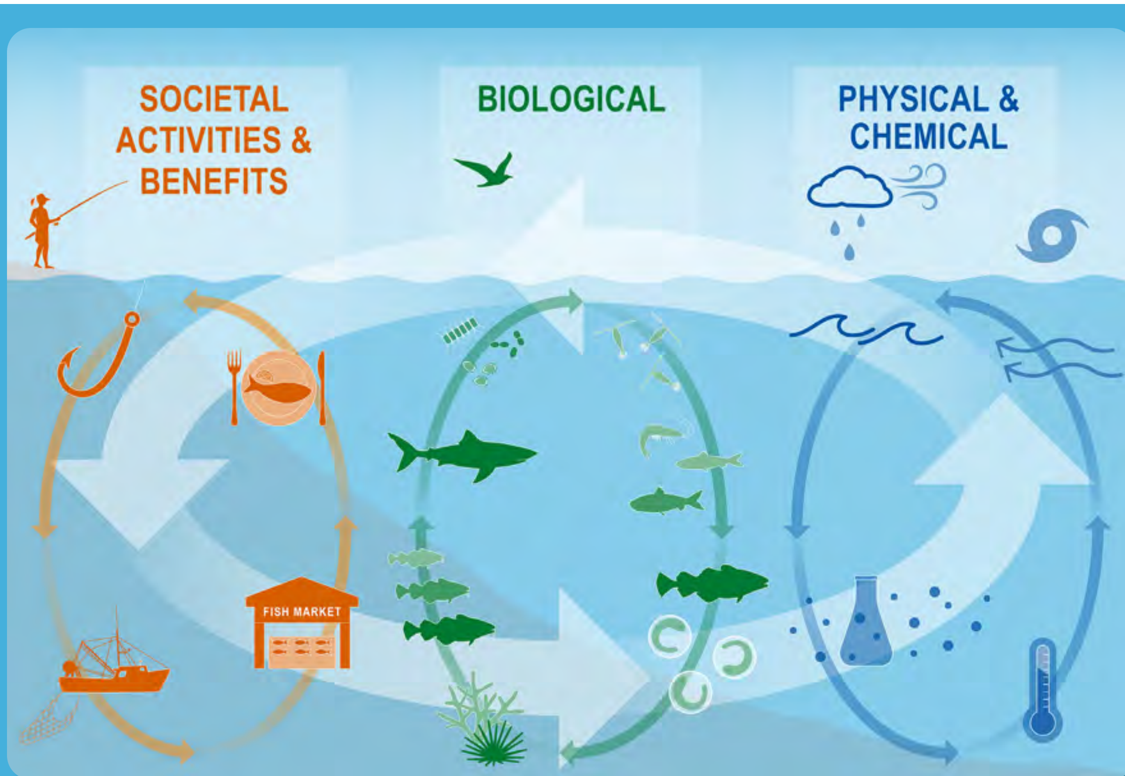
More than 31 offshore wind development projects are proposed for construction on the Northeast shelf, covering more than 2.4 million acres by 2030. Additional large areas are being considered. In existing and proposed leases of the Northeast:

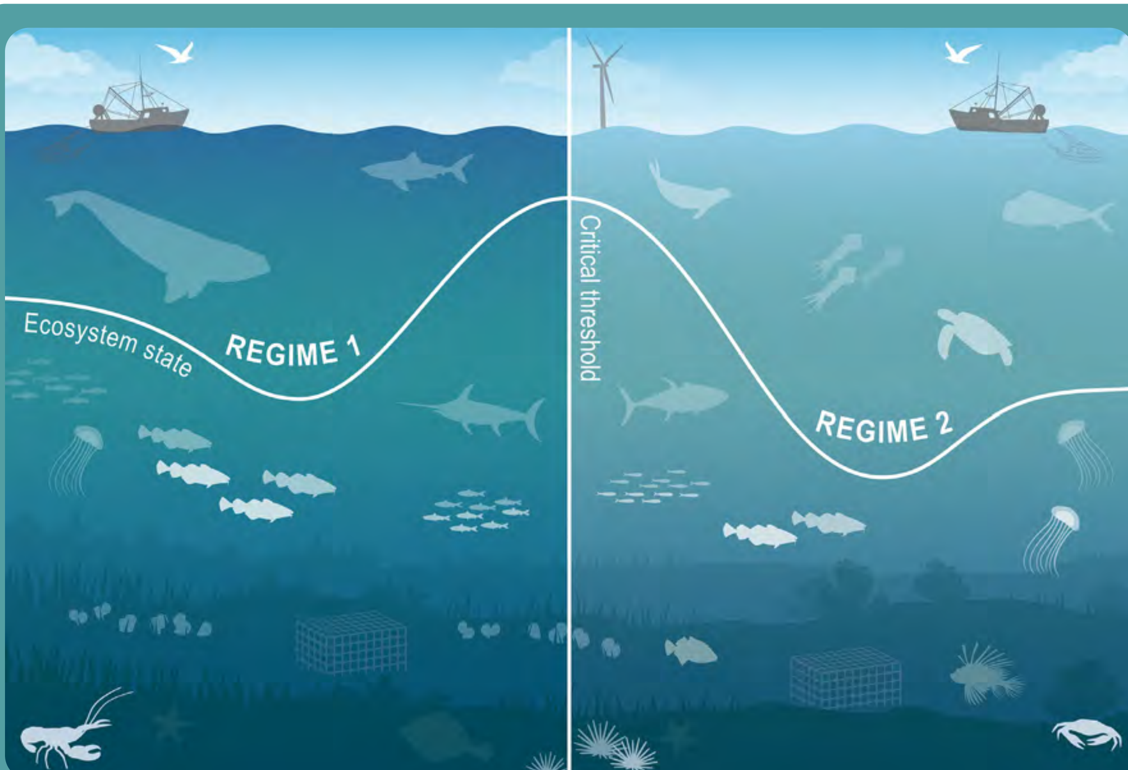
- 1–34% of port revenue from fisheries currently comes from areas proposed for offshore wind development. Some of these port communities score medium-high to high in environmental justice concerns and gentrification vulnerability.
- Up to 17% of annual commercial landings and revenue for Mid-Atlantic managed species occur in lease areas and may shift to other areas.
- Development at different scales 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 important 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.
- Scientific surveys are key to understanding the impacts of climate change and other drivers on managed species, and inform management advice. Planning for impacts to scientific surveys is in progress.
- 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. 57a), categorization of fish and invertebrate species into feeding guilds (Table 3), and definitions of ecological production units (EPUs, including the Mid-Atlantic Bight, MAB; Fig. 57b) 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

Seafood Production

Indicators: Landings; commercial and recreational

This year, we present updated indicators for total commercial landings (all species, all uses, fleets from all nations), US seafood landings (species for human consumption landed by US fleets), and Council-managed US seafood landings (Mid-Atlantic Fishery Management Council (MAFMC) and jointly managed species landed by US fleets for human consumption). Total commercial landings (black) within the Mid-Atlantic have declined over the long term, and total US seafood landings are near their all time low. Because there is no long term trend in MAFMC managed US seafood landings, the decline in US seafood landings in the Mid-Atlantic region is likely driven by recent declines in species not managed by the Mid-Atlantic Council (Fig. 1).

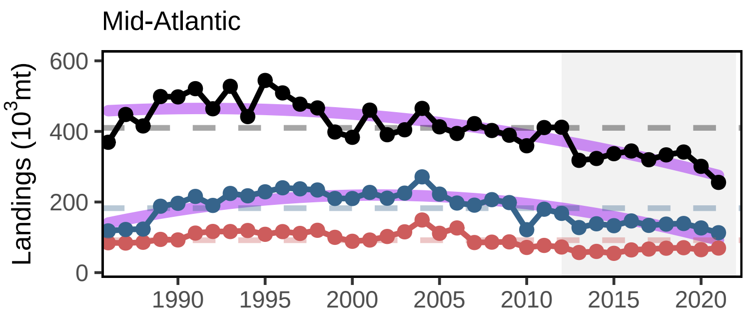


Figure 1: Total commercial landings (black), total U.S. seafood landings (blue), and Mid-Atlantic managed U.S. seafood landings (red)

Landings by guild include all species and all uses, and are reported as total for the guild and the MAFMC managed species within the guild. As reported in previous years, landings of benthos presented a significant downward trend, primarily driven by surf clam and ocean quahog. However, total landings of planktivores is now also presenting a significant downward trend, primarily due to decreases in species not managed by the Mid-Atlantic Council (Atlantic herring and Atlantic menhaden; Fig. 2).

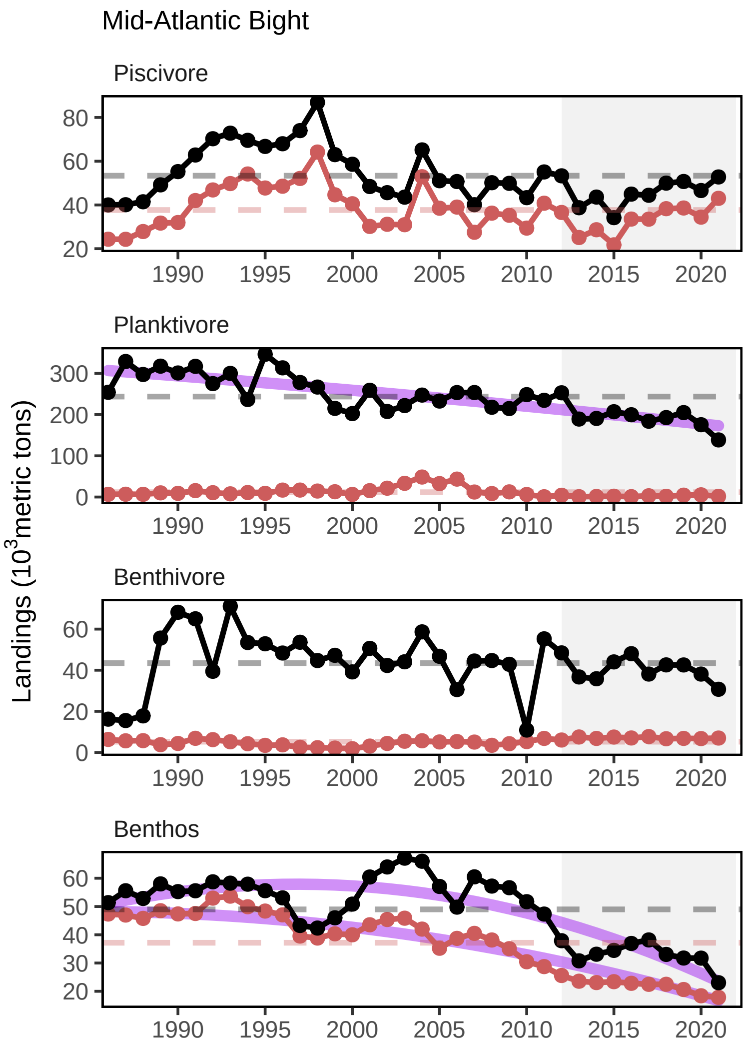


Figure 2: Total commercial landings (black) and MAFMC managed U.S seafood landings (red) by feeding guild.

Total recreational harvest (retained fish presumed to be eaten) is down in the MAB (Fig. 3). Although harvest has increased from a historic low in 2018, it is still below the long term average.

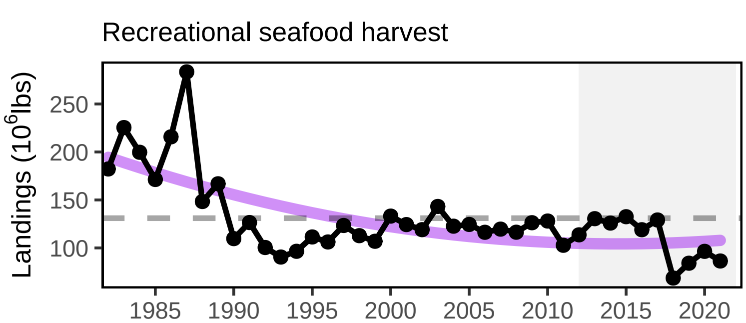


Figure 3: Total recreational seafood harvest (millions of pounds) in the Mid-Atlantic region.

Recreational shark landings show an increase in pelagic sharks over the past decade, with a sharp decrease in 2018 - 2019 persisting through 2022 (Fig 4). 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 (ICCAT) finalized recommendations for a two-year retention ban for shortfin mako (ICCAT Rec.21-09), which will also affect total overall landings of pelagic sharks in coming years.

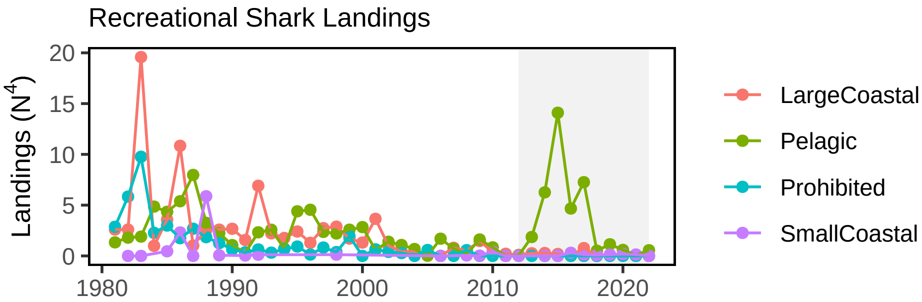


Figure 4: Recreational shark landings from Marine Recreational Information Program.

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 indicates a decline in recent years.[4]

Implications

Declining commercial (total and seafood) 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 one MAFMC managed species, though the status of six stocks is unknown (Fig. 5). In addition, the status of Spiny dogfish and bluefish are based on 2022 research track assessments and are thus waiting for a management track update to finalize stock status.

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

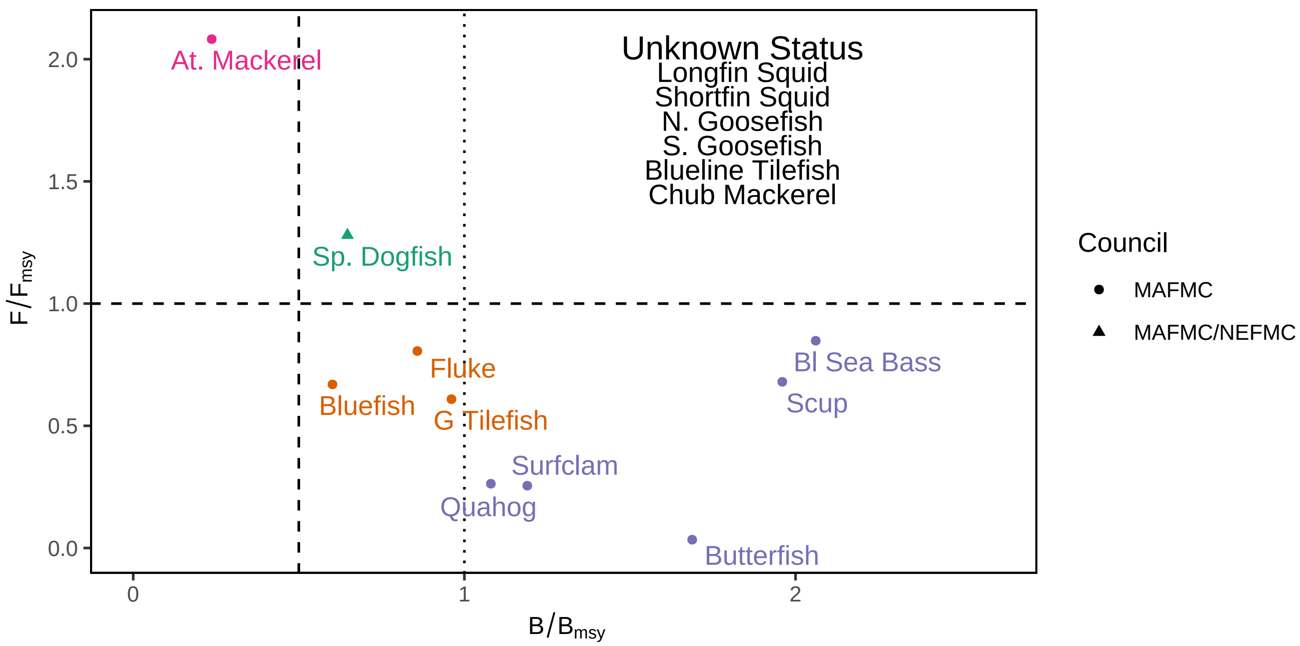


Figure 5: Summary of single species status for MAFMC and jointly federally managed stocks (Spiny dogfish and both Goosefish). The dotted verticxal line is the target bioomass reference point of Bmsy. The dashed lines are the management trehsolds of one half Bmsy (vertical) or Fmsy (horizontal). Stocks in red are below the biomass threshold (overfished) and have fishing mortality above the limit (subject to overfishing), stocks in green are above the biomass threshold but have fishing mortality above the limit. Remaining stocks have fishing mortality within limits: stocks in orange are above the biomass threshold but below the biomass target, and stocks in purple are above the biomass target.

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. 6). Although these figures have not been updated with 2021 data, we do not expect a single year's update to change the narrative. 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.

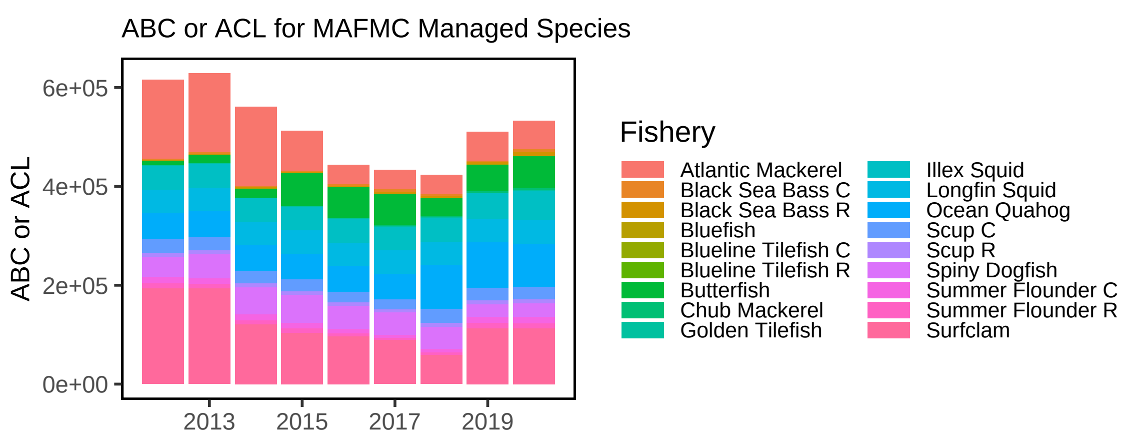


Figure 6: Sum of catch limits across all MAFMC managed commercial (C) and recreational (R) fisheries.

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. 7). Therefore, stock status and associated management constraints are unlikely to be driving decreased landings for the majority of species.

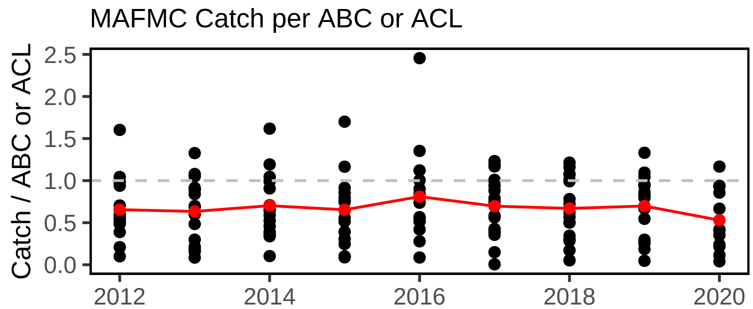


Figure 7: Catch divided by ABC/ACL for MAFMC managed fisheies. High points = Recreational Black Sea Bass. Red line indicates the median ratio across all fisheries.

System Biomass Although aggregate biomass trends derived from scientific resource surveys are mostly stable in the MAB, spring piscivores, spring benthivores, and fall benthos show long-term increases (Fig. 8). 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.

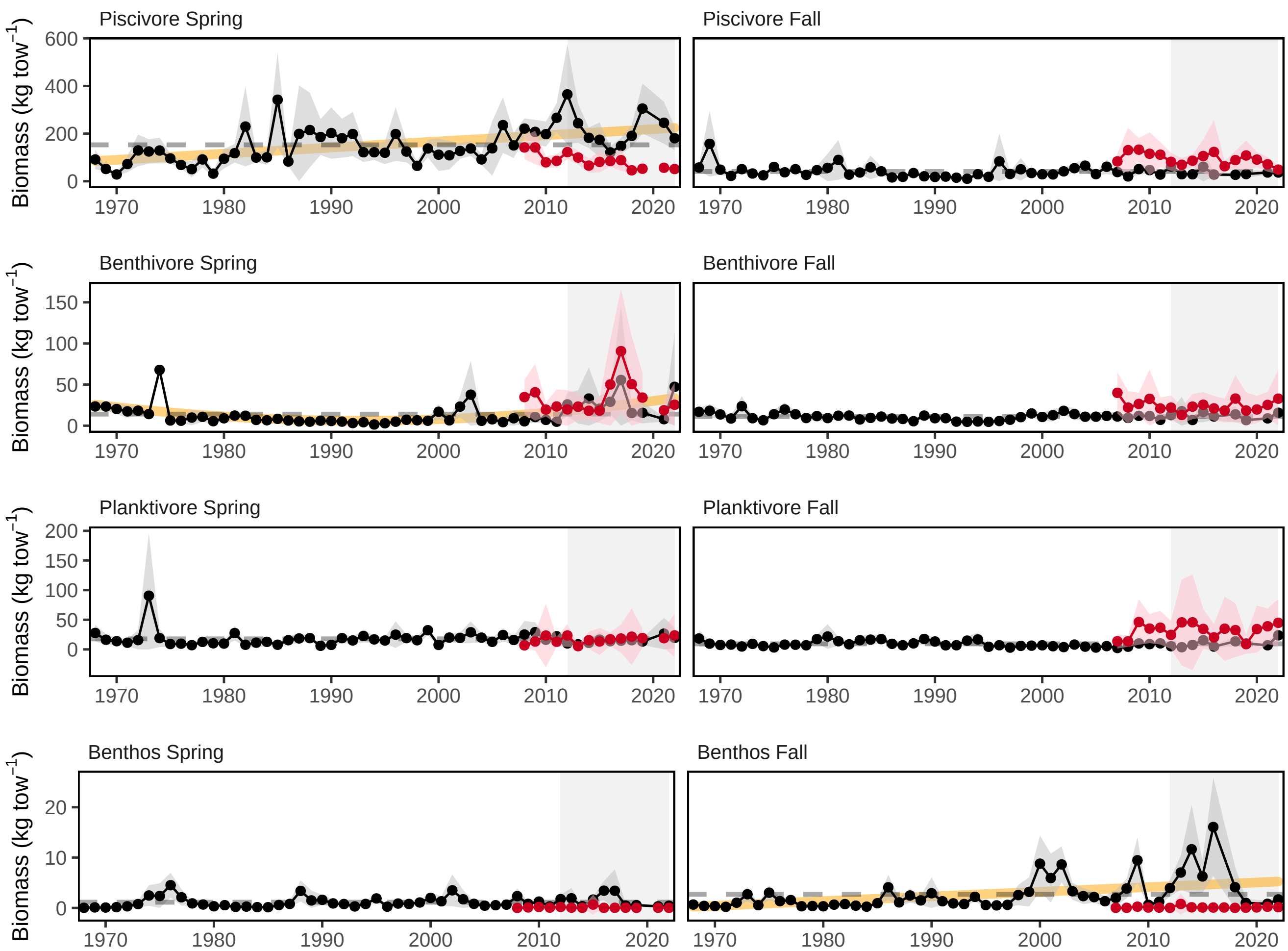


Figure 8: Spring (left) and fall (right) surveyed biomass in the Mid-Atlantic Bight. Data from the NEFSC Bottom Trawl Survey are shown in black, with the nearshore NEAMAP survey shown in red. The shaded area around each annual mean represents 2 standard deviations from the mean.

