Habitat Management Considerations for the Northern Edge of Georges Bank

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Prepared by the

New England Fishery Management Council

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1.4 ACRONYMS

CAI	Closed Area I
CAII	Closed Area II

EFH	Essential fish habitat
EEZ	Economic Exclusive Zone
FESI	Final Environmental Impact Statement
GARFO	Greater Atlantic Regional Fisheries Office
GARM	Groundfish Assessment Review Meeting
GB	Georges Bank
GIS	Geographic Information System
HAPC	Habitat area of particular concern
MAFMC	Mid-Atlantic Fishery Management Council
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NEFMC	New England Fishery Management Council
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OHA2	Omnibus Habitat Amendment 2
TRAC	Transboundary Resources Assessment Committee
VMS	Vessel monitoring system
VTR	Vessel trip report

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE OF THIS REPORT

This report explores information and issues pertinent to habitat management on the Northern Edge of Georges Bank. It is intended to support a Council decision about whether to initiate an action that would consider revisions to Georges Bank habitat management measures, specifically habitat management areas (HMAs) and associated gear restrictions. The Council recommended making changes to management areas on the Northern Edge via Omnibus Habitat Amendment 2 (OHA2), which were intended to allow for access to fishing grounds on the Northern Edge while maintaining some habitat closures and gear restrictions. The changes were disapproved by NOAA Fisheries as described in section 2.4 below. The Council has maintained interest in reconsidering this issue to determine if there is enough justification for revising Georges Bank habitat management measures.

This document focuses on studies on the effects of fishing gears on habitat that were completed after Council took final action on OHA2 on June 16, 2015 (the final rule was implemented on April 9, 2018). Information is discussed in the context of whether it supports different conclusions related to fishing and minimization of adverse effects on habitat than those reached during development of OHA2.

OHA2 included alternatives to minimize the effects of fishing on EFH on a sub-regional basis[1]. A sub-regional organization was used to facilitate discussion, analysis, and decision making, as each location has a unique mix of habitat types, stocks, and fisheries. The Georges Bank sub-region included the entire bank east of the Great South Channel to the Exclusive Economic Zone (EEZ). This document focuses on a subset of Georges Bank, specifically the northern portion east of Closed Area I.

2.2 MAGNUSON STEVENS ACT EFH REQUIREMENTS

In deciding whether to develop an action that may allow fishing access to the Northern Edge, the Council needs to consider Magnuson Stevens Act (MSA) requirements and evaluate which impacts are minimal and temporary based on the best scientific information available and consider which management measures minimize adverse effects to the extent practicable (OHA2 Volume 6, Section 3). Mandatory contents of fishery management plans (FMPs) related to essential fish habitat (EFH) are described in the Magnuson-Stevens Act, with detailed guidance provided in the EFH regulations, which can be found at 50 CFR §600.815. Volume 6, Section 3 of the OHA2 FEIS describes how the action complies with these requirements.

EFH are those waters and substrate necessary for spawning, breeding, feeding, and growth to maturity. EFH designations indicate core areas used by a species and lifestage for spawning, breeding, feeding, or growth to maturity. EFH attributes such as depth, temperature, salinity, substrate type, and in some cases, habitat features like sand waves are identified, and the spatial footprint of EFH is mapped. EFH spatial footprints are generally based on a combination of fishery-independent survey catches, depth, and temperature data. EFH designations on Georges Bank are described further in Appendix A. Habitat areas of particular concern (HAPC) are a subset of EFH designations that require more attention based on one or more of the following criteria: importance of historic and/or current ecological function, sensitivity to anthropogenic stresses, extent of current or future development stresses, and rarity of the habitat type. These areas are intended to promote conservation of specific locations by identifying their importance to a species. EFH and HAPC designations do not carry restrictions by gear type or fishery.

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[1] The sub-regions evaluated for OHA2 are similar to the Ecological Production Units that the Council has used as a foundation for ecosystem-based fishery management discussions. The Northeast Shelf Large Marine Ecosystem includes a Georges Bank-Nantucket Shoals EPU, which extends further west than the OHA2 sub-region.

Regulations state that FMPs must identify and analyze adverse impacts caused by fishing on EFH. For those fishing impacts that are more than minimal and not temporary, fishery management plans must identify measures to avoid, minimize, or compensate for adverse impacts in these areas.

2.3 SUMMARY OF SPATIAL MANAGEMENT ON GEORGES BANK

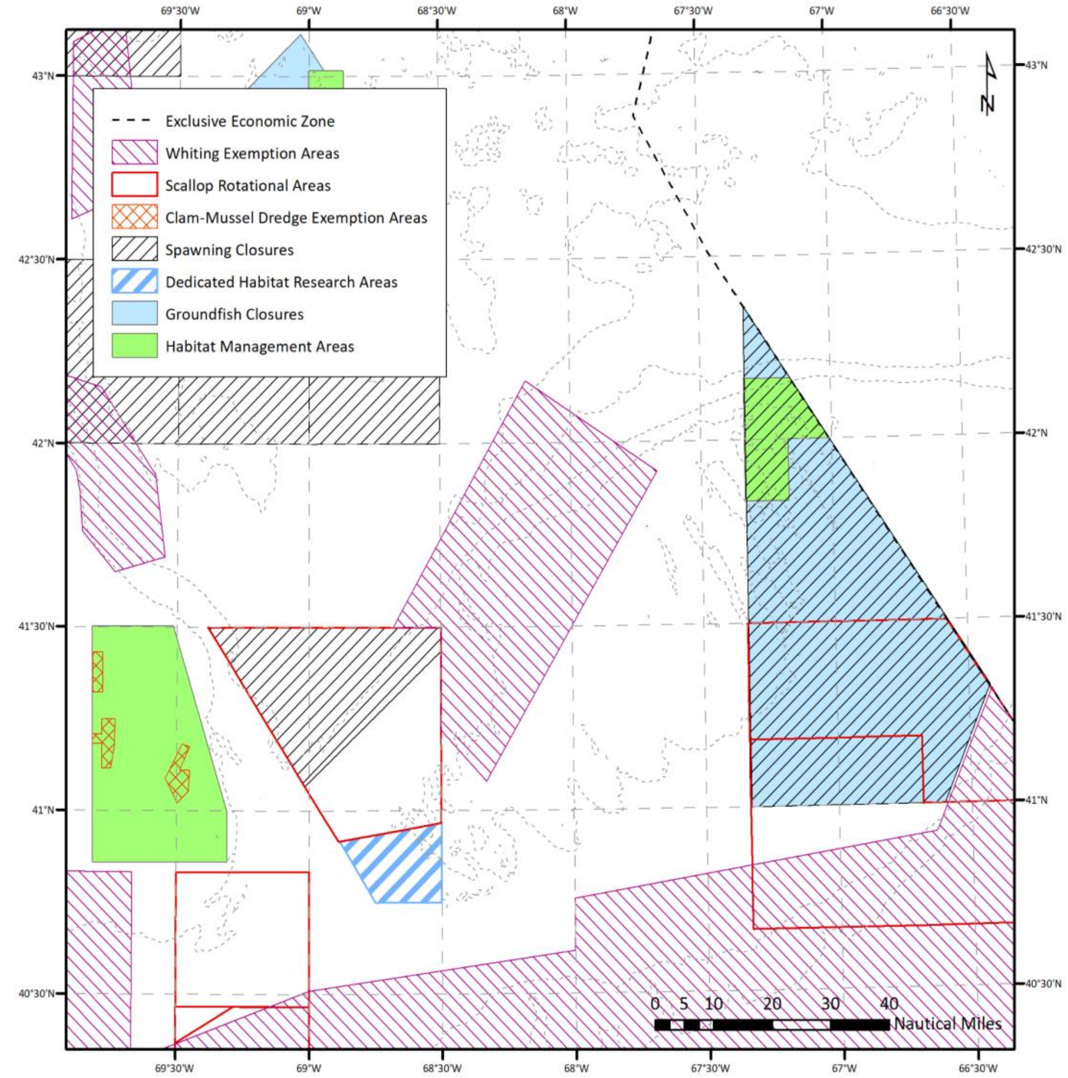
The Council's original goals and intentions in setting up the closures in the Northern Edge region were to protect the area as a habitat area of particular concern specifically because of its vulnerability to fishing (Final Rule response to Comment 46). In Omnibus EFH Amendment 1 (OHA1), the Council desired to integrate adverse effects minimization measures across fishery management plans (OHA2 FEIS Volume 1). A 2000 lawsuit (American Oceans Campaign et al. v. Daley et al) required the Department of Commerce and the Councils to complete "a new and thorough EA or EIS" for each EFH amendment and found OA1's fishing impact analysis and the lack of mitigation measures to minimize the adverse effects of fishing inadequate. As a result, the Council prepared extensive analyses of adverse effects of fishing on EFH with a range of alternatives and descriptions of regional fishing gears, habitats, and summaries of existing knowledge on fishing gear effects on habitats and the NEFMC/MAFMC managed species. In 2003 and 2004, the Northeast Multispecies and Scallop FMPs designated habitat closure areas located inside and outside existing year-round closures to minimize adverse effects of fishing on benthic habitats and also adopted gear modifications that increased dredge size to minimize bottom contact time (Northeast Multispecies Amendment 13, Scallop Amendment 10).

Georges Bank currently has many fishery management areas designed to address various objectives (Map 1). These include year-round groundfish closed areas to limit mortality and promote rebuilding, seasonal closures to protect groundfish spawning, habitat management areas to minimize the effects of fishing on EFH, exemption areas to facilitate certain types of fishing activity outside of more generalized restrictions, scallop rotational access areas to optimize resource yield, and accountability measure areas which are triggered when mortality reductions on a stock are needed. Each area is bound by specific coordinates and has restrictions on fishing activity, which in some cases are by gear type regardless of FMP, but in other instances tied to a certain FMP.

The history of the Council's EFH, habitat closure, and groundfish closure designations is summarized in the OHA2 FEIS, Volume 1, Section 3.3. Closed Area II, which was designated as a year-round groundfish closed area in 1994, remains in place, and was designated via OHA2 as a spawning closure between February 1-April 15. The HAPC on the Northern Edge was first designated in OHA1 and reaffirmed in OHA2 with the same boundaries (see OHA2 Vol 2, section 3.1.2 for rationale). Between OHA1 and OHA2, the designated HAPC had a habitat closure applied to it via an amendment to the Council's Northeast Multispecies FMP, and this co-designation as a habitat management area remains in place. As a habitat closure, the area is closed to mobile, bottom-tending gears to minimize the adverse effects of fishing on EFH.

Additional changes to the habitat and groundfish management areas on the Northern Edge were recommended by the Council through OHA2 but disapproved by NOAA Fisheries as discussed in the next section. The Council's FMPs have continued to evolve since OHA2 was completed, with corresponding adjustments to management areas (e.g., changes in scallop access area boundaries) and new approaches under consideration (e.g., potential herring spawning closures).

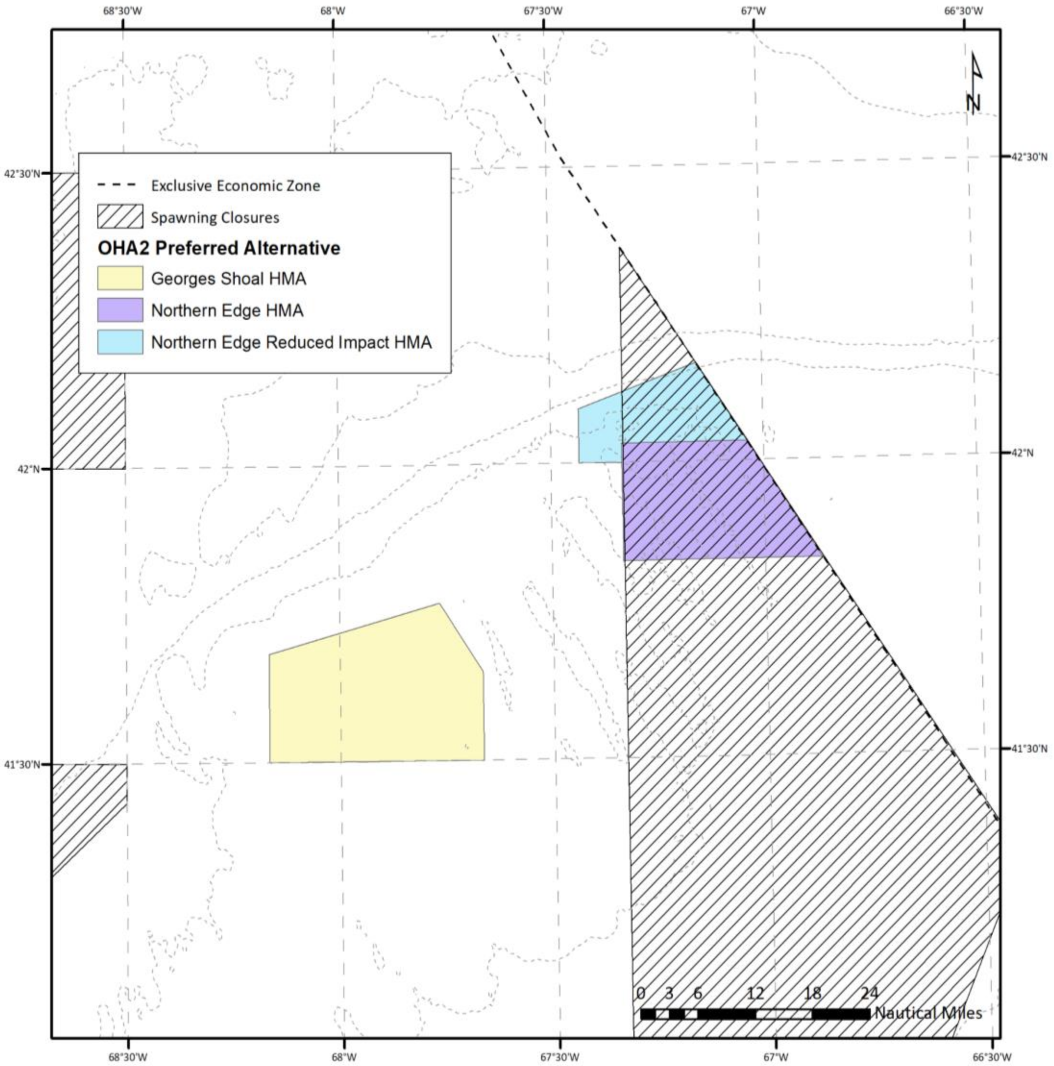
Map 1. Current year-round and seasonal management areas on Georges Bank.



2.4 OHA2 Final Rule and Partial Approval

Via OHA2, the Council recommended retaining the HAPC, converting Closed Area II to a seasonal spawning closure, removing the Closed Area II Habitat Closure Area, and designating three new habitat management areas (HMAs): the Georges Shoal HMA, the Northern Edge Mobile Bottom-Tending Gear Closure HMA, and the Northern Edge Reduced Impact HMA. This proposal is depicted on Map 2.

Map 2. Northern Edge area management changes proposed in OHA2.



The Council's habitat management recommendations for the Northern Edge were disapproved by NOAA Fisheries, with the exception of the addition of a spawning closure in Closed Area II, as noted in the previous section (the current groundfish closure regulations remain in place year-round). Based on the April 9, 2018 final rule (83 FR 15242-15243), these measures were disapproved because adverse effects minimization requirements in the MSA were not sufficiently met (beyond the 2002 EFH regulations). Specifically, the measures did not fully specify the frequency and intensity of fishing in the area that would be allowed with rotational scallop dredging. Thus, NOAA could not effectively determine how the measures would minimize the adverse impact to habitat. In addition, NOAA raised concerns about the inconsistency between the Council's designation of the area as a HAPC, indicating that the area is important to managed species and vulnerable to fishing impacts, while allowing fishing activity with undefined frequency and intensity.

In order to reconsider the closures in the Northern Edge region, "...NMFS contends that any future action should thoroughly evaluate the geographic extent, duration, and frequency of any future scallop dredging activity within any new access area on the northern edge of the bank and the habitat features that are used by groundfish at critical life stages that need to be protected from impacts" (Final Rule, response to Comment 33). NOAA Fisheries identified needing to understand areas critical to juvenile cod spawning and the impact and recovery time of vulnerable habitat features from scallop dredges.

Additional comments from the Final Rule:

- An important consideration is the quality and function of the habitat: "The combination of the Council's two mobile-tending gear closures are significantly larger than the existing Closed Area II habitat closure; however, these areas are less efficient in protecting vulnerable habitat, and, despite their size, include less EFH for managed species and life stages..." (Final Rule, response to Comment 42)."
- "Increased efficiency is not the only way to minimize the adverse effects of fishing on EFH...The combination of reduced overall effort and high-quality closures is one reason we supported the Council's approach that smaller HMAs that protect more vulnerable habitat are preferable to larger HMAs that cover less vulnerable habitat...The Council recommended larger, less efficient closures as compensation for increased impacts in highly vulnerable substrate" (response to Comment 8)
- "...high EFH value of the northern edge of Georges Bank for cod and the low overall EFH value of the Georges Shoal area" (response to Comment 19)
- "The recommendations made by the North Pacific and Pacific Councils, and the decisions made by NMFS in approving those recommendations, may be looked at for guidance on a particular approach, but it is not required" (response to Comment 22)

3.0 NEW INFORMATION ON THE EFFECTS OF FISHING GEAR ON HABITAT

This section summarizes relevant information that is more recent than what was available to the Council during OHA2 development: (1) updates to the Swept Area Seabed Impact approach (SASI; known as the Northeast Fishing Effects Model) with respect to the Northern Edge, (2) the results of two scallop RSA projects related to the impacts of fishing gears on benthic structures, and (3) key findings of the recent gear effects literature published between 2017 and 2021 and not reviewed during preparation of the Fishing Effects Northeast report.

3.1 SASI AND FISHING EFFECTS NORTHEAST MODELS

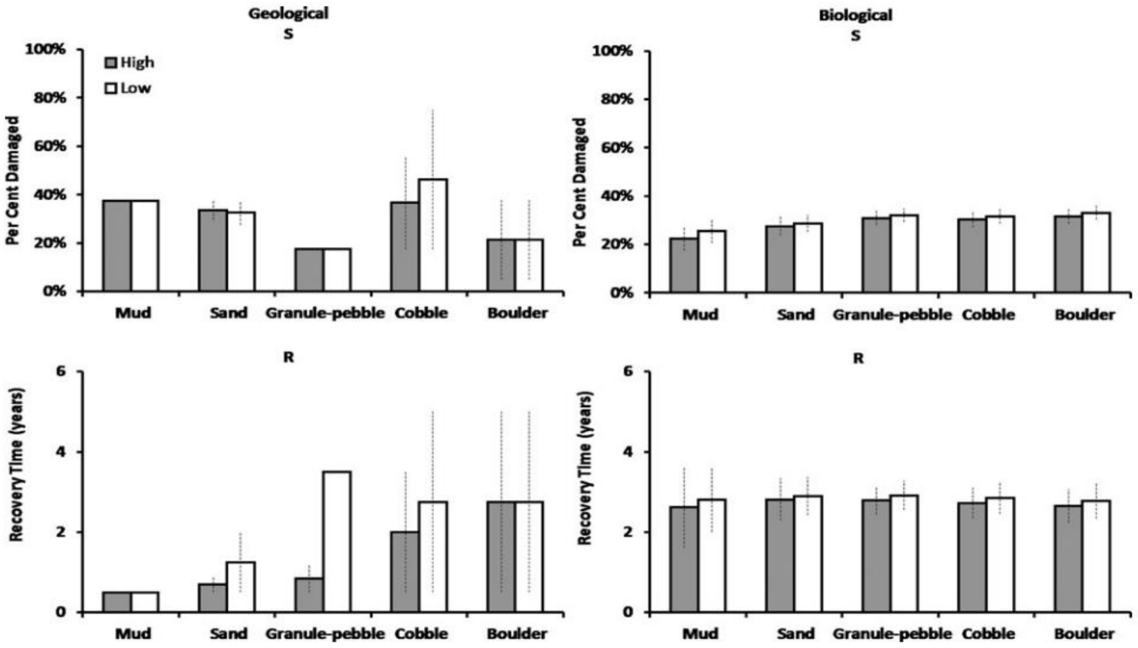
The SASI model was developed during OHA2 as a decision-support tool for the Council to consider spatial- and gear-specific differences in impacts to EFH (NEFMC, 2011). SASI included a literature review and habitat vulnerability assessment, plus a spatially explicit model that combined fishing effort, habitat susceptibility and recovery parameters, and a sediment-based habitat map to identify which parts of the region were expected to be most vulnerable to impact by bottom-tending gears. The Fishing Effects Northeast report updates the literature review (through 2018), vulnerability assessment, and model (including quantitative methods, fishing effort data, and sediment data; NEFMC 2019). The vulnerability assessment developed for SASI was published as Grabowski et al. 2014. Smeltz et al. (2019) describes the North Pacific Fishing Effects Model, a related product. Fishing Effects Northeast was developed in collaboration with researchers in the North Pacific.

