OCS Study
BOEM 2021-036

New York Bight Fish, Fisheries, and Sand Features: Data Review

Volume 1: Literature Synthesis and Gap Analysis

US Department of the Interior
Bureau of Ocean Energy Management
Headquarters (Sterling, VA)

OCS Study
BOEM 2021-036

New York Bight Fish, Fisheries, and Sand Features: Data Review

Volume 1: Literature Synthesis and Gap Analysis

June 2021

Authors:
Thomas M. Grothues, Carolyn M. Iwicki, Gary L. Taghon, Sarah Borsetti, Elias J. Hunter

Prepared under BOEM Agreement # M20AC00003
By
New Jersey Agriculture and Experiment Stations
Rutgers, The State University of New Jersey
88 Lipman Drive
New Brunswick, NJ 08901

US Department of the Interior
Bureau of Ocean Energy Management
Headquarters (Sterling, VA)

DISCLAIMER

Study collaboration and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, DC, under Agreement Number M20AC0003. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REPORT AVAILABILITY

To download a PDF file of this report, go to the US Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2021-036. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

CITATION

Grothues TM, Iwicki CM, Taghon GL, Borsetti S, Hunter E. 2021. Literature synthesis of NY Bight fish, fisheries, and sand features; volume 1: literature synthesis and gap analysis. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-036. 114 p.

ABOUT THE COVER

Contents of a trawl aboard the commercial trawler *FV Viking II* during a study on bycatch along a shoreface sand ridge off Little Egg Inlet, New Jersey. Clearnose Skate, Windowpane Flounder, clams, Channeled Whelk, and Atlantic Horseshoe Crab represent resources that utilize sand habitat in this area.

ACKNOWLEDGMENTS

Margaret Shaw, Miranda Rosen, Thomas Ertle and Thomas TJ Johnson contributed to the literature search, table builds and formatting. Eleanor Bochenek, Kenneth W. Able and Nathalie Grothues helped with editing.

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ASMFC	Atlantic States Marine Fisheries Commission
AUV	autonomous underwater vehicle
BACI	Before-After-Control-Impact
BOEM	Bureau of Ocean Energy Management
BRUVS	Baited Remote Underwater Video Surveys
CDOM	Chromatic Dissolved Organic Material
CPUE	catch-per-unit-effort
DPS	distinct population segments
EFH	Essential Fish Habitat
FMP	Fishery Management Plan
HARS	Historic Area Remediation Site
HMS	Highly Migratory Species
LMA	lobster management area
MAB	Mid-Atlantic Bight
MMP	Marine Minerals Program
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NAO	North Atlantic Oscillation
NMFS	National Marine Fisheries Service
NYB	New York Bight
OA	Ocean Acidification
OCS	Outer Continental Shelf
PAR	Photosynthetically Active Radiation
SEUSCS	South East United States Continental Shelf
SMC	sheared meander crest
SNE	Southern New England (stock designation)
WCR	Warm Core Ring
YOY	young-of-the-year

1 Introduction

1.1 Statement of Need

The Bureau of Ocean Energy Management (BOEM) is receiving increased interest in Outer Continental Shelf (OCS) sand resources for shore protection, beach and wetland restoration, and construction projects. Worldwide, sand and mineral aggregates are the second-most exploited natural resource behind water, and expected demand far outpaces supply (United Nations Environmental Programme 2015). Sand includes aggregates of differing chemical composition, shape, grain size, angularity or roundness, and sorting, and not all sand is suitable for all tasks that require sand (Owen 2017). Sand is an important habitat for many benthic organisms. Sand is indirectly linked to epibenthic and pelagic organisms through food web dynamics. Sand provides temporary refuge from predators or other adverse conditions, and facilitates ambush predation (Byrnes et al. 2004; Diaz et al. 2003; Diaz et al. 2004; Mahon et al. 1998; Vasslides and Able 2008; Walsh et al. 2006). Yet, details about the mechanisms, scale, and specificity of dependency on sand for fishes is not well documented, including for the Northeast Large Marine Ecosystem, the seafloor of which is dominated by soft unconsolidated substrate.

In recognition of the importance of specific habitats in the completion of life cycles for fishes and key invertebrates, the habitat of managed fish species (particularly federally designated essential fish habitat, EFH, inclusive of managed and commercially important invertebrates) is under legal protection by the Magnuson-Stevens Fishery Conservation and Management Act (referenced as Magnuson-Stevens Act, MSA,16 U.S.C. 1801 et seq.). EFH is identified so that it can be managed and protected from other activities. Sand substrate may be an important character of habitat.

For marine species, the value of sand as habitat can change with its environmental, temporal, and ontological context. For example, migrant species of fish that rely on sand substrate on the coast are not there throughout the year, and some even migrate inland to freshwater (Able and Fahay 1998; 2010; Collette and Klein-MacPhee 2002). Fishes with adaptations to unconsolidated benthic habitat, such as having chemosensitive barbels or fin elements for probing sand, are common along the US East Coast. However, ecology along this stretch responds to marked regional differences in climatic, oceanographic, geologic, and bathymetric character, and in the nature of anthropogenic pressure. Intra-regional structuring of fish habitat use and seasonal distribution, such as estuarine entry or shoal occupation and range extent, has influenced geopolitical and cultural boundaries, such as the growth and character of historical fisheries-based communities (German 1987; Hardin 1960; Kunzig 1995; Safina 1990).

There is limited definitive information on ecological function and biological significance of sand features in the Mid-Atlantic region and the New York Bight (NYB). The extraction of sand potentially conflicts with healthy functioning and continuation of marine ecosystems and fisheries. Considerations of the potential impacts of sand dredging and transport to shore include cumulative impacts, space/use conflicts with fisheries extraction, and EFH conflicts.

1.2 Understanding Extraction as Perturbation

Sand resource extraction, or dredging, removes sand substrate and infauna, produces turbidity plumes, and changes bathymetric contours (Pickens and Taylor 2020). Contours and texture (bottom roughness) influence topographic steering including upwelling (Butman 1987; Dalyander et al. 2013; Glenn et al. 2004), see reviews by Michel et al. (2013), Pickens et al. (2020), Wenger et al. (2017). When sand is extracted, damage to the community that depends on it is expected through removal or screening of infauna, exposure to hypoxic sediment horizons and thinning of the oxygenated sediment layer suitable as habitat, resorting of sediment sizes appropriate for different infauna, burial of epibenthic fauna and fish eggs from sediment plumes, clogging of fish gills, behavioral response such as movement, and the consequent depletion of infaunal prey and their trophic transfer to fishes (Nairn et al. 2004; Pickens et al. 2020; United States Army Corps of Engineers 2015). However, similar to the case for natural disturbances, such communities should be expected to recover (see review by Nairn et al. (2004), Waye-Barker et al. (2015)). Recovery can vary in mechanism, timing, or trajectory following a successional dynamic and relative to the type of extraction equipment, substrate, and location (Grassle and Sanders 1973; Pickens et al. 2020). These disturbances occur within a background of diurnal and seasonal photoperiod and production cycles, upwelling, seasonal and advective temperature changes, storms, disease and predation dynamics, migrations, and successional community dynamics that introduce natural variability in the system. Sand resource extraction may emulate aspects of other anthropogenic disturbances such as bottom trawling or clam suction harvest or scallop dredging (Sullivan et al. 2003). Disturbance (defined as “any discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment” (Pickett and White 1985)) or more generally an unbiased perturbation, is an important ecological structuring mechanism, especially as a driver of diversity through interruption of community succession by the suppression of otherwise dominant species (Grassle and Sanders 1973; Hardin 1960). This literature synthesis therefore focuses on a contextual view of spatial and temporal dynamics as perturbations that influence fish and macro invertebrate production and distribution.

1.3 Report Structure

The guiding questions in this literature review and accompanying data synthesis are the following: *what conditions naturally drive dynamics and distribution of fish populations in the study area, and how do these mechanisms scale compared to perturbation from sand resource extraction?* These questions address three specific objectives:

1) To better understand demersal and benthic organisms’ use of habitats and sand features in the Mid-Atlantic for BOEM’s Marine Minerals Program (MMP) to inform and evaluate the use of potential sand borrow areas in Federal waters.
2) To identify gaps and recommend methods for filling gaps. This synthesis should provide a baseline understanding of distribution (diversity and abundance) of demersal and benthic organisms relative to seafloor morphology, and seabed and substrate sedimentary texture.
3) To compile existing datasets into an accessible format. This serves the synthesis of new ideas and testable hypotheses.

This synthesis treats first the abiotic or physical setting (geographical, geological, hydrological, and climatological) and primary productivity setting as a dynamic niche space. Next it treats ecology of NYB fishes and invertebrates starting with the most dynamic stage, early life history and dispersal, followed by habitat use, migration, and range shift as a dynamic response to these factors. Treatments of individual species or species groups follow for those that are likely to be encountered in the region of interest for extraction (see Section 2.1 Geographic Definition) and that have commercial or ecological importance. Species that are common to the NYB and exclusively inshore or offshore (e.g., the tilefish *Lopholatilus chamaeleonticeps* and *Caulolatilus microps*) are not treated. Fisheries are also reviewed.

We conclude with knowledge gaps and recommendations based on a quantification and classification of the available literature, including an appendix of uncited but relevant literature.

A companion volume (**Volume 2: Data Synthesis**) analyzes the spatial temporal distribution of fishes (in both PDF and electronic format) and provides a dynamic crosswalk between predator and prey.

2 Physical Habitat of the NYB

2.1 Geographic Definition

The NYB is a region geographically defined on the west and north by the bowed US coastline and to the east and south as a line drawn between Montauk Point, NY, and Cape Henlopen, DE (**Figure 1**). The apex of the NYB is the entrance to the Hudson River estuary. The Hudson River's historical channel continues across the apex of the NYB as the submarine Hudson Shelf Valley (Beardsley and Boicourt 1981; Castelao et al. 2010; Chen 2018; Chen et al. 2018; Epifanio and Garvine 2001), with important influence on the regional benthic structure and circulation, and therefore on composition of fish and invertebrate communities and on fisheries. The NYB and its apex are concentric with the broader Mid-Atlantic Bight (MAB) defined from Cape Cod, MA, to Cape Hatteras, NC. The NYB must be understood within the context of the MAB's features. However, the geomorphology differs (see Geology), and despite a MAB-wide circulation driver, a strong zonal temperature cline (see Circulation) shapes ecological communities and dynamics of the NYB relative to the MAB.

Due to technological constraints, sand extraction normally occurs in depths of 30 m (98 ft) or less, but this study area extends to 50 m (164 ft) to encompass a buffer should technology advance dredging into deeper waters. This depth corresponds to an offshore distance of about 16.7 km (9 nm). The study region is bounded shoreward by Federal jurisdiction beginning at 3 nm (**Figure 1**). This area focuses the synthesis.