Effect on Seafood Production Stock status is above the minimum threshold for all but one stock, and aggregate biomass trends appear stable, so the decline in commercial seafood 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. The long term decline in total planktivore landings is largely driven by Atlantic menhaden fishery dynamics, including a consolidation of processors leading to reduced fishing capacity between the 1990s and mid-2000s.

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 harvest 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. Nevertheless, the recreational harvest seems to be stabilizing at a lower level than historical estimates.

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

- Climate is trending into uncharted territory. Globally, 2022 was among the warmest years on record[5] (see Climate Risks section).

- Stocks are shifting distribution, moving towards the northeast and into deeper waters throughout the Northeast US Large Marine Ecosystem (Fig. 9).

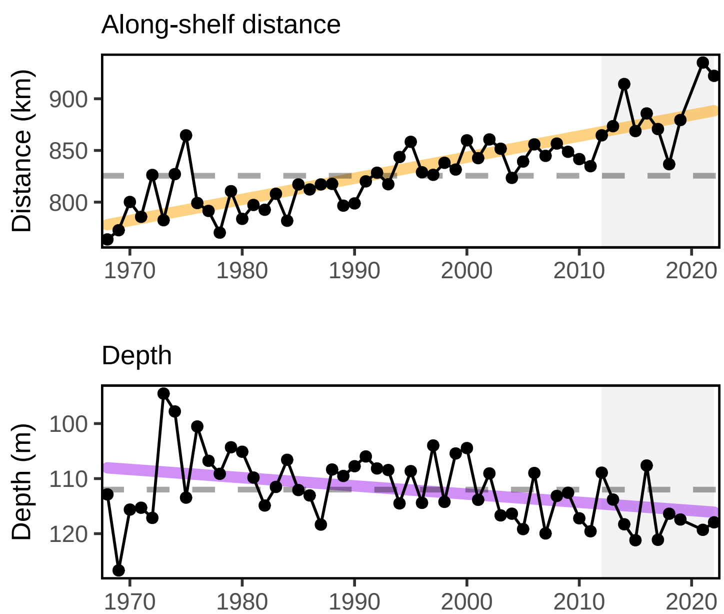


Figure 9: Aggregate species distribution metrics for species in the Northeast Large Marine Ecosystem.

- 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 and Mid-Atlantic managed species revenue both present long-term declining trends. Total revenue is at, and revenue from Mid-Atlantic managed species is near, an all-time low (Fig. 10).

[5] https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

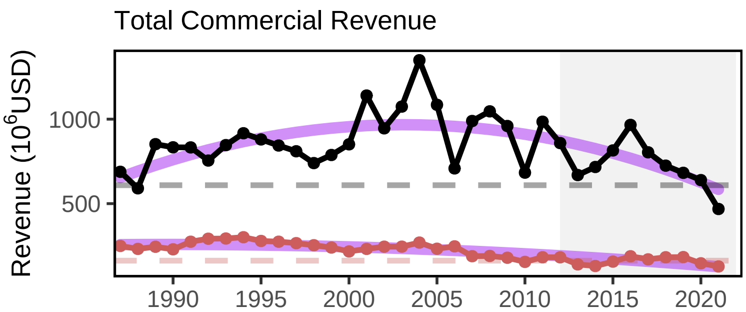


Figure 10: Revenue for the for the Mid-Atlantic region: total (black) and from MAFMC managed species (red).

Revenue earned by harvesting resources is a function of both the quantity landed of each species and the prices paid for landings. Beyond monitoring yearly changes in revenue, it is even more valuable to determine what drives these changes: harvest levels, the mix of species landed, price changes, or a combination of these. The Bennet Indicator decomposes revenue change into two parts, one driven by changing quantities (volumes), and a second driven by changing prices.

Total revenue trends, decomposed to price and volume indicators (Fig. 11), mirror price and volume indicator trends for the benthos (clams; orange in Fig. 12) group, especially over the past decade. However, of note is that only piscivore volume is up across species guilds for either prices or volume when compared to the 2015 benchmark year.

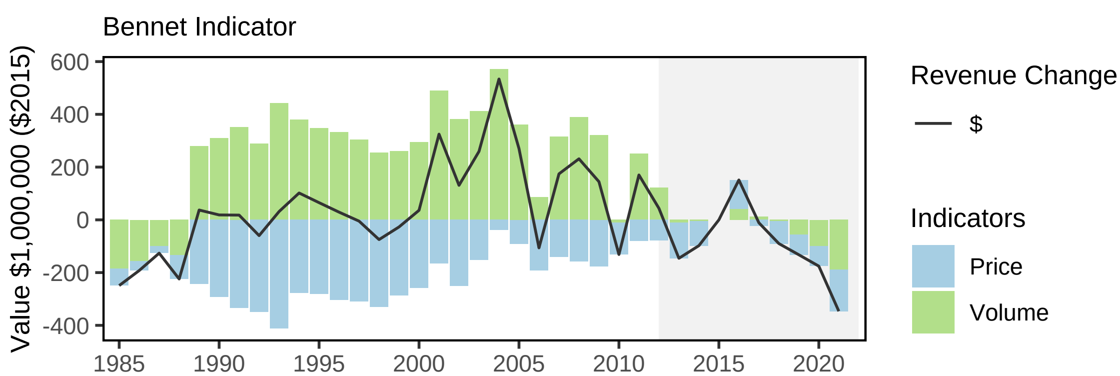


Figure 11: Revenue change from the 2015 values in dollars (black), Price (PI), and Volume Indicators (VI) for commercial landings in the Mid-Atlantic Bight.

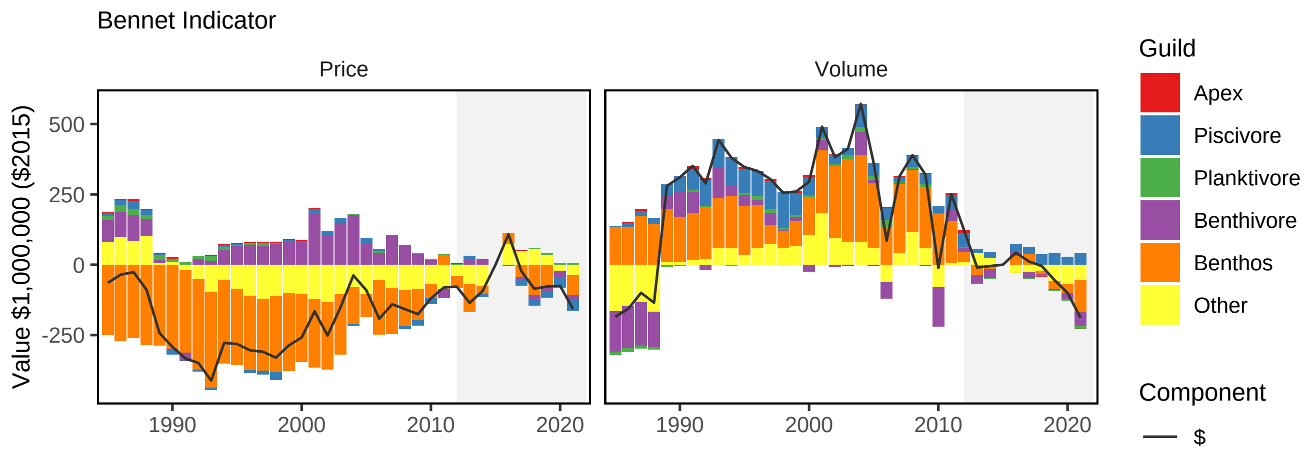


Figure 12: Total component value in dollars (black) for commercial landings in the Mid-Atlantic Bight.

Implications

In a similar manner to seafood landings, the results here are driven in large part by market dynamics affecting the landings of surfclams and ocean quahogs, as landings have been below quotas for these species. 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) in 2021 is around the long-term average (Fig. 13). However, recreational fleet diversity (i.e., effort by shoreside, private boat, and for-hire anglers) has declined over the long term (Fig. 14).

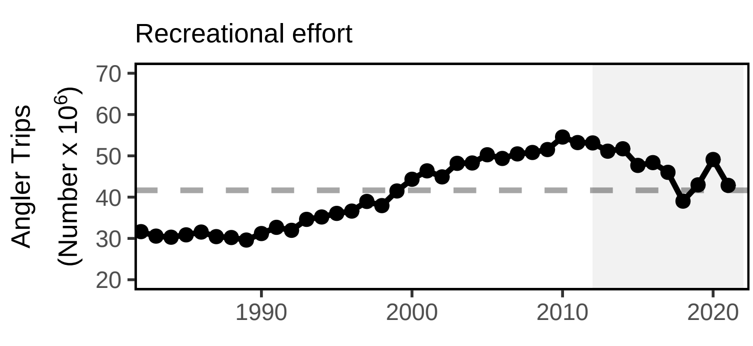


Figure 13: Recreational effort in the Mid-Atlantic.

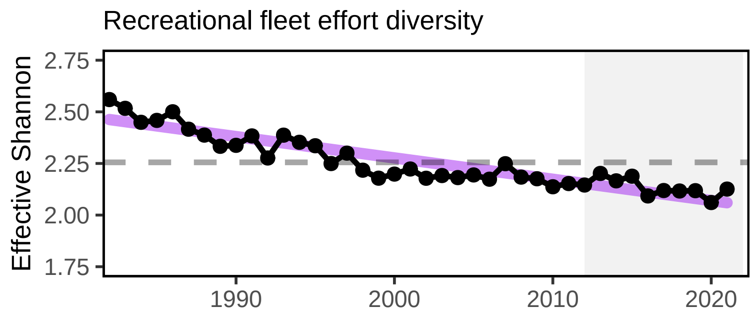


Figure 14: Recreational fleet effort diversity in the Mid-Atlantic.

Implications

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, despite the slight increase in this indicator's value between 2020 and 2021.

The downward effort diversity trend is driven by party/charter contraction (2% currently), and a shift toward shorebased angling, which currently makes up 61% of angler trips.. Effort in private boats remains stable at around 37% of trips.

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. 15). This indicates similar commercial fleet composition and species targeting opportunities over time.

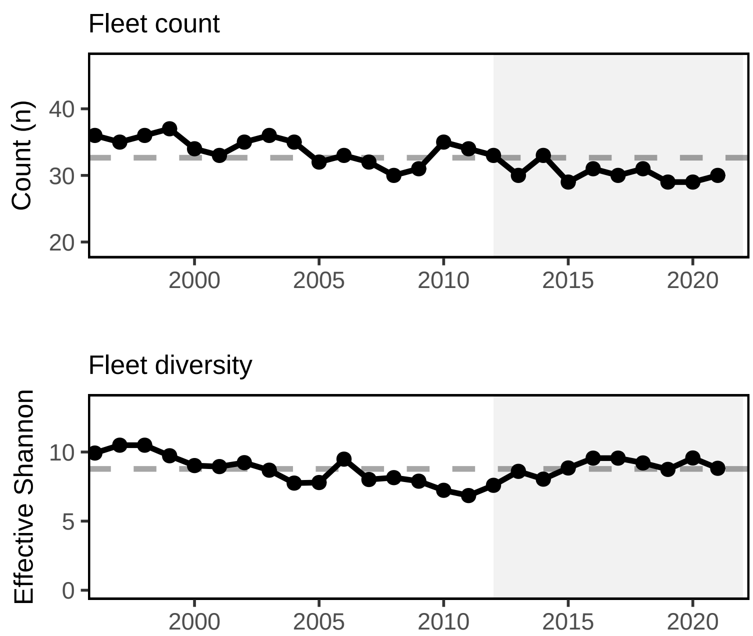


Figure 15: Commercial fleet count and diversity in the Mid-Atlantic.

Commercial fisheries are relying on fewer species relative to the mid-90s, and current species revenue diversity is near the historical low point (Fig. 16). Although with precedent, the drop between 2020 and 2021 is relatively large.

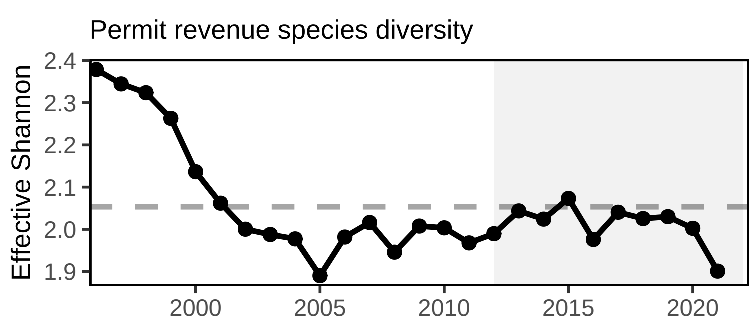


Figure 16: Species revenue diversity in the Mid-Atlantic.

As noted above, recreational fleet effort diversity is declining (Fig. 14), 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. 17).

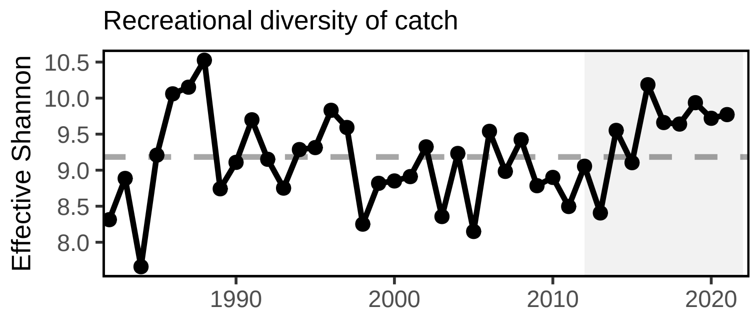


Figure 17: Diversity of recreational catch in the Mid-Atlantic.

Ecological Diversity Ecological diversity indices show mixed trends. Zooplankton diversity is increasing in the MAB (Fig. 18). Larval fish diversity shows no trend, and high interannual variability with 2021 values at the mean. 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. 19).

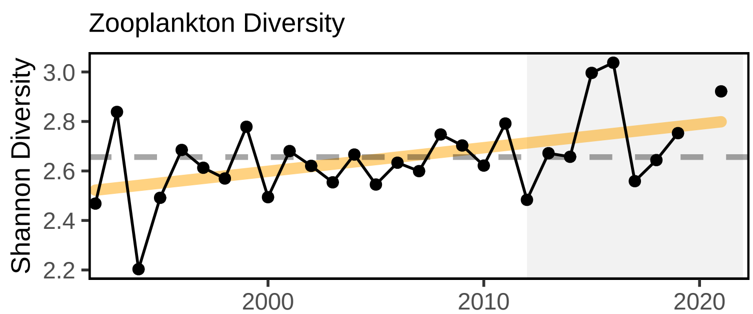


Figure 18: Zooplankton diversity in the Mid-Atlantic Bight, based on Shannon diversity index.

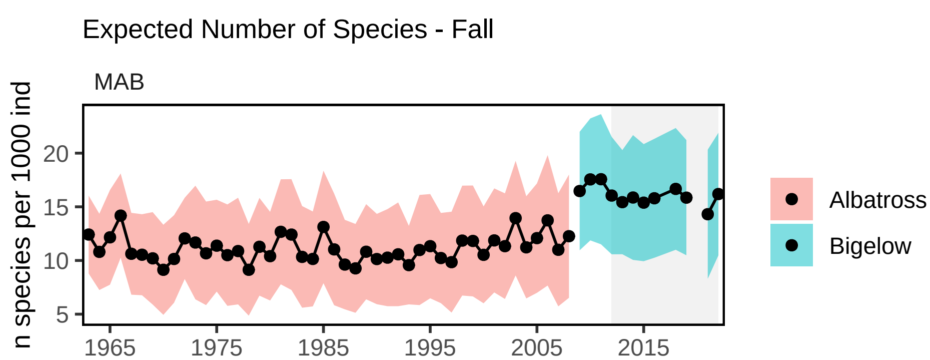


Figure 19: Adult fish diversity in the Mid-Atlantic Bight, based on expected number of species. Results from survey vessels Albatross and Bigelow are reported separately due to catchability differences.

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 [1].

Stability in commercial fleet diversity metrics suggests stable capacity to respond to the current range of fishing opportunities. However, commercial species diversity is relatively low, indicating substantial changes in fishing activities even as the fleet composition sees relative stability.

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 [2]. 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. Increasing zooplankton diversity (due to increases in abundance of several taxa and stable or declining dominance of an important copepod species) suggests a shift in the zooplankton community that warrants continued monitoring to determine if managed species are affected. In addition, the species diversity in landings warrants continued attention given its relatively low value and large year over year decline.

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 factors 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[6].

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 2022, we reported the top ten most engaged, and top ten most reliant commercial and recreational fishing communities and their associated environmental justice vulnerability based on 2019 data. Here we apply the same selection standard for top ten fishing communities for both sectors using 2020 data, and again examine the environmental justice vulnerability in this updated set of communities. Changes in fishing activity between years changed community engagement and reliance rankings, and changes in vulnerability indicators changed environmental justice vulnerability scores.

Communities plotted in the upper right section of Fig.20 scored high for both commercial engagement and reliance using both 2019 and 2020 data, 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 in 2020 are highlighted in bright orange, including Newport News, VA; Atlantic City, NJ; and Beaufort, Columbia and Hobucken, NC. Hampton

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

Bays/Shinnecock, NY ranked medium-high based on 2019 data but decreased to medium for its environmental justice vulnerability based on 2020 data reported here.

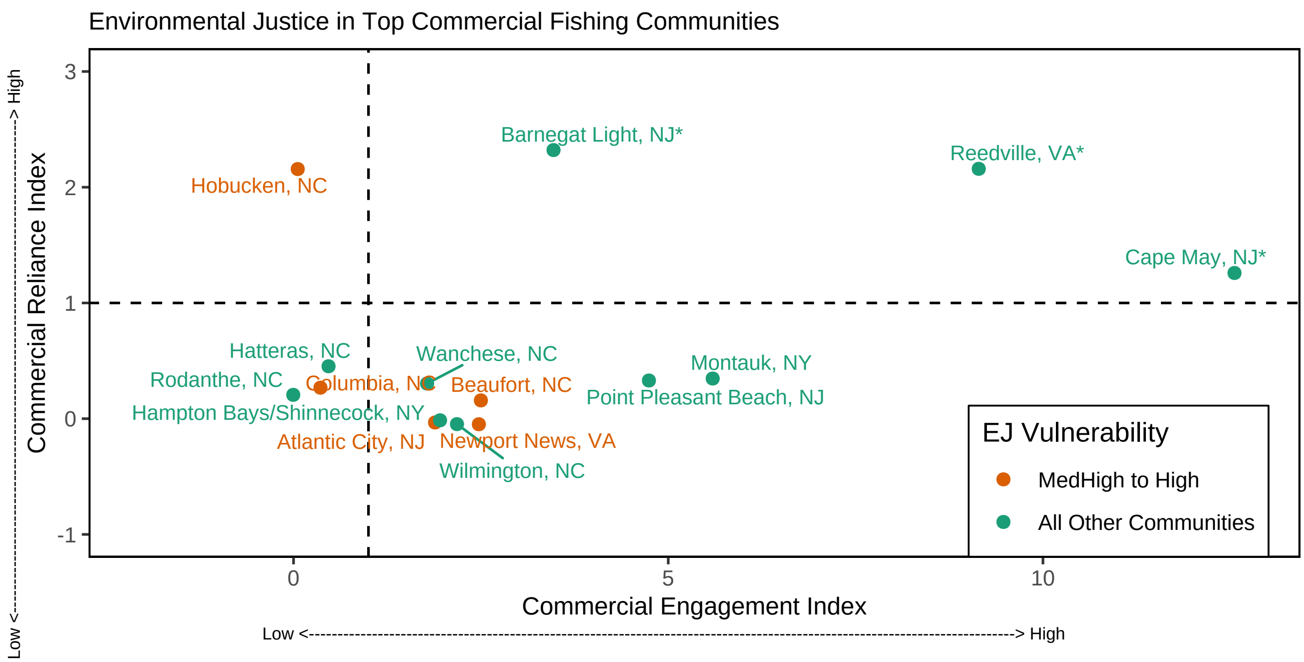


Figure 20: Commercial engagement, reliance, and environmental justice vulnerability for the top commercially engaged and reliant fishing communities in the Mid-Atlantic. Communities ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange. *Community scored high (1.00 and above) for both commercial engagement and reliance indicators.

Fig. 21 shows the detailed scores of the three environmental justice indicators for the same communities plotted in Fig.20. 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, Atlantic City, NJ scored high for all of the three environmental justice indicators. Columbia, NC scored high for the personal disruption index and the poverty index. Hobucken, NC scored high for the personal disruption index. Newport News, VA scored medium-high for the population composition index[7]. Beaufort, NC scored medium-high for the poverty index.