The models combine substrate and energy-based habitat maps with feature-based and gear type specific vulnerability assessments to estimate the spatial distribution of habitat vulnerability in the northeast region. One set of model runs applies a uniform fishing effort distribution to estimate which locations are intrinsically more vulnerable to impact, and another set of runs applies historical fishing effort distributions to estimate where the seabed disturbance has accumulated over time. Fishing gears evaluated include bottom trawls, scallop dredges, hydraulic dredges, pots and traps, sink gillnet, and bottom longline. Fishing Effects has a higher spatial and temporal resolution than SASI did, mapping habitats at a scale of 5x5 km grids and using monthly vs. annual fishing effort. All effort is measured as area swept in km^2 to allow for direct comparison across gear types. The model domain includes the entire northeast region from Maine to the North Carolina-South Carolina border, out to a depth of approximately 1,000 meters.

The vulnerability assessment results are mostly unchanged between SASI and Fishing Effects. Additional literature was added to the assessment when Fishing Effects was developed, but the PDT generally did not change susceptibility or recovery scores developed for SASI upon review of the additional literature. One exception to this is that for the hydraulic dredge gear type, Fishing Effects estimated impacts in additional cobble and boulder habitat types, which were assumed not to be fishable by this gear type when SASI was developed, so susceptibility and recovery parameters were added. Also, Fishing Effects added a sixth habitat type, steep and deep habitats, to be able to model fishing effects on deep water habitats containing deep-sea corals.

A summary figure for trawl gears based on the SASI vulnerability assessment is provided below. Generally, habitat features occurring at low energy sites (white bars in Figure 3, reproduced from Grabowski et al. 2014) are expected to be more vulnerable (higher susceptibility and longer recovery) than those at high energy sites. Biological features occurring in gravel habitats (pebble, cobble, boulder) are on average slightly more susceptible to impacts than those in mud or sand habitats (Figure 1). On average geological features in gravel habitats have longer recovery times compared to those in mud or sand habitats (Figure 1).

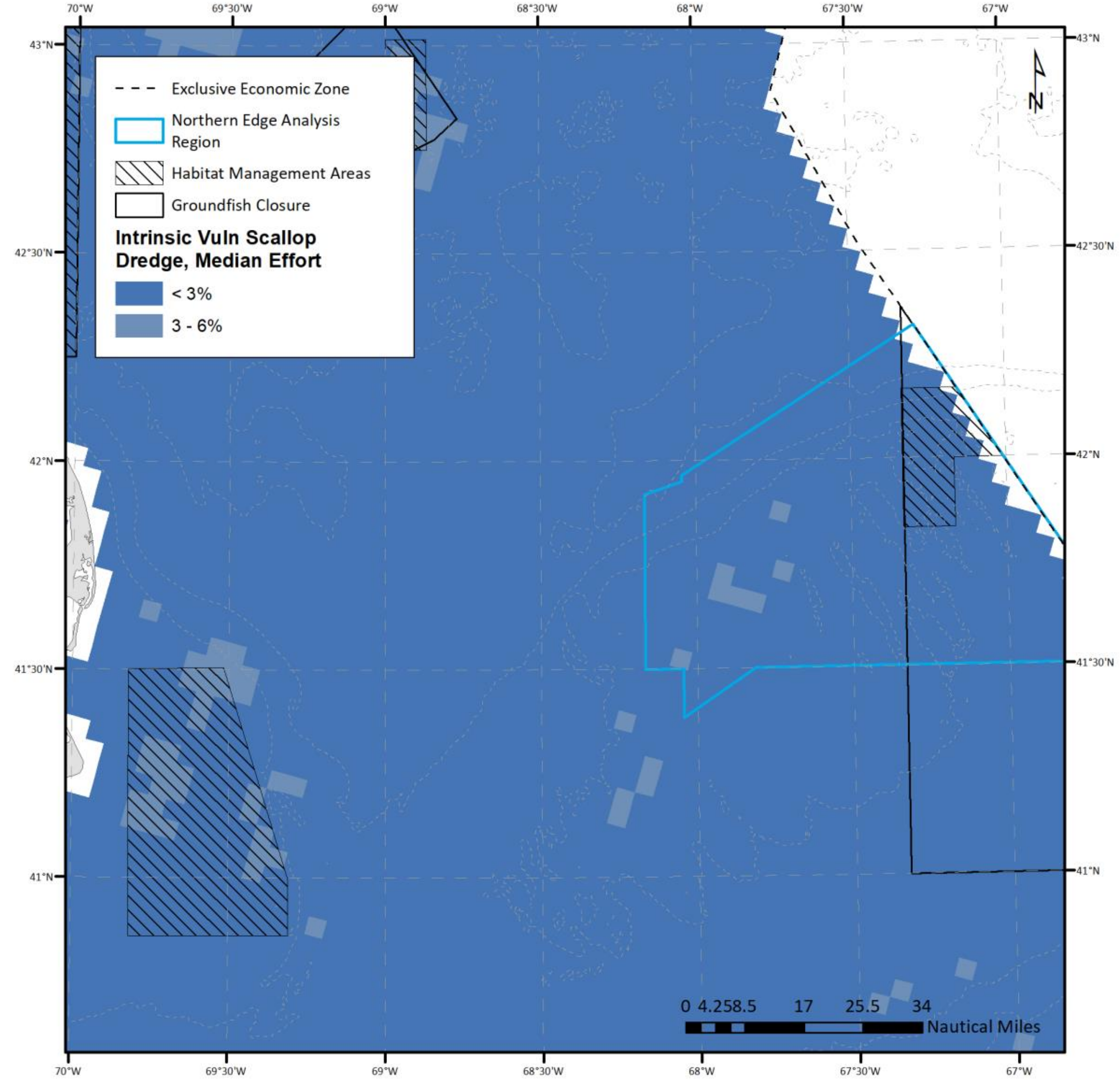
Figure 1. Mean susceptibility (% damaged) and recovery (time in years) of biological and geological features from otter trawl gear impacts; hatched verticals error bars are ±1SE. Scallop dredge values are not shown here but are very similar.



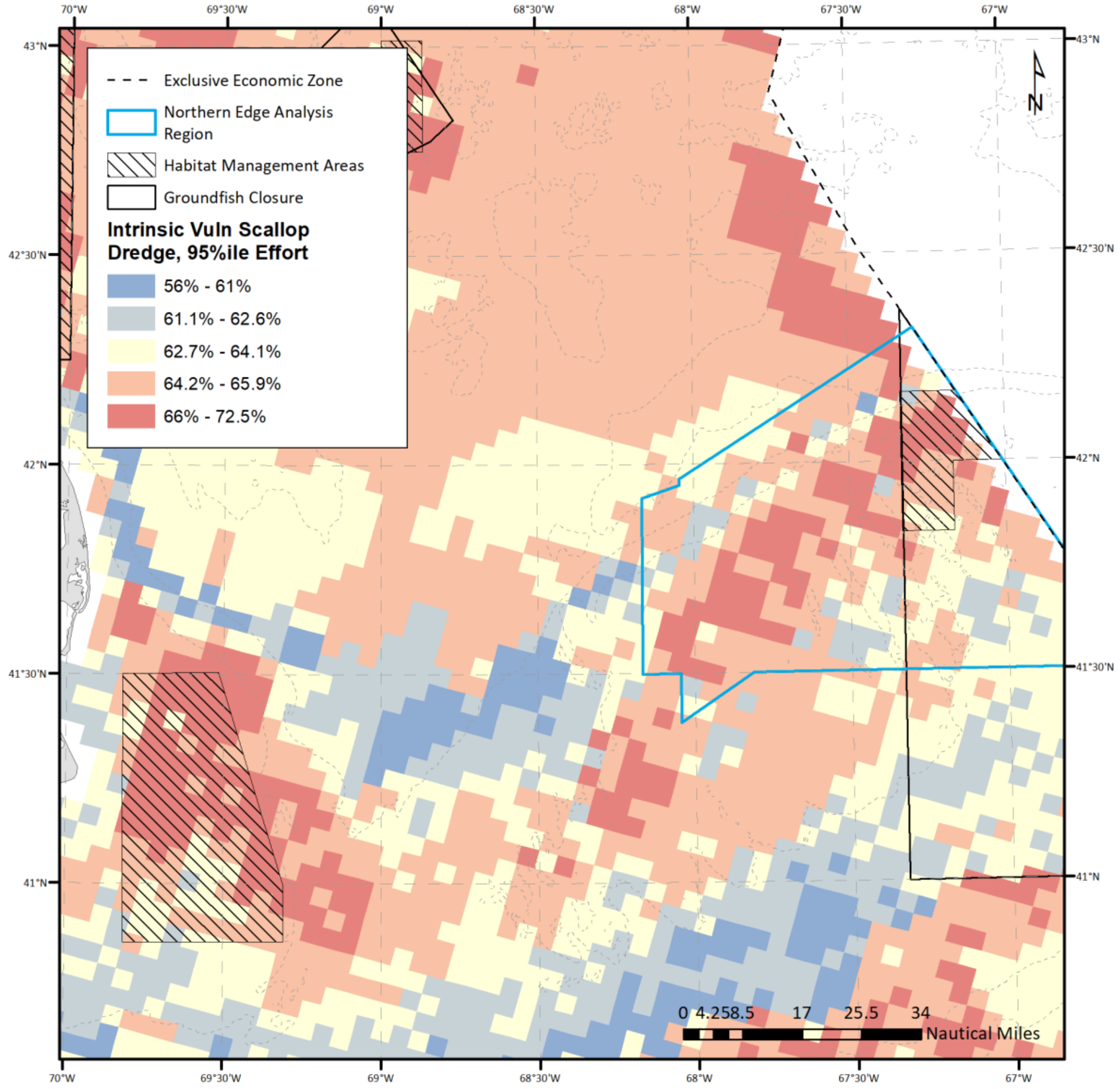
Results for Fishing Effects are summarized in Section 7 of the Fishing Effects Northeast report (NEFMC 2019). The amount of habitat disturbance associated with each gear broadly relates to the amount of fishing (area swept) for that gear type, combined with the degree of seabed contact, which varies by gear, the susceptibility of habitat features to the gear, and the recovery rates of habitat features following impact.

The intrinsic habitat vulnerability runs of the Fishing Effects model show which locations within the region are expected to be most vulnerable to impact, assuming a uniform distribution of fishing effort in space, including within areas currently closed to fishing. Similar SASI model runs were used heavily during development of OHA2. In both models, intrinsic habitat vulnerability varies spatially according to the underlying habitat distribution and the susceptibility and recovery values estimated for seabed features occurring in that habitat type. For SASI, the same uniform effort distribution was modeled for all gear types, but Fishing Effects based this distribution on real fishing intensity magnitudes in the VTR data. One set of Fishing Effects model runs uses the median amount of effort for that gear type, while another uses the 95th percentile of effort for that gear type. For scallop dredge gear, the median runs estimate percent disturbance associated with a 1.5% swept area ratio, which means that 1.5% of each grid cell is contacted with scallop gear on an annual basis (results shown on Map 3). The 95th percentile run uses a swept area ratio of 68% (results shown on Map 4). The estimated percent disturbance varies substantially between these two runs, reflecting the relative amount of fishing effort. When applying these results, it will be important to consider the relationship between these swept area ratio values and realistic estimates of effort within the area.

Map 3. Fishing Effects Model intrinsic habitat vulnerability to scallop dredging, based on median effort.

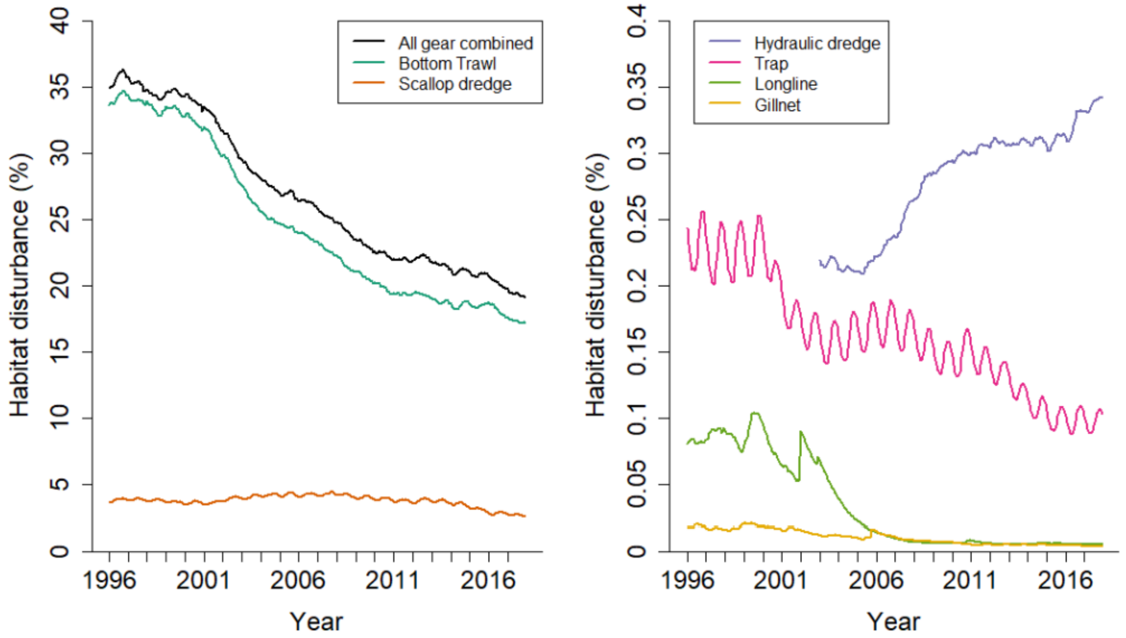


Map 4. Fishing Effects Model intrinsic habitat vulnerability to scallop dredging, based on the 95th percentile of effort.



The percent habitat disturbance runs of the Fishing Effects model using historical fishing effort indicate that over the domain described above and combining all gear types, many grids (30%) show a low (<5%) percent disturbance; 8% of grids show high (> 50%) disturbance, and the remaining 62% of grids show intermediate disturbance. Domain-wide and across all gears, habitat disturbance has declined between 1996-2017 (Figure 2). This is because there is less fishing overall and in the case of clam dredge impacts where there is an increase, this is likely partly due to a shift in effort spatially into more vulnerable habitat types. The trends for individual gear types vary, however (Figure 2). The largest share of habitat disturbance is from bottom trawls, and there is a declining trend in habitat disturbance associated with this gear type. There is a slight recent decline in habitat disturbance due to scallop dredge gear, and a longer-term decline for fixed gears. Impacts associated with sink gillnet and bottom longline are minimal and the trend is relatively flat since the mid-2000s. Hydraulic dredge impacts have increased since the mid-2000s. Maps of percent habitat disturbance resemble maps of fishing effort in that areas of higher disturbance reflect locations where there is more fishing activity, which is consistent with findings from OHA2.

Figure 2. Time series of habitat disturbance (%) throughout the total domain. Left panel shows all gear combined (black line) with individual gears that alone contribute >1% to habitat disturbance. Right panel shows individual gears that alone contribute <1% to habitat disturbance.



3.2 RESEARCH SET ASIDE PROJECT RESULTS

Two studies are described below. The results of the two studies are not directly comparable due to differences in field and analytical methods.

3.2.1 Impact of Disturbance on Habitat Recovery in Habitat Management Areas on the Northern Edge of Georges Bank

Gallager et al. evaluated the impacts of scallop dredging on benthic habitat resilience on the Northern Edge of Georges Bank. The overall goal was to build a habitat suitability map in real time by combining species information and substrate data. More specifically, the project set out to evaluate how ecosystem impacts and resiliency to the impacts of scallop dredge gear differ based on substrate type, namely sand, sand/gravel, and gravel/cobble. The research also sought to identify areas of high scallop abundance to inform potential regions in which the Council could consider renewed fishing opportunities.

Most of the study area is within Closed Area II or the overlapping Closed Area II Habitat Closure Area (=HAPC); these areas have been closed to multiple types of fishing gear, including all mobile bottom-tending gears, since the 1990s. These research findings could help inform whether and where to allow fishing on the Northern Edge of Georges Bank, an essential fish habitat for commercially important species. The study was funded through the 2016 Scallop Research Set-Aside Program, award number NA16NMF4540045. The sources for this summary are (1) the 2018 final report to the RSA program, (2) a

2020 Scallop Research Set Aside Share Day summary and presentation, and (3) two presentations and a report provided to the Habitat Plan Development Team in 2021[2]. While the report and presentation shared with the PDT in September 2021 are the focus here, the 2018 report provided to the RSA program in May 2018 remains useful in that it includes a more detailed description of the project and survey methodology with figures that remain pertinent. The 2021 report to the PDT details the image processing methodology includes references to corresponding slides in the final PowerPoint (which includes data tables and figures not included in the report). Dr. Gallager is interested in conducting another survey for these six sites in 2022 to evaluate the 5-year recovery of complex habitats that were dredged in 2016 against the controls, however, he has yet to receive funding for this work. The 2021 analysis represents an expansion of the earlier work, examining additional images and evaluating individual benthic taxa versus grouping multiple epifauna types. Thus, the 2021 results provide a different picture than the 2018 report and the 2020 presentation during RSA share day.

Methods. The study used a Before-After-Control-Impact (BACI) design, as explained in the 2018 RSA program report with an abbreviated version included in the 2021 final report and presentation provided to the PDT in September. Benthic habitat characteristics and scallop distributions were generally understood based on an initial 2012 survey using WHOI's towed video camera system, HabCam, and side scan sonar. This information was used to select six study sites (1 nm square) with varying benthic characteristics (Table 1). These sites were surveyed using HabCam in 2012 (initial survey), 2016 (pre-impact survey & immediately following impact), 2017 (10 months after impact), and 2018 (22 months after impact). Following the 2016 pre-impact survey, commercial scallop dredge gear was towed nine to eleven times at each study site at a speed of 2 kts over a 15 ft x 1nm distance to generate the impact. Volume and abundance of fishes, invertebrates, and substrates were recorded for each tow. HabCamV5 was towed through each study site, both along the dredge tracks (impact treatment) and outside the dredge tracks (control) (Figure 3, Map 5).

Table 1. Benthic habitat descriptions for the six BACI experimental sites before dredge impact.