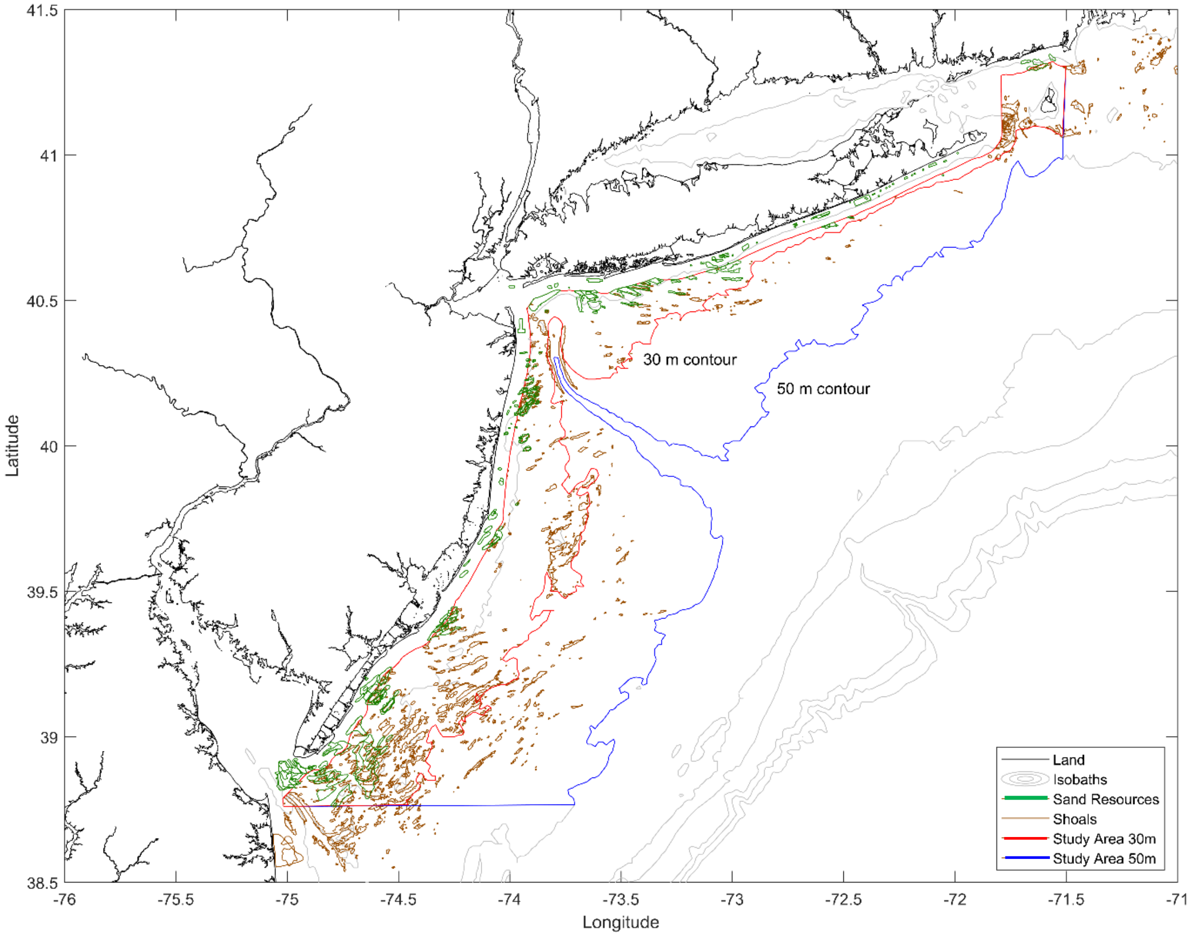


Figure 1. BOEM marine minerals study area in the NYB

A priority (to 30-m isobath) and extended (to 50-m isobath) study areas are identified. Sand resources depicted in this feature class were identified and characterized during various reconnaissance- and design-level studies where geological (e.g., sediment cores, sediment profile images) and geophysical (e.g., high-resolution swath bathymetry, side scan sonar, seismic reflection profiles, magnetometer surveys) data were collected, at least in part, to evaluate OCS sand resources. Delineations mainly consist of approximate delineations based on interpretations of data, drawings, and/or descriptions found in related study reports. Sand resource polygons were provided by BOEM in Esri shapefile format, and follow-up discussions were made with MMP scientists to assign the evaluation stage associated with each polygon in regards to the presence of restoration quality sand and gravel. “Shoals” features are modeled based on the same physical same data but do not consider economic constraints used to classify sand resources.

The seafloor of the NYB is a complex sedimentary wedge of a passive continental margin historically supplied by glacially milled till of the North American ice sheets as well as accumulated biogenic sediments. These sediments are trapped seaward by a sill of relict carbonate reefs (Kennett 1982; Twichell et al. 1981). Resuspension/redistribution of surficial sediments continues (Butman 1987; Dalyander et al. 2013). Aggregates including silt-clay, sand, and gravel dominate the MAB/NYB seafloor with relatively few hard outcrops in comparison to the rocky active margin of the western US or the Gulf of Maine or the reef-built carbonate platform of the South East US Continental Shelf (SEUSCS).

The northern margin of the NYB (Long Island), is a series of parallel terminal glacial moraines that continue underwater to emerge again as Plum Island, Block Island, Nantucket Shoals, Martha’s Vineyard, and Cape Cod before ending as the submerged Georges Bank (**Figure 2**). No large rivers empty directly onto the continental shelf of the NYB north of the Hudson Shelf Valley. Instead, mainland rivers from

Connecticut flow into the Long Island Sound, which then circulates westward through the East River into the Hudson River or over the submerged moraine sill to the east. However, about 120 km (65%) of the southern Long Island shore is fronted by a barrier island, the shallow lagoons of which trap, slow, and direct freshwater flows into highly productive lagoonal estuaries that exchange through several inlets along this shore. The shelf slopes quickly and evenly in comparison to the southern part of the NYB. The Hudson Shelf Valley defines the southern facies change boundary geologically, and coincides with the emptying of the combined Hudson River, East River, and Raritan River flows between the southern end of the moraine (Far Rockaway) and a rocky headland, New Jersey Highlands, to the south.

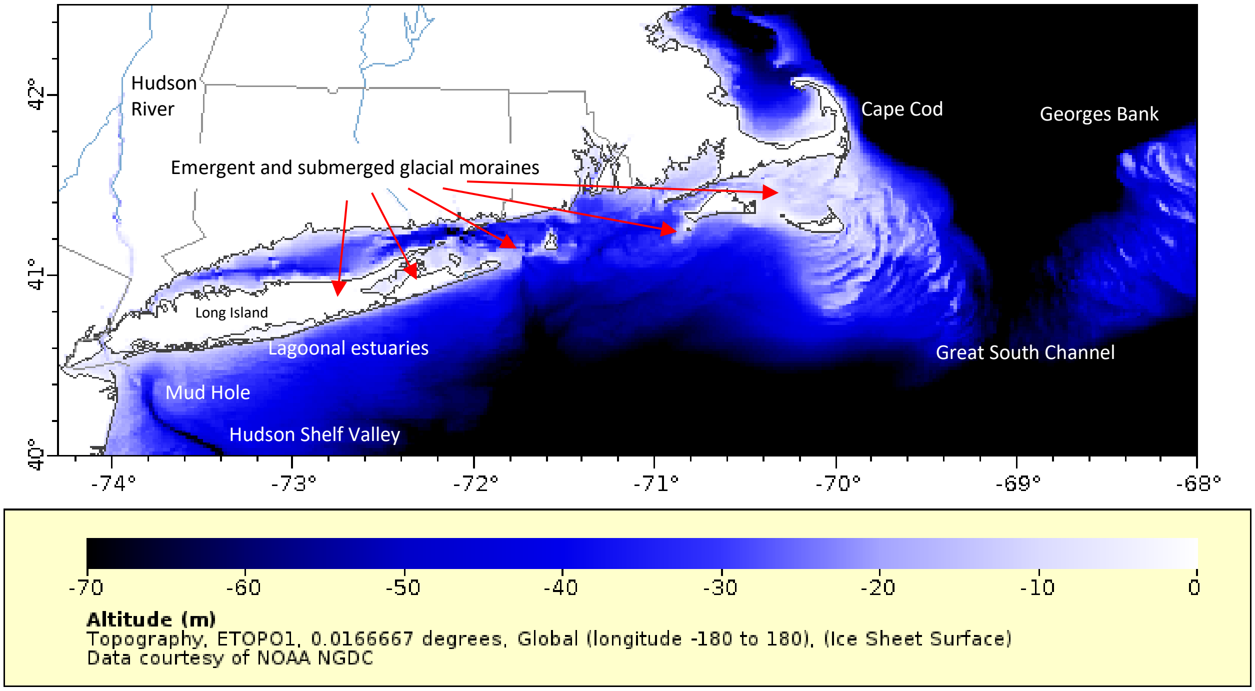


Figure 2. Northern NYB bathymetry

Scaling is focused on 0–70 m (0–229.7 ft) in order to emphasize bathymetric relief in the depths of interest while also showing its contextual surroundings. Generated in https://nybsand.marine.rutgers.edu/erddap/

A barrier sand spit (Sandy Hook) is formed from the northward sediment transport of long-shore flow at the northern terminus of the Atlantic Coastal Plain. The spit narrows the Hudson/Raritan estuary opening and accelerates the current, so that large migratory sand waves characterize the bed morphology there until current velocity slows. The relict channel of the Hudson River, carved at low sea stand, is depositional due to the deepening, and thus slowing, of water and is filled with finer sediments than the surrounding shelf. This corresponds with a Historic Area Remediation Site (HARS). Sediments there are diverse and include natural rocky outcrop of the canyon wall, as well as silt and rocky or cement debris from harbor clearing (Fabrizio et al. 2013; Fabrizio et al. 2014; Lathrop et al. 2006). South of the Apex, the New Jersey Coastal Plain is drained by several rivers, including the Mullica River and Great Egg River, but these empty first into 130 km of barrier island lagoons (Barnegat Bay Estuarine Complex, Great Bay, Egg Harbor). Coastal Plain sediment from ebb tide deltas at both active and relict inlets is reworked into a series of shoreface sand ridges, resulting in a “ridge and swale topography”(Hayes and Nairn 2004; Stahl et al. 1974) known to fishers as “lumps” that may rise as much as 15 m above the surrounding seabed. These occur both close to shore (e.g., off geologically recent inlets) and as relict features farther offshore, which were formed when inlets occurred further east during low sea stand (Goff et al. 1999; Swift et al. 1973). Finally, the Delaware Bay estuary of the Delaware River is a drowned river valley that empties between Cape May, NJ, and Cape Henlopen, DE (**Figure 3**).