[7] Due to missing data, the Poverty Index is missing for Hobucken and Rodanthe, NC

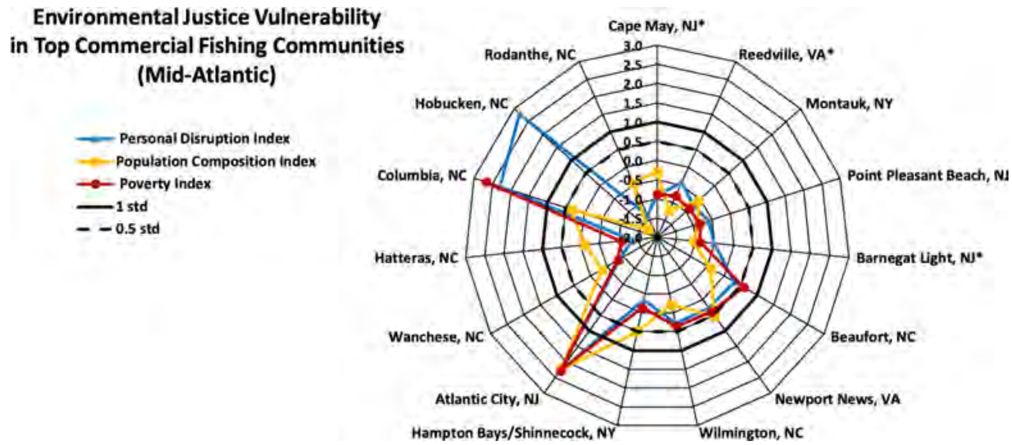


Figure 21: Environmental justice indicators (Poverty Index, population composition index, and personal disruption index) for top commercial fishing communities in Mid-Atlantic. *Community scored high (1.00 and above) for both commercial engagement and reliance indicators.

Considerably more communities scored high for both recreational engagement and reliance based on 2020 data relative to 2019. Joining Barnegat Light, NJ in the upper right section are Babylon, NY, Nags Head, NC, Hatters, NC, Stevensville, MD, Atlantic Highlands, NJ, Morehead City, NC, Montauk, NY, Point Pleasant Beach, NJ, Ocean City, MD, Point Lookout, NY, Manteo, NC, and Vandemere, NC. Fig.22. Communities that ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange, including Ocean City and Bivale, MD; Hatteras, Manteo, Vandemere, and Hobuken, NC.

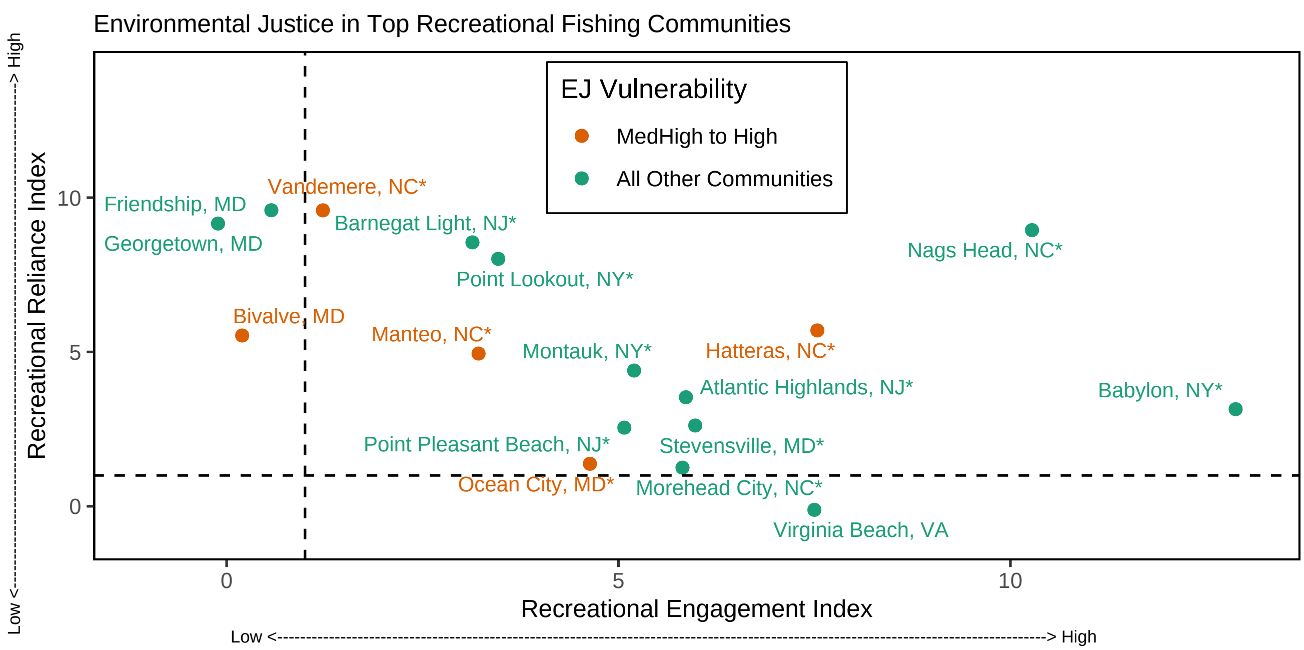


Figure 22: Recreational engagement and reliance, and environmental justice vulnerability, for the top recreationally engaged and reliant fishing communities in the Mid-Atlantic. Communities ranked medium-high or above for one or more of the environmental justice indicators are highlighted in bright orange. *Community scored high (1.00 and above) for both recreational engagement and reliance indicators.

Fig. 23 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. Among the communities with environmental justice concerns, Hatteras and Vandemere, NC scored medium-high for personal disruption and poverty index. Ocean City, MD and Hobucken, NC scored medium-high for personal disruption index. Manteo, NC scored high for poverty index. Bivale, MD scored medium-high for population composition index[8].

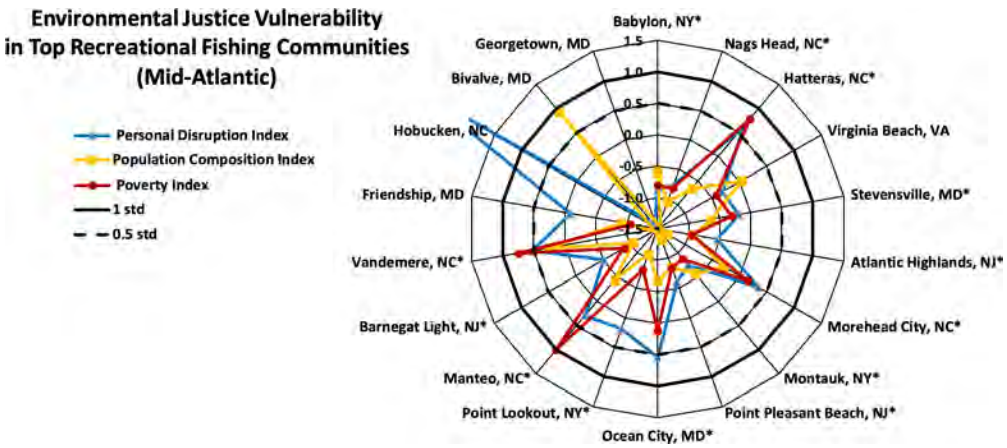


Figure 23: Environmental justice indicators (Poverty Index, population composition index, and personal disruption index) for top recreational fishing communities in Mid-Atlantic. *Community scored high (1.00 and above) for both recreational engagement and reliance indicators.

Both commercial and recreational fishing are important activities in Montauk, NY, Barnegat Light and Point Pleasant Beach, NJ, Hatteras and Hobuken, NC, meaning these communities may be impacted simultaneously by commercial and recreational regulatory changes. Among these communities, Hobucken scored high for the personal disruption index[9]. Hatteras scored medium-high for the personal disruption index and Poverty Index. Montauk, NY, Barnegat Light, Cape May and Point Pleasant Beach, NJ 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

There was an increase in recreational fishing activities in many of the top recreational communities from 2019 to 2020. This increase may be due to multiple factors including the recreational boating boom across the country[10] and increasing interest in for-hire/charter recreational fishing trips as an preferred outdoor recreation activities and ways to social distance in response to the COVID-19 pandemic [3].

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

[8] Due to missing data, the Poverty Index is missing for Hobucken, NC, Bivalve and Georgetown, MD

[9] Due to missing data, the Poverty Index is missing for Hobucken, NC

[10] National Marine Manufacturers Association. 2021. U.S. Boat Sales Reached 13-Year High in 2020, Recreational Boating Boom to Continue through 2021. Available at: https://www.nmma.org/press/article/23527

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

Average indices for both harbor porpoise (Fig. 24) and gray seal bycatch (Fig. 25) are below current PBR thresholds, meeting management objectives. However, the 2019 bycatch estimate for gray seals was highest in the time series.

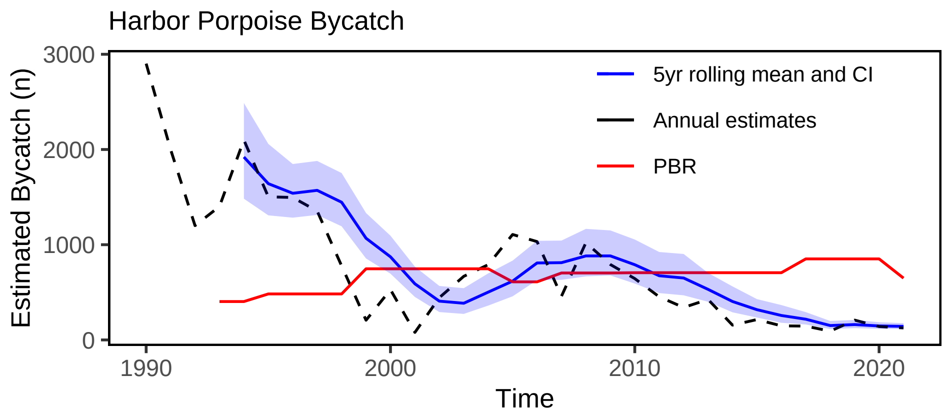


Figure 24: Harbor porpoise average bycatch estimate for Mid-Atlantic and New England gillnet fisheries (blue) and the potential biological removal (red).

The annual estimate for gray seal bycatch has declined since 2019, in part driven by declining gillnet landings. In addition, estimates since 2019 have greater uncertainty stemming from low observer coverage since 2019. The rolling mean confidence interval remains just below the removal threshold.

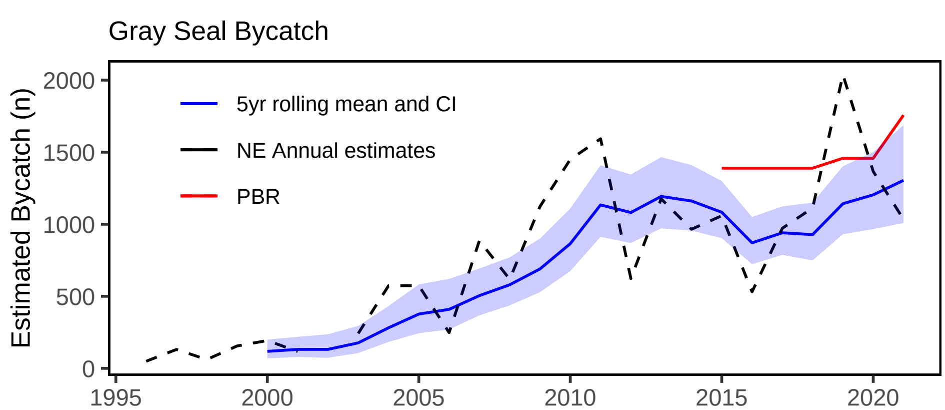


Figure 25: Gray Seal average bycatch estimate for gillnet fisheries (blue) and and the potential biological removal (red).

The North Atlantic right whale population was on a recovery trajectory until 2010, but has since declined (Fig. 26). Reduced survival rates of adult females and diverging abundance trends between sexes have also been observed. It is estimated that there are fewer than 70 adult females remaining in the population.

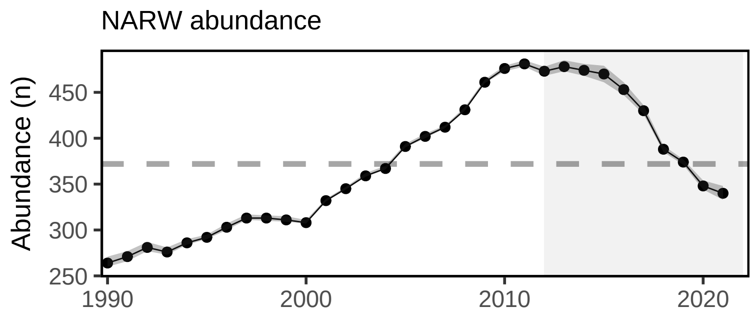


Figure 26: Estimated North Atlanic right whale abundance on the Northeast Shelf.

North Atlantic right whale calf counts have generally declined after 2009 to the point of having zero new calves observed in 2018 (Fig. 27). However, since 2019, we have seen more calf births each year, with 20 births in 2022.

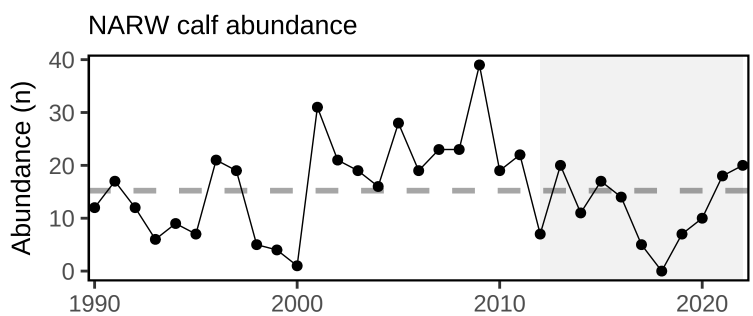


Figure 27: Number of North Atlantic right whale calf births, 1990 - 2021.

This year, the Unusual Mortality Event (UME) for North Atlantic right whales continued. Since 2017, the total UME right whale mortalities includes 35 dead stranded whales, 14 in the US and 21 in Canada. When alive but seriously injured whales (22) and sublethal injuries or ill whales (37) are taken into account, 94 individual whales are included in the UME. 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[11].

A UME continued from previous years for humpback whales (2016-present); suspected causes include human interactions. A UME for both gray and harbor seals on the Maine coast was declared in June 2022 due to a high number of mortalities thought to be caused by highly pathogenic avian influenza virus. A UME for minke whales that began in 2017 remains open, but is pending closure as of January 2023[12].

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

[11] https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2023-north-atlantic-right-whale-unusual-mortality-event
[12] https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events

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]). 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 (the copepod *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 the 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 avian flu 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 The ocean continues to warm, altering habitat conditions experienced by a wide range of species. 2022 was among the warmest years on record in the North Atlantic [11] and ocean temperatures continue to warm at both the surface (Fig. 28) and bottom (Fig. 29) throughout the Mid-Atlantic. Bottom temperature shows a long term warming trend in all seasons, while sea surface temperature shows significant long term warming in spring, summer, and fall. Seasonal sea surface temperatures in 2022 were above average for most of the year, however late spring storms caused deep mixing, which delayed stratification and surface warming in late spring and early summer.

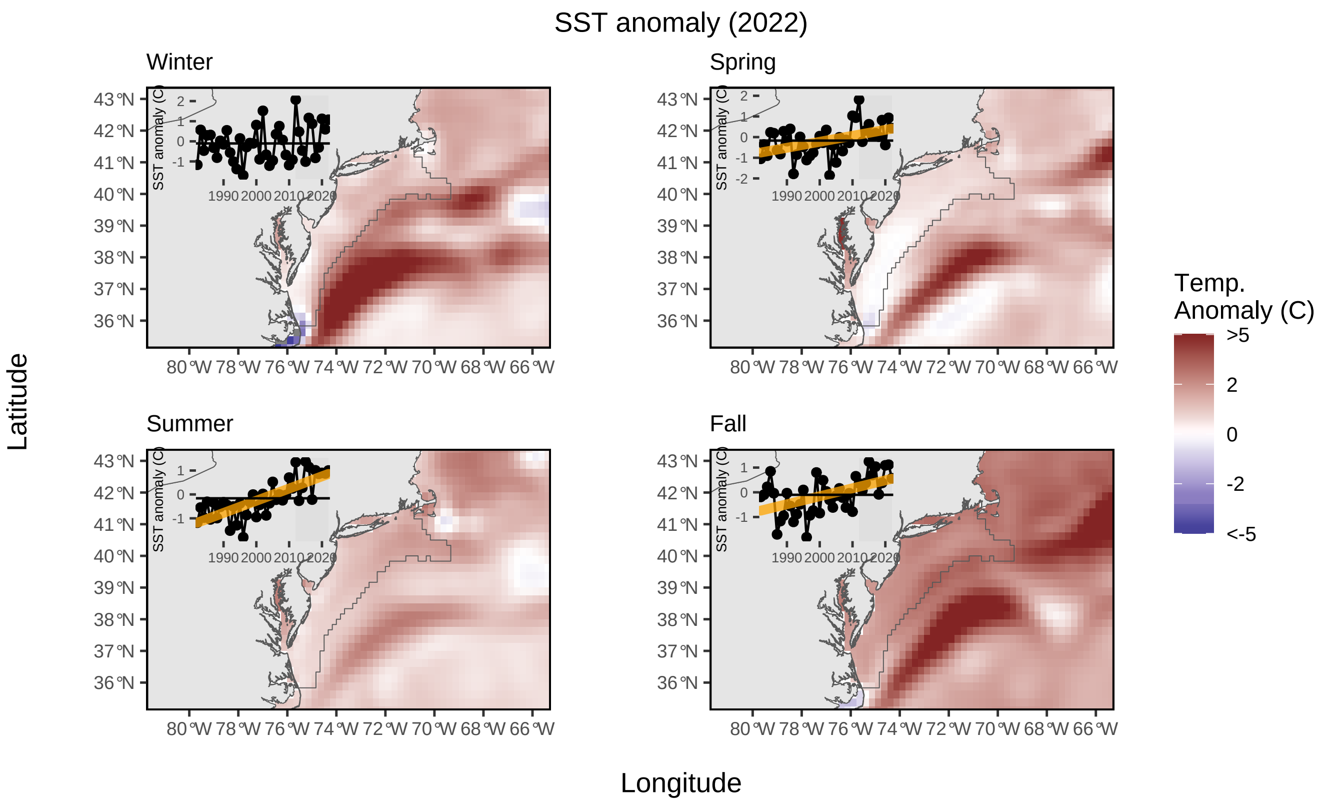


Figure 28: MAB (grey outline) seasonal sea surface temperature (SST) time series overlaid onto 2021 seasonal spatial anomalies. Seasons are defined as: Jan-Mar for winter, Apr-Jun for spring, Jul-Sep for summer, and Oct-Dec for fall.

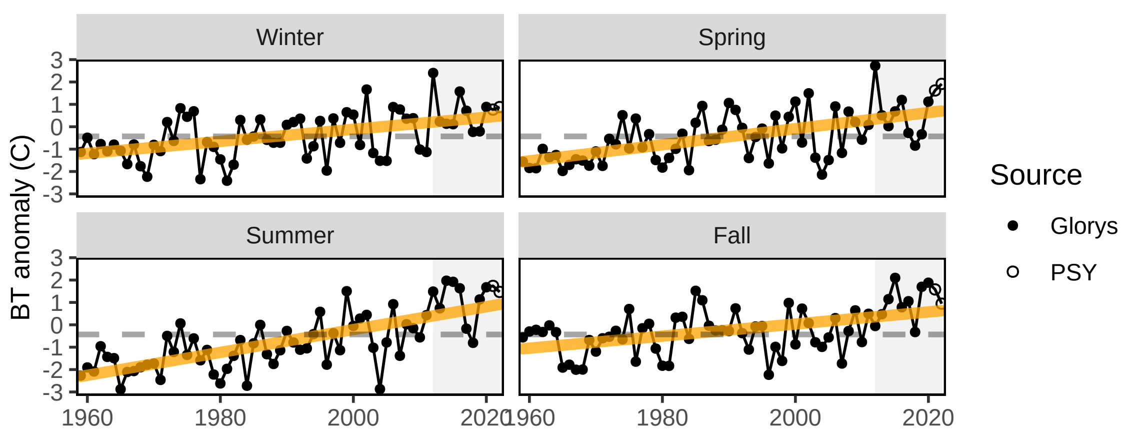


Figure 29: MAB seasonal bottom temperature (BT) anomaly time series. Seasons are defined as: Jan-Mar for winter, Apr-Jun for spring, Jul-Sep for summer, and Oct-Dec for fall. The final 2 years of each time series (open circles) are modeled estimates subject to change.

In addition to increasing temperatures overall, ocean summer conditions now last longer within each year. In the MAB, the transition date from warm stratified summer conditions to well mixed cool fall conditions is getting later (Fig. 30).

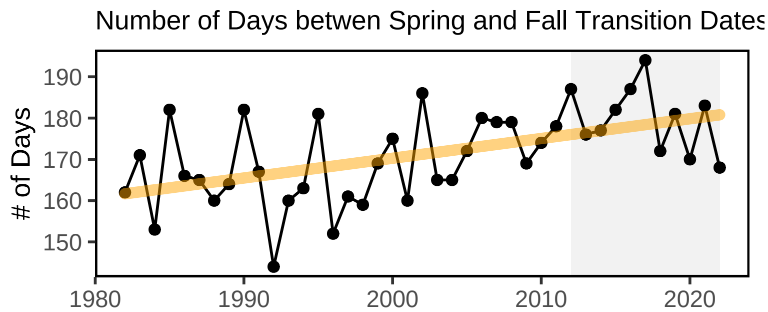


Figure 30: Ocean summer length in the MAB: the annual total number of days between the spring thermal transition date and the fall thermal transition date. The transition dates are defined as the day of the year when surface temperatures changeover from cool to warm conditions in the spring and back to cool conditions in the fall.

The Chesapeake Bay experienced a warmer-than-average winter 2022, and average conditions in the spring and summer. Fall 2022 was cooler relative to the baseline period 2008-2021 as measured by satellites[13] and by buoys[14] (Fig. 31, left panel), which also indicated above-average salinity in the Chesapeake Bay throughout the summer and fall (Fig. 31, right panel).