BACI Impact Site	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Habitat Type (as described in report)	Complex epifauna, mussels	Sand, gravel, patchy epifauna	Complex epifauna, heavy scallops	Sand, gravel	Sand, patchy gravel	Compact mud, dark sand
PDT's epifauna classification	High	High	High	Low	Low	Low

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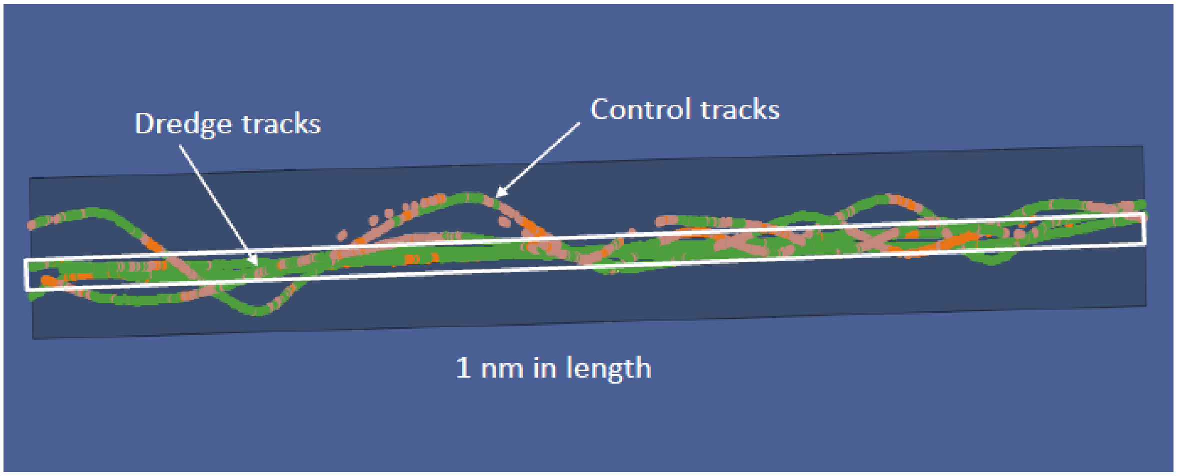
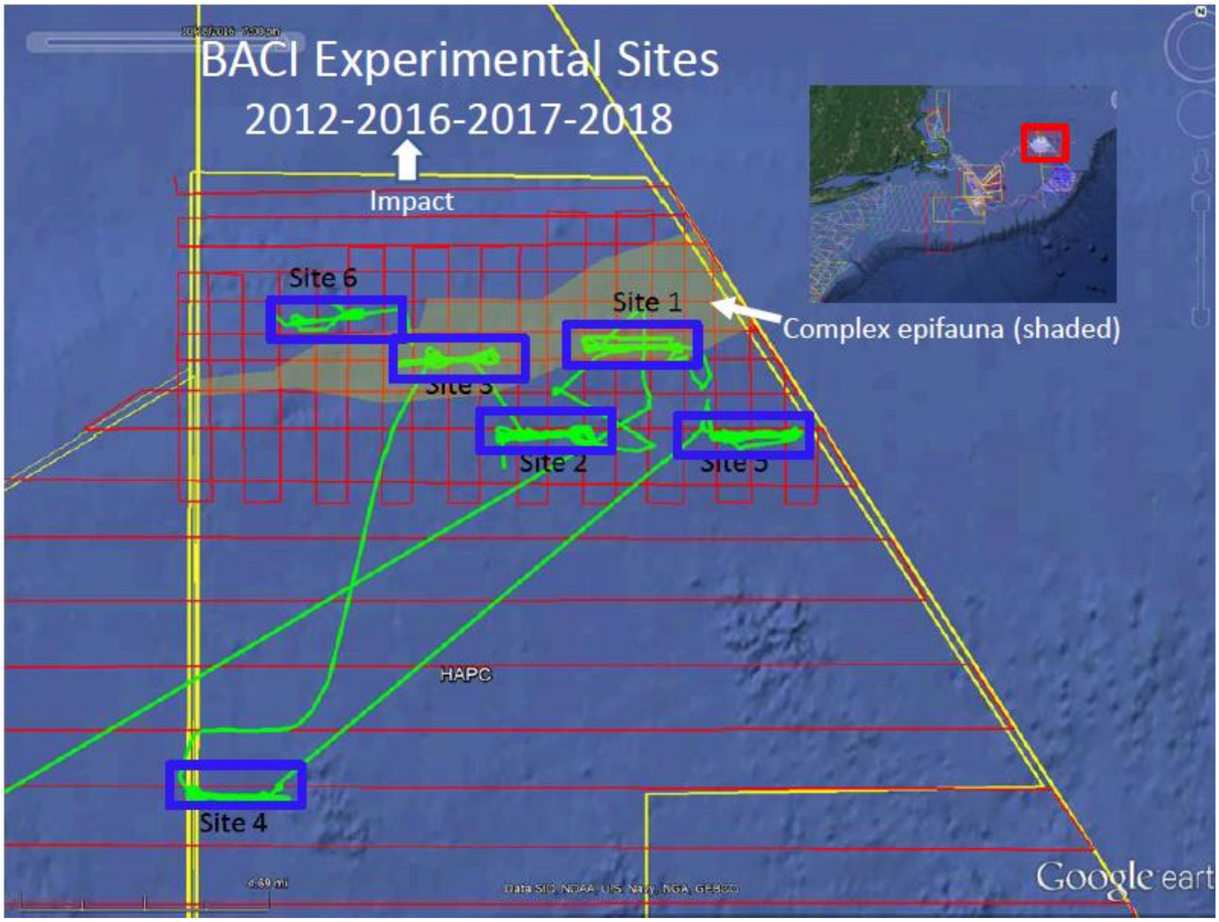
[2] These reports will be provided as documents for the January 18, 2022 Habitat Committee Meeting. https://www.nefmc.org/calendar/jan-18-2022-habitat-committee-webinar

Figure 3. Depiction of dredge (impact) tracks and control tracks (outside the impact strip) within each site.



Map 5. Depiction of HabCam tows (red) within the HAPC (yellow outline) showing the six before-after-control-impact experimental sites (blue boxes) and the dredge gear tracks (green). Sites 1-3 are high epifauna habitat and sites 4-6 are low epifauna habitat.



Over 1.45 million images were collected and analyzed during the study (between 40,000 and 57,000 in each strip, and more than 180,000 outside the strip as controls). The image processing step, which classified 8 images per second automatically by the Conventional Deep Learning Neural Network algorithm (see Gallager, et al. 2020) and every 10th image by humans, identified non-living substrates, attached and mobile epifauna, and fishes (September 2021 final report to PDT). The automated classification of substrate and individual targets was determined to be quite accurate (90-97%) when comparing against a large set of manually annotated images. Substrate percentage composition (mud, sand, gravel, cobble, shell hash, any combination thereof), bathymetry, rugosity, slope, and gradient were determined using optical and acoustic data.

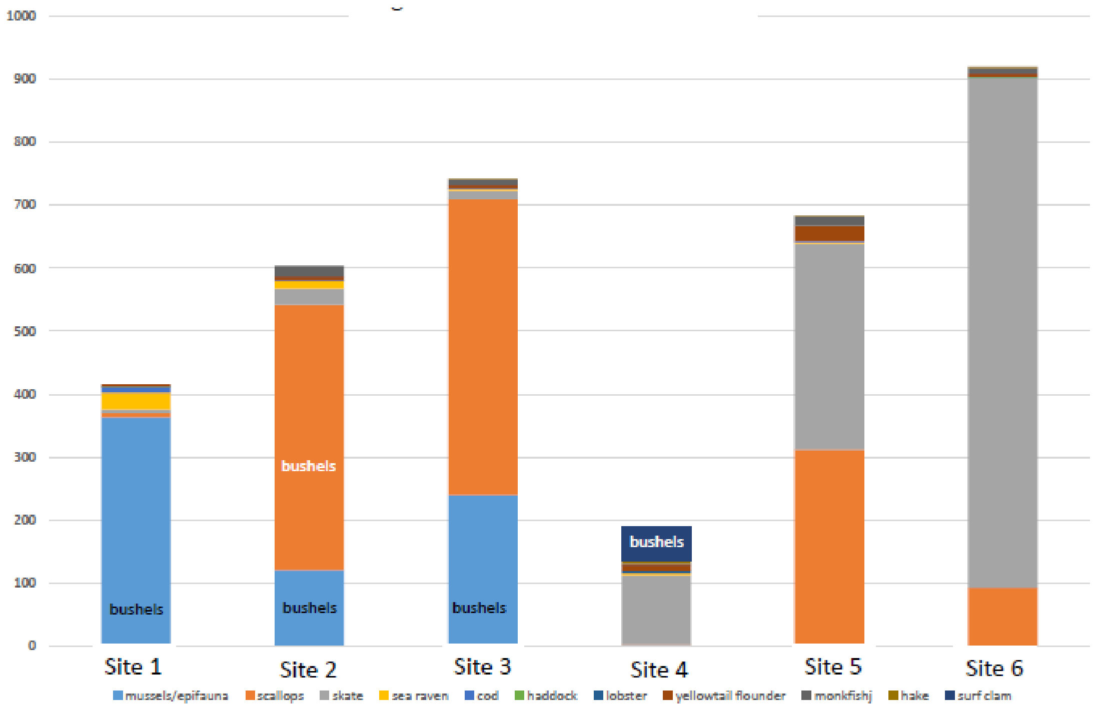
The six study sites were initially analyzed individually, and later binned into two categories, high epifauna and low epifauna, for further analysis (September 2021 final report to PDT). A 3-way Analysis of Variance (ANOVA) was used to test for any biological community differences between the control and impact images and across different time periods (before, immediately after, 10 months after, and 22 months after dredge impact). A 1-way ANOVA was used for significance testing on abiotic and biotic variables. The main indices used to indicate impact and recovery were biodiversity and species richness, but changes in individual structure-forming taxa were also analyzed. Recovery was evaluated as a function of time and habitat type at each site. Percentage change in either numerical abundance or percent cover two years after impact was examined using multi-way ANOVA with p value of 0.05.

Conclusions. The main conclusions related to biodiversity (number of species and evenness of the species), species richness (number of species), and results for structure-forming taxa, based on the September 2021 report provided to the PDT, were as follows. Observations about fishes are also discussed in the report. Note, in this study, recovery is determined by comparing control-impact biodiversity and species richness indices before and after disturbance, thus, recovery does not necessarily mean community structure (species composition and abundance) completely returned to its original, pre-impact state.

Impact-related results

1. The type of habitat at a site strongly influenced the magnitude and duration of impact from scallop dredging, with high epifauna habitat being most impacted and remaining so 22 months post-impact.
    a. There were significant effects between Habitat, Control, and Impact interactions in five out of 10 faunal classes, indicating that the impact made by scallop dredging is strongly influenced by habitat type, with high epifauna habitat being significantly more susceptible to mechanical impact than low epifauna habitats.
2. The epifauna/mussel/tunicate community and more specifically, the fragile, structure-forming species (sponges, tube worms, etc.) significantly decreased in abundance following impact (Figure 4) and remained significantly less abundant after 22 months.
    a. Marine organisms that remained less abundant two years after dredging included: *Iophon* sponge, stalked tunicate, and lacy tube worm in all epifauna/mussel sites and bryozoans and mussels in two of the three epifauna/mussel sites.

Figure 4. Abundance of organisms removed at each site at time of dredge impact (#/km^2 for all organisms except for epifauna, scallops, and surfclams which are measured in bushels).



Recovery-related results

3. Immediately after impact, species richness at all three high epifauna sites was significantly reduced and did not fully recover after two years, while at the low epifauna dominated sites, species richness decreased but not significantly. Biodiversity also significantly decreased immediately after impact for both habitat types and only largely recovered after two years for the low epifauna sites.
    a. After two years, species richness had not fully recovered in any of the high epifauna habitat sites and in one of the low epifauna sites but did recover in the other two low epifauna habitat sites.
    b. Like species richness, biodiversity indices based on richness and evenness did not fully recover in two years for all of the sites characterized as high epifauna habitat; there was no detectable post-impact effect in one low epifauna site with some recovery at the other two low epifauna sites after one year, but a subsequent decline during year two.
4. When accounting for all epifauna, numerical abundance was significantly reduced relative to control values in both the high and low epifauna sites two years after impact. Infauna (*Myxicola* and Northern cerianthid) were still significantly less abundant at the high epifauna sites two years after impact, but not at the low epifauna sites. There were no significant differences in the abundance of echinoderms between the control and impact sites two years after dredging.

3.2.2 Effects of mobile fishing gear on geological and biological structure: A Georges Bank closed versus open area comparison

Harris et al. 2014 used drop still camera and video surveys to examine whether biological and geological structures differed in terms of patterns of density, presence/absence, areal coverage, and vertical height in impact (fished) and reserve (closed to mobile bottom-tending gear) sites. Two locations of Georges Bank were examined, Little Georges/Closed Area I and the Northern Edge/Closed Area II (Map 3); only the results of the Northern Edge region are included here. The main objective of this study was to evaluate whether the mobile-tending gear closures on Georges Bank Closed Area II contain additional geological and biological structure relative to the continuously fished locations located 1-2 km from the closed area. More specifically, the research sought to evaluate the differences in habitat impacts and recovery rates from scallop dredge gear and characteristics that would be important to consider when evaluating future habitat closures. The project also set out to test the fishing impact parameters (i.e., susceptibility and recovery) used in the SASI model which is important for assessing EFH minimization and mitigation strategies going forward.

This study was funded through the 2011 Scallop Research Set-Aside Program, award number NA11NMF4540026. The source for this summary is the final report to the RSA program[3]. This study was not published in the peer-reviewed literature.

Methods. In June 2011, 60 randomly selected stations 200+ m apart were surveyed (sampling four quadrats each) in the impact (scallop dredging) and reserve (closed fishing areas) areas in the Northern Edge area. Both the impact and reserve sites were previously heavily fished with bottom-tending gear until the fishing closure in 1994 and the impact areas continue to have high levels of bottom-tending fishing. Photo-pyramids were deployed at each quadrant and station, generating plan-views (quadrats) and parallel-views (cross-quadrant) to identify sediments by particle size category (silt-mud, sand, granule-pebble, cobble, and boulder) and organism density (sea scallops, sea starts, crabs, hermit crabs, whelks, moon snails), presence/absence (sea scallops, anemones, bryozoans/hydroids, brittlestars, clam siphons, corals, *Ampelisca* tubes, tube worms, mussels, sponges, urchins, stalked tunicates, infaunal holes in seabed, shell debris), and areal coverage using a 5x5 grid, 0.0416 m^2 each (scallops, mussels, macroalgae, brachiopods, anemones, ascidians, bryozoans, hydroids, sponges, polychaetes) by taxonomic group. Due to slight movements of the survey vessel, the repeat quadrats did not overlap (10s of meters apart). Sediment type at each station was based on the most frequently occurring sediment and when there was equal frequency of sediment types, the larger type was used for sediment characterization.

Moran scatter plots and Chi squared tests were used to evaluate the sediment data by quadrant to determine spatial correlation between the impact and reserve areas while vertical height of epifauna was measured using side-view video footage. Benthic shear stress was calculated by the Finite Volume Community Ocean Model. Generalized Linear mixed models were used to determine any difference in biological and geological structures in the impact and reserve sites.

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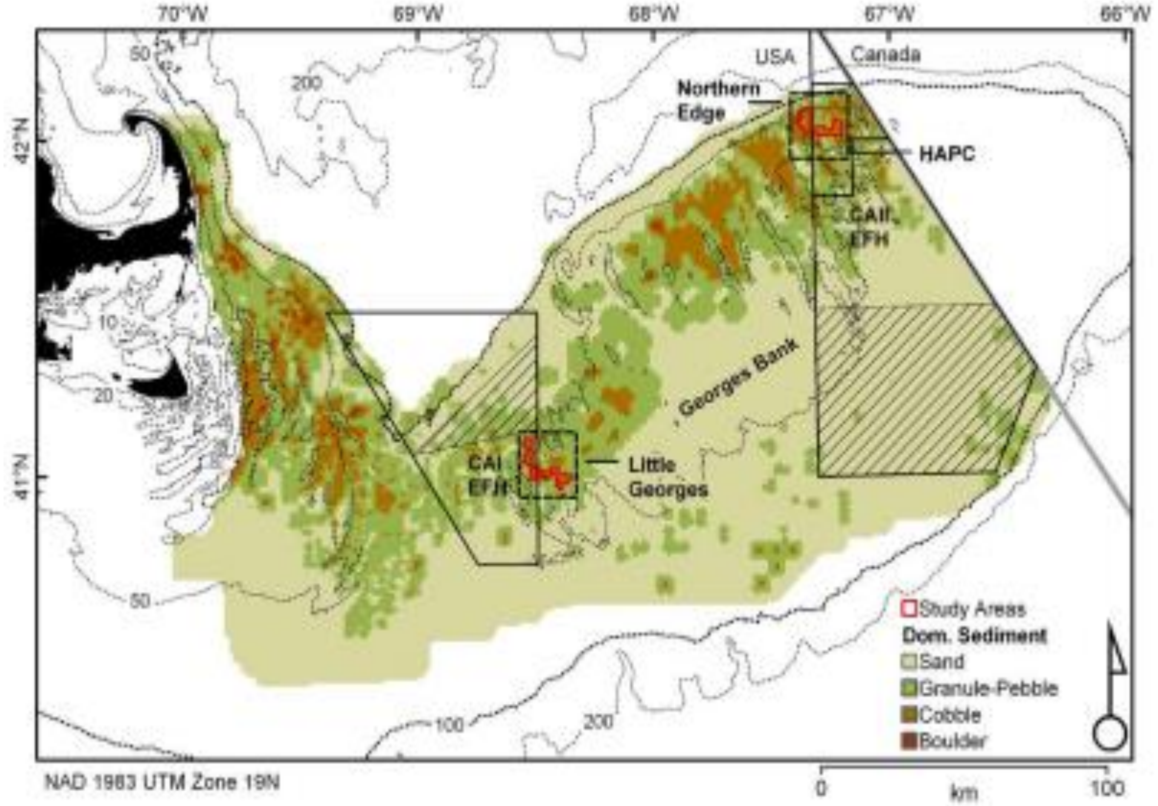
[3] This report will be provided as a document for the January 18, 2022 Habitat Committee Meeting. https://www.nefmc.org/calendar/jan-18-2022-habitat-committee-webinar

Map 6. Study areas and dominant sediment types, with CAII, HAPC, and EFH areas identified.



Results:

1. All samples were collected as expected in the Northern Edge stations.
2. Most reserve (closed) and impact (fishing) sites in Northern Edge areas were gravel (granule-pebble and cobble), however, there was significantly more sand in the impact area.
3. The impact and reserve sites on the Northern Edge did not provide consistent evidence that the impact sites experienced greater habitat damage than the reserve sites, however, the sites did show some patterns in density, presence/absence, areal coverage, and vertical height:
    a. The probability of presence of epifauna (structure forming taxa) in the reserve area was similar or lower than the impact area (except for sea urchins and mussels) in the Northern Edge area.
    b. Organisms such as finger sponges and tunicates were found attached to gravel and sand substrates in the impact sites; hydrozoa were mostly attached to either gravel or sand substrates and to a lesser extent shell substrate while fig sponges were primarily attached to sand substrate. In the reserve sites, organisms especially hydrozoa were attached primarily to gravel substrate.
    c. Reserve sites had higher percent coverage of a few taxa (namely macroalgae and mussels) while sponges, bryozoans, and actinarian anemones had higher percent coverage in the impact sites.
    d. Species richness and diversity were similar in reserve and impact areas.

3.3 RECENT FISHING GEAR EFFECTS LITERATURE

This section summarizes overarching conclusions from recent gear effects literature (published between 2017 and 2021); additional information is within Appendix E. Most of the studies reviewed considered the impacts of and recovery from fishing gear on geological and biological seafloor features, comparing across gear types, fishing intensities, etc. A few studies evaluated biogeochemical changes from fishing gear in various habitats and others tested gear modifications and electric pulse trawling relative to conventional otter trawling to see how catchability of target species changed and how benthic habitat impacts differed between gear types (results not summarized below, only included in Appendix F).

Degree of impact:

- Substrates with higher percentages of gravel and deeper, soft sediment habitat type experienced a greater reduction in benthic community numbers and an overall significant negative impact from marine dredging (removal pressure), sediment disposal (smothering pressure), and bottom fishing (abrasion pressure and sediment resuspension).
- 6% of biota was removed per otter trawl pass at a trawl penetration depth of 2.4 cm with 95% biota recovery in 1.9-6.4 years; bottom trawls depleted 14% of biota/gear pass, penetrating 2.7 cm of the sediment; towed scallop dredges depleted 20% of biota/gear pass, penetrating 5.5 cm of the sediment; hydraulic dredges removed the greatest volume of biota (41%) at 16.1 cm penetration depth. One gear pass reduced invertebrate abundance by 26% and species richness by 19% (gears that penetrate the substrate more have a greater impact), with benthic size structure shifted towards smaller organisms.
- Gravel habitat was most impacted from trawling followed by muddy sand as less sensitive to trawling, and sand as least affected by trawling. Another study found muddy habitats are more impacted by bottom trawling (especially by otter trawling for crustaceans and demersal fish), with coarse sediment and dredging for mollusks having the least impact because of higher trawling intensity (more swept area) over a larger area and lower dredging intensity (less swept area) over a smaller area.

Biogeochemical processes less efficient with trawling:

- Coarse sediment and habitat with less fine sand had greater changes in biogeochemistry (oxygen, nitrate, ammonium, organic carbon) compared to high organic matter/muddy substrate; reduction in respiration led to a reduction in macrofauna species richness.

Recovery:

- More sensitive habitats that are frequently disturbed by human activities will generally have lower recovery rates. Muddy or biogenic habitats not previously fished experienced the highest rate of depletion and fragile, structure forming, and slow growing species experienced higher recovery rates of more than 3 years compared to species with shorter lifespans recovering within a year of fishing disturbance. Species with higher longevity (>1 year) and low shear stress habitats are most sensitive to trawl impacts and have longer recovery rates.
- Habitat quantity and quality did not recover after two-month closure from bottom trawling: 30% reduction in organic carbon, 52-70% loss of substrate that is more susceptible to alteration and increase in coarser sediments after this short closure.
- For benthic invertebrate community recovery rates, gravel had the greatest time to recover to reference state of 500 days, with 300 days to recover in muddy-sand, 200 days to recover in mud, and 100 days to recover in sand.

- Recovery to pre-fishing impact level was less than three years for species that are more habitat generalists, have higher dispersal rates and faster growth rates (such as scallops) while recovery was significantly more (17-20 years for 80% of carrying capacity) for species that are more habitat specialists, have lower dispersal rates and lower growth rates (long lived), such as pink sea fans and corals.