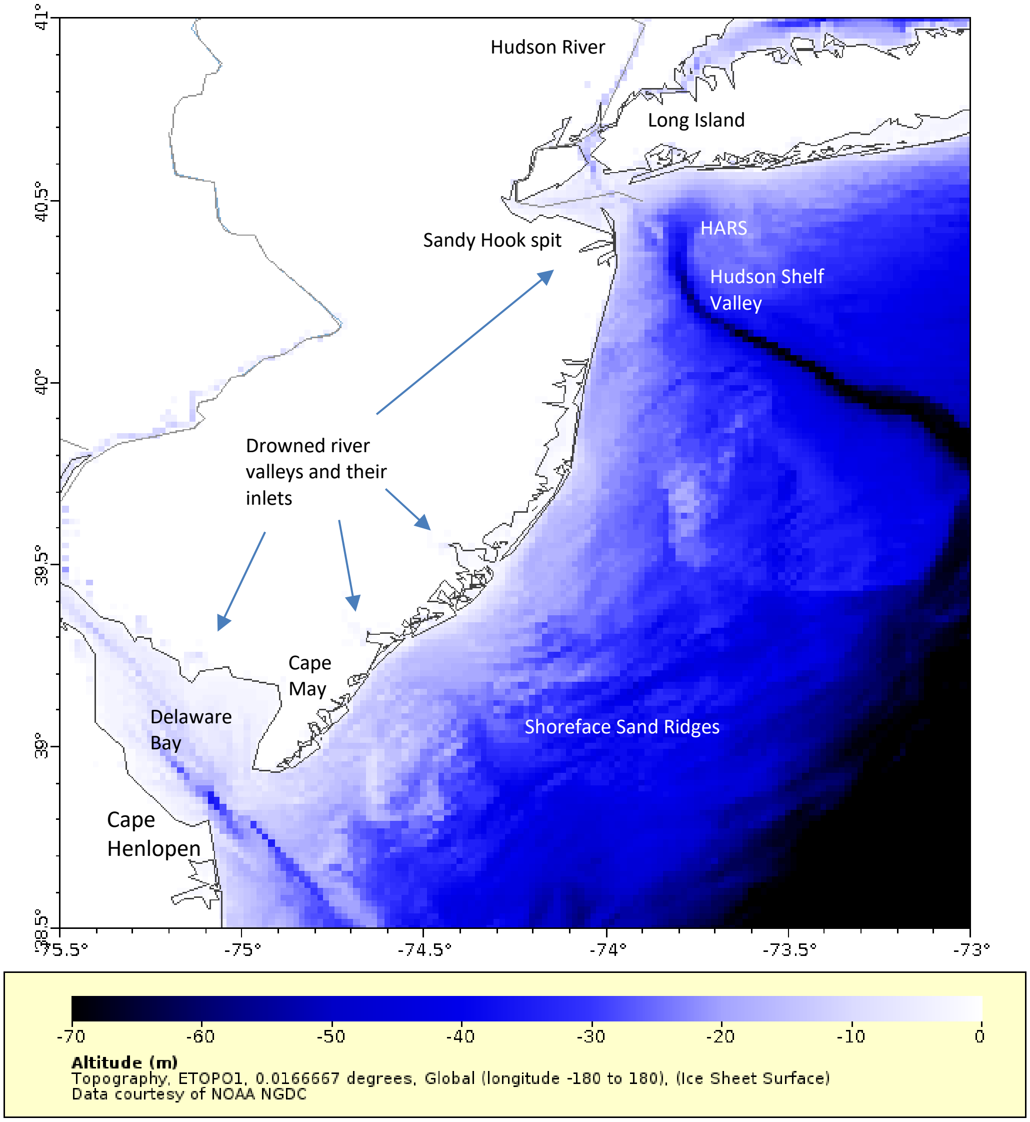


Figure 3. Southern NYB bathymetry

Scaling is focused on 0–70 m (0–229.7 ft) in order to emphasize bathymetric relief in the depths of interest while also showing its contextual surroundings. The prevalence of shoreface sand ridges owes to inlets of drowned river valleys in the southern half of the NYB, where these are blocked by Long Island in the northern half. Generated in https://nybsand.marine.rutgers.edu/erddap/

2.2 Circulation

Several important features define the large-scale circulation of the MAB and the NYB with consequences to fish dynamics. These include the northeastward departure of the warm saline Gulf Stream from along-shelf flow at the Charleston Bump near Cape Hatteras, the southwestward leakage of cold saline water around Cape Cod west to hug the shoreline from the north, and a surface lens of oligohaline water issuing from the three great (and several smaller) estuaries that also turns south along shore until it meets Cape Hatteras (Beardsley and Boicourt 1981) (**Figure 4**). As this low salinity shelf water and plume water approaches Cape Hatteras, both are entrained into the Gulf Stream as Ford Water back northward along the outer shelf and slope, resulting in a cyclonic counter current (Slope Sea) trapped on the broad shelf by the western Gulf Stream edge (Aikman and Posmentier 1985; Levin et al. 2018)). This circulation is modified by several smaller scale features (**Table 1**).

Table 1. Mesoscale circulation features of the MAB

Feature	Description	Behavior
Shingles	Gulf stream meander crests[1,2,3]	Shear off into the Slope Sea
Warm Core Rings	Shear off into the Slope Sea[1,2,3]	Erode into the Slope Sea or traverse south to rejoin Gulf Stream
Intrusions	Lateral tongues of warm salty slopewater[2,4]	Follow isopycnals westward onto the cooler fresher shelf at mid depths
Cold Pool	Relict Gulf of Maine water[5,6,7,8]	Southward winter flow is trapped on the NYB shelf during spring and summer by geostrophic force and thermocline
Buoyancy Driven Plumes	Fresh surface lenses from the Hudson River and smaller estuaries[2,4]	Tend to turn south and hug the coast due to Coriolis force, but may drive circulation and production well out onto the shelf

[1]Churchill and Cornillon (1991b), [2]Aikman and Posmentier (1985), [3]Beardsley and Boicourt (1981), [4]Flagg et al. (2006), [5]Houghton et al. (1982), [6]Chen (2018), [7]Chen et al. (2018), [8]Lentz (2017)

Seasonal warming, wind, and bathymetry help drive the formation and behavior of these features. Following a long summer photoperiod, winds—especially northeasterly and tropical storms—erode summer stratification to release the Cold Pool and episodically allow it to flow southeastward off the shelf edge, as well as force circulation opposite or orthogonal to the buoyancy driven flows. Friction from the bottom topographically steers the resulting currents, (Lentz 2017) (**Figure 4**), which in turn structure water column habitat for fishes (Manderson et al. 2009).

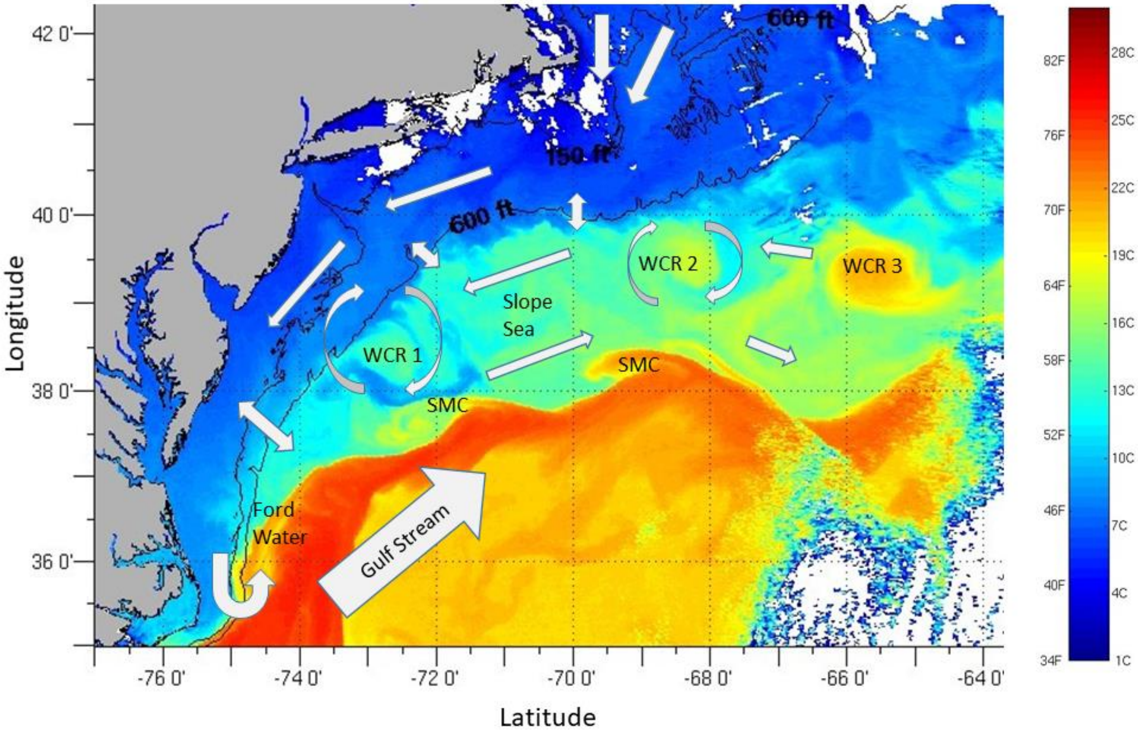


Figure 4. Circulation features of the MAB
Vectors showing direction of flow superimposed on false color imagery of sea surface temperature from March 9, 2020, characteristic of the water masses supplying the flow. Three warm core rings (WCR 1, WCR 2, WCR 3, labeled by rank from oldest to newest) are evident, as is the state of eastward progression, erosion of boundary, and temperature with age progression and mixing with surrounding water. The figure also indicates sheared meander crests (SMC) of the Gulf Stream, cross frontal flux including subsurface shelf intrusions and strengthening to the south, and a surface expression of subsumed Ford Water (the loss of shelf water due to Gulf Stream friction). AVHRR image is from NOAA-18 satellite processed and archived by the Rutgers Coastal Ocean Observation Lab.