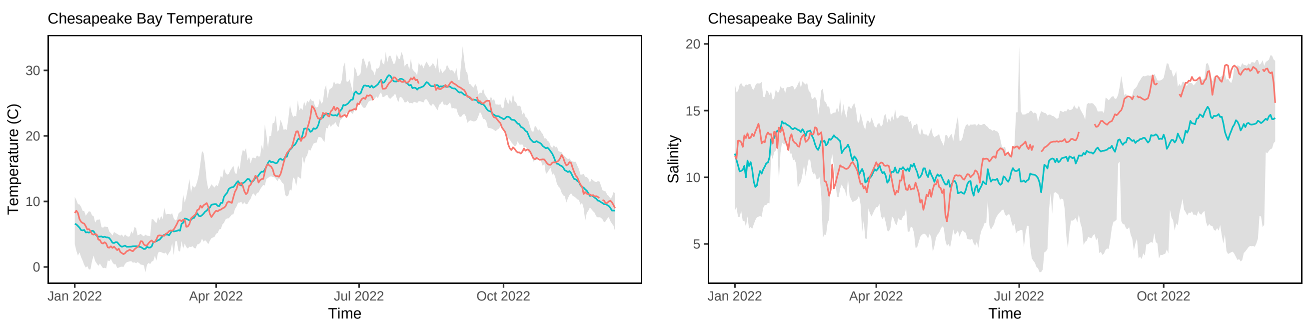


Figure 31: NOAA Chesapeake Bay Interpretive Buoy System Gooses Reef bouy sea water temperature (left) and salinity (right); Red = 2022, Blue = Long term average 2010-2020.

Extreme temperature events The increase in surface and bottom water temperature observed in the Northeast US may represent long term incremental stress on marine organisms, especially those relying on cooler water habitats for some or all life stages. In addition to changes in long-term average conditions, short-term extreme temperature events can produce acute stress on marine organisms, especially when the baseline temperature is increasing. To identify these extreme events separately from the baseline warming, we have changed our methods describing marine heatwaves (MHWs, [12]; [13]; [14]) to remove the global warming signal. Therefore, these indicators look different than in previous reports, but MHWs identified now are truly extreme departures from an already warming ecosystem. A combination of long-term ocean warming and MHWs should be used to assess total heat stress on marine organisms.

In 2022, the Mid-Atlantic Bight experienced two distinct surface marine heatwaves starting on August 29th and November 7th, lasting 9 and 11 days respectively (Fig. 32). Both ranked low among all recorded MWHs (75th and 73rd respectively). The top 4 strongest surface MHWs in the MAB occurred during the last ten years, with the two events in 2012 ranked as 1st and 3rd. No bottom MHWs were observed in 2022. The strongest bottom MHWs occurred in the fall of 1985 followed by the second strongest in the winter/spring of 2012.

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

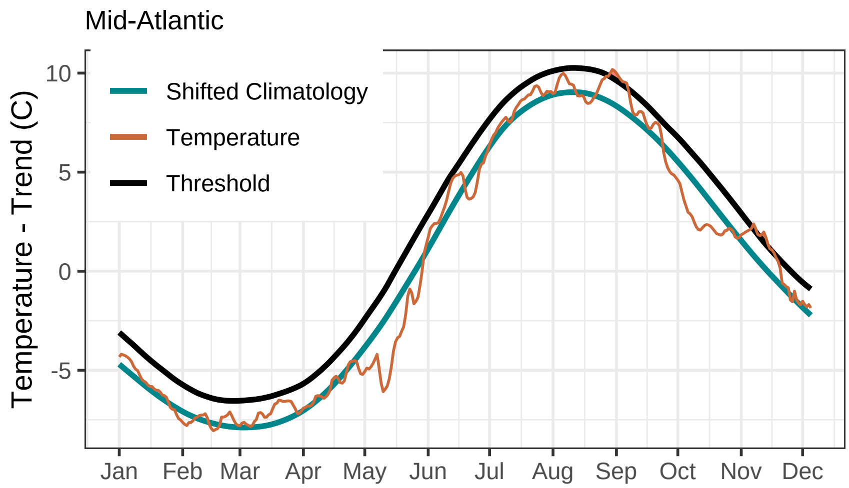


Figure 32: Marine heatwave events (red shading above black line) in the Mid-Atlantic occuring in 2022.

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 [15]. 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 [16,17] (Fig. 33). A more northern Gulf Stream position is associated with warmer ocean temperature on the northeast shelf [18], a higher proportion of Warm Slope Water in the Northeast Channel, and increased sea surface height along the U.S. east coast [19].

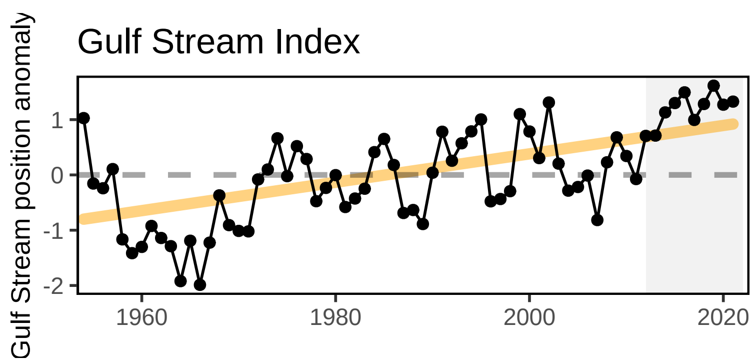


Figure 33: Index representing changes in the location of the Gulf Stream north wall. Positive values represent a more northerly Gulf Stream position.

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 [20]. 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. 34). 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.

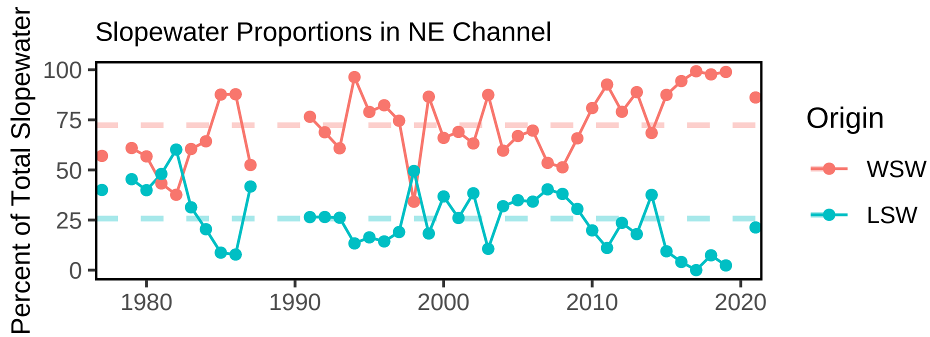


Figure 34: Proportion of Warm Slope Water (WSW) and Labrador Slope Water (LSLW) entering the Gulf of Maine through the Northeast Channel.

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 [15,21] (Fig. 35). When warm core rings and eddies interact with the continental slope they can transport warm, salty water to the continental shelf [22], which can alter the habitat and disrupt seasonal movements of fish [23]. Transport of offshore water onto the shelf is happening more frequently [23,24], and can contribute to marine heatwaves in the Mid-Atlantic Bight [22,25] as well as the movement of shelf-break species inshore [23,26,27].

2022 had the same number of warm core rings (21) as 2021, but most of the 2022 rings formed east of 60 W and fewer were observed near the shelf break region.

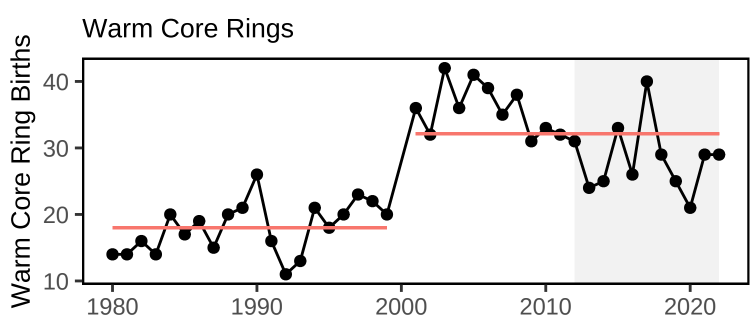


Figure 35: Warm core ring formation on the Northeast U.S. Shelf: Annual number of rings.

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 [28,29]. 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 [28,30]. The average temperature of the cold pool is getting warmer over time [31,32], the area is getting smaller [33], and the duration is getting shorter (Fig. 36).

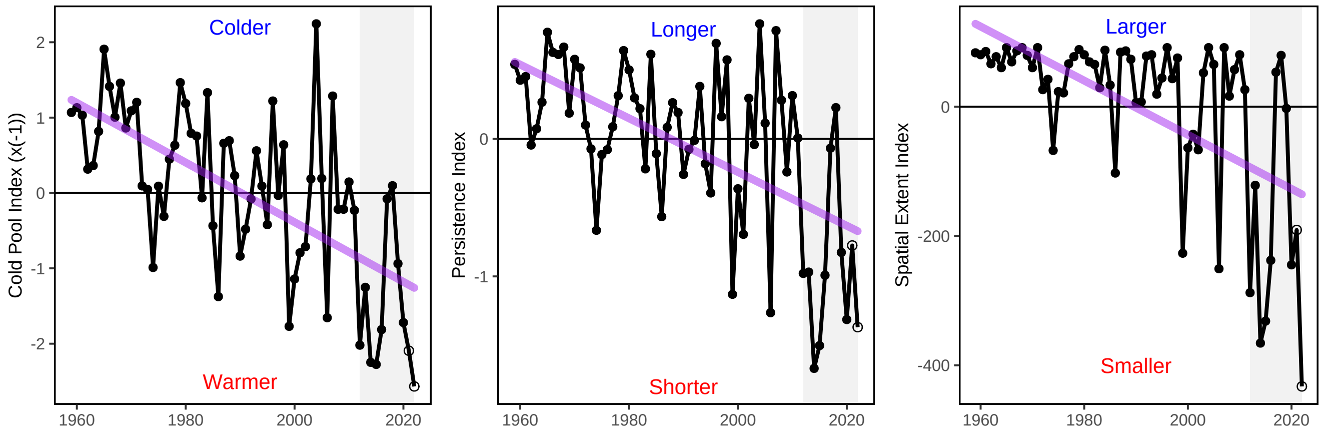


Figure 36: Seasonal cold pool indices: mean temperature within the cold pool, cold pool persistence, and spatial extent.

Ocean Acidification Ocean acidification (OA) has caused measured declines in global ocean pH, and is projected to continue declining if high carbon dioxide emissions continue [34]. OA also changes the availability of minerals required by organisms to form calcified structures such as shells. Calcifying conditions in seawater can be determined by measuring aragonite saturation state (Ω_{Arag}), the tendency of a common type of calcium carbonate, aragonite, to form or dissolve. When Ω_{Arag} is less than 1, shells and other calcium carbonate structures begin to dissolve. Typical surface ocean Ω_{Arag} is 2-4, but extremes can be $<$1 or $>$5 [35]. As the ocean absorbs carbon dioxide, both pH and Ω_{Arag} decrease and can cause organisms to respond with reduced survival, calcification rates, growth, and reproduction, as well as impaired development, and/or changes in energy allocation [37]. However, sensitivity levels vary, and some organisms exhibit negative responses to calcification and other processes when Ω_{Arag} is as low as 3.

Summer-time (2007-present) Ω_{Arag} on the U.S. Northeast Shelf varies in space and time, ranging from 0.64 to 2.49 (Fig. 37, left panel). Spatially, the lowest bottom Ω_{Arag} has occurred in the Gulf of Maine, western Long Island Sound, nearshore to mid-shelf waters of the Mid-Atlantic Bight off the coast of New Jersey, and in waters $>$ 1000 meters. Ω_{Arag} was at or below the sensitivity levels for both Atlantic sea scallop [38] and longfin squid [39,40] in Long Island Sound and the nearshore and mid-shelf regions of the New Jersey shelf (Fig. 37, right panels). The sensitivity levels of bottom Ω_{Arag} occurred during August 2016, July 2018, and August 2019 for both species, and additionally in August 2021 for the Atlantic sea scallop.

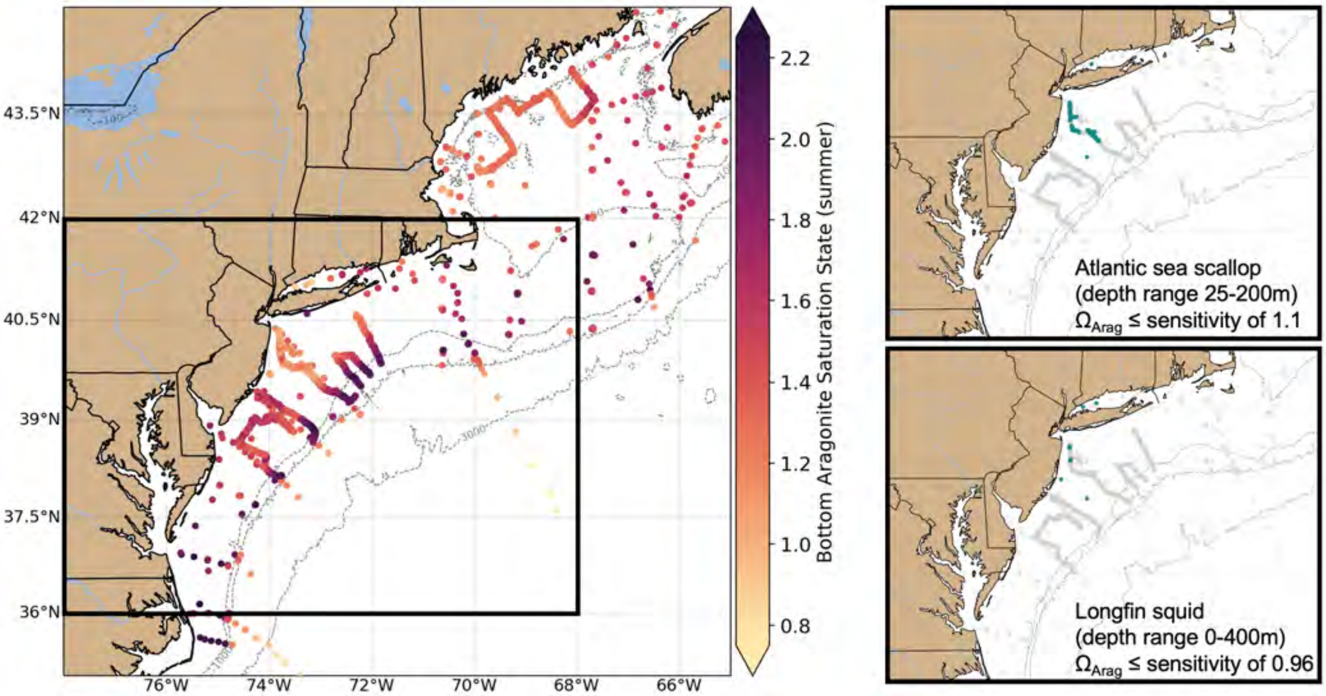


Figure 37: Left panel: Bottom aragonite saturation state (Ω_{Arag}; summer only: June-August) on the U.S. Northeast Shelf based on quality-controlled vessel- and glider-based datasets from 2007-present. Right panel: Locations where summer bottom Ω_{Arag} were at or below the laboratory-derived sensitivity level for Atlantic sea scallop (top panel) and longfin squid (bottom). Gray circles indicate locations where carbonate chemistry samples were collected, but bottom Ω_{Arag} values were higher than sensitivity values determined for that species.

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 2022, MAB phytoplankton biomass (surface chlorophyll) was above average in winter, but below average in August and September. Below average phytoplankton biomass could be due to reduced nutrient flow to the surface and/or increased grazing pressure. Chlorophyll concentrations were above average in early fall and a fall bloom was detected in November/December. Primary productivity (the rate of photosynthesis) was average through spring, above average in the summer and average in the fall (Fig. 38).

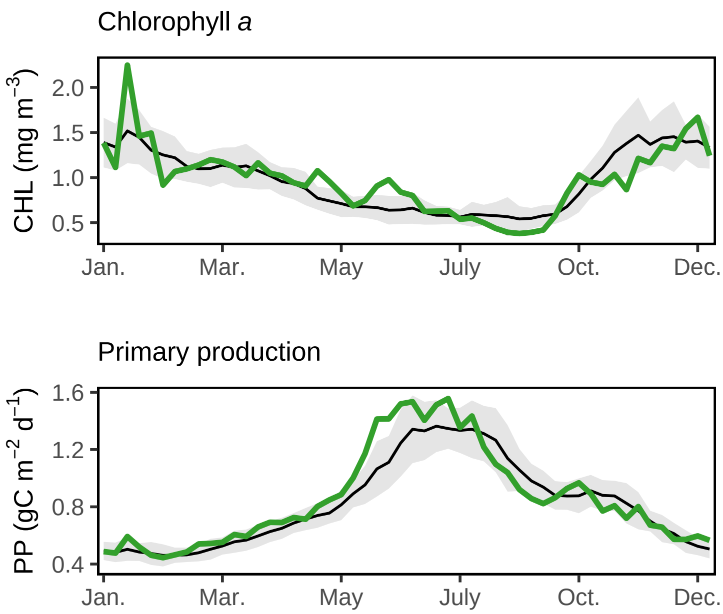


Figure 38: Weekly chlorophyll concentrations and primary productivity in the Mid-Atlantic are shown by the colored line for 2022. The long-term mean is shown in black and shading indicates +/- 1 standard deviation.

The seasonal cycle of phytoplankton size distribution shows that the winter/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 2022, microplankton proportions were average for most of the year, and above average peaks correspond to the bloom periods observed in chlorophyll concentration (Fig. 39).

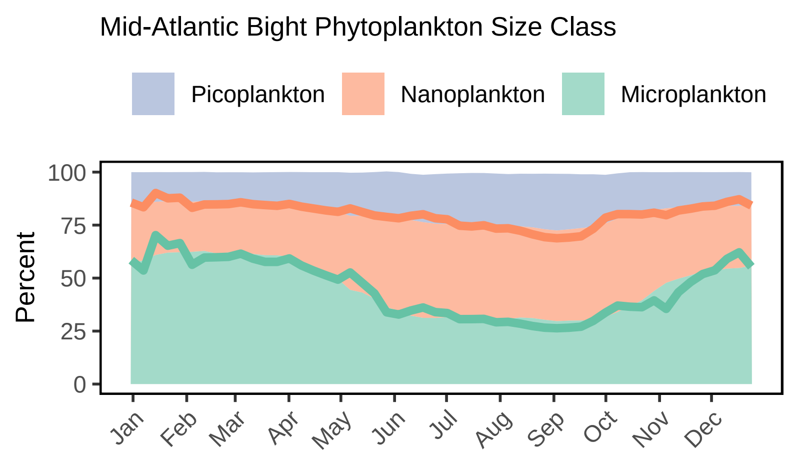


Figure 39: The annual climatology (1998-2022) percent composition of the phytoplankton size classes in the Mid-Atlantic based on satellite observations in the shaded portions. The 2022 proportions for the microplankton (>20 microns, green) and nanoplankton (2-20 microns, orange) are shown in the bold lines.

Zooplankton The zooplankton community is changing in the MAB. Two dominant groups show long term trends: 'sea butterflies' (pteropods) show a long term increase in the MAB, and the copepod *Pseudocalanus* spp. has a long term decreasing trend (Fig. 40). Pteropods are important prey items for planktivores such as herring and mackerel, as well as some sea birds. Despite being susceptible to shell degradation by ocean acidification, their abundance has remained above long term mean since 2004. Pseudocalanus spp. are important prey for many larval fish species, and can influence phytoplankton standing stock through grazing. Pseudocalanus spp. abundance has been below the long term mean since 2000 and continues to decrease with increasing temperature.

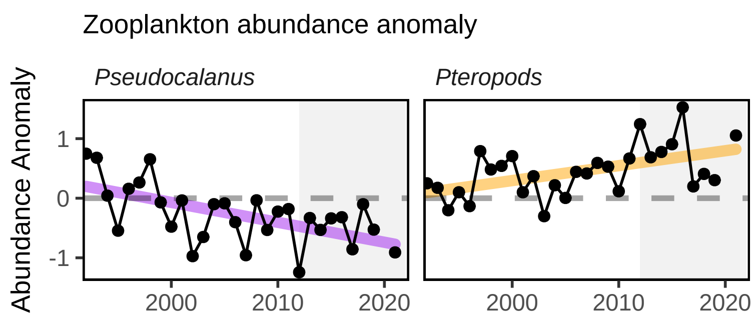


Figure 40: Abundance Annomalies of pseudocalanus and pteropods in Mid-Atlantic Bight.

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 2017-2022 are building toward a time series to evaluate trends (Fig. 41). Data from the fall 2021 and spring 2022 survey measurements were consistent with previous reports: the energy density of Atlantic herring increased to over 7 kJ/g wet weight, but was still well below that observed in the 1980s and 1990s (10.6-9.4 kJ/ g wet weight). Silver hake, longfin squid (*Loligo* in figure) and shortfin squid (*Illex* in figure) remain lower than previous estimates [41,42]. Energy density of alewife, butterfish, sand lance, and Atlantic mackerel varies seasonally, with seasonal estimates both higher and lower than estimates from previous decades.