4.0 IMPORTANT FISHERY ISSUES

Multiple fisheries employing diverse gears are active on the Northern Edge seasonally or year-round. Additional information and data can be found in Appendices A, B, C, D, and F. Appendix A describes Northern Edge EFH designations while Appendix B provides a description on the habitat conditions in the region. Appendix C is a brief review of the literature describing managed species-habitat associations. Appendix D summarizes fishery revenue and landings based on trip report data within two different analysis regions. Appendix E summarizes biological and fishery considerations by fishery management plan. A high-level overview of these appendices is provided below.

An average of 1,247 trips (CY17-19) were taken within the Northern Edge Analysis region, about half of which were bottom trawl, a third fixed gear, and lesser amounts of clam and scallop dredge and midwater trawl (Appendix D). The species consistently with the highest landings include Atlantic herring (except in 2019), surfclam, American lobster, haddock, and winter flounder. The species consistently with the highest revenues include American lobster, sea scallop, surfclam, Atlantic herring (not in 2019), winter flounder, and haddock. The OHA2 Alternative 8 region (smaller than the Northern Edge region) showed similar results.

The Northern Edge is EFH for a majority (17 of 28) Council-managed species (Appendix A). Complex habitats (Appendix B) play an important role for several of the species found in the Northern Edge region, especially coarser substrates with cobble and gravel that are important sources of food and refuge for juvenile Atlantic cod in particular (Appendix C). Based on extensive research, gravel habitats with associated epifauna co-occur with juvenile cod on the Northern Edge of Georges Bank and are important for their survival.

Several **groundfish** species utilize the Northern Edge region during various life stages, some of which are within the top species by landings and revenue in 2017-2019 (Appendix D) including Atlantic cod, haddock, pollock, redfish, white hake, winter flounder, and witch flounder. Species that are found within this region that are depleted include Atlantic cod, yellowtail flounder, Northern windowpane flounder, and winter flounder.

The Northern Edge supports a persistent aggregation of **scallops**, both inside the habitat closure area and just west of the closure boundary, with biomass levels estimated between 10.4 - 14.2 million pounds between 2015 and 2021 in the CAII-N area (Appendix F). Overall scallop biomass has been declining in recent years and scallops in the Northern Flank and CAII-N areas account for a larger portion of the overall biomass in 2021 (~7%).

Atlantic **herring** are known to spawn in late August to December on the northern edge of Nantucket Shoals and along the northern flank of Georges Bank, however the spatial extent varies over time, depending on abundance levels. Before the recent declines in catch limits and the stock's overfished status, the Atlantic herring fishery was a summer / fall midwater trawl fishery (Appendix F). The Northern Edge Analysis region accounted for an average of ~40% herring from 2017-2019, though this is likely not going to be reflected in future years if the stock remains overfished (Appendix D).

Based on recent Atlantic **surfclam** data, there has been a recent expansion of surfclam into deeper waters onto Georges Bank, though landings have generally declined over the past decade; the Northern Edge Analysis region accounts for ~10% of landings and revenue (Appendix D).

American lobster migrate seasonally and Georges Bank including the Northern Edge area is used by lobsters during the summer; OHA2 estimated that allowing non-trap fishing within CAII during the summer could have slight to moderate negative effects. Only <2% of lobster landings and <3% of revenue are from within the Northern Edge Analysis region. Similarly, the monkfish, whiting, and skate fisheries also operate in the Northern Edge Analysis Region, however, the region only accounts for ~1% of landings and revenue in each of these fisheries (Appendix D).

5.0 SUMMARY AND MANAGEMENT CONSIDERATIONS

Based on the SASI approach and the Fishing Effects Northeast modeling work, bottom trawling has generated the greatest habitat disturbance over time throughout the Northeast Region relative to other gear types, because the trawling footprint is much larger than that of other gears. However, SASI and Fishing Effects models estimate that scallop dredges and bottom trawls have similar effects on a per unit area basis, with greater per unit area impacts associated with clam dredges as compared to scallop dredges and trawls, and lower per unit area impacts for fixed gears as compared to dredges and trawls. The percent of habitat disturbance from trawling has declined over time primarily because of a reduction in fishing effort. In the case of scallop and clam dredge gear, there has been an increase in impacts partly due to a spatial shift in effort into more vulnerable habitat types. In addition, structure-forming biological features in gravel substrates are generally more vulnerable to fishing gear impacts, longer lived, and with longer recovery times than in sand or mud substrates. This finding is consistent with other fishing gear effects literature reviewed, though one study found mud habitats can exhibit greater impacts by fishing gear (specifically bottom trawling) in terms of reduction in benthic species composition (richness/diversity), as compared to coarse sediment (Appendix E).

The two RSA studies reviewed here have contrasting results but different study designs and analytical methodologies make them difficult to compare. Based on Dr. Gallager's September 2021 report, complex habitat (structure-forming epifauna including mussel and other fragile species) are most impacted from scallop dredge gear and remain as such 22 months post-impact. In the Harris, et al. 2014 study, the impact (fishing) and reserve (closed) sites on the Northern Edge provided inconsistent evidence that the impact sites experienced greater habitat damage than the reserve sites. However, the sites did show some patterns in density, presence/absence, areal coverage, and vertical height consistent with closure benefits to habitat. Gallager et al.'s study concluded that species richness and biodiversity in complex habitat sites did not fully recover 2 years after scallop dredge fishing, while Harris, et al. noted that species richness (the number of species) was similar in reserve and impact areas. Interestingly, the Harris et al. reserve sites had a higher percent coverage of some structure-forming taxa (macroalgae, mussels) while the impact sites had higher percent coverage of sponges, bryozoans, and scallops. Based on the literature, species that are habitat generalists with higher dispersal and faster growth rates (such as scallops) have shorter recovery time. In the Gallager, et al. study, however, scallops did not fully return to the impact sites. Conclusions of the updated literature review are consistent with prior syntheses, i.e., more sensitive habitats with fragile, structure-forming and slow growing species that are frequently disturbed will have lower recovery rates.

There is no new information to suggest that OHA2's assumptions and analyses related to minimization of adverse fishery effects on EFH on the Northern Edge are invalid. The concerns listed in the OHA2 Final Rule (see section 2.4) relate to maintaining consistency with the Northern Edge HAPC designation and the lack of specificity about the frequency and intensity of fishing that would be authorized in future actions. While the Council conveyed an intention to analyze the impacts of fishing on the Northern Edge region in trailing actions (see OHA2 Vol 3), the Council did not set an upper bound on the amount of effort that could be allowed without causing more than minimal adverse effects on EFH, nor was an appropriate rotational fishing time interval determined that would allow for habitat recovery. Gallager et al.'s study indicates that full recovery of diverse benthic taxa does not occur within 22 months of scallop dredging. Further research to examine recovery at longer time intervals could help inform the efficacy for developing rotational fishing access strategy that would allow sufficient time for habitat recovery while minimizing loss of habitat value to managed species. Adverse effects modeling, i.e., Fishing Effects, could be used to estimate how much fishing effort would generate an acceptably low range of habitat impacts, as defined by the Council. The percent habitat disturbance Fishing Effects model runs explore low (median) and high (95th percentile) area swept scenarios only. The former would likely be insufficient to support a fishery (i.e., effort would be very low) and the latter produces relatively high estimates of habitat disturbance. Note that the Council has not identified a percent disturbance threshold that corresponds to acceptable/unacceptable levels of adverse habitat effects at either local or regional scales.

Development of new habitat management approaches would occur in the context of regional fishing activity and account for stock status. Area closures can affect the intensity and efficiency of fishing elsewhere, and thus affect the overall magnitude of impacts to habitat within the New England region. Further, while a subset of fishery stocks in the Northern Edge region are in a depleted state, there are stocks that are healthy and targeted by both the commercial and recreational fleets. It will be important in the future to protect habitats from the adverse effects of fishing in order to encourage the recovery of depleted stocks as well as maintain the productivity of healthy stocks. In considering management changes in this region, the Council will need to identify and evaluate the tradeoffs between species productivity (depleted and healthy), habitat conservation, and the effects on fisheries and fishing fleets.

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7.0 APPENDIX A: NORTHERN EDGE EFH DESIGNATIONS

The occurrence of EFH for NEMFC species on the Northern Edge is summarized below (Table 2). The EFH text and maps were used in combination to determine whether EFH occurs on the Northern Edge. The colored shading indicates no (white), slight (light blue), moderate (medium blue), or high/full spatial overlap between a management area and designated EFH for the species and lifestage. The Alternative 8 area referenced in the table is the same area evaluated in Appendix D, section 10.2.2.

Table 2. Overlap between existing and proposed management areas and EFH designations. Species and life stages in bold italicized type are associated with complex substrate. Juveniles shaded grey were positively weighted in the OHA2 groundfish hotspot analysis.

Species and lifestage	Closed Area II (1)	Closed Area II Habitat Closure Area (1)	Northern Georges MBTG Closure (8)	Northern Edge RI HMA (10)	Northern Edge MBTG HMA (10)	Depth range	Substrate
Atlantic cod juvenile	3	3	2	3	3	0-120	YOY: Inshore, prefer gravel and cobble habitats and eelgrass beds after settlement, but also utilize adjacent un-vegetated sandy habitats for feeding; also settle on sand and gravel on Georges Bank (see haddock). Older: Structurally-complex habitats, including eelgrass, mixed sand and gravel, and rocky habitats (gravel pavements, cobble, and boulder) with and without attached macroalgae and emergent epifauna
Atlantic cod adult	3	3	3	3	3	30-160	Structurally complex hard bottom habitats composed of gravel, cobble, and boulder substrates with and without emergent epifauna and macroalgae
Atlantic halibut juveniles and adults	2	1	1	1	1	60-140	Sand, gravel, or clay substrates
Atlantic wolffish juveniles and adults	3	3	3	3	3	70-184 (j); less than 173 (a)	Juveniles occur over various substrates but no strong substrate preferences. Adults spawn in rocky habitats; occupy a wider variety of sand and gravel substrates once they leave spawning habitats, but are not caught over muddy bottom
Haddock juvenile	3	3	2	3	3	40-140	Hard sand (particularly smooth patches between rocks), mixed sand and shell, gravelly sand, and gravel
Haddock adult	3	3	2	3	2	50-160	Hard sand (particularly smooth patches between rocks), mixed sand and shell, gravelly sand, and gravel substrates
Ocean pout adult	2	3	2	3	3	20-140	Mud and sand, particularly in association with structure foming habitat types; i.e. shells, gravel, or bouders; congregate in rocky areas prior to spawning and frequently occupy nesting holes under rocks or in crevices
Pollock juvenile	1	2	1	*0*	3	40-180	Rocky bottom habitats with attached macroalgae (rockweed and kelp); YOY also use eelgrass. Older juveniles occupy same habitats as adults
Pollock adult	1	1	1	*0*	1	80-300	Tops and edges of offshore banks and shoals (e.g., Cashes Ledge) with mixed rocky substrates, often with attached macro algae.
Red hake egg, larvae, and juvenile	2	2	2	3	2	0-80	YOY settle in depressions on the seabed. Older juveniles in bottom habitats providing shelter, including biogenic depressions in mud, eelgrass, macroalgae, shells, live bivalves, anemone and polychaete tubes, and artificial reefs.
Red hake adult	3	2	2	2	3	50-750	Shell beds, soft sediments (mud and sand), and artificial reefs.
Silver hake juvenile	2	2	2	2	2	40-400	YOY settle on muddy sand substrates, find refuge in amphipod tube mats. Older juveniles found in association with sand-waves, flat sand with amphipod tubes, and shells, and in biogenic depressions in the Mid-Atlantic
White hake juvenile	3	3	3	3	3	0-300	Fine-grained, sandy substrates in eelgrass, macroalgae, and un-vegetated habitats
Windowpane flounder juvenile	2	3	2	3	3	0-60	Mud and sand substrates
Windowpane flounder adult	2	3	2	3	3	0-70	Mud and sand substrates
Winter flounder egg	3	3	2	3	3	0-70	Eggs are adhesive and deposited in clusters on mud, sand, muddy sand, gravel, and submerged aquatic vegetation, especially in areas with reduced bottom current where they are not buried by suspended sediment settling to the bottom; south of Cape Cod, sand seems to be the most common substrate.
Winter flounder larvae and adult	2	3	2	3	3	0-70	Muddy and sandy substrates, and on hard bottom on offshore banks; for spawning, also see eggs.
Winter flounder juvenile	2	3	2	3	3	0-60	Variety of bottom types, such as mud, sand, rocky substrates with attached macro algae, tidal wetlands, and eelgrass
Yellowtail flounder juvenile	2	2	2	2	3	20-80	Sand and muddy sand
Yellowtail flounder adult	3	3	2	3	3	25-90	Sand, shell hash, muddy sand, and sand with gravel
Barndoor skate – juv/adu	2	3	2	2	3	40-400	Mud, sand, and gravel substrates
Little skate juvenile	3	2	2	3	2	0-80	Sand and gravel, also found on mud
Little skate adult	3	3	3	3	3	0-100	Sand and gravel, also found on mud
Winter skate juvenile	3	3	3	3	3	0-90	Sand and gravel, also found on mud
Winter skate adult	3	3	3	3	3	0-80	Sand and gravel, also found on mud
Atlantic sea scallop juvenile and adult	3	3	2	3	3	18-110	When very small, attach to shells, gravel, and small rocks (pebble, cobble), preferring gravel; older juveniles not attached, occupy same habitats as adults.
Atlantic herring egg	2	3	2	3	3	5-90	Deposited on the bottom in beds, stick to coarse sand, pebbles, cobbles, and boulders and/or on macroalgae

8.0 APPENDIX B: HABITAT CONDITIONS ON THE NORTHERN EDGE

Georges Bank is a shallow, elongated extension of the continental shelf that was formed during the Wisconsinan glacial episode. It is characterized by a steep slope on its northern edge and a broad, flat, gently sloping southern flank. Bottom topography on eastern Georges Bank is characterized by linear ridges in the western shoal areas; a relatively smooth, gently dipping sea floor on the deeper, easternmost part; a highly energetic peak in the north with sand ridges up to 30 m high; and steeper and smoother topography incised by submarine canyons on the southeastern margin.

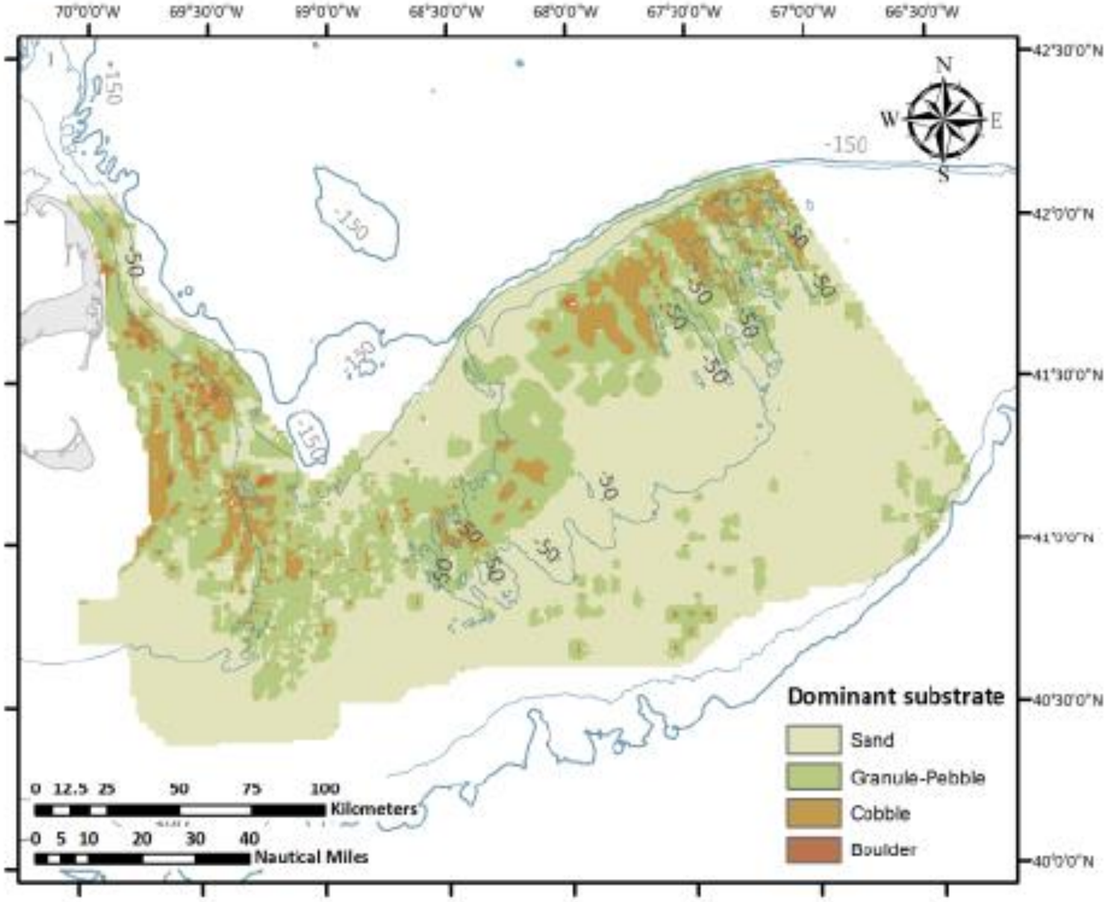
On the flanks of the bank between 60 and 100 m, where the tidal currents are weaker, sediment movement is less frequent and transport is primarily associated with strong winter storms. The sediment here is somewhat finer than on the crest of the bank and the seafloor is largely featureless. In these areas, sediments are generally stable due to lower flows. On top of the bank, only the larger grain sizes are stable, in particular sand-dominated areas with cobble, and granule-pebble, cobble, and boulder-dominated sediments.

Northeastern Georges Bank is composed of a series of parallel northwest-southeast trending sand waves with intervening troughs of coarse gravel (granule-pebble and cobble) substrate. There are also some areas dominated by boulders (diameter >10 inches). Strong tidal currents constantly move the sand back and forth and the shallower portions of the bank are also periodically affected by wave action, particularly during winter storms. The coarser gravel substrate is much more stable and provides a more suitable substrate for attached epifaunal organisms (e.g., sponges, bryozoans). Glacial retreat during the late Pleistocene deposited the bottom sediments currently observed on the eastern section of Georges Bank.

The interaction of several environmental factors, including availability and type of sediment, current speed and direction, and bottom topography, has formed seven sedimentary provinces on eastern Georges Bank (Valentine and Lough 1991). The Northern Edge/Northeast Peak province encompasses depths of 40-200 meters, and is dominated by gravel with portions of sand, common boulder areas, and tightly packed pebbles (Map 7). Representative epifauna (bryozoa, hydrozoa, anemones, and calcareous worm tubes) are abundant in areas of boulders. The area has strong tidal and storm currents. The northern slope/Northeast Channel province encompasses depths of 200-240 meters and has variable sediment types (gravel, gravel-sand, and sand) and scattered bedforms, with strong tidal and storm currents. The fauna of this region tend to be sessile (coelenterates, brachiopods, barnacles, and tubiferous annelids) or free-living (brittle stars, crustaceans, and polychaetes), with a characteristic absence of burrowing forms (Theroux and Grosslein 1987). The invasive tunicate *Didemnum vexillum* has been observed on the Northern Edge in multiple surveys (Valentine et al. 2007, Kaplan et al. 2017). This species encrusts gravel substrates and can overgrow other organisms and has been shown as a driver of variation in benthic community structure when present (Kaplan et al. 2017).

Oceanographic frontal systems separate water masses of the Gulf of Maine and Georges Bank from oceanic waters south of the Bank. These water masses differ in temperature, salinity, nutrient concentration, and planktonic communities, which influence productivity and may influence fish abundance and distribution. Currents on Georges Bank include a weak, persistent clockwise gyre around the Bank, a strong semidiurnal tidal flow predominantly northwest and southeast, and very strong, intermittent storm-induced currents, which all can occur simultaneously. Tidal currents over the shallow top of Georges Bank can be very strong and keep the waters over the Bank well mixed vertically. This results in a tidal front that separates the cool waters of the well mixed shallows of the central Bank from the warmer, seasonally stratified shelf waters on the seaward and shoreward sides of the Bank. The clockwise gyre is instrumental in distribution of plankton, including fish eggs and larvae, and the strong, erosive currents affect the character of the biological community.

Map 7. Dominant sediment (Harris and Stokesbury 2010) and sediment stability (Harris et al 2012). Depth contours in meters.