2.3 Climate and Seasonality

The climate of the NYB reflects that of the MAB and is distinct from that of the Gulf of Maine and SEUSCS. Climate is a major constraint on primary productivity and introduces important dynamics to the general circulation. The NYB is far enough north to have a long summer photoperiod but far enough south that photosynthetically active radiation (PAR) flux is high and the Gulf Stream and its recirculation warm the bight. It is also far enough south to be regularly impacted by hurricanes, tropical storms, and their remnants in summer and fall, and far enough north to be affected by nor'easters in fall and into winter. The result is fast vernal warming and high chlorophyll concentration in surface water that works in concert with spring estuarine freshets to isolate the deeper southward Gulf of Maine flow through strong stratification. Another result is summer formation of a distinct river of isolated cold and lower salinity bottom water, the Cold Pool, along the middle of the NYB (Lentz 2017). The resistance to vertical mixing creates a positive feedback loop, so that Gulf of Maine water that continues to enter it the NYB from the north is seasonally trapped. This cold water is also shaded from PAR by chlorophyll in the surface layer, so that primary production and oxygen evolution are depressed. The Cold Pool is normally constrained to the middle shelf as a current that pushes through the NYB towards eventual mixing off Cape Hatteras. By August of most years, it may be cut off from its Gulf of Maine source to the north so that it is isolated as a relict pool to the middle of the NYB coincident with the region of interest, but it may periodically flow eastward much further to the north, leaving the southern part of NYB to warming flooding by shelf and slope water (Fisher et al. 2014; Lentz 2017). The cold, hypoxic water of the Cold Pool may also be brought to the surface by summer coastal upwelling. Coastal upwelling happens when long-shore (south westerly) winds push the surface water mass at right angles to the coast (due to Coriolis force) so that water from below the seasonal thermocline must replace it (Glenn et al. 2004). Such events may also disrupt fish activity (Mann and Grothues 2009) and kill warm-adapted active fish such as Northern Puffer *Sphoeroides maculata* and Scup in mass mortality events (Collette and Klein-MacPhee 2002). These upwellings are steered or trapped into eddies in part by shoreface sand ridges (Glenn et al. 2004). Eventually, late summer storms become strong and frequent enough to mix through the surface layer. The Cold Pool is rapidly warmed by entrainment of the surface layer and vice versa, homogenizing the water column and warming the benthic layer ahead of winter. These storms may also be strong enough to perturb the sediment and suspended fine grained material in the water column (Miles et al. 2013a; Miles et al. 2015). Seasonal winds are also an important part of cross-shelf exchange. Prior to spring, a strong shelf-break front embedding a long-shore, buoyancy-driven flow forms at the meeting of the Gulf Stream-warmed Slope Sea and the MAB shelf water (**Figure 5**). This front extends from the benthos to the surface and traps or concentrates fish larvae arriving from southern spawning regions to its eastern (offshore) side (Grothues and Cowen 1999). Erosion of the top of the front by northeasterly wind in spring and summer allows this water to spill onto the shelf water and further aids the transport of fish larvae in the upper layer towards coastal nursery habitat (Hare and Cowen 1996; 1997).

Figure 5. Surface expression of a front between shelf and Gulf Stream originating water
A sharp division between coastal (green) and oceanic water (blue) is an expression of resistance to mixing. Because it floats, *Sargassum* (orange color), a brown algae, has accumulated at the convergence as one or both adjacent water masses sink rather than mix. Flows may also converge at the bottom, forcing the two adjacent water masses up, where they diverge back towards their origin along with their respective plankton, including larval fish. Image credit: Dr. Frank Hernandez, University of Southern Mississippi.

Overall, the seasonal range of temperature of the NYB, which is at the center of the MAB, is the greatest of any oceanographic province in the world. Within its estuaries, lows reach -1.2 C° in winter, and highs can reach 36 C°. However, this range is moderated offshore by thermal inertia of the great mass and by advection of Gulf Stream or slope water, including up through the Hudson Shelf Valley (Churchill and Cornillon 1991a; 1991b; Flagg et al. 2006), and the lag effect of very warm surface layers having been mixing down to the bottom and away from subsequent surface cooling in fall (Aikman and Posmentier 1985; Castelao et al. 2010; Miles et al. 2013a). The consequence of these dynamics on fish distribution and seasonal abundance is treated in **Section 3**.

2.4 Productivity and Benthic-pelagic Coupling

Primary production is necessarily limited by PAR and nutrients. In contrast to regions just north, day length and solar zenith in the NYB are sufficient for high productivity even in winter. In spring, the rate of primary production is high from increased PAR, but the standing crop of phytoplankton is grazed down by zooplankton early so that spring blooms do not occur regularly as detectable seasonal maxima in the NYB (Friedland et al. 2015). Zooplankton in the region of interest specifically (but not further out on the shelf) of the NYB, especially the copepods *Centropages typicus* and *C. hamatus*, appear to access this production early (Durbin and Kane 2007; Friedland et al. 2015). Chlorophyll concentration declines from a winter high until at least late June. The timing between chlorophyll maxima and zooplankton maxima is inverted, possibly because timing of secondary production is limited by benthic temperature and the emergence of copepods from benthic diapause instead of by phytoplankton availability (Friedland et al. 2015), or because it is under nutrient limitation controlled by river discharge on the inner shelf and wind mixing on the outer shelf (Xu et al. 2020). There is no detectable relationship between chlorophyll concentration and zooplankton biomass by year on the continental shelf of the NYB.

For temperate systems globally, including proximal to the NYB, the assemblage structure of a zooplankton community responding to a bloom is set by the lag time between the two. This assemblage structure is an important determinant of recruitment success for fishes in many temperate systems because the species and size of zooplankton determine the energy transfer rate (Friedland et al. 2008). Variable lag time may thus contribute to high variability in early feeding success or mortality rates of fishes in the NYB. It is possible that the early access of phytoplankton by zooplankton emerging from the benthos or staying year-round in the water column prevents an excess crop of phytoplankton that would (in other systems) be un-grazed and transferred to benthic invertebrate production, but is instead transferred to a pelagic trophic system. If this is the case, recruitment variation in fishes is under middle-up-and-down trophic control. The dynamics of these zooplankton could be under temperature control. If the winter water gets cold enough, these will form a resting diapause phase in the sediment (Friedland et al. 2015; Friedland et al. 2018), see also Water Temperature Change section.

3 Ecology of NYB Fishes and Invertebrates

3.1 Early Life History

3.1.1 Pelagic Larvae

The majority of bony fish and invertebrates (and especially managed species in the NYB) begin life hatched from semi-buoyant drifting eggs and grow through a planktonic larval dispersal phase before metamorphosing into juvenile forms. For benthic species, metamorphosis is dramatic (**Figure 6**). For fishes, it is typified by squamation (development of scales), extensive pigmentation, hardening of bony elements such as fin spines, and musculature for robust swimming (Moser 1984; Richards 2006) and usually coincides closely with settlement and the adoption of new habitat, feeding, and movement habits.

Figure 6. Transforming Witch Flounder larvae
Larvae of Witch Flounder *Glyptocephalus cynoglossus* collected in the NYB during transformation. The lower individual is further along in the eye migration from the left to the right side of the fish. White flesh is an artifact of preservation in ethanol. Early pigmentation is apparent over an otherwise translucent or transparent body, and fin rays have developed to support the dorsal, anal, and caudal fins. The yolk sack is gone, and the gut is complete in these individuals of about 25 mm length. Image credit: Rutgers University Marine Field Station

For invertebrates, the metamorphosis may be even more dramatic and in many taxa larvae are the only truly motile form preceding a sessile or buried adult phase that can neither migrate nor pair (Brusca et al. 2016). This pelagic larval phase, common to marine fishes and invertebrates worldwide, promotes wide dispersal from spawning sites (Able and Fahay 1998; 2010; Boehlert and Mundy 1988; Grothues et al. 2002; Leis 1991). As allowed by the circulation pattern discussed in Section 2.3, the NYB is populated by larvae of species from the Gulf of Maine, SEUSCS, and even the Sargasso Sea, as well as local areas (Able and Fahay 2010; Able et al. 2011a; Morson et al. 2019; Sebunka and Silverman 1989). Use of the NYB as a nursery by fishes with southerly adult ranges may be an evolved trait that capitalizes on the high productivity of the MAB and access to its unique concentration of estuaries (Able and Fahay 1998; 2010; Able et al. 2011a; Able et al. 2017; Able et al. 2009; Able et al. 2012b; Hare et al. 2005; Juanes et al. 1994). Recruitment in OCS waters occurs year-round due to the mix of northern, central, and southern affiliated species and arrival of larvae that use the regions estuaries—especially between May and June, when productivity increases (Section 2.5)—so that their larvae or growing juveniles have abundant food (Able and Fahay 1998; 2010; Juanes et al. 1994) (**Figure 7**).