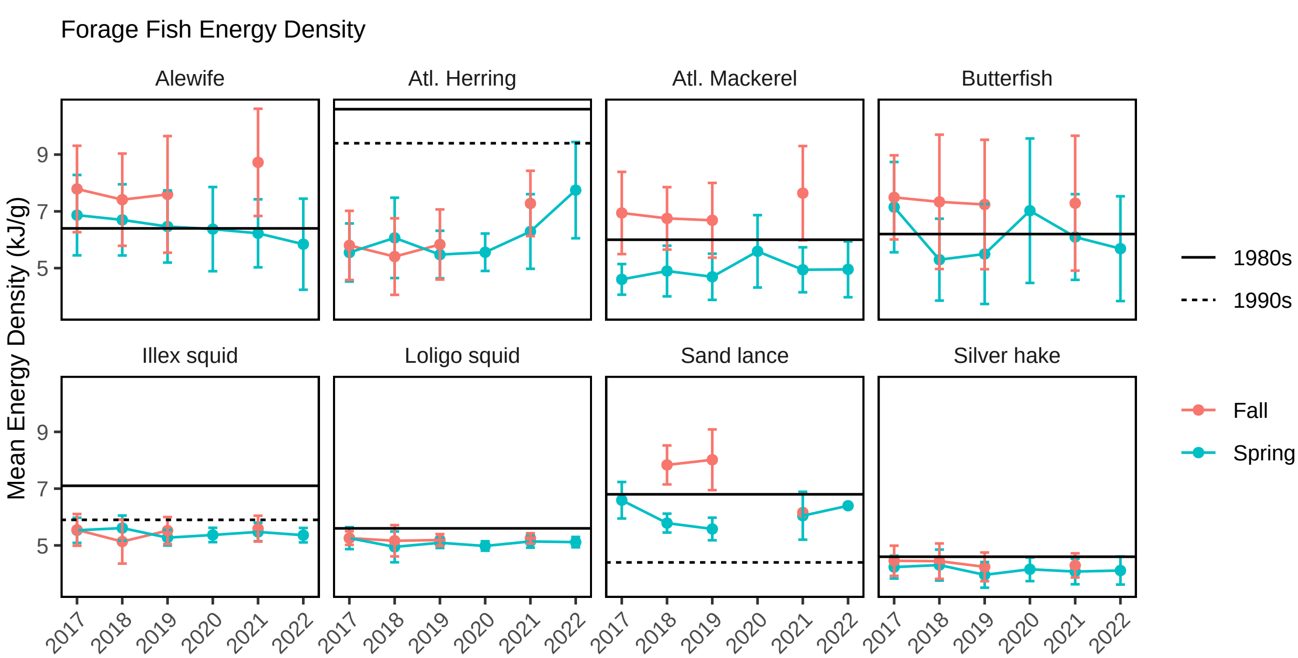


Figure 41: Forage fish energy density mean and standard deviation by season and year, compared with 1980s (solid line; Steimle and Terranove 1985) and 1990s (dashed line; Lawson et al. 1998) values.

Forage Fish Biomass Index The amount of forage fish available in the ecosystem combined with the energy content of the forage species determines the amount of energy potentially available to predators in the ecosystem. Changes in the forage base could pose a risk to managed and protected species production. A new spatially-explicit forage index estimated the combined biomass of 20 forage species using stomach contents information from 22 predatory fish species collected on bottom trawl surveys. While the resulting indices show no long term trends in the Mid-Atlantic, they do show overall higher forage fish in fall relative to spring (Fig. 42), with highest forage biomass during fall in the mid-1980s. Changes in the distribution of forage biomass also affects predator distribution. Spatial subsets of this index were included in the bluefish research track stock assessment to investigate forage-driven changes in bluefish availability to recreational fisheries and surveys.

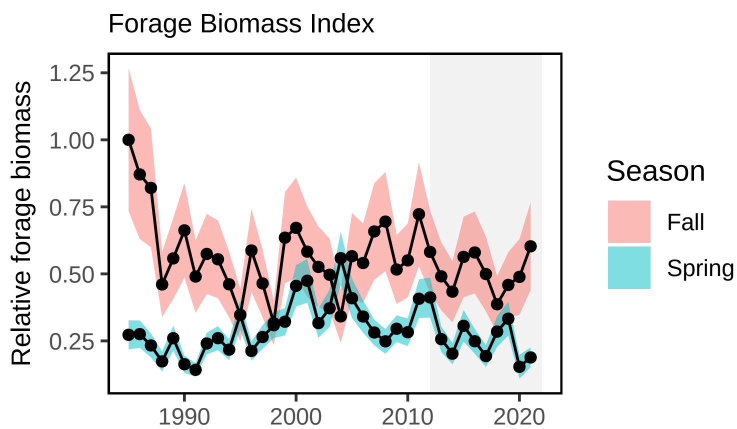


Figure 42: Forage fish index based on spring and fall survey predator diets.

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 [43]. 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 from 2011-2019. Condition was again mixed in 2022, but a number of species improved in condition from the relatively low condition year in 2021 (Fig. 43). Preliminary results of synthetic analyses show that changes in temperature, zooplankton, fishing pressure, and population size influence the condition of different fish species.

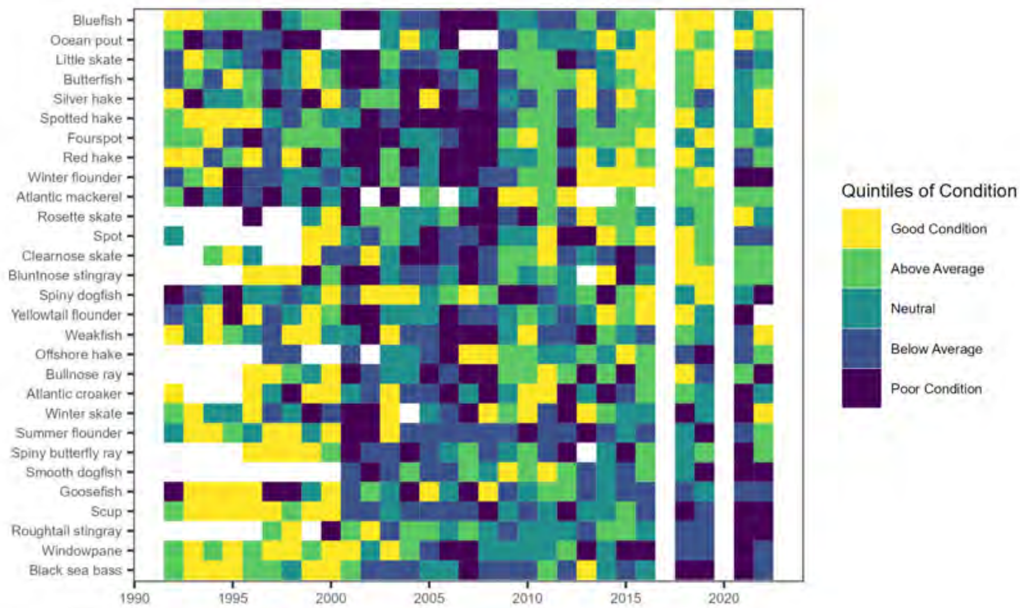


Figure 43: Condition factor for fish species in the MAB based on fall NEFSC bottom trawl survey data. MAB data are missing for 2017 due to survey delays, and no survey was conducted in 2020.

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. 44). The indicator shows that productivity has been declining in this region since 2010. A similar analysis based on stock assessment model outputs (recruitment per spawning stock biomass anomaly) for stocks primarily inhabiting the Mid-Atlantic region also shows a decline in productivity.

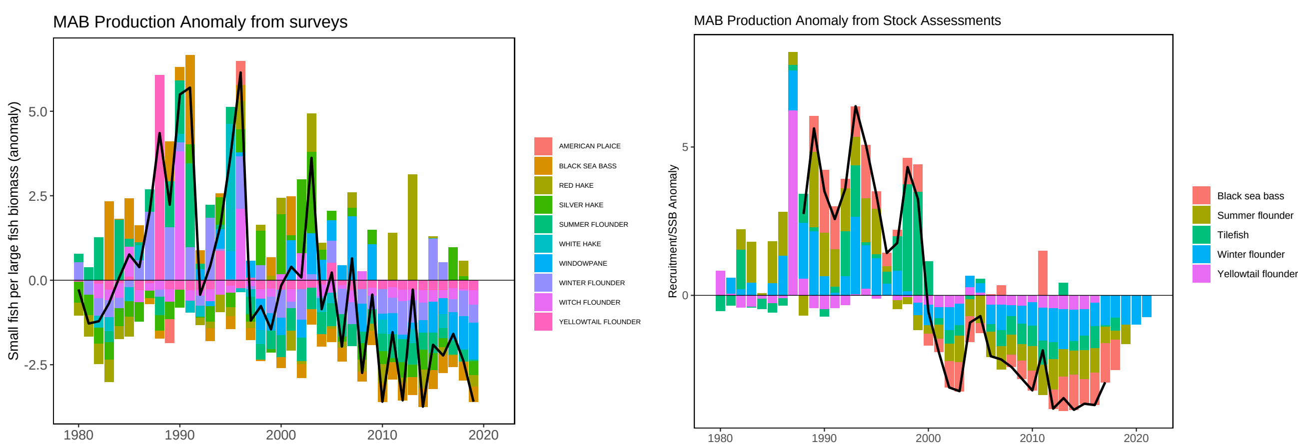


Figure 44: Fish productivity measures. Left: Small fish per large fish survey biomass anomaly in the Mid-Atlantic Bight. Right: assessment recruitment per spawning stock biomass anomaly for stocks mainly in the Mid-Atlantic. The summed anomaly across species is shown by the black line.

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 is increasing in the MAB, 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).

Indicators for shark populations, combined with information on gray seals (see Protected Species Implications section, above), suggests predator populations range from stable (sharks, Fig. 45) 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.

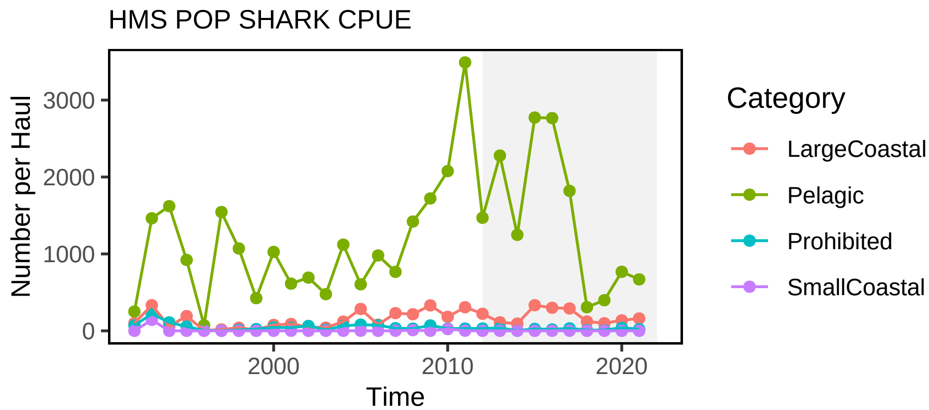


Figure 45: Estimated number of sharks per unit effort from Highly Migratory Species Pelagic Observer Program data.

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. 46), suggesting the potential for robust predator populations among these managed species.

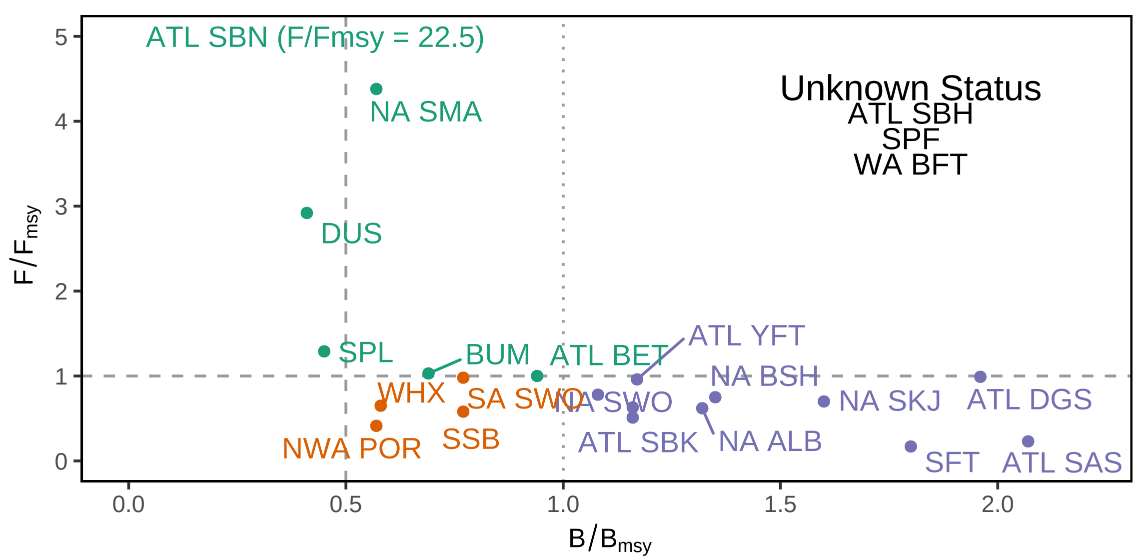


Figure 46: Summary of single species status for HMS stocks; key to species names at https://noaa-edab.github.io/tech-doc/atlantic-highly-migratory-species-stock-status.html.

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 stable isotope study utilizing gray seal scat samples obtained from Massachusetts habitats showed individual gray seals can specialize on particular prey [44]. 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 sandlance 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 [45,46], with sandlance and menhaden dominant off Monomoy, MA [47]. 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[15].

New habitat model-based richness estimates Species richness was derived from habitat models for 55 common species sampled by the spring and fall NEFSC bottom trawl surveys during the years 2000-2019 as part of the NRHA. The joint species distribution model controls for differences in capture efficiency across survey vessels, revealing patterns of declining richness in the Mid-Atlantic Bight and increasing richness in more northerly regions (i.e., the Gulf of Maine; Fig. 47). These patterns reflect the decreasing probability of occurrence of cooler-water species in the south (Atlantic cod, American plaice, pollock, thorny skate) and the growing prevalence of warm-water species in the north (weakfish, spotted hake, and black sea bass), likely as a result of rising water temperatures.

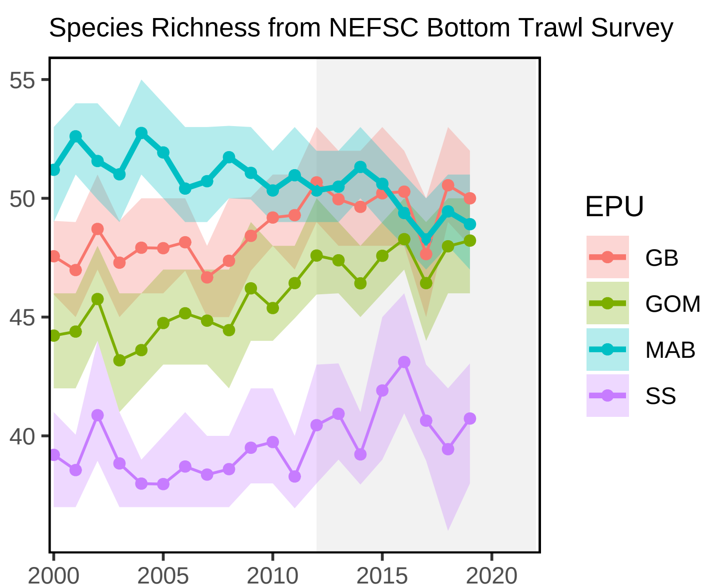


Figure 47: Habitat model-based species richness for 55 common species sampled by NEFSC bottom trawl surveys.

[15] https://www.mafmc.org/nrha

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. 48) 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. 48), increased water temperatures continue to inhibit eelgrass expansion. In 2021, the return to normal water temperature in the summer corresponded to a slight improvement in both eelgrass and widgeon grass coverage.

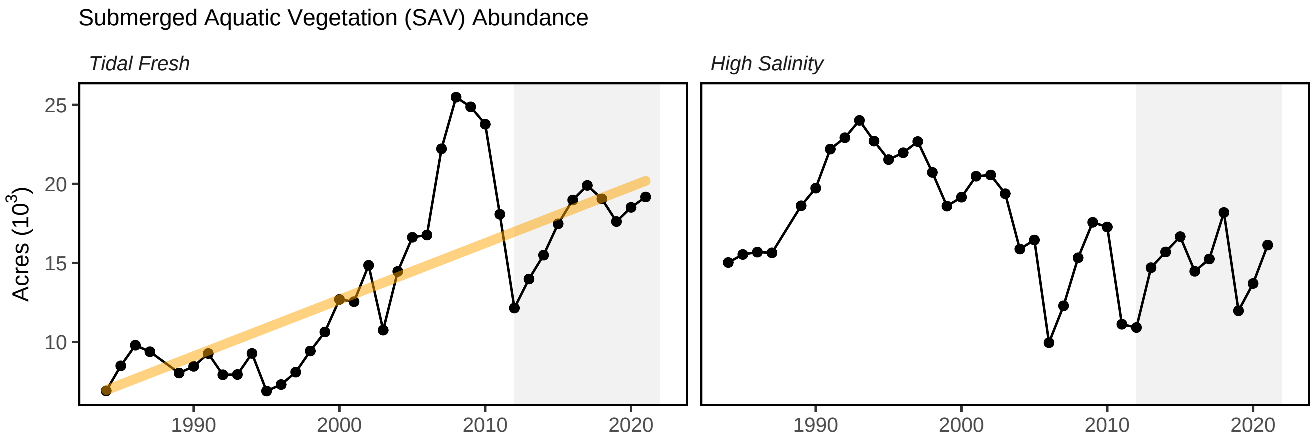


Figure 48: Submerged Aquatic Vegetation (SAV) coverage in tidal fresh and high salinity regions of the Chesapeake Bay.

Fishing Gear Impacts Estimates of the impacts of fishing gear on habitat are available through the habitat section of the Northeast Ocean Data Portal[16]. 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.[17]

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.

Estuarine habitat and managed species Relative habitat use of Chesapeake Bay by several finfish species, including Atlantic croaker, spot, summer flounder, weakfish, clearnose skate, and horseshoe crab is declining [48]. There is evidence suitable habitat for juvenile summer flounder growth has declined by 50% or more [49]. Climate change is expected to continue impacting habitat function and use for multiple species. Restoration of oyster reefs (see below) and marshes could help address these challenges.

Average water temperatures in 2022 (Fig. 31, left) and below-average hypoxic volume throughout the summer suggest favorable conditions for striped bass and blue crabs. Strong winds from the remnants of Hurricane Ian reduced hypoxia by mixing the water column in early October. However, the juvenile striped bass index was low, similar to the past four years, and the total population of blue crabs was at its lowest point in the history of the winter dredge survey. Lower winter temperatures may have contributed to higher overwintering mortality of adult female and juvenile blue crabs. The updated ASMFC striped bass stock assessment shows population numbers

[16] https://www.northeastoceandata.org/data-explorer/
[17] https://noaa-edab.github.io/catalog/northeast-fishing-effects-model.html

remain below the management threshold. Habitat conditions in the Chesapeake Bay could be one factor limiting striped bass population recovery and may have contributed to poor blue crab recruitment over the past few years, leading to lower overall abundances.

Forage and structure-forming species were likely favored by 2022 conditions in Chesapeake Bay. Average water temperatures in 2022 and above-average salinity conditions mean a suitable habitat year for bay anchovy, a key forage species. Bay anchovy abundances are directly correlated with the area of suitable habitat. Above-average salinities beginning in June 2022 (Fig.31, right) were associated with strong oyster recruitment [50]. However, oyster populations are severely depleted from historical levels. Large-scale restoration in 10 tributaries across the Chesapeake Bay is helping recover oyster reef habitat and populations in select areas.

Offshore habitat and managed species Ocean acidification also has different implications, depending on the species and life stage. Summer aragonite saturation was at or below the sensitivity levels for both Atlantic sea scallop and longfin squid in Long Island Sound and the nearshore and mid-shelf regions of the New Jersey shelf (Fig. 37, right panels) several times over the past decade. Recent lab studies have found that surf clams exhibited metabolic depression in a pH range of 7.46-7.28 [51]. Aggregated data from 2007-2021 show that summer bottom ocean pH (7.69-8.07) has not yet reached the metabolic depression threshold observed for surfclams in lab studies so far. The projected effects of changing temperature and ocean chemistry over the coming century may alter surfclam growth and reproduction [52].

While offshore habitat conditions have degraded for some species, they have improved for others. Between 2017 and 2021, extraordinarily high availability of northern shortfin squid (*Illex*) were 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 and as a transport mechanism of higher salinity water to the shelf. In addition, fishing effort is often concentrated on the eastern edge of warm core rings, which are associated with upwelling and enhanced productivity. There were fewer warm core rings near the continental shelf in 2022, which combined with economic fishery drivers may have contributed to total catch of *Illex* squid being 20% less than the total catch reported in 2021.

Marine heatwave impacts The adjustment to the marine heatwave methodology shows that extreme temperature events happen intermittently in many years, but have not been increasing over time in the Mid-Atlantic. While temperature variability in isolation has not changed, considering the overall increase in ocean temperature at both the surface and the bottom in the region, extreme events can represent additional stress to organisms. While marine heatwaves lasting over days may disturb the marine environment, long lasting events such as the warming in 2012 (Fig. 49) can have significant impacts to the ecosystem [25]. The 2012 heatwave affected the lobster fishery most notably, but other species also shifted their geographic distributions and seasonal cycles [53]. During the 2017 event, warm water fish typically found in the Gulf Stream were caught in shallow waters near Block Island, RI [23].

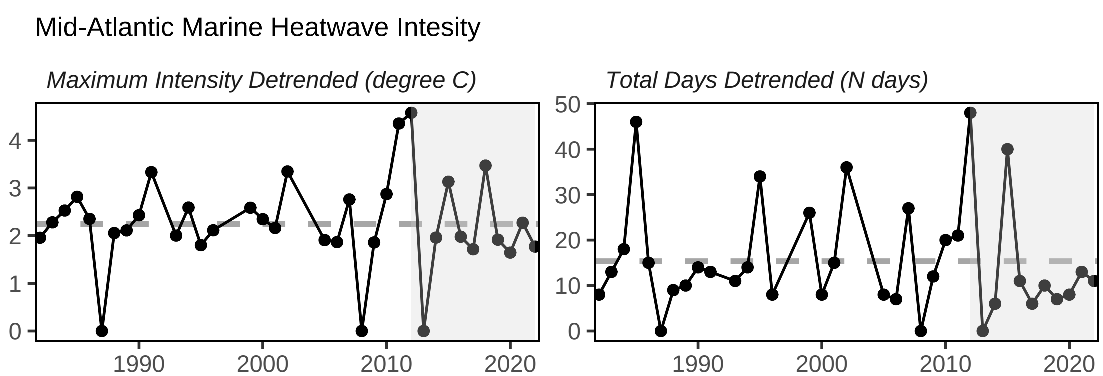


Figure 49: Marine heatwave maximum intesity (left) and total days each year (right) in the Mid-Atlantic Bight.

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 [31]. 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 [31,32]. The cold pool also provides habitat for the ocean quahog [33,54]. 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 [55].