9.0 APPENDIX C: FUNCTIONAL ROLE OF HABITATS FOR MANAGED SPECIES

The HAPC provides an important ecological function related to the survival of post-settlement juvenile cod, which experience high mortality rates due to high levels of predation (Tupper and Boutilier 1995). Several studies document the importance of complex habitats to the survival of these juveniles, namely age-0+ compared to mud and sand (Lough et al. 1989; Valentine and Lough 1991; Gotceitas and Brown 1993; Gotceitas et al 1995; Tupper and Boutilier 1995; Valentine and Schmuck 1995; Fraser et al. 1996; Gotceitas et al 1997; Gregory and Anderson 1997; Grant and Brown 1998; Lindholm et al. 1999; Linehan et al 2001; Laurel et al 2004; Bradbury et al 2008). Structurally complex habitats, including gravel, cobble, seagrass, and eelgrass as compared to unstructured habitat like sand allows sufficient space for newly settled juvenile cod to find shelter and avoid predation (Lough et al. 1989; Valentine and Lough 1991; Gotceitas and Brown 1993; Tupper and Boutilier 1995; Valentine and Schmuck 1995; Laurel et al 2004; Lough 2010; Thistle et al 2010; Lilley and Unsworth 2014; Grabowski et al 2019). Presence of epifauna contributes towards mortality reduction, as the epifauna may obstruct visual cues (Lindholm et al. 1999).

Age-0+ cod can also be found in unstructured habitat like sand where cod may be schooling to avoid predation if perhaps more structurally complex habitat are either not available or are fully occupied with other fish (Grant and Brown 1998; Laurel et al 2004; Laurel and Brown 2006; Robichaud and Rose 2006; Grabowski et al 2018). This could result in cod expending more energy relative to when in more complex habitats where avoiding predation is likely less costly (Schwartzbach et al 2020).

There is mixed use of structurally complex habitat by cod of larger size classes, where age 1 cod were found in deeper and less complex habitats like rocky, macroalgae substrates (Keats et al 1987; Gotceitas et al 1997; Dalley and Anderson 1997; Gregory and Anderson 1997; Cote et al 2001; Cote et al 2004; Lazzari and Stone 2006; Lilley and Unsworth 2014). Slightly older juvenile cod were found in habitats with coarser substrates with rocks and boulders that serve as refuge and food source, including in the western part of Gulf of Maine and around offshore wind turbines where reefs are artificially created (Gregory and Anderson 1997; Lindholm et al 1999; Lindholm et al 2001; Cote et al 2001; Cote et al 2003; Cote et al 2004; Reubens et al 2013; Knickle and Rose 2014). Overall, as cod grow in size over time, their threat of predation decreases, which suggests that their dependence on structurally complex habitat becomes less important (Borg et al 1997; Sogard 1997; Lindholm et al 2001).

Juvenile cod and gravel habitats with associated epifauna co-occur on the Northern Edge of Georges Bank. Specific areas on the Northern Edge of Georges Bank have been extensively studied and identified as important areas for juvenile cod survival (Lough et al. 1989; Valentine and Lough 1991; Valentine and Schmuck 1995, Lough 2010).

Gravel pavement habitats are not rare but they do comprise a relatively small fraction of Georges Bank habitat types, and gravel pavements in this condition do not occur elsewhere on the U.S. side of Georges Bank.

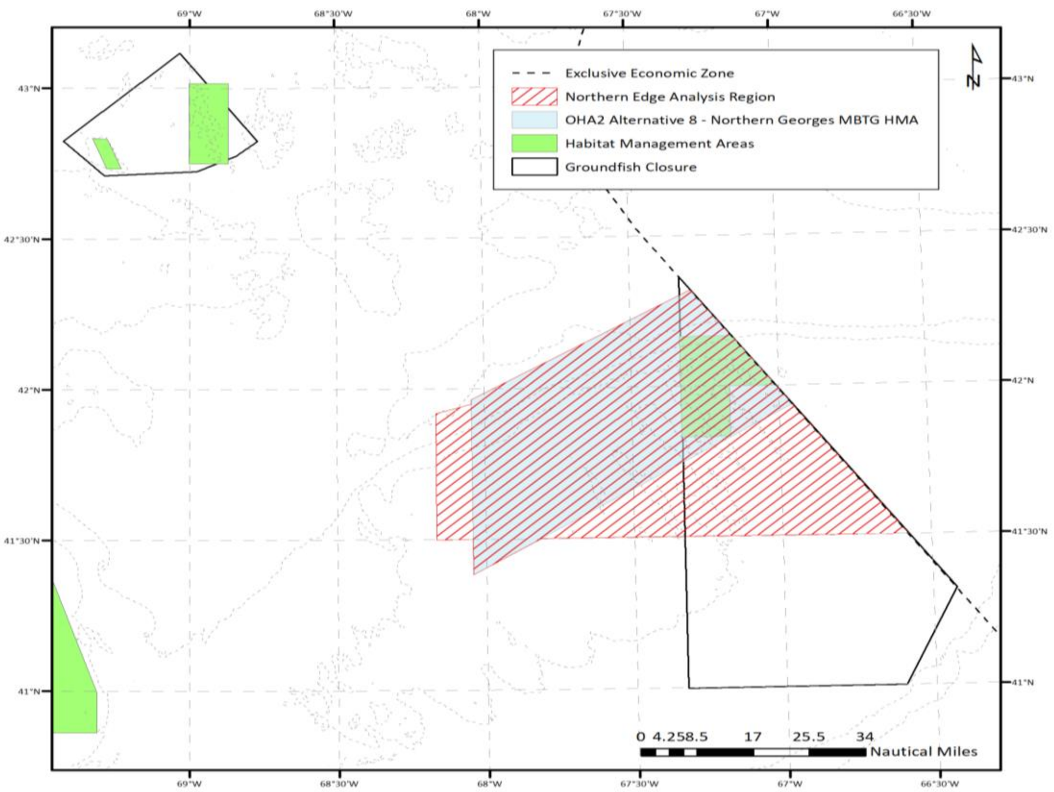
Cod prey items are also found within the HAPC. Collie et al. (1997) describe the relative abundance of several cod prey items such as shrimps, polychaetes, brittle stars, and mussels in unfished sites within the HAPC. These species are found in association with emergent epifauna such as bryozoans, hydroids, and tube worms that are prevalent in the area.

A related series of studies (Collie et al. 1997, Collie et al. 2000, Hermsen et al. 2003, Collie et al. 2005, Asch and Collie 2008, Collie et al. 2009, Smith et al. 2013) investigated the benthic ecology of and evidence for recovery from fishing impacts in the HAPC by comparing habitats inside and outside fishery closures on the Northern Edge. Overall, while the effects of fishing on the benthic community as measured by species diversity, relative abundance of different taxa, cover of different species of emergent epifauna, etc. are clear, natural disturbance is an important factor in this location, and interannual variation in these factors is often observed.

10.0APPENDIX D: FISHING EFFORT OVERVIEW

This appendix summarizes recent (CY 2017-2019) fishing activity on the Northern Edge based on vessel trip report data. Using the Fishing Footprints method developed by NEFSC, revenues and landings were compiled by species and gear type for two areas (Map 1). The first, larger analysis area (red hatching) combines all areas analyzed in the Georges Bank section of OHA2, except for Closed Area I. The intent of this area is to capture the maximum diversity of fishing activities that might be affected by a management action on the Northern Edge. The second area (light blue shading) was previously considered and analyzed as Alternative 8 in the OHA2 FEIS. The results for this smaller area can be directly compared to the Alternative 8 analysis in the FEIS, which is provided in Volume 4, Section 4.2.4.8.

Map 8. The area of Georges Bank encompassing the Northern Edge. Post-OHA2 habitat management areas and year-round groundfish closures are also shown.



10.1 METHODS

The Fishing Footprints analysis is described in various NOAA publications and websites (DePiper 2014, Kirkpatrick et al. 2017, Benjamin et al. 2019, NEFSC SSB website, Socioeconomic Impacts of Offshore Wind website) and has been used to support NEFMC actions including OHA2, the Omnibus Deep-Sea Coral Amendment, and the Clam Dredge Framework. Fishing Footprints is based largely on VTR data. Trip reports generally provide a single point location for each fishing trip. Rather than inferring the entirety of the trip's landings to that point, the method assumes that the footprint of each fishing trip falls in a circle around the point location reported on the VTR, with more effort falling closer to the reported point. These individual trip footprints and their associated data (gear type, landings by species, revenue by species, date, etc.) are compiled in a database. This database is then queried for specific locations.

If a trip's circular footprint partially overlaps the analysis area, only a fraction of its landings and revenue are inferred to the analysis area. If a portion of the footprint falls inside a closed area, on land, or beyond the edge of the U.S. EEZ, these areas are buffered out, and effort is apportioned amongst the remainder of the footprint. Caution is warranted when considering the number of overlapping trips or permits using an area, because some of these may only overlap the analysis area by a small amount, while others are more centered on the area of interest. In the context of this analysis, it is also important to remember that existing fishery closures including Closed Area II and the Closed Area II Habitat Closure Area overlap the eastern portion of the analysis area.

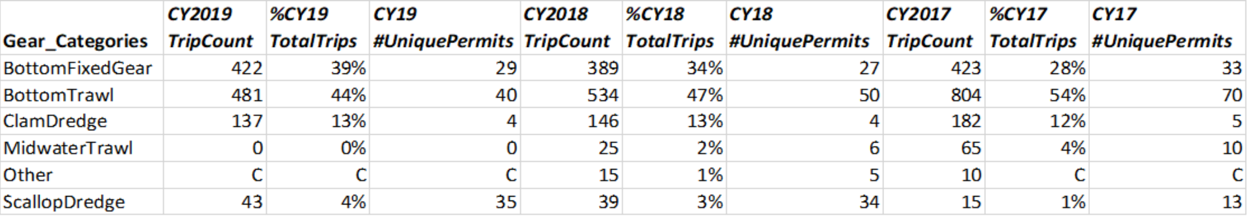
10.2 RESULTS

10.2.1 Northern Edge Analysis Region

Within the Northern Edge Analysis region, the total number of trips is estimated to be 1,093 in CY19; 1,148 in CY18; and 1,499 in CY17. Averaging across the three years, bottom trawl accounted for the greatest number of trips at 48%, followed by bottom fixed gear at 34% of trips, clam dredge at 12%, scallop dredge at 3%, midwater trawl at 2%, and other gear types at 1% (Table 3). The species with the highest landings (>50,000 lb) by gear type are included in Table 4. The sum of days at sea is the probability-weighted effort metric for the area (scaled by the percentage of the trip estimated to have fallen within the region).

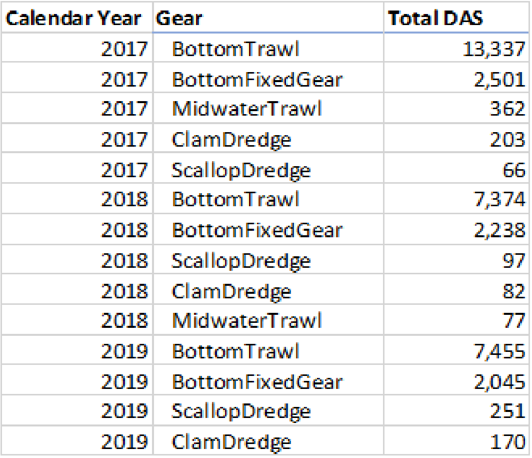
The species consistently with the highest landings include Atlantic herring (except in 2019), surfclam, American lobster, haddock, and winter flounder (Figure 7). The species consistently with the highest revenues include American lobster, sea scallop, surfclam, Atlantic herring (not in 2019), winter flounder, and haddock (Figure 8).

Table 3. Number and percentage of trips and number of unique permits by gear type in the Northern Edge Analysis region, calendar years 2017-2019. Source: Vessel trip reports. 'C' represents data with <3 trips and/or permits.



Gear_Categories	***CY2019 TripCount***	***%CY19 TotalTrips***	***CY19 #UniquePermits***	***CY2018 TripCount***	***%CY18 TotalTrips***	***CY18 #UniquePermits***	***CY2017 TripCount***	***%CY17 TotalTrips***	***CY17 #UniquePermits***
BottomFixedGear	422	39%	29	389	34%	27	423	28%	33
BottomTrawl	481	44%	40	534	47%	50	804	54%	70
ClamDredge	137	13%	4	146	13%	4	182	12%	5
MidwaterTrawl	0	0%	0	25	2%	6	65	4%	10
Other	C	C	C	15	1%	5	10	C	C
ScallopDredge	43	4%	35	39	3%	34	15	1%	13

Table 4. Sum of day at sea (DAS) by gear type for calendar years 2017-2019 in the Northern Edge Analysis region, excluding species with landings < 50,000 lb.



Calendar Year	Gear	Total DAS
2017	BottomTrawl	13,337
2017	BottomFixedGear	2,501
2017	MidwaterTrawl	362
2017	ClamDredge	203
2017	ScallopDredge	66
2018	BottomTrawl	7,374
2018	BottomFixedGear	2,238
2018	ScallopDredge	97
2018	ClamDredge	82
2018	MidwaterTrawl	77
2019	BottomTrawl	7,455
2019	BottomFixedGear	2,045
2019	ScallopDredge	251
2019	ClamDredge	170

Note: Species caught with:

- Bottom trawl gear include American plaice flounder, American lobster, cod, haddock, monkfish, pollock, redfish, silver hake, skates, white hake, and winter flounder.
- Bottom fixed gear include American lobster, cod, and hagfish.
- Midwater trawl gear include Atlantic herring and blueback herring.
- Clam dredge gear include surfclam.
- Scallop dredge gear include sea scallop.

Figure 5. Top species by landings (lb) inside the Northern Edge Analysis Region, calendar years 2017-2019. Source: Vessel trip reports.

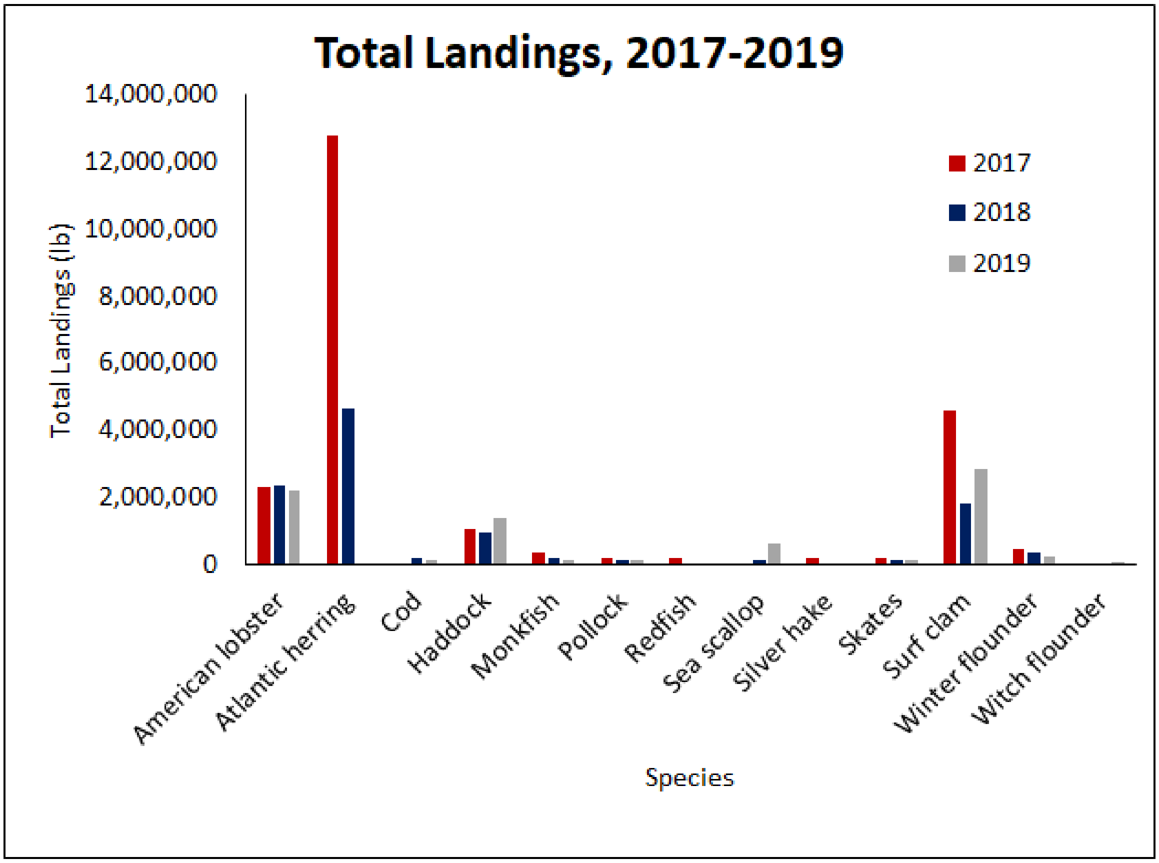
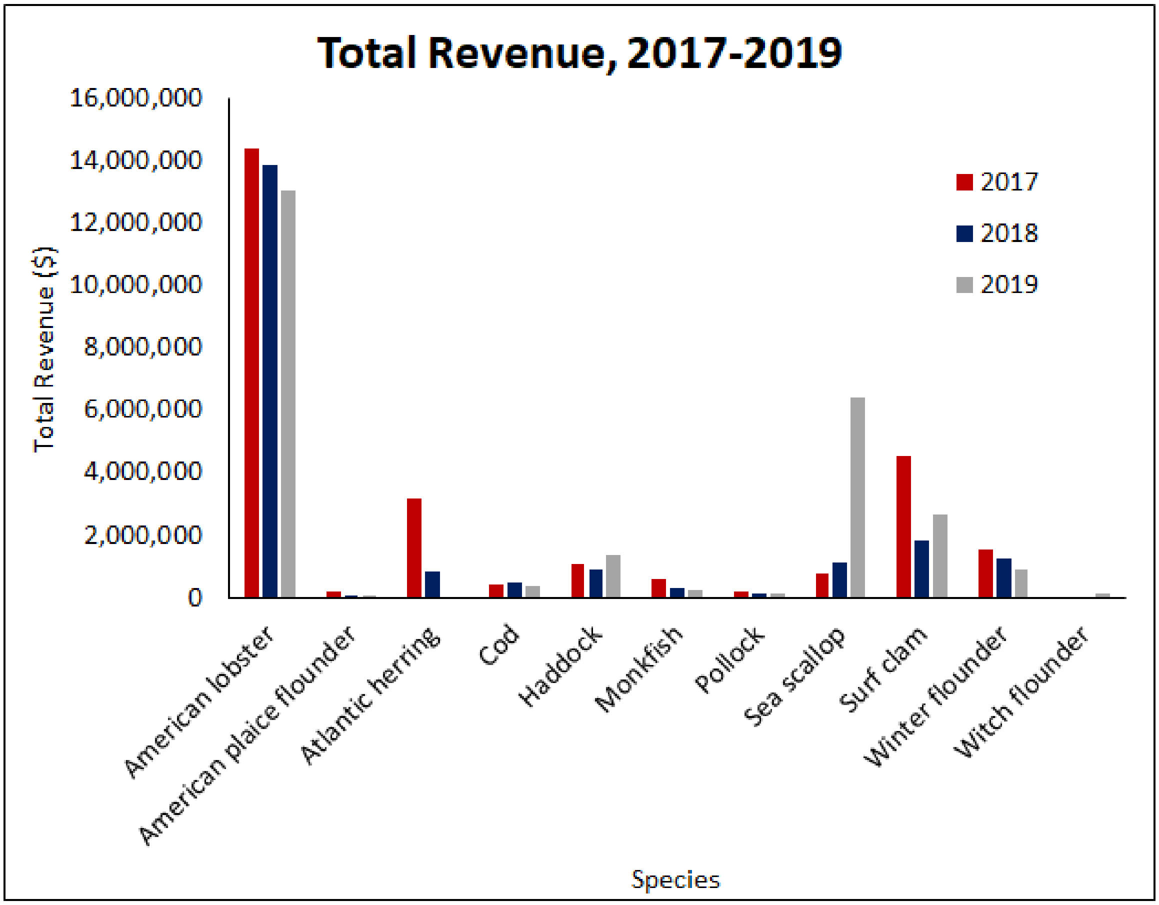


Figure 6. Top species by revenue ($) inside the Northern Edge Analysis Region, calendar years 2017-2019. Source: Vessel trip reports.



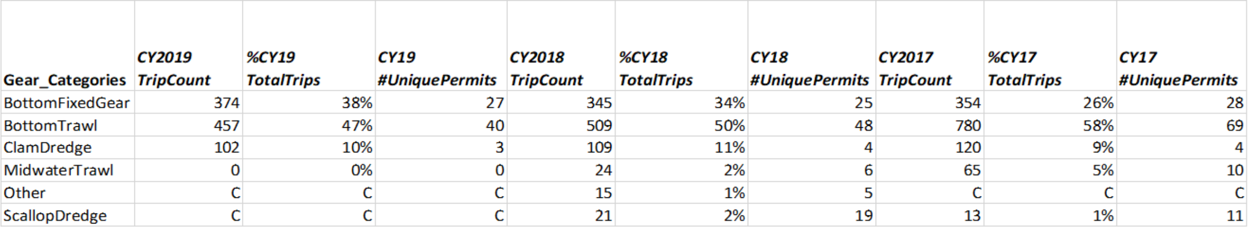
10.2.2 OHA2 Alternative 8

Within OHA2 Alternative 8, the total number of trips attributed to the region is estimated to be 977 in CY19; 1,203 in CY18; and 1,324 in CY17.