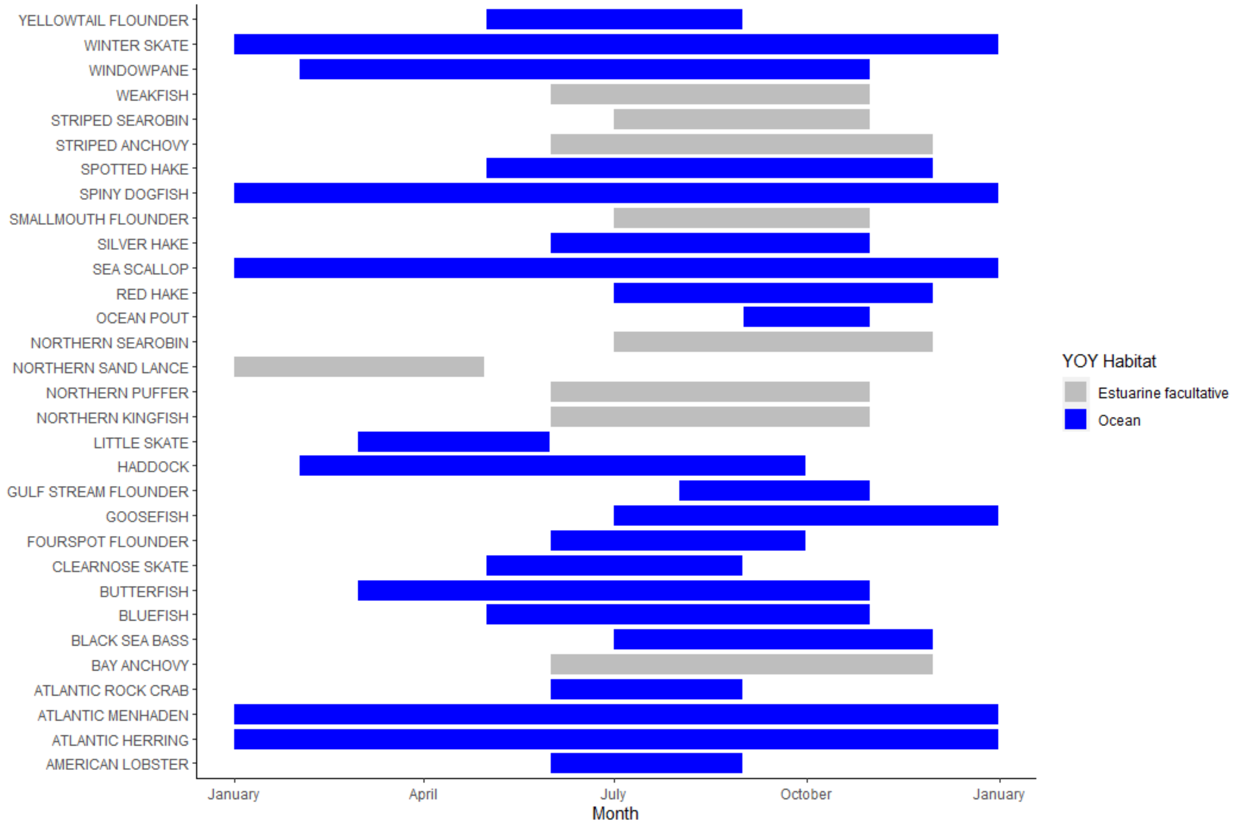


Figure 7. Seasonal trends in fish recruitment

Gant plot of recruitment timing for selected species that use the NYB study area as nursery habitat. Recruitment is defined here as settlement from the plankton to the substrate or parturition in the case of live birth or egg case laying. Species that remain entirely pelagic or entirely in estuaries during their first year are not considered. Data is drawn from Palma et al. (1998), Steves et al. (1999), Collette and Klein-MacPhee (2002), Hart and Chute (2004), Sulikowski et al. (2004), Able et al. (2007), Able and Fahay (2010).

Mortality is extremely high previous to settlement or even during pelagic juvenile stages, usually exceeding 99% in the first month (Houde 1987; Houde 2006). Although larvae are still too small to swim effectively relative to water viscosity (Vogel 1994), they are able to influence their orientation and position in the water column to influence their fate in terms of transport (Boehlert and Mundy 1988; Checkley et al. 1988; Epifanio and Garvine 2001; Hare et al. 2005; Hare and Cowen 1996; 1997; Rowe and Epifanio 1994a; 1994b). Estuarine dependency is an evolved trait common to many species of the MAB/NYB (Able and Fahay 1998; 2010). This trait capitalizes on the high availability and productivity of the warm, shallow, oligotrophic and structured estuaries described in Section 2.2 (Geology) that is a defining character of the NYB. Estuarine-dependent or facultative users are called out specifically in the individual taxa treatments below. The pelagic egg and larval stage of most NYB bony fishes means that these life stages likely do not intersect with sand extraction activity, and the segregation of estuarine-dependent juveniles further isolates these from perturbations on the shelf specifically, in contrast to their vulnerability to estuarine dredging, where both direct removal and burial by plume silt is a threat (Kennish 1992; Wilber and Clarke 2001). However, the settled juveniles of many non-estuarine-dependent species do potentially intersect with offshore dredging) (Vasslides and Able 2008) as does the activity of adult fishes (**Appendix A**).

3.1.2 Anadromy and Brooding

There are several important exceptions to the common pelagic dispersal life history stage of NYB continental shelf fishes. Economically and ecologically important Atlantic Horseshoe Crab, which do occupy OCS habitat as adults (Swan 2005), migrate inshore to bury their eggs on estuarine sandy beaches above the tide line; larvae and early juveniles stay in estuaries (Botton 2009; Burton et al. 2009; Rudloe 1981). Winter Flounder (*Pseudopleuronectes americanus*) lay sticky demersal eggs in estuaries and on the shelf. Several managed species that occasionally occur on the OCS, Striped Bass (*Morone saxatilis*) and Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), are anadromous and their eggs, larvae, and juveniles to several years of age remain primarily in natal rivers, while three Alosine herring species are anadromous with river residence time of many months each year. Ocean Pout (*Macrozoarcies americanus*), a managed eel-like relative of the cod that utilizes OCS sediment habitat, are brooders that guard demersal gelatinous egg clutches in crevices of rocky outcrops, trash, or shells; larvae are semi-pelagic. Another brooder that supports a limited pot fishery, Oyster Toadfish (*Opsanus tau*) moves to estuaries to spawn (Able and Fahay 2010). Lined Seahorse (*Hippocampus erectus*) and Northern Pipefish (*Syngnathus fuscus*) are pouch brooders, typically in estuaries although the adult stages migrate onto the continental shelf (Able and Fahay 2010). Northern Pipefish are probably minimally important as forage because they are common, but not abundant, prey of piscivores. Harvest of Lined Seahorse is restricted for the aquarium trade under a voluntary agreement after CITES Section II listing as a species of concern (U.S. Fish and Wildlife Service 2004). Early life stages of most, but not all, commercially important brooders and all anadromous fishes are thus isolated from sand extraction on the continental shelf even though they may be extremely vulnerable to sand extraction or dredging in estuaries.

3.1.3 Live Birth and Egg Capsule Birth

No elasmobranchs (sharks, rays, and skates) have a planktonic egg or juvenile dispersal phase. All have small broods delivered through one of three mechanisms; viviparity (live birth after gestation supported by a placenta-like organ and intrauterine cannibalism or ovophagy), ovoviviparity (live birth after internal egg hatching), or ovipary (egg laying) (**Appendix A**). Only the oviparous species have an egg stage on the benthos. In the NYB, the leathery rectangular egg capsules, or “mermaids purses,” of skates have hooked stiff filaments called “horns” protruding from the corners that promote entanglement with algae, gravel, or shell hash (Carrier et al. 2012) and help conceal it and keep it from drifting (**Figure 8**).

Most elasmobranchs, including those of the NYB, mature late compared to bony fishes (Hoenig and Gruber 1990). Brood sizes range from one to a dozen live births depending upon the species, and egg capsules contain from one to seven individuals, also species dependent. The variation in delivery cuts across higher taxonomic order, with egg (capsule) layers among the skates (Rajidae) and also some sharks, and ovoviviparity in Myliobatid rays (**Appendix A**). Several NYB species, such as Sand Tiger Shark (*Carcharias taurus*), Sandbar Shark (*Carcharhinus plumbeus*), and Dusky Smoothhound (*Mustelus canis*, also known as the Smooth Dogfish) promote estuarine nursery habitat by parturating in estuaries, with residence times of months for the pups before moving onto the shelf (Casey et al. 1985; Conrath and Musick 2002; Rountree and Able 1996). The females of other species, including White Shark and Common Thresher Shark, are thought to parturate at certain continental shelf sites based on the distribution of pups and movement of tagged females. The extended and annually repeated residency behavior, and the subsequent distribution of juveniles relative to other areas, is indicative of nursery use (Heupel et al. 2007), but how nursery is functionally delineated for sharks when their predators are not restricted from access is unclear. A nursery for White Sharks (*Carcharadon carcharius*) was recently discovered within the northern NYB off Montauk Point, Long Island, based on electronic tagging, which showed localized residence in water less than 50 m deep for up to 11 months and return to this location during migration in their early years (Curtis et al. 2018; Curtis et al. 2014b).

Figure 8. Mermaids Purse

The egg case of a skate with projecting "horns" that tangle and hold the case in place on the bottom. The case has split along the top edge to release the neonate, contributing to the "purse" moniker. Image credit: Danny Schissler under Wikimedia Commons licensing.

3.2 Overwintering

"Overwintering" is recognized as a life stage in the ecology literature based on reduced physiological activity during cold temperature that is faced by fishes in the NYB and elsewhere (Hurst 2007). As for ontogenetically defined stages (e.g., larval stage, adult maturity), there are habitat requirements of this phase, such as reduced osmotic stress (see Water temperature change). A number of species that are centered in the Gulf of Maine seasonally shift south to overwinter in the warmer NYB (**Appendix A**). Some species centered within the NYB shift south to overwinter in the SEUSCS, while others shift offshore. Anadromous Striped Bass may overwinter in estuaries to reduce osmotic stress during this non-feeding period (Hurst 2007).

3.3 Distribution and Habitat Use

3.3.1 Habitat Suitability

Fish and invertebrate abundance and distribution reflects that of algae and zooplankton production (see Section 2.5) and a physiologically favorable environment in which to exploit that food for growth and reproduction. The physiological constraints are foremost sufficient dissolved oxygen and temperature, and their interaction; more dissolved oxygen is required by the higher metabolic rate stimulated by warmth but is often less available because solubility varies inverse to temperature. If these are met, physical habitat structure becomes an important determinant of distribution and abundance. Structural 3-dimensional elements create microhabitat niches on fine scale gradients of exposure to current, light, laminar vs. turbulent flow, concealment or disruptive pattern for camouflage, and holes or barriers for shelter against predators (Bartholomew et al. 2000; Scharf et al. 2006). This includes the vertical structure of sand waves—the ridges, slopes, and troughs of which harbor different invertebrate assemblages and even rugosity of sand deposits (Fabrizio et al. 2014). The troughs especially aggregate organic materials necessary for the growth of some filter feeders (Rutecki et al. 2014). Juvenile fish may shelter among debris accumulations and bedform features scaled to at least twice their own size (Auster et al. 1997; Auster et al. 1995; Auster et al. 1991; Diaz et al. 2003) (**Figure 9**). Fish distribution changes at night to occupancy of bare sand habitat, suggesting functional differences in value of foraging vs. sheltering habitat. Differences in grain size and sorting also structure habitat for fishes and invertebrates as it relates to burying or burrowing capability. This relationship is documented in the field and laboratory choice experiment in the Lesser Sandeel (*Ammodytes marinus*) (Wright et al. 2000), a congener of the American Sand Lance (*A. americanus*) and Northern Sand Lance (*A. dubius*), which are highly important forage species of the NYB. BOEM is currently funding research to investigate the impacts of dredging on Northern Sand Lance in the North Atlantic.