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. 9). Habitat model-based species richness suggests shifts of both cooler and warmer water species to the northeast (Fig. 47). Similar patterns have been found for marine mammals, with multiple species shifting northeast between 2010 and 2017 in most seasons (Fig. 50, [56]).

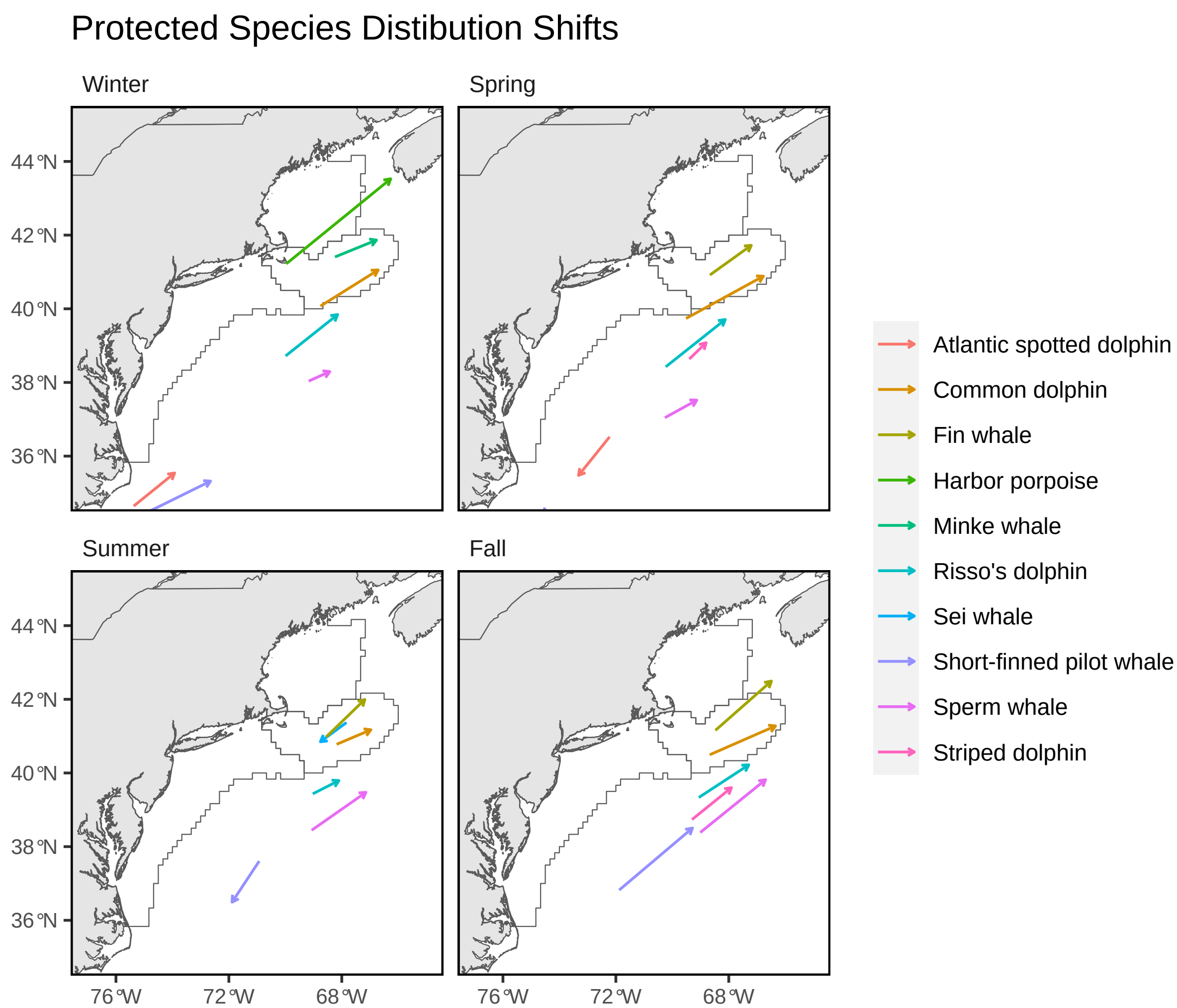


Figure 50: Direction and magnitude of core habitat shifts, represented by the length of the line of the seasonal weighted centroid for species with more than 70 km difference between 2010 and 2017 (tip of arrow).

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 affecting the rate of photosynthesis at the base of the food web. Warm temperatures can increase the rate of primary production, however they also increase stratification, which limits the flux of deep water nutrients to the surface. Thus most of the increased summer production in the MAB is from smaller phytoplankton and may not translate into increased fish biomass.

While pteropods are increasing over time, smaller zooplankton are periodically shifting abundance between the larger, more nutritious copepod *Calanus finmarchicus* and smaller bodied copepods, and common *Pseudocalanus* copepods show a long term decrease in the MAB. The nutritional content of forage fish 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. Overall forage fish biomass has fluctuated in the MAB over time. 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 mixed fish conditions in 2022, also suggest changing ecosystem productivity at multiple levels. During the 1990s high relative abundance of smaller bodied copepods and a lower relative abundance of *Calanus finmarchicus* was associated with regime shifts to higher fish recruitment [57]. 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 January 2023, 31 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 2.4 million acres by 2030 in the Greater Atlantic region (Fig. 51). Beyond 2030 values include acreage for future areas in the Central Atlantic and Gulf of Maine Area planning area for floating research array.

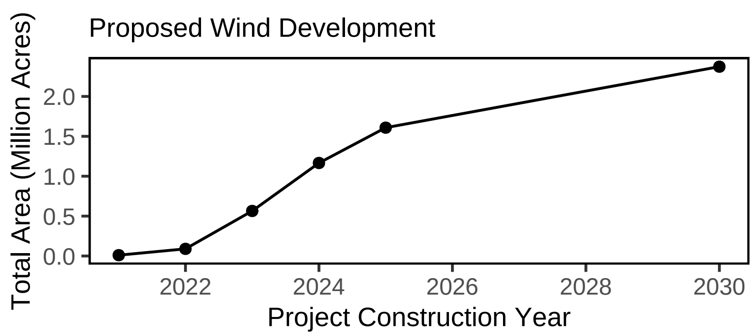
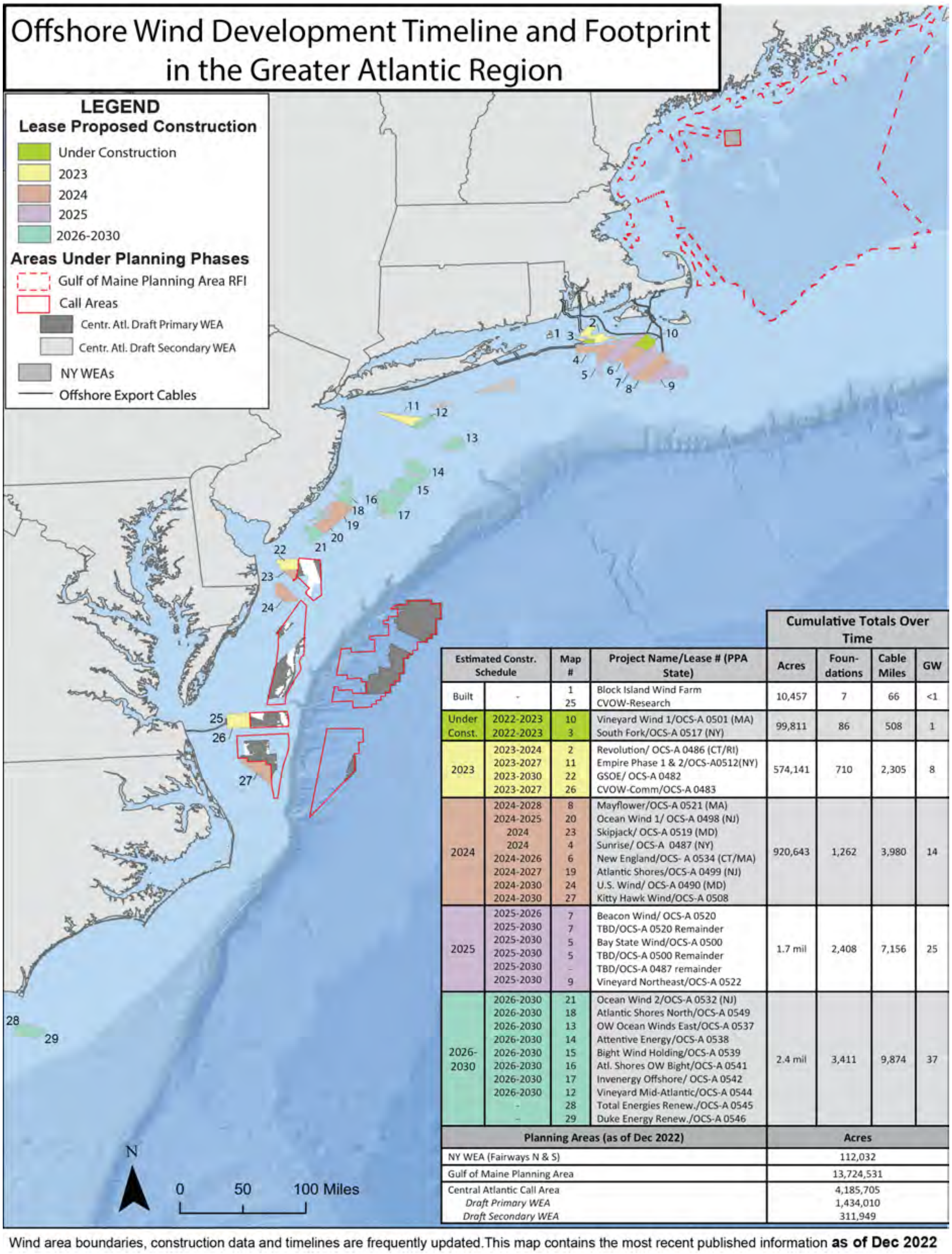


Figure 51: Proposed wind development on the northeast shelf.



Estimated Constr. Schedule		Map #	Project Name/Lease # (PPA State)	Cumulative Totals Over Time: Acres	Foun-dations	Cable Miles	GW
Built	-	1 25	Block Island Wind Farm CVOW-Research	10,457	7	66	<1
Under Const.	2022-2023 2022-2023	10 3	Vineyard Wind 1/OCS-A 0501 (MA) South Fork/OCS-A 0517 (NY)	99,811	86	508	1
2023	2023-2024 2023-2027 2023-2030 2023-2027	2 11 22 26	Revolution/ OCS-A 0486 (CT/RI) Empire Phase 1 & 2/OCS-A0512(NY) GSOE/ OCS-A 0482 CVOW-Comm/OCS-A 0483	574,141	710	2,305	8
2024	2024-2028 2024-2025 2024 2024 2024-2026 2024-2027 2024-2030 2024-2030	8 20 23 4 6 19 24 27	Mayflower/OCS-A 0521 (MA) Ocean Wind 1/ OCS-A 0498 (NJ) Skipjack/ OCS-A 0519 (MD) Sunrise/ OCS-A 0487 (NY) New England/OCS- A 0534 (CT/MA) Atlantic Shores/OCS-A 0499 (NJ) U.S. Wind/ OCS-A 0490 (MD) Kitty Hawk Wind/OCS-A 0508	920,643	1,262	3,980	14
2025	2025-2026 2025-2030 2025-2030 2025-2030 2025-2030 2025-2030	7 7 5 5 - 9	Beacon Wind/ OCS-A 0520 TBD/OCS-A 0520 Remainder Bay State Wind/OCS-A 0500 TBD/OCS-A 0500 Remainder TBD/OCS-A 0487 remainder Vineyard Northeast/OCS-A 0522	1.7 mil	2,408	7,156	25
2026-2030	2026-2030 2026-2030 2026-2030 2026-2030 2026-2030 2026-2030 2026-2030 2026-2030 - -	21 18 13 14 15 16 17 12 28 29	Ocean Wind 2/OCS-A 0532 (NJ) Atlantic Shores North/OCS-A 0549 OW Ocean Winds East/OCS-A 0537 Attentive Energy/OCS-A 0538 Bight Wind Holding/OCS-A 0539 Atl. Shores OW Bight/OCS-A 0541 Invenergy Offshore/ OCS-A 0542 Vineyard Mid-Atlantic/OCS-A 0544 Total Energies Renew./OCS-A 0545 Duke Energy Renew./OCS-A 0546	2.4 mil	3,411	9,874	37

Planning Areas (as of Dec 2022)	Acres
NY WEA (Fairways N & S)	112,032
Gulf of Maine Planning Area	13,724,531
Central Atlantic Call Area *Draft Primary WEA* *Draft Secondary WEA*	4,185,705 1,434,010 311,949

Figure 52: All Northeast Project areas by year construction ends (each project has 2 year construction period).

Just over 3,400 foundations and more than 9,000 miles of inter-array and offshore export cables are proposed to date. The colored chart in Fig. 52 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 January 2023. 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 call areas, which may eventually become lease areas, totalling over 488,000 acres in the Central Atlantic[18] may be identified for BOEM's anticipated 2023 lease sale. It's anticipated that the Central Atlantic leases will fulfill outstanding offshore wind energy production goals for VA and NC.

Based on federal vessel logbook data, commercial fishery revenue from trips in the current offshore wind lease areas and the draft Central Atlantic Bight Primary and Secondary Call Areas have varied annually from 2008-2021, with less than $1 million in revenue overlapping with these areas for most fisheries. However, some fisheries see periodic spikes in revenue overlap with wind energy lease areas, including up to $4.7 million affected in the surfclam fishery and nearly $4.3 million affected in the longfin squid fishery in 2008 and 2016, respectively.(Fig. 53).

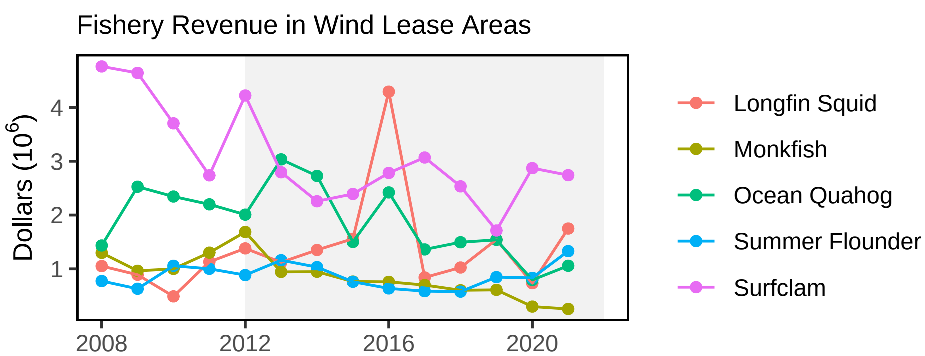


Figure 53: Fishery revenue in wind energy lease areas in the Mid-Atlantic.

Of MAFMC-managed fisheries, the chub mackerel fishery could be the fishery most affected by offshore wind development, with a maximum of 17% of annual regional fishery revenue occurring within potential wind lease areas and the Central Atlantic draft call areas during this period, followed by the surfclam (16%), black sea bass (15%), ocean quahog (13%), and blueline tilefish fisheries (10%). The spiny dogfish fishery was the least affected, at 3% maximum annual revenue affected, while 5% of annual revenues were affected for several others (bluefish, butterfish, and summer flounder). A maximum of 10% of the annual longfin squid revenues were affected by these areas, with similar effects for the scup (9%), Atlantic mackerel (8%), monkfish (7%) and golden tilefish (6%) fisheries (see Table 2). While up to 14% of annual *Illex* squid revenue overlapped with offshore wind areas, this is likely overestimated due to the precision of logbook data when compared to vessel monitoring system data (see Table 2).

Table 2: Top Species Landings and Revenue from Wind Energy Areas. * Landings and revenue for these species are likely underestimated due to limited coverage of these fisheries in historic reporting requirements for vessels issued federal permits by the NMFS Greater Atlantic Regional Fisheries Office. However, such limitations also suggest an inaccurately higher proportion of such landings and revenues in existing lease areas. ** Clearnose skates were reported separately from skates, which is presumed to include all skates managed under the Northeast skate complex. *** Based on comparison with other data sources, the high values for Illex squid are likely overestimates affected by the methods used to model logbook data to estimate spatial overlap of fishign operations with wind energy areas.

NEFMC, MAFMC, and ASMFC Managed Species	Maximum Percent Total Annual Regional Species Landings	Maximum Percent Total Annual Regional Species Revenue
Black drum*	36	34
American eel*	15	29
Clearnose skate**	19	20

[18] https://www.boem.gov/sites/default/files/images/draft_wea_primary_secondary3.jpg

NEFMC, MAFMC, and ASMFC Managed Species	Maximum Percent Total Annual Regional Species Landings	Maximum Percent Total Annual Regional Species Revenue
Atlantic menhaden*	25	19
Atlantic chub mackerel*	16	17
Atlantic surfclam	17	16
Black sea bass	15	15
Yellowtail flounder	15	15
Illex squid***	14	14
Offshore hake	14	14
Ocean quahog	13	13
Atlantic sea scallops	13	12
Blueline tilefish*	8	10
Skates**	10	10
Longfin squid	9	9
Scup	8	9
Atlantic mackerel	8	8
Monkfish	9	7
Red hake	11	7

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 [58].

Equity and environmental justice (EJ) are priority concerns with offshore wind development and fisheries impacts in the Northeast. Fig. 54 links historic port revenue (2008-2021) 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 Mid-Atlantic ports are sorted from greatest to least revenue from within wind areas.

For example, Atlantic City, NJ had a minimum of 11% and maximum of 30% overlap of fisheries revenue in potential wind development areas to the total port fisheries revenue between 2008-2021. 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. 54). 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 [59].

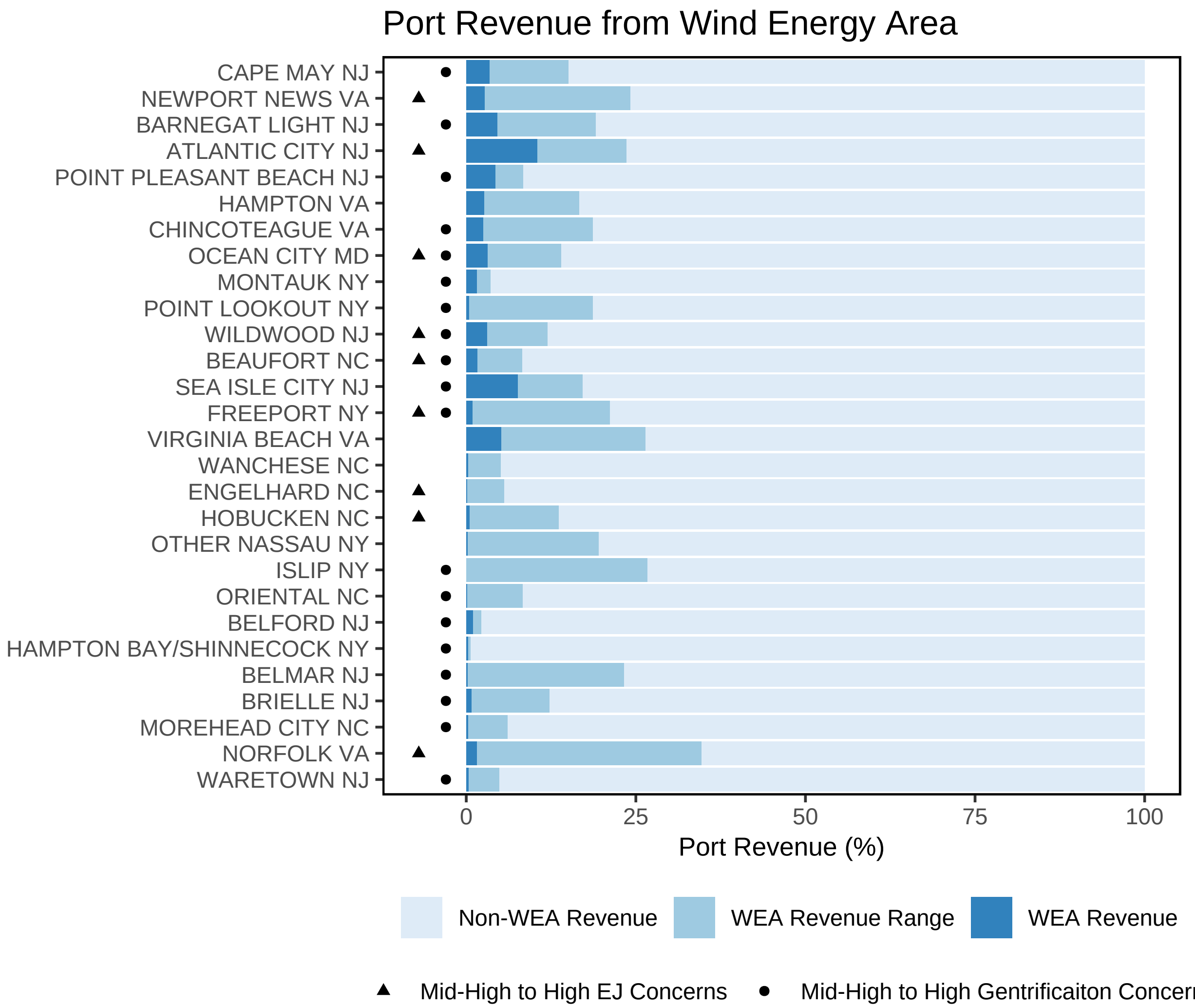


Figure 54: Percent of Mid-Atlantic port revenue from Wind Energy Areas (WEA) in descending order from most to least port revenue from WEA. EJ = Environmental Justice.

Some ports in New England land Mid-Atlantic managed species from wind areas as well. For the maximum percent value reported in each New England port, the majority (at least 50% based on both value and pounds) of those landings were Mid-Atlantic managed species within wind areas for Barnstable, MA, Boston, MA, Hyannis, MA, North Kingstown/Davisville, RI, and Point Judith, RI. Woods Hole, MA would be added to this list based on pounds only, but did not exceed 50% of value from Mid-Atlantic managed species within wind areas.