Averaging across the three years, bottom trawl accounted for the greatest number of trips at 52%, followed by bottom fixed gear at 33%, clam dredge at 10%, midwater trawl at 2%, and scallop dredge and other gear types each at 1% (Table 5). The species with the highest landings (>50,000 lb) by gear type are included in Table 6. The sum of days at sea is the probability-weighted effort metric for the area (scaled by the percentage of the trip estimated to have fallen within the region).

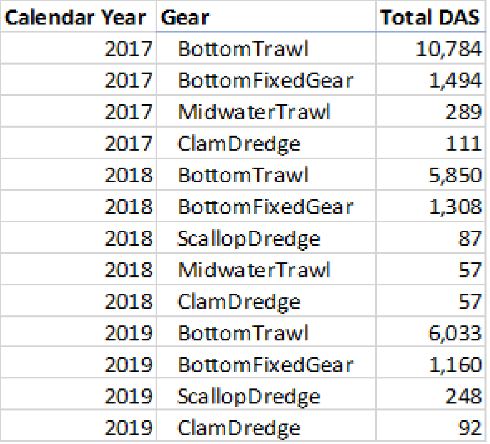
The species consistently with the highest landings include Atlantic herring (except in 2019), surfclam, haddock, American lobster, sea scallop, and winter flounder (Figure 7). The species consistently with the highest revenues include American lobster, sea scallop, surfclam, Atlantic herring (except in 2019), winter flounder, and haddock (Figure 8).

Table 5. Number and percentage of trips by gear type in the Alternative 8 area, calendar years 2017 - 2019. Source: Vessel trip reports. ‘C’ represents data with <3 trips and/or permits.



Gear_Categories	CY2019 TripCount	%CY19 TotalTrips	CY19 #UniquePermits	CY2018 TripCount	%CY18 TotalTrips	CY18 #UniquePermits	CY2017 TripCount	%CY17 TotalTrips	CY17 #UniquePermits
BottomFixedGear	374	38%	27	345	34%	25	354	26%	28
BottomTrawl	457	47%	40	509	50%	48	780	58%	69
ClamDredge	102	10%	3	109	11%	4	120	9%	4
MidwaterTrawl	0	0%	0	24	2%	6	65	5%	10
Other	C	C	C	15	1%	5	C	C	C
ScallopDredge	C	C	C	21	2%	19	13	1%	11

Table 6. Sum of day at sea (DAS) by gear type for calendar years 2017-2019 in the Alternative 8 area, excluding species with landings < 50,000 lb.



Calendar Year	Gear	Total DAS
2017	BottomTrawl	10,784
2017	BottomFixedGear	1,494
2017	MidwaterTrawl	289
2017	ClamDredge	111
2018	BottomTrawl	5,850
2018	BottomFixedGear	1,308
2018	ScallopDredge	87
2018	MidwaterTrawl	57
2018	ClamDredge	57
2019	BottomTrawl	6,033
2019	BottomFixedGear	1,160
2019	ScallopDredge	248
2019	ClamDredge	92

Note: Species caught with:

- Bottom trawl gear include American plaice flounder, American lobster, cod, haddock, monkfish, pollock, redfish, silver hake, skates, white hake, and winter flounder.
- Bottom fixed gear include American lobster, cod, and hagfish.
- Midwater trawl gear include Atlantic herring and blue back herring.
- Clam dredge gear include surfclam.
- Scallop dredge gear include sea scallop.

Figure 7. Top species by landings (lb) inside OHA2 Alternative 8, calendar years 2017-2019. Source: Vessel trip reports. Data from sea scallop trips in 2019 were removed because the data represent <3 trips and/or permits.

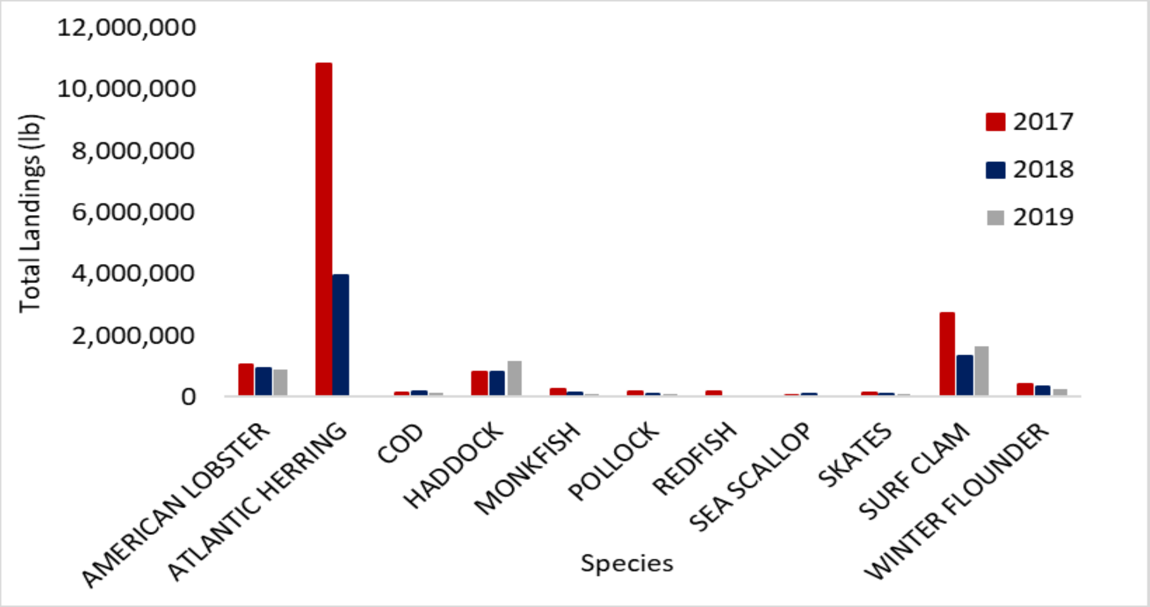
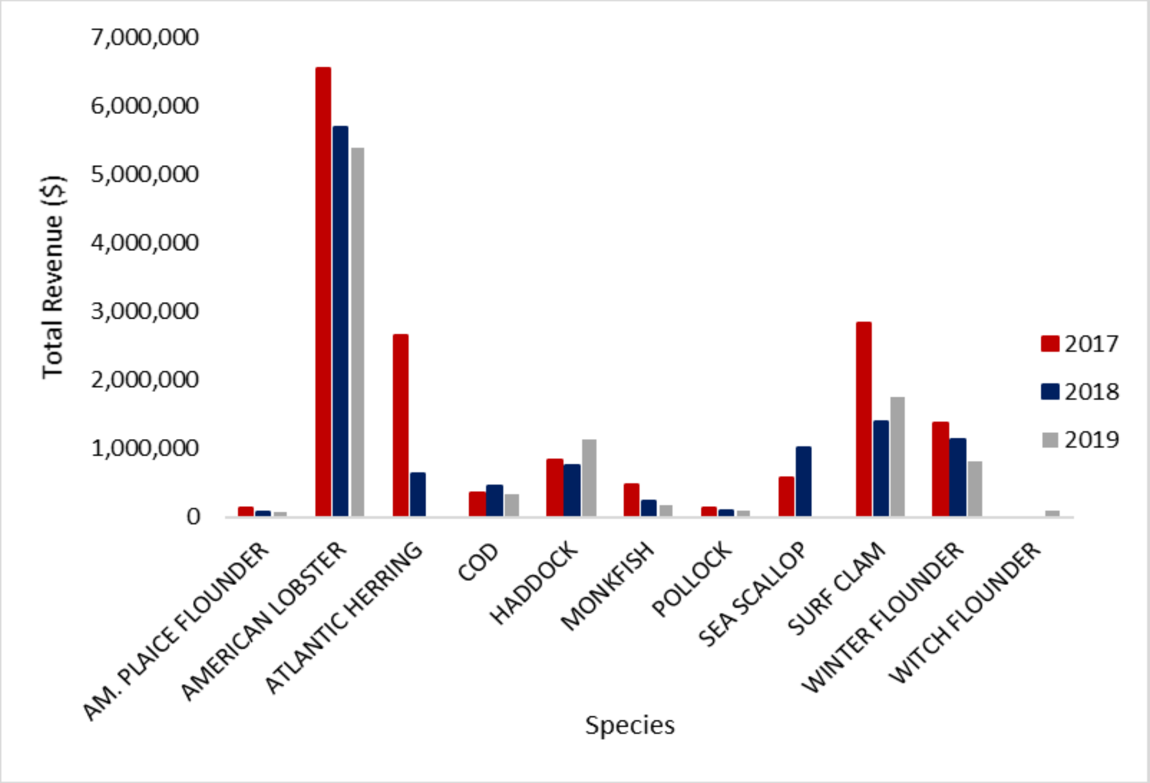


Figure 8. Top species by revenue ($) inside OHA2 Alternative 8, calendar years 2017-2019. Source: Vessel trip reports. Data from sea scallop trips in 2019 were removed because the data represent <3 trips and/or permits.



11.0APPENDIX E: RECENT FISHING GEAR EFFECTS LITERATURE

This review encompasses any bottom tending gear types, i.e., dredges, bottom trawls, and fixed gear. Most of the studies reviewed considered the impacts of fishing gear on geological and biological seafloor features, comparing across gear types, fishing intensities, etc.

- Barnett, et al. 2017 evaluated the impact of spatial closures such as catch shares on gear-habitat interactions and found that these interactions likely increase outside of the closure areas due to effort displacement and fragile, structure-forming habitat interactions increase with increase in effort. {Barnett, 2017 #1412}
- Bruns et al. 2020 provide a method for assessing the distribution and persistence of trawl gear marks on the seabed using side-scan sonar data. Their study sites were located in the German EEZ within the North Seas.
- De Borger, et al. 2021 modeled the biogeochemical changes from trawling and found increased oxygen and nitrate concentrations and lower ammonium and organic carbon at the sediment surface for both deeper and shallower penetrating trawl gear, though with less of an effect than deeper gear. The denitrification changes are caused by the perturbation and sediment resuspension from trawling. Low organic fine sand and coarse sediment have greater biogeochemical changes/effects compared to fine sand with high organic matter and muddy substrate because the latter’s fauna helps mitigate against denitrification from trawling effects. {De Borger, 2021 #2491}
- Gladstone-Gallagher et al. 2021 considered biological traits at individual and landscape scales in two different systems, one more heterogeneous and one more homogeneous, examining recovery pathways following mechanical disturbance. They found differences among the two systems in recovery pathways.
- Hiddink, et al. 2017 evaluated depletion and recovery rates of benthic communities after trawling impacts and generally found more biota were removed as trawl penetration depth increased. Hydraulic dredges had the greatest impact with 41% of biota removed and a penetration depth of 16.1 cm and otter trawls with the least impact with 6% biota removed and a penetration depth of 2.4 cm; after trawling activity, recovery rates varied between ~2 and 6.4 years to achieve upwards of 95% unimpacted biomass. Community biomass did not seem to be affected by the interaction between gear type and habitat type, however, the sample size was small for this evaluation. Substrates with higher percentages of gravel experienced a greater reduction in benthic community numbers. {Hiddink, 2017 #1368}
- Jac et al. 2020 present a methodology to determine “good ecological status” thresholds for various habitat types in three different sub-regions in European waters. They then used the methodology to assess and map habitat status.
- Kenny, et al. 2018 identified benthic habitat function changes from small infaunal species to large immobile species when hard structure like renewable energy devices are placed in more shallow and mobile sediment bottoms. Marine dredging (removal pressure type), sediment disposal (smothering pressure type), and bottom fishing (abrasion pressure type) significantly negatively impacted the deeper, sediment habitat type. More sensitive habitats that are frequently disturbed by human activities will generally have lower recovery rates. {Kenny, 2018 #1415}
- Kopp, et al. 2020 evaluated the seafloor habitat impact from lightweight and heavy static fishing gears, namely fish traps, and did not observe any habitat penetration or any significant movement from the gear. {Kopp, 2020 #2448}

- Mengual, et al. 2019 modeled the resuspension of sediment/sediment fluxes from trawl gear in different concentrations of mud substrate and found trawling significantly contributed to horizontal and vertical sediment fluxes, with areas next to the trawl zone having 10-50% higher mud content and areas with a history of intense trawling activity having significantly reduced seabed mud in some areas of the shelf. While trawling contributed almost 100% of the sediment resuspension in summer in mid and outer parts of the shelf due to higher fishing activity, in winter, erosion from waves and currents was dominant and trawling effects were minor. Overall, trawling contributed between 3-40% of mud and sand fluxes, with greater concentration poleward.
- Paradis, et al. 2021 evaluated the effect of trawling closure on sediment recovery and found after a two-month trawling closure, there was a 30% reduction in organic carbon, a degradation loss of 52-70% in substrate that is more susceptible to alteration, and an overall increase in modified coarser sediments relative to areas that had not been previously trawled (i.e., reduction in quantity and quality of organic matter from trawling). The properties and the composition of sediments were both modified as a result of bottom trawling, even after the two month closure, based on analysis of biomarker indicators. This suggests habitat quantity and quality do not recover after a short closure.
- Pitcher, et al. 2017 calculated relative benthic status against an unimpacted baseline to evaluate how trawled habitats (and benthic invertebrate communities) change with varying degrees of trawl impact, recovery rate, and exposure to trawling and found gravel habitat as most impacted from trawl followed by muddy-sand as less sensitive to trawling, and sand as least affected by trawling. The benthic invertebrate community recovery rates followed a similar pattern: gravel had the greatest time to recover to reference state of 500 days, with 300 days to recover in muddy-sand, 200 days to recover in mud, and 100 days to recover in sand. {Pitcher, 2017 #1729}
- Ramalho, et al. 2020 tested the effect of different trawling intensity on changes in bioturbation, sediment nutrient flux, and biodiversity and found a reduction in macrofauna species richness due to a decrease in total biomass and respiration. As trawl intensity increased, biomass decreased and benthic size structure shifted towards smaller organisms. The study also estimated a reduced efficiency in biogeochemical processes and bacteria productivity from higher trawling activity as evidenced by high ammonia concentrations and species with lower individual biomass. Additional research is needed to better understand any changes in meiofaunal species richness and for a more thorough evaluation of results given the low sample size. {Ramalho, 2020 #2433}
- Rijnsdorp, et al. 2020 (‘Different bottom trawl fisheries...’) shows muddy habitats are more impacted by bottom trawling, especially by otter trawling for crustaceans and demersal fish, with coarse sediment and dredging for molluscs having the least impact. Muddy habitats are most impacted because of higher trawling intensity, impacting the seafloor habitat over a larger area. Overall trawling has a high CPUE per unit of impact relative to surrounding untrawled areas. Three methods were used to determine seafloor habitat impacts including estimation of percentage of benthic community with lifespan > trawling period, estimation of decrease in median longevity of benthic community due to trawling activity, and population dynamic estimation from trawling (incorporating recovery time). {Rijnsdorp, 2020 #2468}
- Sciberras, et al. 2018 estimated benthic habitat disturbance and recovery from bottom fishing and found one gear pass reduced invertebrate abundance by 26% and species richness by 19% (gears that penetrate the substrate more have a greater impact). Muddy or biogenic habitats not previously fished experienced the highest rate of depletion and species with fragile, structure forming and slow growing species experienced higher recovery rates of more than 3 years compared to species with shorter lifespans recovering within a year of fishing disturbance. {Sciberras, 2018 #1681}

- Smeltz, et al. 2019 found 3.1% of habitat was impacted from modeled fishing gear impact, with gear modifications such as lifting trawl gear off the seafloor resulting in a significant decline in disturbance {Smeltz, 2019 #1733}.

A few references evaluated the link between life history attributes to impact and recovery from towed mobile fishing gear: Kaiser, et al. 2018, Hiddink,et al. 2019, Rijnsdorp, et al. 2018.

- Hiddink, et al. 2019 similarly evaluated the relationship between the longevity of benthic invertebrate species and trawling impacts with recovery rates and found that the trawling most negatively affects species with longer life spans (> 1 year) with upwards of 9% reduction in abundance relative to those species with shorter life spans (< 1 year) where abundance increased in the short term. The species with the higher longevity also have longer recovery rates (larger intrinsic population growth rates) as they are most sensitive to trawl impacts. The life history attributes used in this study included growth rates, depletion estimates, biomass, and carrying capacity at different longevity categories. (Hiddink, 2019)
- Kaiser, et al., 2018 found that recovery to pre-fishing impact level is less than three years for species that are more habitat generalists, have higher dispersal rates and faster growth rates (such as scallops) while recovery was significantly more (17-20 years for 80% of carrying capacity) for species that are more habitat specialists, have lower dispersal rates and lower growth rates (long lived), such as pink sea fans and corals. This study evaluated impact and recovery of 9 species based on changes in mean body size in four reserve areas with different combinations of fishing history (previously scallop-dredged Y/N) and current fishing status (open/closed). {Kaiser, 2018 #1671}
- Rijnsdorp, et al. 2018 developed a conceptual framework using the relationship between shear stress (water flow rate along the seabed), sediment composition, and benthic invertebrate community to predict changes in the benthic community from trawl fishing. Similar to other studies including Pitcher, et al. 2017, this study found that trawling most impacted low shear stress habitats with long-lived species and more gravel than mud sediment while trawling had the least impact on high shear stress habitats with shorter-lived species. In this study, high shear stress is considered 1 N/m2 and low shear stress as -.1 N/m2 (the SASI/Fishing Effects model used a threshold of 0.194; the Northern Edge is considered a high shear stress area with a shear stress value generally above 1.0 N/m2) (Rinjsdorp, 2018). To note, not all taxa on the Northern Edge in high shear stress environments are weedy, short-lived species.

Some studies focus specifically on gear modifications that might be employed to allow fishing in an area while reducing the effects of that activity on the seafloor. The concept of gear modifications in habitat management areas was discussed extensively during development of OHA2 (see Vol. 4, Section 3.2.1.3). The purpose of including such studies here is not to suggest that the gear modifications analyzed would have direct application to Georges Bank. However, given past discussions at the Council it seemed important to note the body of work on this subject in the event that the Council wishes to explore these approaches further. A few references tested gear modifications and electric pulse trawling relative to conventional otter trawling to see how catchability of target species changed and how benthic habitat impacts differed between gear types. These references may or may not be relevant for any habitat management considerations for Georges Bank. {McHugh, 2020 #2293}{Rijnsdorp, 2020 #2447}{Tiano, 2020 #2321}{Tiano, 2019 #2493}

- McHugh, et al. 2020 found that batwing otter board (maintain 20 degrees angle of attack with a baseplate width of < 0.1 m) in penaeid trawls reduced artificial habitat impact by up to 61% relative to the control group of flat-rectangular otter board. The soft-brush ground gear did not reduce habitat impacts, however. Additional research is needed to evaluate the effectiveness of these gear modifications under real oceanographic conditions and habitat with other target species.

- Rijnsdorp, et al. 2020 (‘Mitigating seafloor disturbance...’) assessed the difference in habitat impacts between pulse trawling and beam-trawling and found a reduction in the trawling footprint by 23% along with decreases in the impact on median longevity of the benthic community (20%) (proxy for biodiversity), on community benthic biomass (61%), mobilization of sediment (39%), and reduction in benthic community potentially impacted by trawling (39%). Overall, the pulse fishing shifted sediment composition from muddy to coarse and resulted in species with higher longevity. The authors noted that mechanical disturbance causes the most impact to habitat, though additional research is needed to differentiate habitat impacts and substrate differences at finer geographic scale (e.g., troughs, ridges, etc.). {Rijnsdorp, 2020 #2447}
- Tiano, et al. 2020 and Tiano, et al. 2019 evaluated the difference in the biogeochemical processes and habitat impacts between beam trawls and electric pulse trawl gears in the North Sea. These gears were found to have similar, significant impacts to infaunal communities, though showed different biogeochemical effects, with traditional trawl gear altering the benthic nutrient cycling to a greater extent than electric pulse trawl gear, especially oxygen, chlorophyll a, ammonium, phosphate, and silicate concentrations. {Tiano, 2020 #2321}{Tiano, 2019 #2493}
- An unpublished study that was funded by the 2019/2020 sea scallop RSA Program evaluated the N-Viro dredge to reduce bycatch and improve fuel efficiency. During field trials N-Viro dredge was shown to select for large scallops where other year classes were present (scallop catch rates ~50% of New Bedford dredge catch rates); selectively target scallops in sensitive habitats; reduced habitat impacts and catch of rocks while towing the gear; and reduce catch rates of 50+% of other bycatch species (skates, monkfish, flatfish species) compared to New Bedford dredges.