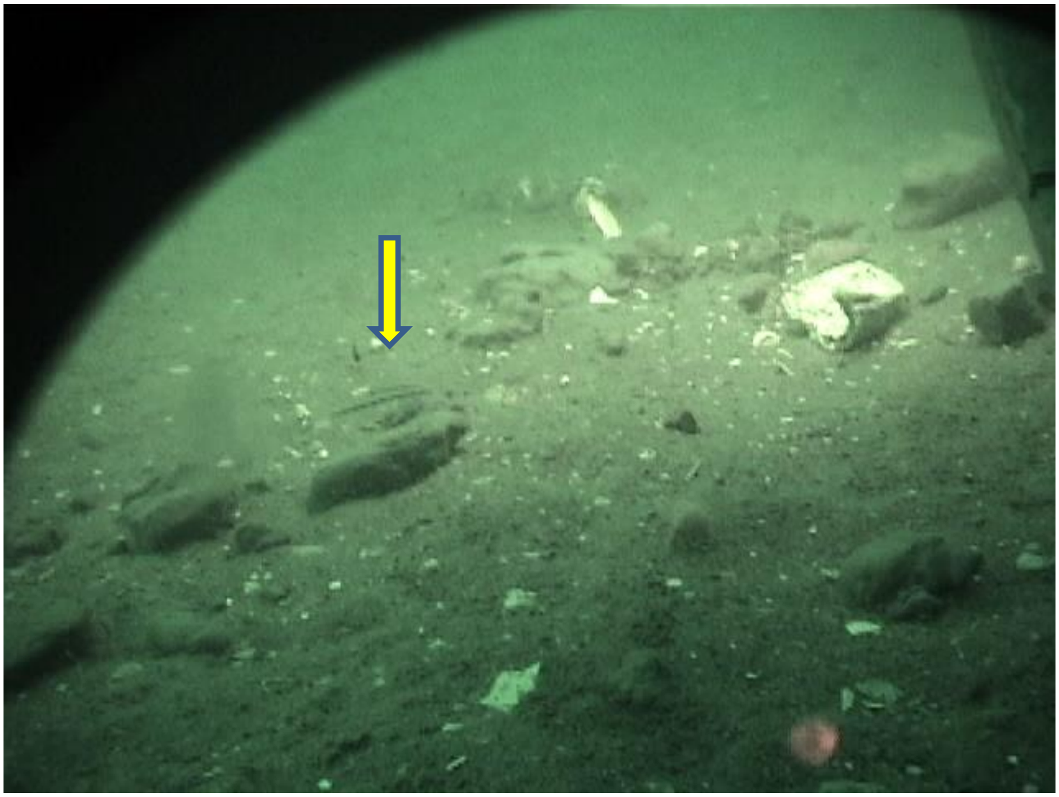


Figure 9. Juvenile Black Sea Bass sheltering

A juvenile Black Sea Bass (under arrow) shelters among aggregated clay clasts and shell hash on sand bottom off Delaware, as imaged in a screen capture from a video on a towed camera sled. The video shows the fish moving into the shell fragment to the right as the sled approaches and further shows the patchy distribution of the accumulations. Image credit: Dr. Robert Diaz.

3.3.2 Dispersal, Migration, and Ranging

The movement of individual juvenile and adult fish comes in three primary forms; each impart unique characteristics to the connectivity of fish habitat, even though the diversity of life history and habitat continuity scales blurs the definition of these forms into a spectrum. Dispersal and migration modify the first order of distribution by connecting temporally or spatially disjunct habitats, including habitats that provide resources only temporarily, and possibly for different needs. Migration is cyclical and reconnects an adult fish with disjunct spawning habitat and/or seasonal forage habitat (the “migration triangle”) (Harden-Jones 1968). For some fish, it can be triggered by cues that have little to do with habitat quality (Dingle 2006; Ramenofsky and Wingfield 2007; Sutherland 1996). Adults may move to spawn in areas that do not support adult fish growth because those destination areas naturally limit predators of their young. Within the NYB, Striped Bass and Atlantic Sturgeon undertake repeated upriver migrations. Fish of a single stock that mingle in one area may break into “contingents” with different migratory destinations or paths, including residency (Secor 1999; Secor and Piccoli 2007). Recognition of flexibility in migration is growing for a number of species along the US East Coast such as Striped Bass (Grothues et al. 2009; Secor 2000; Secor 1999), Winter Flounder (DeCelles and Cadrin 2010; Sagarese and Frisk 2011), and Bluefish (Shepherd et al. 2006). Dispersal is not cyclical and results in a net displacement or extension of range. For example, larvae of parochial species may be largely captive to currents and be transported to new places where they settle and stay (Boehlert and Mundy 1988). Both dispersal and migration differ in that sense from ranging, which is search behavior of local sensed habitat responding to prey patchiness or resource depletion (Sutherland 1996). Note that the definition for individual ranging (a movement type) differs from “population range,” which is the geographic limits at which a species may be distributed. There may also be microscale differences in resources as above, where juvenile fishes in the NYB may range around sheltering sand wave troughs and debris onto open sand at night (Diaz et al. 2003).

A disconnect among habitats that provide different or changing resources is possible. For example, a change from favorable currents or the lack of traversable connecting thermal corridor may result in favorable habitat being unfilled or habitat reached not being favorable (Hare and Cowen 1991; Manderson et al. 2011; McBride and Able 1998; Polacheck et al. 1992). Finally, evolution provides mechanisms for some species to exploit unfavorable habitat, at least briefly, for refuge or to pursue prey into these refuges. For example, some sharks and scombrids have counter current vascular plexus for retaining body heat in the eyes or swimming, or cardiac muscles to exploit prey in refuge water below the thermocline (Andrzejaczek et al. 2019). In the NYB, thermal refuges are particularly prevalent, which in the case of the Cold Pool can be accessed by vertical migration on the order of just 10–40 m or horizontally on the order of kilometers. Benthic structure, including sand itself and also benthic organisms or reef, is an important refuge as reflected in such traits as disruptive camouflage, lateral or dorsoventral compression, and burrowing ability (Ansell and Gibson 1993; Diaz et al. 2003; Ellis et al. 1997; Grothues et al. 2012; Olla et al. 1972).

In the NYB, the intense seasonal cycle drives both long-shore and cross-shelf annual migration of fishes and some invertebrates, resulting in a partial overturn of the shelf assemblage that is reset annually by egress/ingress. Because of the unique position between subtropical SEUSCS and subpolar Gulf of Maine large marine ecosystems, the NYB/MAB provides migratory destinations for species from both; migrants from the Gulf of Maine enter in winter to access warmer water and migrants from the south enter in summer to access more productive water. Young of other species arrive as expatriates of dispersal; some are able to grow to a size where ranging in response to cooling conditions allows retreat in winter, but for others this is a fatal sink (Hare and Cowen 1993; Hare and Able 2007; Hare and Cowen 1991; 1996; McBride and Able 1998). Thus, habitat use by benthic or benthic-coupled species in the NYB is highly dynamic, and this holds true even for “reef resident” species. For example, telemetered Black Sea Bass gradually vacated shallow (less than 28 m deep) reef and rubble at the HARS during autumn cooling

(Fabrizio et al. 2014). The extent of seasonal migration, which may define the population range, is then modified by oceanographic climate and events at many scales, from the 1–7 year modes of the North Atlantic Oscillation (NAO) to days-long slope-water intrusions, persistent wind-induced and topographically steered upwellings, storms, and plume water forcing **(Figure 10)**. Finally, within the NYB, fishes and invertebrates distribute relative to sand type, bathymetry, and surficial features selected on the basis of foraging, spawning, nursery, or refuge substrate (see individual species accounts and burial).

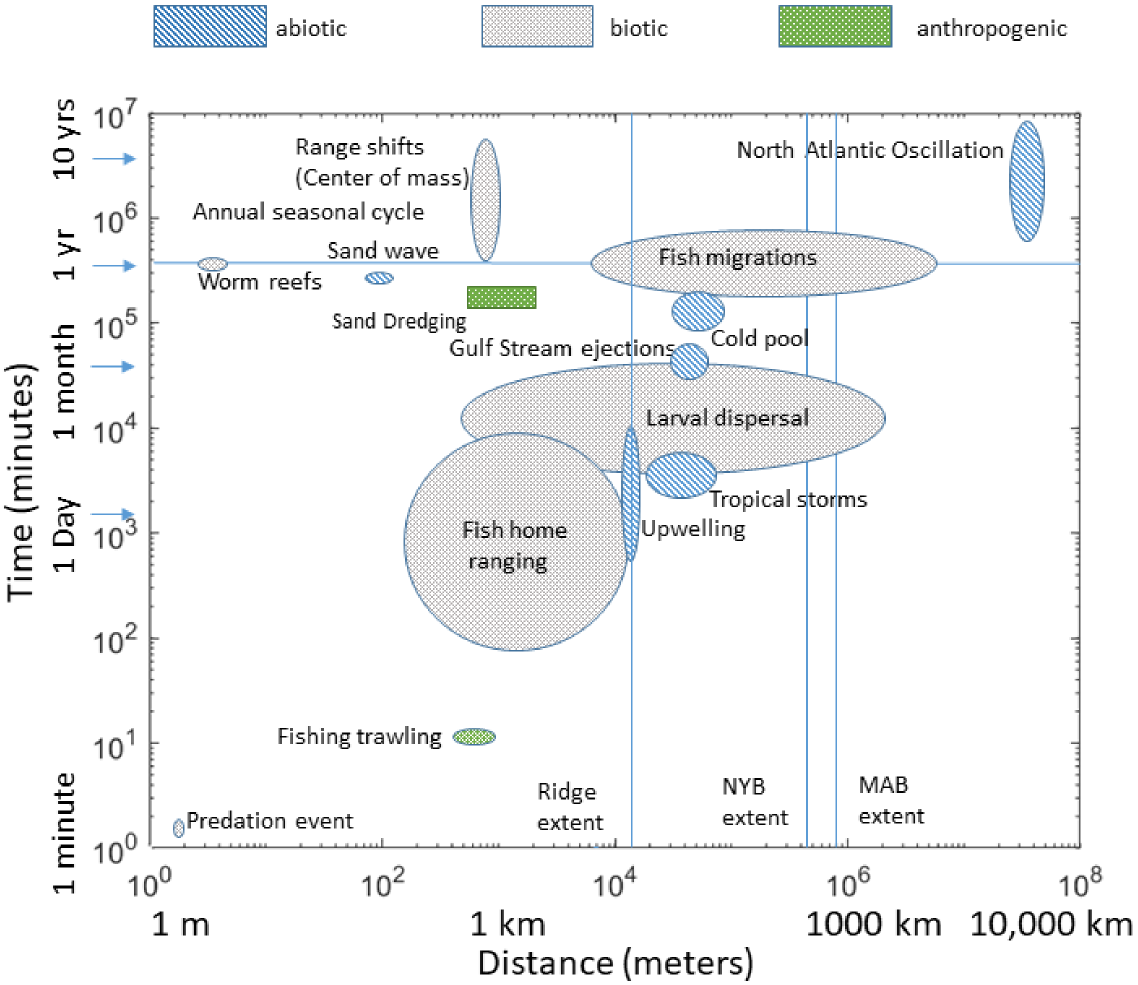


Figure 10. Perturbation scale

Scale of disturbance mechanisms that drive the dynamic distribution of fishes and invertebrates in the NYB for both temporal and spatial quantities or dynamics. Relevant to this synthesis, examples include temporal perturbations measures in years, seasons, months, weeks, days, and spatial disturbance scales of 100s, 10s or less kilometers, and down to meters following Vanblaricom (1982) and Hall (1994).