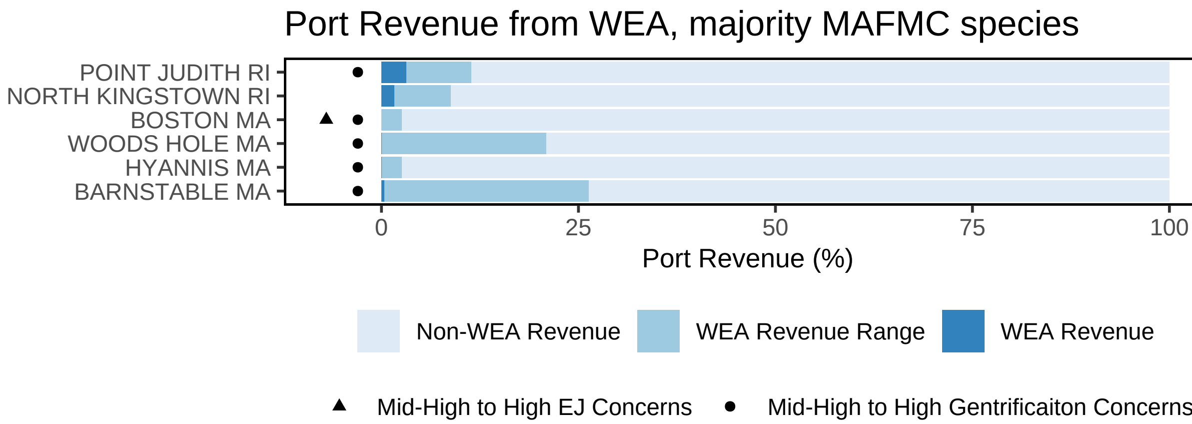


Figure 55: Percent of New England port revenue with majority MAFMC landings from Wind Energy Areas (WEA) in descending order from most to least port revenue from WEA. EJ = Environmental Justice.

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. 52).

Up to 17% of maximum annual fisheries revenue for major Mid-Atlantic commercial species in lease areas and draft call 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, along with impacts to and responses of affected fish species.

Planned development overlaps right whale mother and calf migration corridors and a significant foraging habitat that is used throughout the year [9] (Fig 56). Turbine presence and extraction of energy from the system could alter local oceanography [60] and may affect right whale prey availability. For example, persistent foraging hotspots of right whales and seabirds overlap on Nantucket Shoals, where unique hydrography aggregates enhanced prey densities [61,62]. Wind leases (OCS-A 0521 and OCS-A 0522) currently intersect these hotspots on the southwestern corner of Nantucket Shoals and a prominent tidal front associated with invertebrate prey swarms important to seabirds and possibly right whales. Proposed wind development areas also bring increased vessel strike risk to whales from construction and operation vessels, in addition to potential impacts such as displacement, increased levels of communication masking, and elevated stress hormones from pile driving and operational noise.

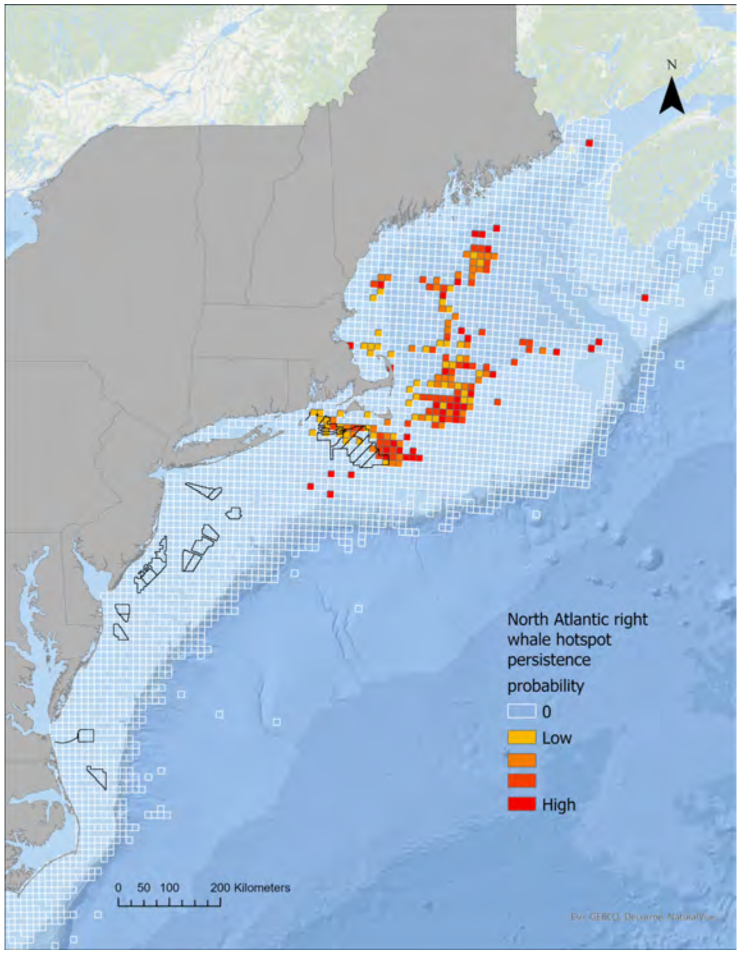


Figure 56: Northern Right Whale persistent hotspots and Wind Energy Areas.

Scientific data collection surveys for ocean and ecosystem conditions, fish, and protected species will be altered, potentially increasing uncertainty for stock assessments and associated 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 fisheries revenue overlap with offshore wind development areas 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 57a. 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 2022, 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. 57b) level.

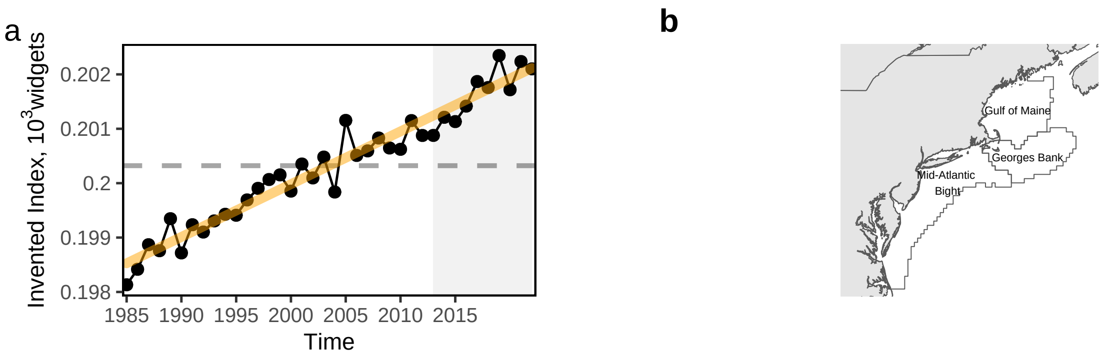

Figure 57: Document orientation. a. Key to figures. b.The Northeast Large Marine Ecosystem.

Fish and invertebrates are aggregated into similar feeding categories (Table 3) to evaluate ecosystem level trends in predators and prey.

Table 3: Feeding guilds and management bodies.

Guild	MAFMC	Joint	NEFMC	State or Other
Apex Predator				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		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		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		sea scallop	blue mussel, channeled whelk, sea cucumber, sea urchin and sand dollar uncl, sea urchins, snails(conchs)

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026

22 March, 2023

Mid-Atlantic Fishery Management Council
800 North State Street, Suite 201
Dover, DE 19901

To the Council,

In this memo we list comments and requests received on the 2019-2022 State of the Ecosystem (SOE) reports, and how we responded to those requests. We include comments from both Councils because adjustments to the report were made in response to both. We welcome feedback on whether this memo is useful and how to improve it for future SOE reporting.

The memo is now reorganized into categories of requests in descending order of overall Council priority. The new Rank column summarizes priority and was derived from combined discussion with the Mid-Atlantic SSC ecosystem working group and a survey of selected MAFMC members coordinated by Council staff in July 2022.

The attached document includes a table where we summarize all comments and requests with sources. The Status and Progress columns briefly summarize how we responded, with a more detailed response in each memo section. In each detailed response, we refer to SOE sections where changes are found or describe information that was not sufficiently developed to include in the 2023 SOE in an effort to solicit feedback on how best to develop indicators for future reports.

We welcome comments on the entire SOE report as well as information included in this memo, and look forward to feedback from the SSC and Council.

Sincerely,

Sarah Gaichas, PhD
Research Fishery Biologist
Ecosystem Dynamics and
Assessment Branch
Northeast Fisheries Science Center

encl: State of the Ecosystem 2023: Request Tracking Memo

cc: Jon Hare

State of the Ecosystem 2023: Request Tracking Memo

March 22, 2023

Introduction

In the table below we summarize all comments and requests with sources. The memo is now reorganized into categories of requests in descending order of overall Council priority. The new Rank column summarizes priority and was derived from combined discussion with the Mid-Atlantic SSC ecosystem working group and a survey of selected MAFMC members coordinated by Council staff in July 2022. The Progress column briefly summarizes how we responded, with a more detailed response to each request in a section for each request category. In the Status column, "In SOE" indicates a change included in the report(s).

Table 1: State of the Ecosystem requests by category and Council priority.

Request	Year	Rank	Source	Status	Progress
System level thresholds/ref pts					
Compare EOF (Link) thresholds to empirical thresholds (Large, Tam)	2021	Highest	MAFMC SSC	In progress	Analysis planning with Mid SSC
Trend Analysis / Inflection / Break points	2019 - 2022	Highest	Both Councils and SSCs	In progress	Prototype analysis 2022-2023
Optimum yield for ecosystem	2021	Highest	NEFMC	In progress	Analysis planning with Mid SSC
How does phyto size comp affect EOF indicator, if at all?	2021	High	MAFMC	In progress	Analysis planning with Mid SSC
Sum of TAC/ Landings relative to TAC	2021	Moderate	MAFMC SSC	In SOE-MAFMC, In progress-NEFMC	Seafood Production section
Nutrient input, Benthic Flux and POC (particulate organic carbon) to inform benthic productivity by something other than surface indicators	2021	Low	MAFMC SSC	Not started	Lacking resources this year
Reduce indicator dimensionality with multivariate statistics	2020	Lowest	NEFMC	In progress	Analysis planning with Mid SSC
Management					
Incorporate social sciences survey from council	2020	High	NEFMC	Not started	Lacking resources this year
Management complexity	2019	High	MAFMC	In progress	Student work needs further analysis, no further work this year
Recreational bycatch mortality as an indicator of regulatory waste	2021	High	MAFMC SSC	Not started	Lacking resources this year
Include New England ports with significant reliance on mid species be included in the Mid SOE	2022	Unranked	MAFMC	In SOE	Other Ocean Uses: Offshore Wind section
Re-evaluate EPUs	2020	Lowest	NEFMC	Not started	Lacking resources this year
Short term forecasts					
Using phytoplankton trends to forecast fish stocks	2022	High	MAFMC	Not started	Lacking resources this year
Short term forecasting (water temp, productivity)	2022	High	NEFMC	Not started	Lacking resources this year
Regime shifts					
Time series analysis (Zooplankton/Forage fish) to tie into regime shifts	2021	High	MAFMC SSC	In progress	Individual projects started
Regime shifts in Social-Economic indicators	2021	High	NEFMC SSC	In progress	Analysis planning with Mid SSC
Multiple system drivers					
Linking Condition	2020	High	MAFMC	In progress	Not ready for 2023
Avg weight of diet components by feeding group	2019	High	Internal	In progress	Part of fish condition project
Cumulative weather index	2020	Moderate	MAFMC	In progress	Data gathered for prototype

Request	Year	Rank	Source	Status	Progress
Fall turnover date index	2021	Moderate	MAFMC SSC	In SOE	Climate and Ecosystem Productivity section
Modeling cold pool/warm core ring and wind development interactions	2022	Moderate	MAFMC	Not started	Lacking resources this year
Impact of climate on data streams (changes in catchability of survey)	2022	Moderate	NEFMC SSC	Not started	Lacking resources this year
Young of Year index from multiple surveys	2019	Moderate	MAFMC	Not started	Lacking resources this year
Links between species availability inshore/offshore (estuarine conditions) and trends in recreational fishing effort?	2021	Unranked	MAFMC	In progress	Bluefish prey index inshore/offshore partially addresses
Tell Social stories like we try to tell biological stories	2022	Unranked	GARFO	Not started	Lacking resources this year
What determines a "risk"? Include aquaculture as a risk?	2022	Unranked	NEFMC SSC	Not started	Lacking resources this year
Mean stomach weight across feeding guilds	2019	Low	MAFMC	In progress	Intern evaluated trends in guild diets
Environmental Justice - Further Explanation and maybe have Soc Sci folks on call to explain	2022	Low	MAFMC SSC	In SOE	Social and cultural section
Changing per capita seafood consumption as driver of revenue?	2021	Low	MAFMC	Not started	Lacking resources this year
Relate OA to nutrient input; are there "dead zones" (hypoxia)?	2021	Low	MAFMC	Not started	Lacking resources this year
Estuarine Water Quality	2020	Low	NEFMC	In SOE-MAFMC, In progress-NEFMC	Intern project 2021 needs expansion
Decomposition of diversity drivers highlighting social components	2021	Lowest	MAFMC SSC	Not started	Lacking resources this year
Indicators of chemical pollution in offshore waters	2021	Lowest	MAFMC	Not started	Lacking resources this year
Estuarine condition relative to power plants and temp	2019	Lowest	MAFMC	Not started	Lacking resources this year
Functional group level status/thresholds/ref pts					
Forage availability index (Herring/Sandlance)	2021	Moderate	NEFMC	In SOE	Climate and Ecosystem Productivity section
VAST and uncertainty	2020	Moderate	Both Councils	In progress	Not ready for 2023
Seal index	2020	Low	MAFMC	In progress	Not ready for 2023
Apex predator index (pinnipeds)	2021	Low	NEFMC	In progress	Protected species branch developing time series
Biomass of spp not included in BTS	2020	Lowest	MAFMC	Not started	Lacking resources this year
Stock level indicators					
Shellfish growth/distribution linked to climate (system productivity)	2019	Moderate	MAFMC	In progress	Project with A. Hollander
Indicator of scallop pred pops poorly sampled by bottom trawls	2021	Moderate	NEFMC	Not started	Lacking resources this year
Sturgeon Bycatch	2021	Lowest	MAFMC SSC	Not started	Lacking resources this year
SOE admin					
SOE usage tracking	2022	Unranked	MAFMC SSC	In progress	Request in to communications experts
Include estimates of inclusion years in request memo	2022	Unranked	NEFMC SSC	In progress	Reorganized memo to clarify project timing

Responses to comments

System level thresholds/reference points

Further refining ecosystem level overfishing (EOF) indicators and investigating optimum yield (OY) at the ecosystem level was identified as highest priority by both the MAFMC SSC working group and by surveyed MAFMC members. Methods for evaluating ecosystem indicator trends, inflection points, and breakpoints (regimes, see below) were also ranked highest priority by both SSC and Council as these methods apply to ecosystem level thresholds and reference points, as well as to indicators at the functional group or stock level, or to indicators of climate or habitat risk. Several other SSC and Council requests are related to or support these analyses and can likely be addressed by planned analyses.

The EOF indicators were first presented in 2021 and were discussed in depth with the MAFMC SSC working group in April 2022 and February 2023. Considerable progress has been made on updating data inputs for the EOF indicators and planning for system level threshold analyses with the MAFMC SSC. After reviewing previous presentations of the EOF indicators, Andy Beet (NEFSC) reviewed solutions to several data input problems identified in July 2022 (menhaden landings were added and differences between different data sources were resolved). An outstanding data input task is completing discard estimates for all species in the Northeast US, which is in progress.

An in depth review of methods and associated thresholds for the three EOF indicators has been completed. A plan for adapting these methods to data specific to our region (primary production and landings) was discussed with the MAFMC SSC. Finally, a simulation study is being planned to use the Northeast US Atlantis ecosystem model [1] to investigate robustness of thresholds and determine how informative they can be. This portion of the research will likely address the MAFMC request to evaluate how phytoplankton size composition might affect the EOF indicator. It will also address SSC questions raised about tradeoffs between fishing for different species groups to address EOF, and how climate driven changes in transfer efficiency might be incorporated into or impact EOF indicators. In addition, the NEUS Atlantis model may be able to address the lower priority requests on nutrient input and benthic flux contributions to system productivity once model sensitivity analysis determines whether these model components behave reasonably. We expect to present results of EOF analyses to the SSC in late 2023. If reviews are positive, EOF indicators may appear in the 2024 SOE, and if further work is needed they should appear in the 2025 SOE.

Automated methods for estimating both short term and long term trends, evaluating time series inflection points, and identifying breakpoints (regimes) are being tested.

- The `ecodata` R package already incorporates long term trend estimation based on Hardison et al. [2]. This research found that trends were most robustly distinguished from autocorrelation in indicator time series of 30 years or longer. However, there is still considerable interest in robust methods for assessing short term trends, especially for the most recent portions of time series and for shorter indicator time series. In 2022, work was initiated on short term trend analysis robust to autocorrelation by Andy Beet and Kim Bastille (NEFSC). The short term trend fitting method needs more simulation testing to address performance with missing data. If this simulation can be completed, it is likely to be available for SOE and risk assessment analyses in 2023 for possible inclusion in the 2024 SOE.
- Kim Bastille (NEFSC) has also been working on methods to identify inflection points in indicator time series based on Large et al. [3] and [4]. A standardized method has been implemented as a prototype and applied to several existing SOE indicators in 2022, but several questions on default approaches to be used across multiple indicators require more in depth analysis and review. If this work can be completed, it is likely to be available for SOE and risk assessment analyses in 2023 for possible inclusion in the 2024 SOE.
- A method for identifying breakpoints has been implemented by Kim Bastille and Laurel Smith (NEFSC) and a prototype analysis developed using SOE indicators in 2022. If this method can be further developed, it may be reviewed in 2023 along with other regime shift analyses (see below).

Work is in progress by John Walden and Geret DePiper (NEFSC) to combine multiple indicators into single integrated indices (Index Numbers) using Data Envelopment Analysis. This work has been reviewed by the MAFMC SSC ecosystem working group in July 2022 and again in February 2023. Index Numbers evaluate sets of environmental indicators and management output indicators to determine system performance. The approach combines important management outputs linked to objectives (e.g. commercial revenue, recreational days fished, right whale abundance) and likely ecosystem drivers of change in these outputs (e.g., chlorophyll a, zooplankton, aggregate fish biomass) into an analysis evaluating aggregating inputs and outputs into single indicators used to determine whether system performance has improved over time relative to a reference year. An initial case study using the SOE indicators identified above was presented in July 2022, and a follow up analysis evaluating individual Index Numbers for SOE management objectives (Seafood Production, Recreational Opportunities, etc.) was presented in February 2023. Integrated Index Numbers based on some of these case studies may be further reviewed by the MAFMC SSC ecosystem working group and developed for the 2024 SOE.

Management

Council members tended to give higher priority rankings to requests in this category relative to the SSC working group, but overall both ranked management related requests high priority.

In 2022, MAFMC requested that New England ports with significant reliance on Mid-Atlantic managed species be included in the Mid-Atlantic SOE analysis of potential risks to fishery management from offshore wind development. Angela Silva (NEFSC) evaluated landings for all New England ports by both value and pounds, and included New England ports with over 50% of maximum value or pounds MAFMC managed species landed from wind areas between 2008-2021. Six ports were identified as "significantly reliant" using this criteria, and we included this information in the 2023 MAFMC SOE (p.43-44).

We lacked resources to address three high-ranked requests this year, including incorporating a social sciences survey from the NEFMC, continuing development of a management complexity indicator started by an intern in 2020, and developing an indicator of regulatory waste based on recreational bycatch mortality.

We are unfamiliar with the social sciences survey highlighted by NEFMC. Additional information on this survey is needed in order to follow up on this request.

It may be possible to address the requests on management complexity and recreational bycatch mortality as part of the Mid-Atlantic EAFM risk assessment update in 2023 if appropriate expertise can be brought into this process.

The request to re-evaluate Ecosystem Production Units (EPUs) was ranked lowest priority. We do not forsee having the resources to address this request, which is a large project, in the near future.

Short term forecasts

The SSC working group ranked these new requests higher priority relative to Council members, but overall both ranked short term forecasting requests high priority.

While using phytoplankton trends to forecast fish stocks may be feasibly simulation tested within the Atlantis modeling framework described above for EOF indicators, this is a long term project that would require dedicated effort to achieve, likely by a postdoctoral researcher.

Some experimental short term forecasts of regional water temperature are currently available, and could be investigated or presented to the SSCs during the 2024 cycle if this remains a high priority. Short term forecasts of species distributions for fisheries management are in progress with Rutgers University and MAFMC, which may also address this request. Skill assessment of these forecasts, as well as determining the context in which they would be used (stock assessment projections? habitat projections? other uses?) would be needed to bring them into the management process (this is better developed for the ongoing Rutgers/MAFMC project). Incorporating short term forecasts into the SOE outside the ongoing Rutgers/MAFMC project would require a similar level of effort to the phytoplankton/fish forecasting project above.

Additional resources are needed to address these requests in the coming year.

Regime shifts

Adding information on regime shifts was considered a high priority by both the Council and SSC. Time series analysis of zooplankton and forage fish to evaluate potential linked regime shifts is currently in progress, and multiple projects may contribute to this. We are working to coordinate existing projects (see below) into a synthesis product for the

SOE. Because the projects are on different timelines, it is difficult to give a target date for SOE synthesis. However, we expect to have some project results published prior to the 2024 SOE. With these publications complete, some synthesis may be presented in the following SOE cycle.

Table 2: Selected Regime Shift Projects. Methods: rpart = recrusive partitioning R package, DFA = dynamic factor analysis, EOF = empirical orthoganal function, SEWS = spatial early warning signals, DEA = data envelopment analysis, GAMs = general additive models. Ecosystem Component: Env = environmental drivers, Fish = fish, Zoo = zooplankton, Landings = fishery landings.

Analysis	**Methods**	**Ecosystem Component**	**Temporal Scale**	**Spatial Scale**	**Availability**
SOE Indicator Comparison	rpart	Env to Fish	Annual	EPU	Available Now
Condition (1)	rpart	Env to Fish	Annual, fall only	EPU or shelf	Multi species available now
Condition (2)	DFA	Fish	Annual?	EPU	In progress
Zooplankton	multiple	Zoo	Seasonal	EPU	In review
Zooplankton VAST	EOF	Zoo	Seasonal	EPU	In progress
SST	SEWS	Env	Annual?	NW Atlantic	In progress
DEA	DEA	Zoo to Landings	Annual	EPU	In progress
Stock Recruit	changepoint and GAMs	Fish	Annual	Stock	Not started, could use stock smart

Regime shifts in socio-economic indicators may be addressed in the ongoing work described above by John Walden and Geret DePiper (NEFSC) integrating multiple indicators into Index Numbers. Once the structure of the Index Numbers is determined, these time series can be evaluated for change points using any of the methods described in the table above.