12.0 APPENDIX F: FMP-SPECIFIC CONSIDERATIONS

12.1 NORTHEAST MULTISPECIES

Several groundfish species utilize the Northern Edge region during various life stages (Table 2), some of which are within the top 10 species by landings and revenue in 2017-2019 (Figure 5, Figure 6, Figure 7, Figure 8) including Atlantic cod, haddock, pollock, redfish, white hake, winter flounder, and witch flounder. Current fishing conditions are determined by management decisions and allocation of stocks by region. Species that are found within this region that are of greatest importance from a conservation and stock status standpoint include Atlantic cod, yellowtail flounder, Northern windowpane flounder, and winter flounder.

Eastern GB cod: overfished with unknown overfishing status; catch has declined from over 5,600 mt in 2011 to <700 mt in 2020. The 2020 Atlantic Cod Stock Structure Working Group concluded that instead of the two management unit stocks (Gulf of Maine and Georges Bank units), there are five distinct biological cod stocks, including Georges Bank cod in the eastern part of the region specifically in statistical areas 522, 525, 561, and 562 in the US waters and 551 and 552 in Canadian waters (Map 9). This proposed five biological stock determination is based upon genetic variation, movements, spawning locations and seasons, and larval dispersal. Even though area 521 is proposed as a separate biological stock, the area is currently in the Georges Bank Management Unit and does have a lot of mixing and is a transition zone for cod and other species.

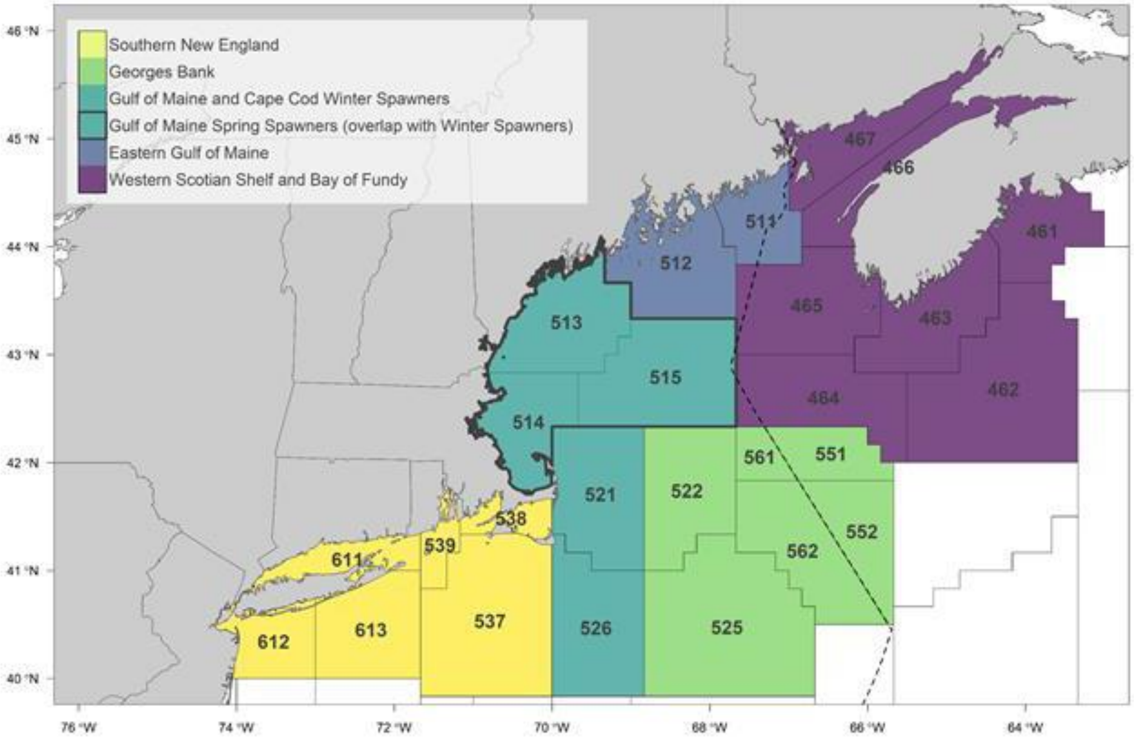
GB Yellowtail flounder: overfished, unknown overfishing status for FY21 and FY22, poor recruitment, 125 mt ABC (FW61 Appendix 1).

Gulf of Maine/GB Northern Windowpane flounder: unknown stock status based on the 2020 Peer Review Panel; however, the stock is considered overfished with overfishing not occurring based on NOAA. On Georges Bank, spawning occurs during the summer but peaks in October and November (FW61).

GB Winter flounder: overfished, overfishing not occurring, little progress towards rebuilding, and weaker recruitment in recent years; Georges Bank is an important fishing ground for this species.

GB Haddock: Ongoing research track assessment to be completed in 2022, annual transboundary resource assessment committee (TRAC) meetings for Eastern Georges Bank haddock and other shared resources across the U.S.-Canada boundary.

Map 9. Proposed biological stock structure of Atlantic cod in NAFO division 5 and adjacent division 4X. Source: Atlantic Cod Stock Structure Working Group 2020.



Groundfish area closure history (Section 3.3.2 of OAH2 & Sherwood/Grabowski 2016): Seasonal and year-round closures used to: protect spawning cod and haddock on Georges Bank, reduce discards of small yellowtail flounder in SNE, reduce mortality on overfished fish stocks, and make DAS more effective. Amendment 13 (2003) designated multiple habitat closures including Closed Area II, prohibiting fishing gears capable of catching groundfish - recreational groundfish fishing was/is allowed. Five year-round closed areas implemented on GB and GOM from 1994 to 2002 to help recovery of groundfish (namely cod) (Sherwood and Grabowski 2016) "to replace or augment a series of rolling closures which had been in effect in various forms since the 1970s." CAII established in their current form in 1994 - allow certain types of fishing (recreational fishing, special access areas for scallop dredging and longline). The main goals were to: 1) protect benthic habitats and 2) reduce groundfish mortality (namely for cod, haddock, yellowtail flounder). Progress to date includes (see closed area evaluation questions from OHA2 Section 7): 1) Protection of benthic habitat: increase abundance and biodiversity of benthic organisms, creating additional feeding opportunities for cod and 2) increased abundance of GB haddock.

12.2 ATLANTIC SEA SCALLOP

The Northern Edge supports a persistent aggregation of scallops, both inside the habitat closure area and just west of the closure boundary. Scallop spatial distribution is related to depth, sediment type, flow, temperature, salinity, food availability, and distribution of predators. On Georges Bank, scallops occur to depths of 110 meters, and show highest persistence in areas where sediments are stable (Harris, 2011). Persistence was defined as a location where a high concentration of scallops occurred in at least five out of eight years sampled.

The Scallop Area Management Simulator (SAMS) model is used to estimate the spatial distribution of abundance, biomass, and mean weight on Georges Bank and in the Mid-Atlantic Bight. Where possible, dredge, drop camera, and HabCam survey results are combined to estimate the number of scallops, biomass (including exploitable biomass), and size/age structure (including indices of recruitment) (Table 7). Two SAMS areas overlap the Northern Edge, Northern Flank (NF) and Closed Area II North (CL-2(N)) (Map 10, Map 11). Scallops in the Northern Flank area are smaller and less numerous than those inside Closed Area II N. The scallop resource on the Northern Edge, particularly within Closed Area II, has a diverse age structure. A recruitment event occurred in 2019, and there many three-year old animals as of 2021 (Figure 9).

The Northern Flank and Closed Area II-North SAMS areas have been surveyed using both dredge and optical (i.e., drop camera and Habcam) technologies during the late spring and early summer months (Table 8). Summer 2021 was the first time in several years that the Closed Area II-North area has been surveyed using all three techniques. Scallops in Closed Area II N are somewhat challenging to assess using optical surveys, given the extensive epifauna that occur on and around the scallops that can make identification difficult. Larger animals are typically encrusted with barnacles and tunicates. The 2021 dredge and optical surveys also encountered substantial areas of mussels, which can also attach to sea scallop shells.

Map 10 shows predicted scallop biomass from the 2021 HabCam survey of CAII-N and surrounds, and Map 11 shows scallop density estimated from the 2021 School for Marine Science and Technology (SMAST) drop camera survey of the same area. Biomass estimates for Closed Area II-North ranged between 10.4 - 14.2 million pounds between 2015 and 2021, while estimates of the Northern Flank placed biomass levels between 2.2 - 8.2 million pounds over the same time period (Table 8). Scallop biomass has been declining in recent years in both the Mid-Atlantic and on Georges Bank as the exceptional 2012- and 2013-year classes have declined due to fishing and non-harvest mortality. Recruitment since 2013 has been average or below average in most areas of the resource. Scallops in the Northern Flank and Closed Area II-North estimation areas account for a larger proportion of the overall biomass (~7%) in 2021 as the estimates of overall biomass decline (Table 8, Figure 10).

Sea scallops typically lose up to 20% of their meat weight around the time that they spawn. Model-based mean monthly anomalies show this strong seasonal cycle, with meats varying by 20% or more in both Georges Bank and the Mid-Atlantic over an average year (Figure 11. Mean monthly meat weight anomalies on Georges Bank (left) and Mid-Atlantic (right) open areas from modeled predictions (Source: SARC 65, Appendix II, p.195).Figure 11). Scallops spawn on Georges Bank in the fall which means that meat yields are best in May, June and July, and are poorer in the months right after spawning. Since rotational scallop fishing is managed based on possession limits and access trip allocations are in pounds, the timing of fishing relative to seasonal fluctuations in yield has implications for the amount of fishing effort that would be required to harvest an access area possession limit, and thus the impacts on the scallop resource. Seasonal closures could be used as a tool by the Council to focus fishing during times of the year when yields are highest.

Another consideration related to the scallop resource is the extent to which the scallops on the Northern Edge may produce spat that recruit to other areas of Georges Bank, and thus contribute to the success of the population at broader scales. Understanding the implications here requires knowing how eggs originating on the Northern Edge move to other locations, and whether the number of successful recruits is related to the population size on the Northern Edge.

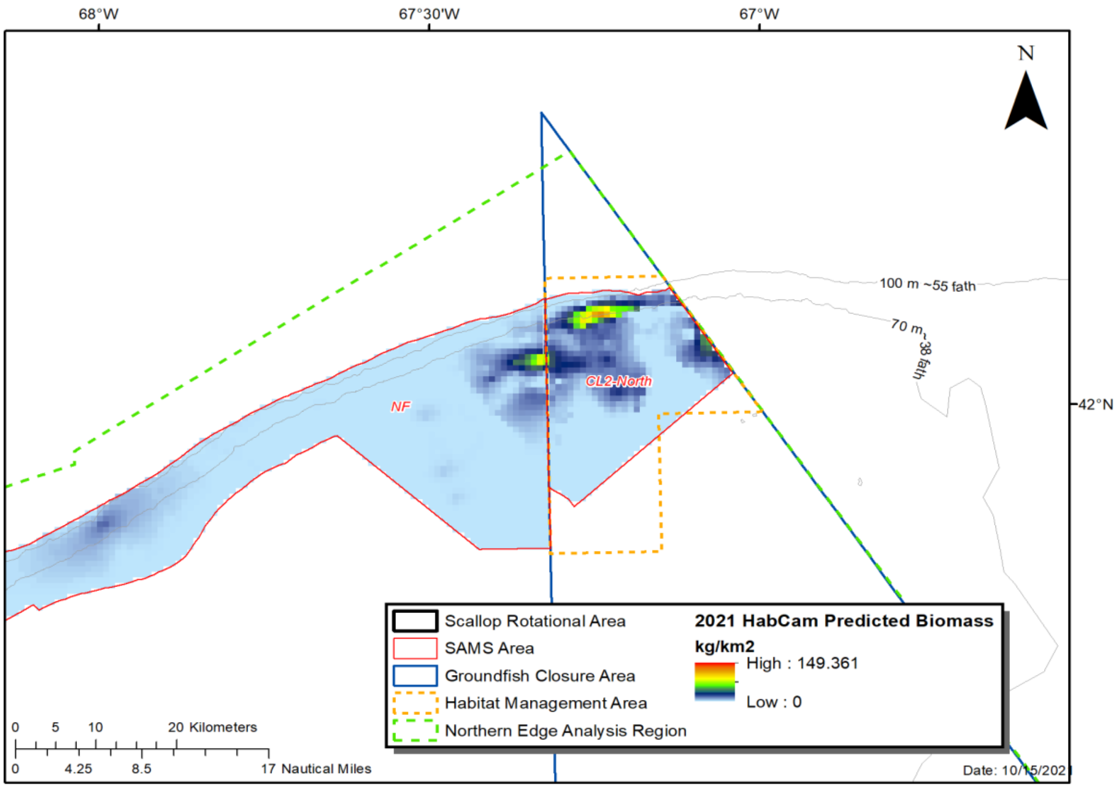
The scallop resource was last assessed in 2020. As of 2019, the stock was not overfished and overfishing was not occurring. Over the past several years, sea scallop landings in the New England and Mid-Atlantic region have generally increased from a low of 33.7M lb in 2014 to a high of 60.5M lb in 2019; 48.7M lb were landed in 2020 (NOAA Stock SMART). Over 2017-2019, sea scallop landings averaged 56.7M lb, generating an average revenue of $536.6M.

Based on the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) and average scallop landings and revenue in the entire fishery from 2017-2019, scallops within the Northern Edge Analysis region account for ~0.5% of scallop landings and ~0.5% of scallop revenue and in the OHA2 region, 0.65% of scallop landings and 0.7% of scallop revenue. It is important to note that this is not necessarily going to reflect future years given that scallops are managed through rotational management.

Table 7. Scallop surveys of Closed Area II-North, including HAPC, between 2016-2021.

Survey Year	Dredge	Drop Camera	HabCam
2016	Yes	No	Yes
2017	Yes	Yes	Yes
2018	Yes	No	Yes
2019	Yes	Yes	No
2020	No	No	No
2021	Yes	Yes	Yes

Map 10. Predicted scallop biomass (kg per km^2) from the 2021 HabCam survey of Georges Bank relative to Scallop Area Management Simulator (SAMS) areas, scallop rotational areas, habitat/groundfish closures, and the Northern Edge analysis region.



Map 11. Scallop density per m2 from the 2021 School for Marine Science and Technology (SMAST) drop camera survey of Georges Bank relative to Scallop Area Management Simulator (SAMS) areas, scallop rotational areas, habitat/groundfish closures, and the Northern Edge analysis region.

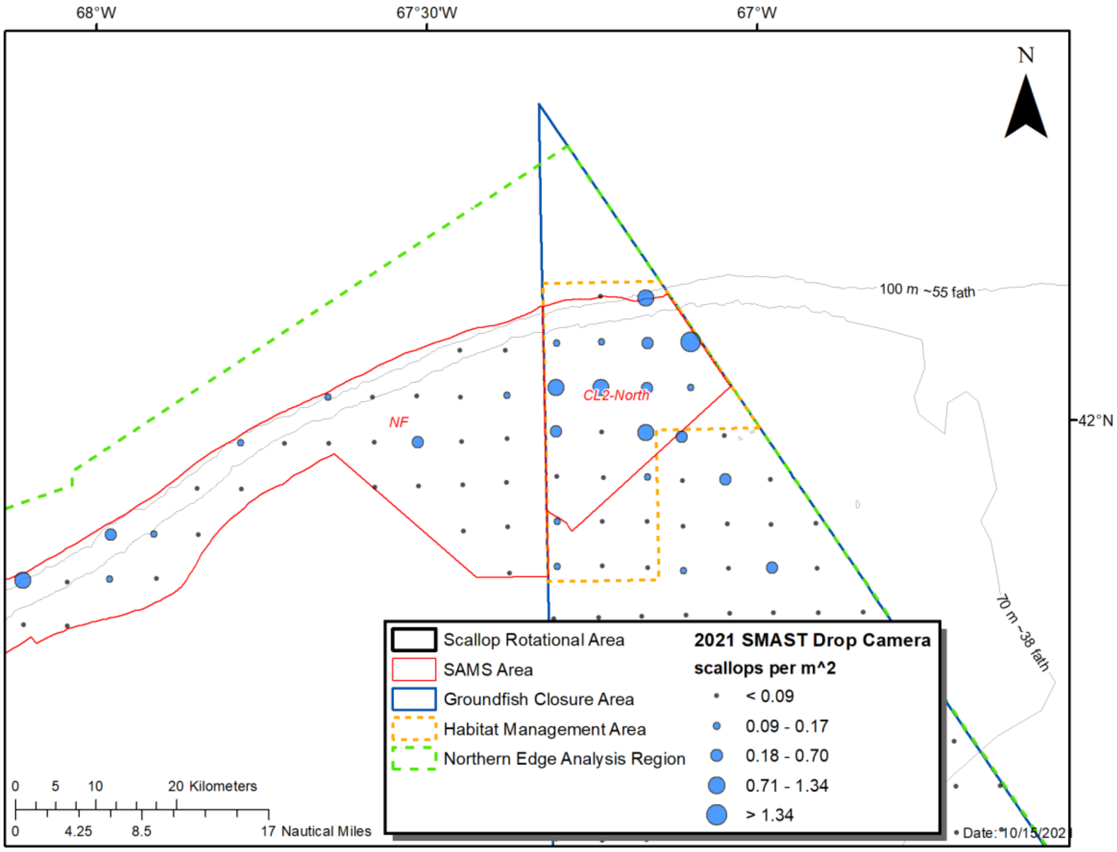
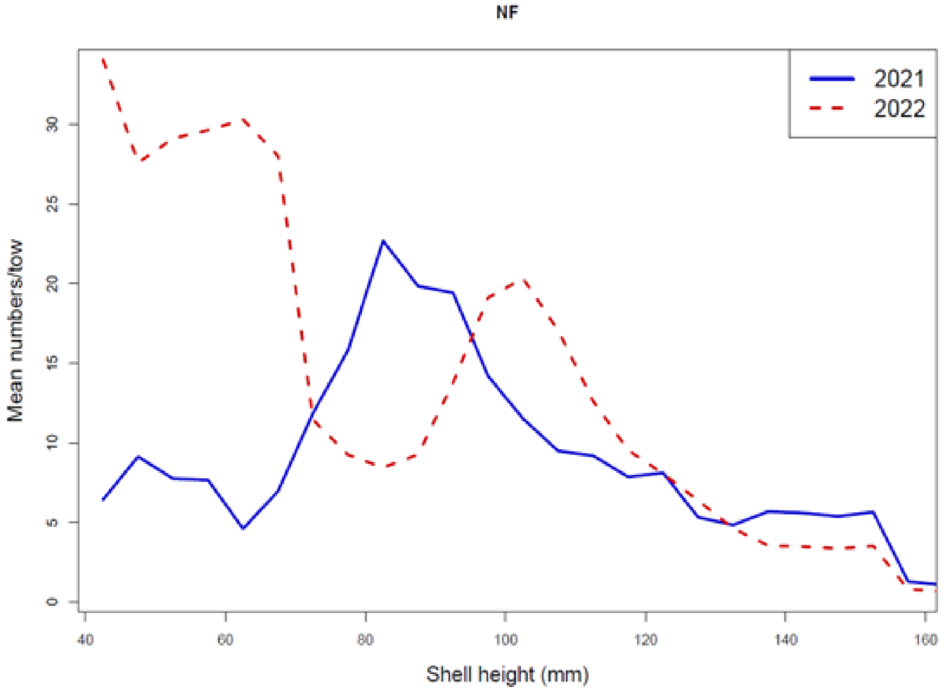


Table 8. Scallop survey biomass estimates from 2015-2021 for Closed Area II-North, Northern Flank, with total biomass for all Georges Bank and the Mid-Atlantic.

Survey Year	CAII-N	Northern Flank	Georges Bank & Mid-Atlantic Total
2015	10,593,601	6,694,824	435,835,093
2016	12,431,867	8,278,358	517,495,477
2017	12,284,152	3,880,276	593,509,896
2018	14,177,928	2,169,349	481,518,240
2019	12,901,452	2,858,293	407,356,308
2020	--	3,161,429	309,391,583
2021	10,446,237	5,798,892	243,090,288

Figure 9. 2021 survey dredge length frequencies for the Northern Flank (NF) and Closed Area II-N (CA2-N) areas, with projected growth and recruitment from the SAMS model for 2022.