3.3.3 Burial

Many invertebrates (including commercially important clams, gastropods, and crabs) and many fishes (especially flatfishes, skates, and rays) bury. Burrowing into sediments is a principal defense of infaunal organisms to protect themselves from predation and potentially parasites. Horseshoe crabs burrow in sediment in response to decreasing water temperature or as a predator avoidance behavior (Stephens 1964; Vosatka 1970). Burrowing activity of Atlantic Surf Clam is linked to the animal's ability to cope with extremes in temperature and dissolved oxygen (Savage 1976). In natural conditions, surf clams rarely voluntarily evacuate their burrows; however, storms and strong currents can move clams a considerable distance from their burrows (Fay et al. 1983). In contrast, Ocean Quahogs can only intermittently burrow in sandy sediment and respire anaerobically for up to seven days (Taylor 1976). Laboratory studies show that surf clams burrow fastest at 16–26°C, and their burrowing rate declines as temperatures rise above 30°C (Savage 1976). Surf clams' siphons are approximately the clam's length, which allows them to burrow to depths equal to their shell length with their incurrent siphon protruding above the sediment (Ropes 1980; Ropes and Merrill 1973). Larger clams can burrow deeper to depths of approximately 12–14 cm, with their siphons positioned between smaller clams which are 2–4 cm below the sediment (Meyer et al. 1987). Research on surf clam burial depths is needed.

Slow-moving predatory gastropods, such as the Waved, Channel, and Knobbed Whelk, typically forage with their bodies buried below the surface sediment (Bruce 2006; Nielsen 1975; Powers and Kittinger 2002). Buried whelk emerge to the sediment surface to consume prey (Scolding et al. 2007).

Among fishes that bury, the ability to do so is achieved early in their life cycle, suggesting that it is important (Ellis et al. 1997). Selection of substrate by young settled flatfish is based on how easily they can bury in it (Corn et al. 2018; Gibson and Robb 2000; Nasir and Poxton 2001; Neuman and Able 1998), and this relates to habitat suitability for survival and development (Gibson and Batty 1990) (Section 3.2.1). Burial is important life history trait for adult Sand Lance (Bizzarro et al. 2016). However, the great majority of studies on burial focus on young (juvenile) fishes and are in estuaries or laboratory settings, and relatively few are for fishes in our study area of the NYB; see Grothues et al. (2012) and Neuman and Able (1998). Ease of burial may relate to habitat choice in adult flatfishes in marine shelf waters, e.g., McConnaughey and Smith (2000) in the Bering Sea, but this may also be a function of preferred prey. Reasons for burial are suspected to be mostly for concealment from predators (Ryer et al. 2004) and couples with cryptic coloration (Kelman et al. 2006). Ambush has also been suggested as a reason for burial by predators, as is evident in observations of species such as Goosefish and Northern Stargazer (a roundfish) and flounders (Stoner and Ottmar 2003), but Summer Flounder at least do not attack from buried ambush based on studies in large aquaria (Olla et al. 1972). Instead, burial by adult or large flatfish may help keep position in currents and is an energy-saving technique especially as it follows satiation (Olla et al. 1972), or it may provide a temperature refuge (Grothues et al. 2012).

3.3.4 Species Accounts

Examples for managed or ecologically important species or species complexes that occur in the NYB are treated in further detail below and in taxonomical order. This section synthesizes the ecology of the species or groups of species that share life history traits, including close ancestry, reproductive mode, trophic niche distribution, habitat use, and spatial and temporal distribution.

Species identified by an asterisk (*****) are included analytically in **Volume 2**.

3.3.4.1 Atlantic Horseshoe Crab*

Managed by the Atlantic States Marine Fisheries Commission (ASMFC), Atlantic Horseshoe Crabs (*Limulus polyphemus*) are distributed along the Atlantic coastline of North America. They are a multiple-use resource with economical, medical (Novitsky 2009), and ecological (Botton 2009) importance. The MAB, especially the NYB, serves as the primary spawning grounds (C. N. Shuster and Botton 1985) for Atlantic Horseshoe Crabs, supporting the largest population in the world (Atlantic States Marine Fisheries Commission 2019a). Population declines in the early 1900s were due to harvest of horseshoe crabs for fertilizer. Further decline in the 1990s was linked to exploitation for the bait fishery and biomedical harvest (Anderson et al. 2013; Atlantic States Marine Fisheries Commission 2019a; Berkson and Carl N. Shuster 1999). Coastwide population abundance has fluctuated through time but varies by region (Atlantic States Marine Fisheries Commission 2019a), resulting in the listing of this species as "vulnerable" by the IUCN Red List (Smith et al. 2016).

Adults are distributed along the inner continental shelf, typically in waters shallower than 30 m (Able et al. 2019; Botton and Ropes 1987). Atlantic Horseshoe Crabs are dietary generalists, feeding on mollusks, arthropods, and polychaetes that they encounter while moving over the bottom or by burrowing through the sediments (Botton and Haskin 1984; C. N. Shuster 1950). Horseshoe crabs can burrow in sediment in response to decreasing water temperature or as a predator avoidance behavior (Stephens 1964; Vosatka 1970).

During late spring, adults migrate from offshore to the intertidal, where they spawn in summer on estuarine sandy beaches (Botton et al. 2010; Swan 2005). This annual migration from overwintering deep waters to spawn is triggered by increasing water temperature (C. N. Shuster 1982; Watson 3rd et al. 2009). Horseshoe crab eggs serve as an essential food source for migratory shorebirds (Castro and Myers 1993), fishes (Nemerson and Able 2004; Nemerson 2001), and other estuarine species (Botton 2009). Atlantic Horseshoe Crabs in the MAB may spend numerous years in estuaries as juveniles, but burial precludes frequent capture for study (Able et al. 2019). Their residence time in the NYB and year's long residence in estuaries (and later in much of the continental shelf) means that they encounter a wide range of temperature and salinity, but preferences are not published.

3.3.4.2 American Lobster*

American Lobster (*Homarus americanus*) supports a fishery based primarily to the north of, and extending into, the NYB. They are found at a temperature range from -1ºC to over 25ºC but prefer temperatures between 5°C and 18°C at depths of 4–50 m (Northeast Fisheries Science Center 2017). There is evidence of extremely low recruitment for the Southern New England (SNE) stock in recent years. State surveys inclusive of New York through Massachusetts indicate that shell disease has become prevalent in lobsters in this region beginning in the 1990s (Atlantic States Marine Fisheries Commission 2015a); however, there are no consistent data on shell disease prevalence through time in New Jersey. There are two lobster management areas (LMAs) that overlap the NYB study area: LMA 4 from roughly Barnegat Inlet north and LMA 5 to the south. Both areas have instituted management measures to achieve a mandated 10% reduction in fishing effort in recent years, which included measures such as v-notching the tail to identify known released breeding females in case of recapture, release of all egg-bearing females, and seasonal closures (Atlantic States Marine Fisheries Commission 2018b).

In a ventless trap survey of New Jersey artificial reefs, American Lobster catch was lowest on sand sites in Little Egg Inlet, equivalent across all substrate types on Sea Girt Reef, and highest on sand sites on Manasquan Inlet Reef (Jensen and Zemeckis 2019). In a BACI design, traps were deployed on sand before artificial reef construction and subsequently on the constructed reef, and the change was compared to the change across the same years on two existing reefs (Jensen and Zemeckis 2019). Lobster catch-per-unit-effort (CPUE) decreased on the sand sites after deployment of artificial reef there, whereas the control traps had a significant increase in mean lobster CPUE of 0.05. The treatment traps had a significant decrease in mean CPUE of 0.23. Therefore, the net decrease in mean lobster CPUE was 0.28 lobster per trap per day (Jensen and Zemeckis 2019).

American Lobster are managed jointly by the states, ASMFC, and National Marine Fisheries Service (NMFS) outside the 3-mile state line (https://www.fisheries.noaa.gov/species/american-lobster).

3.3.4.3 Atlantic Rock Crab*

Atlantic Rock Crabs (*Cancer irroratus*) are important prey for several species in the NYB, including American Lobster (Hanson et al. 2014). Rock Crab, like Jonah Crab, have been harvested as incidental catch in the American Lobster fishery in New England for decades (Krouse 1980). To a lesser extent than the Jonah Crab fishery, the rock crab fishery has recently expanded and is not regulated (Atlantic States Marine Fisheries Commission 2015b; Bradt et al. 2016). The Atlantic Rock Crab is distributed along the Atlantic Coast from South Carolina to Labrador, with the center of abundance from the NYB to Virginia (Haefner 1977; Stehlik et al. 2004) and a mean-temperature-of-catch (also labeled "preferred temperature") of 20ºC (Cheung et al. 2013). The species' bathymetric range within the Mid-Atlantic region spans from 0–751 m (Haefner 1977), with highest densities between 40–60 m and a preference for sandy bottom (Musick and McEachran 1972; Stehlik 1993). Atlantic Rock Crab undergo seasonal migrations, migrating inshore to coastal and estuarine waters in the fall and offshore in the spring to avoid high summer temperatures (Haefner 1977). Atlantic Rock Crabs are managed by state agencies under coordination from the ASMFC.

3.3.4.4 Jonah Crab*

As the species name implies, Jonah Crab (*Cancer borealis*) is a northern cold-water species with a preferred temperature of 11ºC (Cheung et al. 2013) extending into Canada and New England, where it is ecologically and economically important (McKay and Heck 2008; Perez et al. 2009) and where it ranges into the intertidal zone (Ellis et al. 2007; Krouse 1980). In the southern part of its range, including the NYB, it is relegated to deeper water. Although it occurs in spring to fall in the study area, it is most abundant at 61–160 m and in winter deeper yet (150–400 m) (Haefner 1977; Robichaud and Frail 2006). Based on the limited knowledge of the spatial dynamics, the seasonal migration is size-dependent and sex segregated (Carpenter 1978; Haefner 1977; Jeffries 1966; Krouse 1980; Stehlik et al. 1991). Habitat preference is also size-dependent, with smaller crabs preferentially selecting cobble, while large crabs indiscriminately selecting cobble or sand, with the ability of all sizes to bury in their selected sediment (Anne Richards 1992). Jonah Crab has long been considered a bycatch of the American Lobster (*Homarus americanus*) fishery, but in recent years, there has been increasing targeted fishing pressure and growing market demand for crab. The decline of the lobster fishery in Southern New England and growing market demand for Jonah Crab has resulted in a 650% increase in landings since 2000, and over 17 million pounds landed in 2014, worth $13 million dollars (Atlantic States Marine Fisheries Commission 2018a; 2018b). A mixed crustacean fishery has emerged, where fishers seasonally target either lobster or Jonah Crab. The first Fishery Management Plan for the Jonah Crab fishery was published in 2015, motivated by concerns about the sustainability of this rapidly growing yet unregulated fishery (Atlantic States Marine Fisheries Commission 2015b). Jonah Crab are managed by the ASMFC and state agencies.