Multiple system drivers

This category contains a wide array of requests with many projects currently in progress. There were two requests ranked high priority, eight ranked moderate priority (or unranked because they are newer requests), and eight ranked low or lowest priority. Given the number of SOE requests, those ranked lowest priority that have not already been started are unlikely to be addressed.

The high priority request in this category is incorporating the ongoing fish condition project and associated analyses into the SOE. Regime shift analyses of fish condition may be available for the 2024 SOE, while linking fish condition to ecosystem drivers using GAMs will require more time with current resources.

One moderate priority request was included in the 2023 SOE: a fall turnover index has been included in both the MAFMC and NEFMC reports in the Climate and Ecosystem Productivity sections.

One low priority request was included in the 2023 SOE: we updated text with further explanation of the Environmental Justice indicators.

An unranked request to evaluate links between species availability inshore and offshore and trends in recreational fishing effort was partially addressed using a spatial index of forage fish to evaluate bluefish availability to the recreational fishery during the research track assessment in December 2022. This forage fish index has been included in the 2023 SOE.

Several other moderate/unranked and low priority requests are currently in progress or started as intern projects, including a cumulative weather index, mean stomach weights across feeding guilds, and estuarine water quality for the NEFMC SOE. If sufficient resources are found to finish these projects, they could be included in the 2024 SOE.

Functional group level status/thresholds/ref pts

Requests in this category were considered moderate to low priority by the SSC and Council. However, many were already in progress prior to ranking, and one has been included in the 2023 SOE.

The NEFMC requested a forage availability index (including both managed species such as herring and unmanaged species such as sandlance). A spatial index of forage availability was developed for the bluefish research track assessment as described above. This index was partitioned into EPUs and presented in both the 2023 MAFMC and NEFMC SOEs in the Climate and Ecosystem Productivity sections.

Gray seal pup count indices are already included in the NEFMC SOE, and indices of populations for other seals and apex predators are in development by the protected species branch. These additional indices were not ready for the 2023 report.

Investigating time series of biomass for species not well represented in bottom trawl surveys was partially addressed by the forage index included in the 2023 report. However, only a subset of forage species are not well represented in bottom trawl surveys, and other species that are not forage are also not well represented in bottom trawl surveys. This request was ranked lowest priority by the Council and SSC, and given the difficulty of synthesizing data on poorly sampled species, is unlikely to be addressed in the near future.

Stock level indicators

Requests in this category were ranked moderate to lowest priority by the SSC and Council. Indicators of this nature would be well suited to Ecosystem and Socioeconomic Profiles (ESP) developed during research track assessments for individual stocks. Some aspects of these indicators may benefit SOE reporting as well.

One request, linking shellfish growth and distribution to climate change and system productivity, is in progress. Alexis Hollander (VIMS) completed her thesis on surfclam growth in relation to bottom temperature in 2022, and information from this work can likely be included in the 2024 SOE, pending publication of student thesis results.

The request for indicators of scallop predators that are poorly sampled by bottom trawls is similar to the request in the category above addressing all species not well sampled by bottom trawls. It is possible that this request could be clarified and addressed during a scallop research track assessment.

The request for a sturgeon bycatch indicator was ranked lowest priority by the SSC and Council, so is unlikely to be addressed in the near future.

SOE admin

These relatively new requests were not ranked; however, both are in progress.

Investigation of uses of the SOE as requested by the MAFMC SSC is in progress with the assistance of NOAA communications experts using a combination of website analytics and citation information. We hope to have an update on uses of the SOE for the 2024 report/request memo.

The restructuring of this memo according to prioritization is intended to partially address the requests for timelines on in progress SOE requests by the NEFMC SSC. While not all project timelines are currently available, we have reported estimates in this document where possible. In addition, the effort to prioritize requests in 2022 ensures that limited resources are applied to the highest priority issues.

References

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Review of SSC Ecosystem Working Group Objectives and Intended Outcomes

The MAFMC SSC Ecosystem Working Group (WG) was established in May 2021 to assist the Council in developing short term and long term objectives to advance the operational use of ecosystem information in management decisions. As reported in September 2021, March 2022, and September 2022 the WG has identified three general objectives:

1. Expanding and clarifying the ecosystem portion of the SSC OFL CV determination process (short term objective)
2. Developing prototype processes to provide multispecies and system level scientific advice appropriate for Council decision making, in particular where there are multispecies and multifleet tradeoffs linking directly to economic and social outcomes (long term objective)
3. Collaborating with SSC species leads, stock assessment leads, and relevant working groups in developing the stock-specific Ecosystem and Socio-economic Profiles (ESP) process to specify stock-specific Ecosystem ToRs that are impactful and can be integrated into assessments (moderate-term objective)

Objectives 1 and 3 aim to integrate appropriate ecosystem information at the stock level of management decision making, while objective 2 applies to current Council EAFM processes and potential future multispecies and system level objectives.

Intended outcomes of WG work for the Council include:

- An OFL CV process that makes better use of ecosystem information in determining the ABC
- Evaluation of multiple ecosystem indicators and potential development of thresholds for use in a revised EAFM risk assessment and/or other Council processes
- Increased range of opportunities for relevant ecosystem information to be considered in management decision processes

Progress

At the joint Council/SSC meeting in October 2022, the SSC Ecosystem Working Group provided an update on current work, and sought Council feedback on priorities for development and use of integrated ecosystem-level indicators within existing or new Council processes (see October 2022 report to the Council, p.3-8 and Presentation, slides 6-11).

Since October 2022:

- WG member Sarah Gaichas submitted a summary of the SCS7 Keynote "Using Ecosystem Information in the Stock Assessment and Advice Process" that highlights MAFMC SSC and SSC Ecosystem WG projects (see draft attached at the end of this document).
- The Bluefish Research Track assessment's ESP document addressing ToR 1 ecosystem effects on the stock received high praise from CIE reviewers.
- The State of the Ecosystem (SOE) request prioritization completed by the WG in 2022 has been incorporated into work going forward for 2023 and future SOEs, and is reflected in the 2023 SOE request tracking memo.
- The WG met 27 February 2023 to review updates on four projects related to the objectives above. Notes from the review are detailed below.

Objective 1: OFL CV and ecosystem effects

These projects will enhance the SSC's current OFL CV process or address stock reference points, and therefore fit within existing Council decision processes.

ABC decisions with environmentally driven recruitment WG member Mike Wilberg's lab (U. Maryland) is collaborating with John Wiedenmann's lab (Rutgers) to simulate an environmental effect on stock recruitment and test how it impacts assessment uncertainty. Implications of choosing both the appropriate OFL CV based on an environmental effect linked to recruitment and an inappropriate OFL CV will be evaluated using an updated MSE framework. The group is conducting a mini-review on environmental drivers in the region to get an idea of trends, periodicity, autocorrelation to inform the analysis. A simulated species based on Summer flounder is the initial case study.

Jeewantha Bandara (Rutgers) presented current work in progress. A literature review of summer flounder environmental influences along with analysis of relationships between multiple SOE environmental indicators and summer flounder recruitment has been completed. A significant relationship between temperature anomalies and summer flounder recruitment has been found. In addition, hypothetical relationships between environmental drivers and summer flounder recruitment (gaussian and sigmoidal) have been developed for testing within the MSE framework. The goal is to have a range of feasible relationships for testing, not necessarily limited to those found in this region for summer flounder. The group is compiling a list of harvest control rules representing those used across the US (including the MAFMC risk policy) as well as environmentally-driven control rules to be tested within the framework. The goal is to have simulations, including the MSE framework and harvest control rule options, ready to start by May. Key performance metrics will include SSB, catch, and variability in catch under different environmental conditions.

The Ecosystem WG agreed with reducing the scope of work to focus on a summer flounder-like species, rather than extending to an additional life history type, and looks forward to reviewing initial results this summer.

Alternative stock performance metrics considering current conditions WG member Paul Rago and SSC member Brian Rothschild presented a method to recast stock assessment outputs taking explicit account of current (perhaps environmentally driven) realized recruitments, rather than all observed historical recruitments. The method uses available stock assessment information (catch, SSB, recruitment) and potentially can consider stock, economics, and ecosystem information. Examples were developed for bluefish, summer flounder, and sea bass, each showing relative SSB and relative yield plots (with expected SSB and expected yield given current conditions as a basis). Preliminary analysis suggested that we could have done better had we fished at optimal rate for bluefish. Summer flounder could have had better SSB with less catch. Black sea bass rebuilt above target, suggesting management overshot? The analyses revealed some stocks that did not necessarily produce higher recruitment at higher SSB such as summer flounder, where the odds ratio suggested that recruitment is higher when stock size is lower. In contrast, bluefish did produce higher recruitment under higher SSB, and sea bass performed similarly.

The SSC WG discussed potential to use this type of comparison to expectations given recent productivity within ABC mode or rebuilding analyses. The approach asks how effectively we are managing given the hand we are dealt currently, which can be measured using current recruitment, as well as current weight at age, maturation, and selectivity. There are likely connections with the simulation analysis described above, as well as the Index Numbers approach described below, which can also evaluate performance relative to current ecosystem conditions. The WG and full SSC could consider how this approach might be incorporated into current decisions, and how to more formally use current ecosystem and economic information in determining expected SSB and yield.

Objective 2: Multispecies and system level ecosystem advice

These projects can be used to inform the existing Council EAFM process, or new Council decision processes at the multispecies or ecosystem level.

Ecosystem overfishing indicators Andy Beet (NEFSC) presented an update from the April 2022 meeting on data inputs, data analysis, methodology, and planned empirical and simulation analyses to further develop regionally specific ecosystem overfishing (EOF) indicators at the February 2023 meeting. These indicators were presented in the 2021 SOE, but were not updated due to data constraints in 2022. Because the data inputs are still incomplete and discussion of analyses with the SSC are planned to evaluate appropriate thresholds, the EOF indicators are not included in the 2023 SOE.

The 2021 EOF indicators were based on commercial landings of federally managed species. However, EOF indicators are designed to be based on total catch. In 2022, catch data for Atlantic menhaden was added; because this is the highest volume fishery on the US East Coast it is important to include menhaden catch in the EOF indicators. Work continues to include commercial discards and recreational catch of all species. Comparisons among commercial landings data sources were also completed to ensure that inputs to the indicators are correct. Discrepancies between the Sea Around Us data source and NEFSC data sources were resolved by including live weight instead of meat weight for shellfish landings. The Ecosystem WG agreed that these changes to input data were appropriate, and suggested double checking that all state landed species (not federally permitted) were included in the input data.

Detailed methods were reviewed for each of the three EOF indicators: Ryther (total catch per unit area), Fogarty (total catch per total primary production), and Friedland (total catch per mean chlorophyll). Because the originally published thresholds for each indicator were based on global average ocean productivity and trophic level of the catch, the initial step is to recalculate the thresholds using regional estimates of productivity and catch trophic level. As a next step, simulation analysis was proposed using the Northeast US Atlantis ecosystem model to test the robustness of the resulting regional thresholds to different levels of fishing.

The SSC Ecosystem WG agreed with this general approach and had several suggestions for simulation scenarios. First, evaluating tradeoffs between functional groups is desirable as there are many combinations of group fishing levels that may lead to, or relieve, ecosystem overfishing. Evaluating both biomass/biodiversity objectives and economic and social objectives will be important (not all species are equally valued). Finally, the relationship between transfer efficienciy and ocean warming should be investigated. If transfer efficiency is assumed constant but climate change means it is not, how is that accounted for in the EOF indicators and simulations?

Index Numbers for ecosystem performance John Walden (NEFSC) presented an update to the Index Numbers analyses following initial presentation and WG suggestions at the July 2022 meeting. The approach combines any number of related indices into a single index, with weighting determined by an output distance function created using Data Envelopment Analysis (DEA). The output set contains all outputs that can be produced from a given set of inputs, and is used to compare a realized output from the maximum potential output given an input. Index Numbers can be used to evaluate performance relative to the best potential performance in a given year, and determine whether system performance has improved over time relative to a reference year. It also allows many indicators to be collapsed into a single indicator.

Based on previous discussion, new analysis integrated multiple indicators addressing a particular management objective into Index Numbers. Initial SOE management objectives included seafood production, recreational opportunities, and environmental quality, using data from 1982-2019. For these initial tests, 1982 is the reference year, although the choice of the reference year could be made using managers' judgement of a particularly ideal year or poor year as a baseline. The index was demonstrated to scale appropriately, and several visualizations were shown, including line plots presented previously and heatmaps comparing each index to its baseline to look across indices.

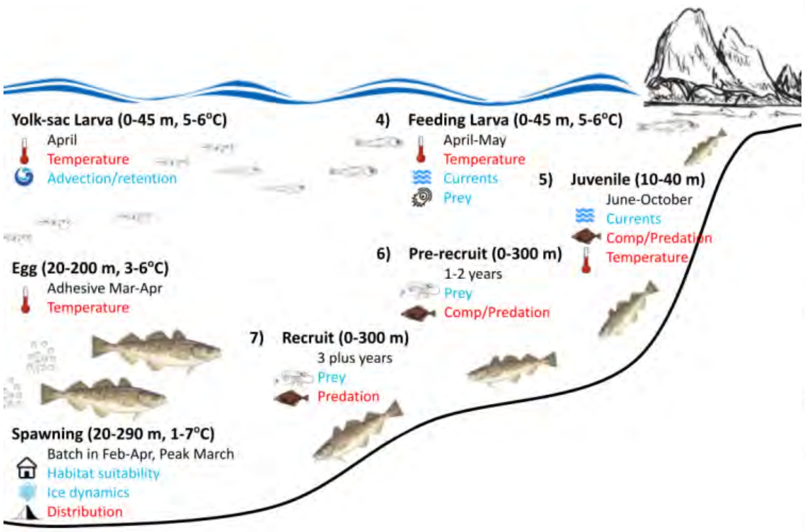
Results of these example Index Numbers showed that current seafood landings are lower than initial year in both the Mid-Atlantic and New England, with the Mid doing slightly better than New England at present. Indices for both seafood landings and recreational opportunities dropped after 2010, although the recreational opportunities index did not drop that much relative to 1982, and the Mid and New England looked similar across recreational index numbers. The combined environmental quality index is currently above the 1982 baseline in the Mid-Atlantic, and near the baseline in New England. Using these Index Numbers, the state of environment is 40% better in the Mid-Atlatnic relative to the 1982 reference year.

The SSC Ecosystem WG discussed the potential to apply this analysis with the risk assessment review, for instance to help establish targets or thresholds that the EOP Committee has expressed interest in seeing. WG members Geret DePiper and Sarah Gaichas plan to meet with other SOE leads to explore how to bring Index Numbers forward in the upcoming SOE cycle. This could involve taking some of the indicators with a common theme (Seafood production for example) to condense into input and output indices through this analysis.

Objective 3:

Development of Ecosystem-Socioeconomic Profiles in Research Track assessment working groups facilitates the inclusion of ecosystem information within the current stock assessment process, and therefore fits within existing Council decision processes.

Ecosystem and Socioeconomic Profiles (ESPs) are used within the North Pacific stock assessment process as a structured way to include stock-relevant ecosystem information within stock assessments. An overview of the North Pacific ESP development process is available here. An example conceptual model of ecosystem interactions with Eastern Bering Sea Pacific cod demonstrates pathways for ecosystem indicators to enter the assessment process.



Indicator category	Indicator	2017 Status	2018 Status	2019 Status	2020 Status	2021 Status
Physical	Spawning Heatwave GOA Model	neutral	neutral	high	neutral	neutral
	Winter Spring Pacific Cod Spawning Habitat Suitability GAK1 Model	neutral	neutral	low	neutral	neutral
	Summer Temperature Bottom GOA Model	neutral	neutral	high	neutral	neutral
	Annual Eddy Kinetic Energy Kodiak Satellite	neutral	neutral	neutral	high	neutral
Lower Trophic	Spring Chlorophyll a Peak WCGOA Satellite	low	low	high	low	neutral
	Summer Large Copepod Abundance Shelikof Survey	low	NA	neutral	NA	NA
	Summer Euphausiid Abundance Kodiak Survey	low	NA	neutral	NA	NA
	Spring Pacific Cod CPUE Larvae Shelikof Survey	neutral	NA	neutral	NA	neutral
	Annual Common Murre Reproductive Success Chowiet Survey	neutral	neutral	high	NA	neutral
Upper Trophic	Summer Pacific Cod Condition Juvenile GOA Survey	neutral	NA	neutral	NA	neutral
	Summer Pacific Cod Condition Adult GOA Survey	neutral	NA	neutral	NA	neutral
	Summer Pacific Cod Center Gravity Northeast WCGOA Model	low	NA	high	NA	neutral

Figure 1. Left, AFSC caption "In 2021, our scientists developed a working conceptual Ecosystem and Socioeconomic Profile model of Eastern Bering Sea Pacific cod stock showing various indicators impacting the Pacific cod populations.", Right, Gulf of Alaska Pacific Cod risk table from the ESP. Credit: NOAA Fisheries.

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ESPs are currently in development in the Northeast US for multiple Mid-Atlantic and New England stocks. Work under Objective 3 continues with the participation of Gavin Fay in the black sea bass WG. The Bluefish Research Track ESP was presented December 7 2022, and was well received by CIE reviewers. Reviewers commented that it was the most complete treatment of a stock assessment “ecosystem ToR” they had seen, and formed a good basis for integrating further ecosystem information into the stock assessment in the future. The full ESP document is available as a working paper from the stock assessment data portal.

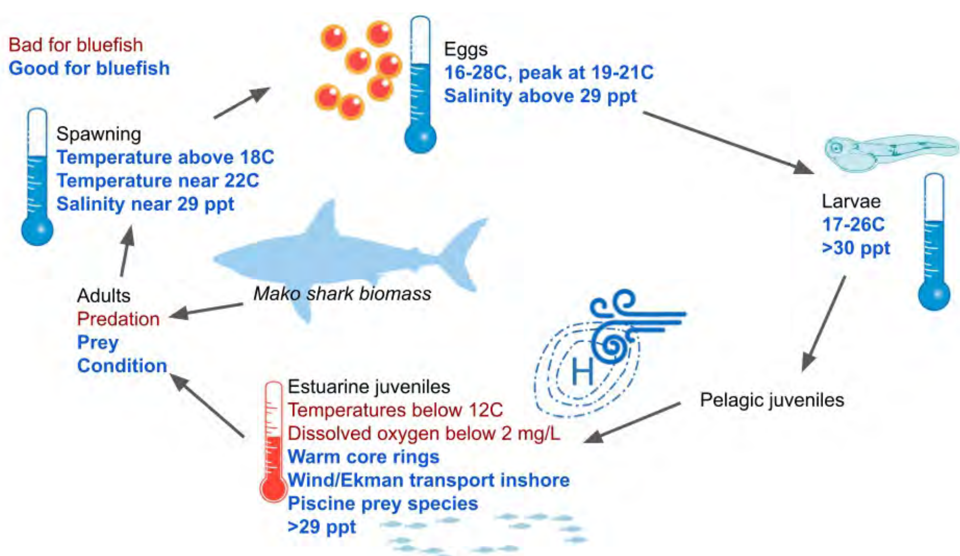

Figure 2: Bluefish conceptual model from the 2022 Research Track ESP Credit: Abigail Tyrell, Bluefish RT WG

In addition to the conceptual model, a summary table was developed for bluefish ecosystem indicators. This type of summary could contribute to OFL CV decisions with further information on how these indicator levels affect uncertainty in assessment.

Ecosystem indicators summary

Indicator category	Indicator	2017 Status	2018 Status	2019 Status	2020 Status	2021 Status
Distribution	Fall center of gravity of small (<=30.3cm) bluefish (northings, km)	neutral	**high**	neutral	NA	NA
	Fall center of gravity of medium (30.3-50.0cm) bluefish (northings, km)	neutral	neutral	**high**	NA	NA
	Fall center of gravity of large (>=50.0cm) bluefish (northings, km)	neutral	**high**	**high**	NA	NA
	Fall center of gravity of small (<=30.3cm) bluefish (eastings km)	neutral	neutral	neutral	NA	NA
	Fall center of gravity of medium (30.3-50.0cm) bluefish (eastings km)	neutral	neutral	**high**	NA	NA
	Fall center of gravity of large (>=50.0cm) bluefish (eastings km)	neutral	neutral	**high**	NA	NA
Climate	First day of the year when the mean temperature of the region is warmer than 18C	neutral	neutral	**neutral**	neutral	*low*
	Last day of the year when the mean temperature of the region is warmer than 18C	**high**	neutral	neutral	**high**	**high**
	Number of days when at least 75% of the region is warmer than 18C	**high**	neutral	neutral	neutral	**high**
	Proportion of the central Atlantic colder than 18C in July	neutral	neutral	neutral	*low*	*low*
	Proportion of the central Atlantic between 18-25.6C in July	neutral	neutral	*low*	*low*	**high**
	Proportion of the central Atlantic warmer than 25.6C in July	neutral	neutral	**high**	**high**	neutral
	Mean crossshore wind in the central Atlantic in April and May	neutral	**high**	neutral	*low*	*low*
	Mean alongshore wind in the central Atlantic in April and May	*low*	**high**	*low*	neutral	neutral
Natural mortality	Spring condition of small (<=30.3cm) bluefish	neutral	neutral	neutral	*low*	neutral
	Spring condition of medium (30.3-50.0cm) bluefish	neutral	neutral	neutral	high	neutral
	Spring condition of large (>=50.0cm) bluefish	*low*	neutral	**high**	**high**	**high**
	Fall condition of small (<=30.3cm) bluefish	neutral	neutral	neutral	**high**	**high**
	Fall condition of medium (30.3-50.0cm) bluefish	neutral	neutral	neutral	**high**	**high**
	Fall condition of large (>=50.0cm) bluefish	neutral	**high**	neutral	**high**	neutral

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Figure 3: Bluefish indicator summary table from the 2022 Research Track ESP Credit: Abigail Tyrell, Bluefish RT WG

The SSC Ecosystem WG looks forward to the feedback of the full SSC on any of these topics, and always welcomes new members.