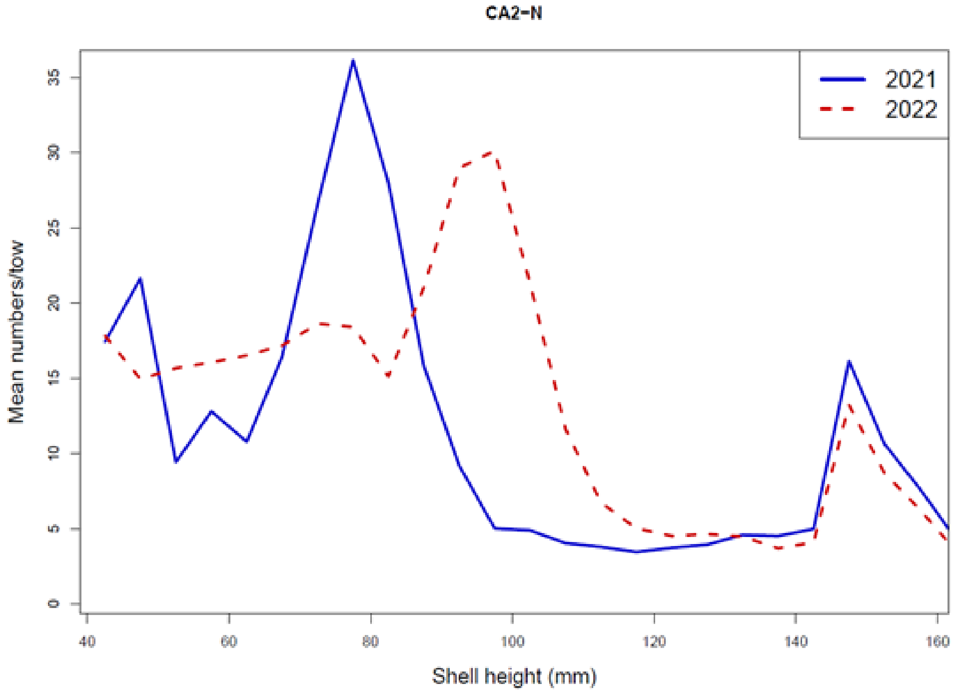


Figure 10. Scallop survey biomass 2015-2021 for Georges Bank and the Mid-Atlantic, and percentage of total biomass located in the Northern Flank (NF) and Closed Area II-North estimation areas.

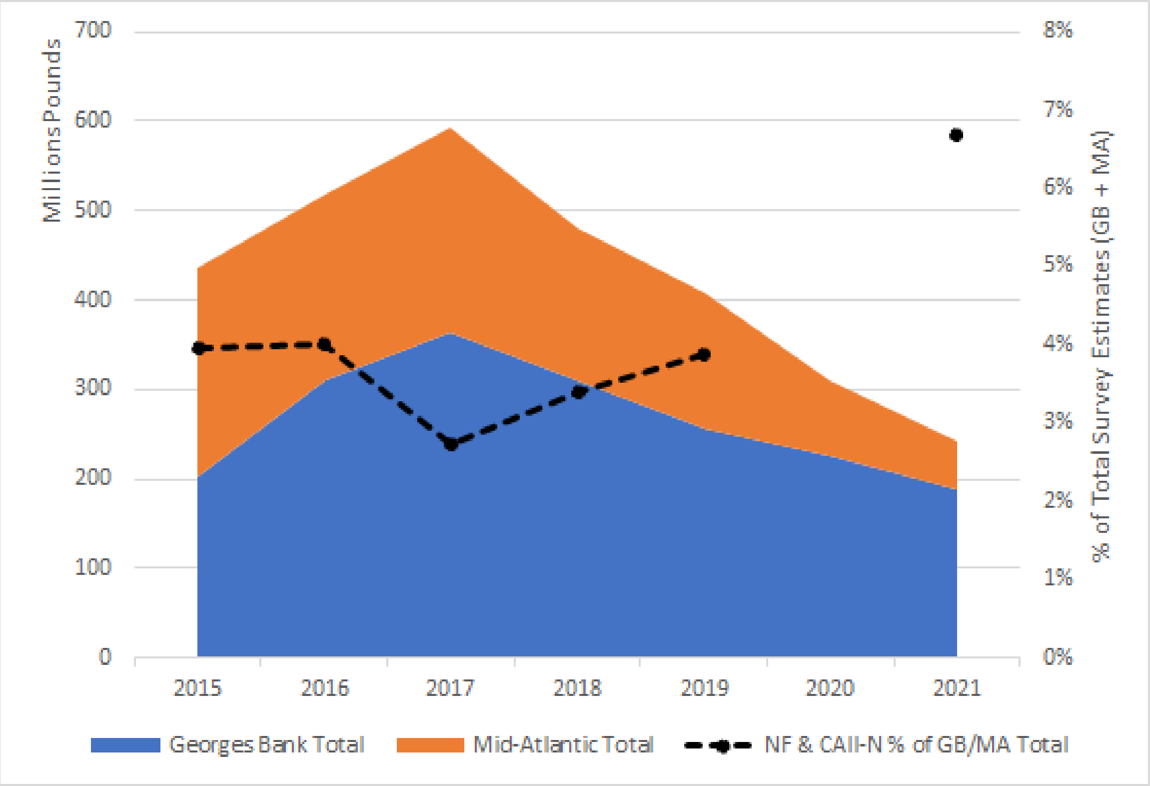
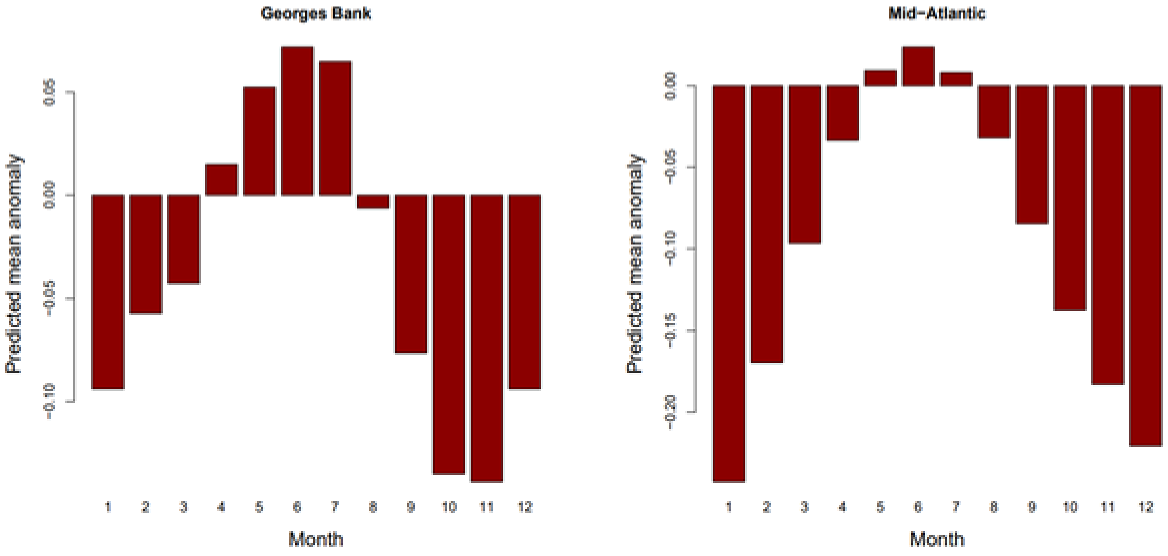


Figure 11. Mean monthly meat weight anomalies on Georges Bank (left) and Mid-Atlantic (right) open areas from modeled predictions (Source: SARC 65, Appendix II, p.195).



12.3 ATLANTIC HERRING

Ideally, to understand the implications of spatial management of fishing activity on herring spawning and recruitment, we would want to know when and where both spawning activities and egg deposition occur on Georges Bank. The Council recently commissioned a review of this information (Sherwood, Weston, and Whitman, 2019) which is being used to inform a management action (Atlantic Herring Framework 7) that seeks to minimize fishery impacts on herring spawning. Atlantic herring spawn in aggregations, depositing eggs in discrete mats on the seafloor in areas with strong tidal currents at water depths ranging from 5 to 90 m (Stevenson and Scott, 2005). Atlantic herring are known to spawn on the Northern Edge of Nantucket Shoals and along the northern flank of Georges Bank, however, the spatial extent of spawning and egg habitats has varied over time. These spawning areas have historically contracted to a few isolated locations during periods of low abundance and expanded to cover the entire northern flank of Georges Bank during periods of high abundance (Melvin and Stephenson, 2007; Stevenson and Scott, 2005).

Egg mats, which can measure up to 5 cm in thickness, may consist of many layers and can cover large regions of the sea floor (Stevenson and Scott, 2005); in 1964, an egg mat observed on Georges Bank measured about 65 km^2 (Noskov and Zinkevich, 1967). Eggs may be deposited on a variety of sediment types, but gravel has been identified as the predominant egg mat substrate on the Northern Edge of Georges Bank (Drapeau 1973; Valentine and Lough 1991). Surveys conducted on Georges Bank from 1964 to 1970 found egg beds to be restricted to elongated areas of gravel substrate at depths of 40 to 50 m, situated between gravelly sand regions and sand ridges about 10 to 20 m in height (Valentine and Lough 1991). Due to the strong bottom currents present in spawning areas on Georges Bank, finer sediments (i.e., sand and mud) are not sufficiently stable for secure adhesion of egg mats, and transitions from gravel to finer sediment have been observed to delineate the edges of egg beds (Stevenson and Scott, 2005). It is inferred that strong currents provide oxygen to eggs, prevent siltation, and remove metabolites (Drapeau 1973). Herring egg incubation period is influenced by temperature but generally varies between 10 and 15 days in the Gulf of Maine region (Stevenson and Scott, 2005).

Egg beds have occasionally been surveyed directly, but data on larval distributions are more routinely gathered. Herring larvae hatch at between 4-10 mm total length (Fahay 2007), so larvae that are 10 mm or smaller in size are expected to be close to the location where their eggs were incubated. Herring larvae have exhibited a similar distribution pattern to spawning adults, occupying increasingly large areas of Georges Bank as the herring population grew in the late 1980s and 1990s (Figure 12).

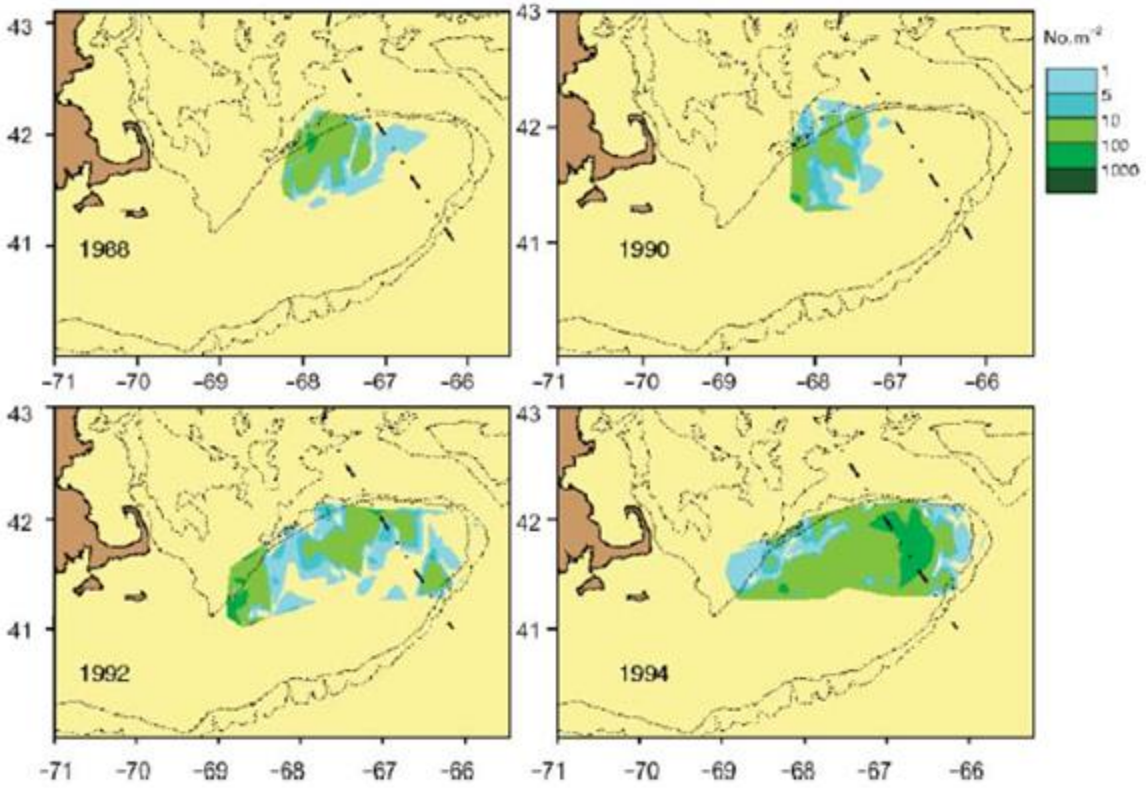
Exact timing of Atlantic herring spawning events may vary year-to-year by several weeks due to interannual variability in oceanographic conditions (Winters and Wheeler, 1996). Spawning occurs from late August to December in the Georges Bank/Nantucket Shoals region, with a peak in September and October (Stevenson and Scott, 2005). Larval surveys in 1971-1975 indicated that spawning occurred on a temporal-spatial gradient, starting with northeast Georges Bank in September and extending southwest over a period of weeks to Nantucket Shoals, where spawning occurred in October (Grimm 1983).

In a laboratory study, covering Atlantic herring eggs with a thin layer of sediment caused 85% mortality, although suspended sediments at concentrations of up to 7,000 ml/l were not shown to influence hatching success (Messieh et al. 1981). The potential for resettled sediments to cover herring egg mats due to fishing gear disturbance has not been directly studied; while there could be risk of increased sediment loads on egg beds, the strong currents in spawning areas could mitigate this effect by sweeping suspended sediments away from spawning sites. Fishing activity may also disturb herring spawning activity, and harvest may remove animals before they can spawn.

Before the recent declines in catch limits, the Atlantic herring fishery was a summer / fall midwater trawl fishery. Based on the 2020 stock assessment and an October 2020 NOAA Fisheries letter to NEFMC, Atlantic herring are overfished but are not subject to overfishing. As a result, the NEFMC began developing FW8 which contains measures to develop a rebuilding plan and adjust herring accountability measures; final Council action was taken in September 2021. Over the past couple of years, herring landings in the northeast region have declined significantly from a high of 31.8M lb in 2013 over the past decade and a low of 9.1M lb in 2019 and 6.8M lb in 2020 (NOAA Stock SMART). Over 2017-2019, herring landings averaged 19.8M lb, generating an average revenue of $21.6M.

Comparing data from the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) with total average herring landings and revenue from 2017-2019, herring within the Northern Edge Analysis region account for 44% of herring landings and 9% of herring revenue, and in the OHA2 region, 37% of herring landings and <8% of herring revenue. It is important to note that because landings have significantly declined within the recent couple of years and because of the overfished state of the stock, these percentages of landings and revenue within the Northern Edge and OHA2 regions are likely not going to be reflected in future years.

Figure 12. From Melvin and Stephenson, 2007. Distribution of recently hatched larvae (<10 mm total length) on Georges Bank in four representative years, 1988, 1990, 1992, and 1994.



12.4 SURFCLAM

Atlantic surfclams are distributed from the Gulf of St. Lawrence to Cape Hatteras, North Carolina, with the fishery concentrated off of New Jersey, Southern New England, and Georges Bank in recent years (MAFMC Atlantic Surfclam Fishery Information Document April 2021). Of note and based on recent data, there has been a recent expansion of the surfclam resource into deeper waters onto Georges Bank and between the west of the Great South Channel and east of Nantucket, which could continue in the future, though there is some uncertainty (Powell et al 2019). Overall, due to warming bottom temperatures, some research suggests the resource distribution has contracted and has started shifting northeastward and further offshore, into deeper waters (Hoffmann et al 2018, Weinberg et al 2005). Based on the SAW 61 Assessment Report for Atlantic Surfclam (2020), the southernmost areas are thought to have the greatest amount of warming, and thus, greatest impact on surfclams relative to the northernmost regions.

The surfclam fishery uses hydraulic dredges exclusively in this region and is managed under one fishery management plan by the Mid-Atlantic Fishery Management Council. Surfclam vessels are not permitted to operate in the Closed Area II northern habitat closure nor in the Closed Area II groundfish closure due to both closure regulations and an overlapping paralytic shellfish poisoning closure. Surfclam landings and revenue fluctuated in recent years, generally declining over the past decade, with an average landings of 29.9M lb in 2017-2019, generating an average ex-vessel revenue of $26M over 2017-2019 (NOAA Stock SMART).

Comparing data from the Northern Edge Analysis and OHA2 regions (Figure 7-Figure 10) with total average surfclam landings and revenue, surfclams caught within the Northern Edge Analysis region account for ~10% of surfclam landings and 11.5% of surfclam revenue, and in the OHA2 region, ~6% of surfclam landings and ~8% of surfclam revenue.

12.5 AMERICAN LOBSTER

The American Lobster fishery is managed as two stocks (Gulf of Maine / Georges Bank and Southern New England, SNE) by the states and NOAA Fisheries, occurring from Maine to North Carolina and has 7 conservation management areas, Areas 1 - 6 and Outer Cape Cod Area. The SNE stock has very low abundance and is depleted due to recruitment failure from water conditions >= 20 deg. C, while the northern stock has record high abundance (2020 American Benchmark Stock Assessment and Peer Review Report). Over the past decade, landings from both stocks ranged from 120M lb to 150.5M lb, with 2017-2019 averaging 137.2M lb. Ex-vessel revenue fluctuated between $404M - $670M, with 2017-2019 averaging $611.3M (NOAA Stock SMART).

Gulf of Maine fishing occurs inshore from July through November. SNE fishing was an inshore fishery, however, slightly more landings are from offshore than inshore most recently (2020 American Lobster Benchmark Stock Assessment Peer Review). Georges Bank is an offshore component of the fishery. Most of the Georges Bank stock landings in MA are from statistical areas 521, 522, 561, and 562, with increased landings from these areas over time, while Rhode Island GB landings are primarily from statistical areas 525 and 526, with generally decreased landings from these areas in recent years. The Georges Bank fishery represents <10% of total lobster landings based on the 2020 American Lobster Benchmark Stock Assessment Peer Review report. Since 2005, landings have increased the most in the summer and fall in the Georges Bank region, relative to other times of the year. Unlike many other gears and fisheries, the lobster pot fishery can be prosecuted inside the Closed Area II habitat and groundfish closures.

Comparing data from the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) with total average lobster landings and revenue, lobster caught within the Northern Edge Analysis region account for <2% of lobster landings and <3% of lobster revenue, and in the OHA2 region, <1% of lobster landings and <1% of lobster revenue.

Lobsters migrate seasonally, and Georges Bank including the Northern Edge area is used by lobsters during the summer. OHA2 Volume 5, Section 17 describes potential impacts of changes in spatial management on the lobster resource, based on the potential for incidental mortality on ovigerous females. Impacts of allowing non-trap fishing gears within Closed Area II during the summer period when lobsters migrate onto Georges Bank was estimated to have slight to moderate negative effects.

12.6 MONKFISH, WHITING, AND SKATES

The monkfish fishery is jointly managed with the Mid-Atlantic Fishery Management Council and consists of a northern stock in the Gulf of Maine/Northern Georges Bank region, primarily caught with trawl gear, and a southern stock in the Southern Georges Bank/Mid-Atlantic region, primarily caught with gillnet gear. There were 23 M lb of commercial monkfish landings in FY 2019, generating $14.5M in revenue, which is slightly higher than the average 22M lb landings/year, averaged over the past five years. Comparing data from the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) with total average monkfish landings and revenue, monkfish caught within these regions account for <1% of monkfish landings and <2% of monkfish revenue.

The small-mesh multispecies fishery consists of two stocks of whiting (silver hake), two stocks of red hake, and one stock of offshore hake. Silver and offshore hake are considered whiting. Vessels use small-mesh trawl gear, with commercial whiting landings accounting for ~12M lb/year, generating $10 M in revenue annually, averaged over the past few years. Whiting landings and revenue have been declining since 2014. Comparing data from the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) with total average whiting landings and revenue, whiting caught within these regions account for 1% of whiting landings and <1% of whiting revenue.

Skate wing and bait fisheries (2 components, one open access permit) are primarily caught with gillnet (wings) and trawl gear (bait and wings). In the last 10 years, the wing fishery landed 18-25M lb (live weight), generating $4-8M in revenue; the bait fishery landed 7-12M lb (live weight), generating $1.1-1.8M in revenue, annually. Comparing data from the Northern Edge Analysis and OHA2 regions (Appendix D, section 0) with total average skate landings and revenue across both fisheries (i.e., wing and bait), skates caught within these regions account for <1% of skate landings and <1% of skate revenue.