3.3.4.5 Ocean Quahog (Clam)*

Ocean Quahog (*Arctica islandica*) adults bury and are most abundant in fine to medium-sand bottoms. Ocean Quahog are found nearshore from Cape Hatteras, NC, to the Canadian Arctic, and they reach their maximum abundances between 25- and 60-m water depths (https://www.sealifebase.ca/summary/Arctica-islandica.html). The fishery is currently concentrated off Long Island (Northeast Fisheries Science Center 2020 (in press)). Shifts in distribution will be difficult to document because adults are sedentary and the species is extremely long-lived; adults can live up to 500 years (Butler et al. 2010; Butler et al. 2013). Predators in the NYB include Rock Crabs, sea stars, and other crustaceans, and fish such as Longhorn

Sculpin (*Myoxocephalus octodecemspinosus*), Ocean Pout, and Atlantic Cod. Ocean Quahogs mature slowly; average age of first reproduction is about 12 years (Based on Cargnelli et al. (1999b) and references therein). Spawning is protracted, usually occurring from summer through fall, sometimes continuing into winter. Eggs hatch into planktonic larvae that feed on phytoplankton during three stages of development. The larval period is temperature dependent, ranging from 30 days (at 13°C) to 55 days (at 8°C), after which the larvae metamorphose into juveniles and settle to the bottom. Ocean Quahog are managed under NMFS through a plan developed by the Mid-Atlantic Fishery Management Council.

3.3.4.6 Atlantic Surfclam*

Surfclam (*Spisula solidissima*) adults are most abundant on the inner and middle shelf, at depths of 18–37 m, in well-sorted medium sands. Modeling studies of larval dispersal for this sessile species suggest that populations are connected throughout the MAB but that there is limited connectivity with populations in the Gulf of Maine (Munroe et al. 2018). Predators include Moon Snails (*Neverita duplicate* and *N. delissertiana*), Lady Crab (*Ovalipes ocellatus*), Atlantic Horseshoe Crabs, sea stars, Sevenspine Shrimp, and fish such as Atlantic Cod (Cargnelli et al. 1999c; 1999d; Hofmann et al. 2018; Narváez et al. 2015; Pace et al. 2018; Pace et al. 2017; Zhang et al. 2015; Zhang et al. 2016). Based on Cargnelli et al. (1999c) and references therein, Atlantic Surfclam age of first reproduction may be as short as 3 months for clams off New Jersey. On the inner shelf, where abundances are greatest, Atlantic Surfclams spawn in May–June, when bottom water temperatures warm to 12–13°C. Eggs hatch into a feeding larva that can spend up to 35 days as plankton before metamorphosis and settlement, and this allows dispersal from the sessile adults. The settled stage occurs in summer, a heightened period of activity for snails, crabs, and echinoderms. The small size and shallow burial at settlement leaves the settling clams vulnerable to these predators (C. L. MacKenzie et al. 1985; Weissberger and Grassle 2003), as was demonstrated when a hypoxic event that eliminated their predators allowed strong recruitment (Garlo 1982). Atlantic Surfclam are managed under a by the Mid-Atlantic Fishery Management Council.

3.3.4.7 Atlantic Sea Scallop*

Atlantic Sea Scallop (*Placopecten magellanicus*) are distributed on the OCS from the Gulf of St. Lawrence to Cape Hatteras, NC (Shumway and Parsons 2006). Optimal growth is between 10 and 15ºC (Shumway and Parsons 2006). Based on the most recent (2013) stock assessment for the MAB (Northeast Fisheries Science Center 2014), about 65% of commercial landings of Atlantic Sea Scallop from 2003 through 2012 were from the Mid-Atlantic region, and 32% were from Georges Bank. These percentages reversed in 2013, when the focus of the commercial fishery shifted to Georges Bank. Atlantic Sea Scallops are found in greatest abundance on coarse sand and gravel bottoms (Thouzeau et al. 1991). The commercial harvest focuses mainly on scallops at depths of 30–100 m, but this is not spatially explicit to the NYB (see **Volume 2** for NYB-specific patterns). In the NYB region, the abundance of sea scallops varies considerably with location, and the accompanying **Volume 2** treats distribution relative to the study area specifically. Predators on juvenile and adult scallops that occur frequently in the NYB include Atlantic Cod, Eel Pout, Winter and Yellowtail Flounders, crabs, and sea stars. Recruitment is significantly affected by the density of adults upstream, so that northern fishery closures have spillover effects as increased recruitment to the south (Hart et al. 2020). Disease outbreaks, such as from the parasitic nematode *Sulcascaris sulcatei*, are density dependent (Rudders et al. 2019) and should result in southern recruitment depensation similar to a fishery overexploitation. Atlantic Sea Scallop spawning usually occurs in late summer to early fall on Georges Bank, although there may be a smaller, incomplete spawning in spring (Thompson et al. 2014). In the MAB, the spring spawn may be more substantial (DuPaul et al. 1989). Reproduction begins in one-year-old Atlantic Sea Scallops, and output increases with age. Bivalve mollusks are notably fecund, but even in this group Atlantic Sea Scallops stand out; one female can produce up to 270×10^6 eggs per spawn (Langton et al. 1987). Eggs hatch into feeding larvae that spend at least 30 days in the plankton and potentially up to 80 days in a thermally stratified water column (Pearce et al. 2004), before metamorphosis and settlement. NMFS and the New England Fishery Management Council manage Atlantic Sea Scallops.

3.3.4.8 Blue Mussel

Blue Mussel (*Mytilus edulis*) is an abundant and widespread bivalve mollusk that occurs in intertidal and shallow coastal waters of the Atlantic. Lower depth limits are not documented. Blue Mussel anchor together to the bottom substrate to form dense beds over hard bottom or on soft sediment (Newell 1989; Seed and Suchanek 1992). Mussels play an important role in benthic community structure due to their ability to serve as ecosystem engineers, providing hard substrate for numerous species that would not be present without this assemblage of shell (Bayne 1976; Gutiérrez et al. 2003). Blue Mussel beds can form on a range of substrates (silt-clay, sand, mixed sediment with stones and shell). Blue Mussels on soft substrata are especially vulnerable to storm-induced dislodgement because the mussels are not fixed to stable hard substratum (e.g., bedrock) but attach to conspecifics only (Nehls and Thiel 1993). Laboratory studies have shown that they are able to emerge from burial in the sediment as facilitated by increased byssus production (attaching to vertical surfaces as sediment particles). Emergence was higher within coarse sediments and when burials were shallow; mussels had to emerge within 16 days to survive (Hutchison et al. 2016).

Blue Mussel beds provide important habitat and shelter for numerous species (Coen and Grizzle 2007; Seed and Suchanek 1992). Subtidal shell accumulation (shell hash) of Blue Mussels provides more complex habitat when compared to sandy or silt-clay bottom substrates, supporting commercially and recreationally important fish along with smaller organisms or early life stages (Auster et al. 1995; Auster et al. 1991; Steimle and Zetlin 2000). For example, Sand Lance are found in high densities burrowed in substrate associated with shell-dominated bottoms (Nizinski 2002). Mussels are an important food source for many species (Bayne 1976). Disturbances that increase suspended sediment concentration, such as dredging, can decrease the efficiency of Blue Mussel’s filtration, but less so in winter their activity is low (Wijsman et al. 2012).

Blue Mussels typically reach sexual maturity between 1 and 2 years on average and live up to 12 years (Newell 1989).

Blue Mussel are managed by Federal, state, and local governments.

3.3.4.9 Whelk

Whelk species of primary interest within the NYB include the Channeled Whelk (*Busycotypus canaliculatus*), the Waved Whelk (*Buccinum undatum*), and to a lesser extent the Knobbed Whelk (*Busycon carica*). Export market fisheries for all have grown (Nelson et al. 2018). Eggs clutches or strings are deposited directly to the sea bottom or the hard features on it (**Figure 11**) and develop to emerge as fully formed juveniles (Magalhaes 1948; Martel et al. 1986). Slow growth, low fecundity, late onset of maturity, and limited dispersal make these species especially vulnerable to disruptions in habitats where eggs are deposited and to harvest pressure (Borsetti et al. 2018; Harding 2011).

The Channel and Knobbed Whelk are found along the Atlantic Coast from Cape Cod, MA, to Cape Canaveral, FL (Abbot 1974; Edwards and Harasewych 1988). Channel Whelk are the most abundant of the three species in the NYB, with Knobbed Whelk becoming more abundant south of New Jersey (Magalhaes 1948; Walker 1988; Wood and Wood 1927). These two species account for most whelk harvested in the Mid-Atlantic, but Knobbed Whelk harvest is typically estuarine, while Channeled Whelk are taken in near and offshore marine habitats (Fisher and Rudders 2017). In recent years, many lobster fishermen in Southern New England have shifted effort to the Channeled Whelk fishery due to an increase in whelk price and a serious decline in lobster (Atlantic States Marine Fisheries Commission 2015a).

Channeled Whelk typically occupy littoral and subtidal habits in waters less than 30 m on sandy, silt, shell hash, and silt and clay sediments (Nelson et al. 2018). Eggs are deposited in estuaries in the fall and hatch the following spring (Harding 2011). Newly hatched whelk remain nearshore and burrow into the sediment before moving to deeper coastal waters as adults (Nelson et al. 2018). Adult Channeled Whelk exhibit thermal preferences, burying into the sediment when water temperatures become too warm or too cold (Magalhaes 1948). These carnivorous scavengers are important bivalve predators in nearshore coastal communities, commonly feeding on various shellfish species, some with commercial importance (i.e., Northern Quahog [*Mercenaria mercenaria*], Softshell Clam [*Mya arenaria*], Atlantic Surfclam [*Spisula solidissima*], Blue Mussel [*Mytilus edulis*], or Slipper Shell [*Crepidula fornicata*]) (Nelson et al. 2018).

Waved Whelk are not generally of significant commercial importance; however, there has been interest in this unmanaged fishery in the NYB region in recent years (Borsetti et al. 2018). Within the NYB, this population is most abundant at depths of 40–75m and is found in almost all habitat types, but they typically occur in soft sediment habitats, where they burrow a few centimeters below the sediment surface (Borsetti et al. 2018; Nielsen 1975). Waved Whelk is a boreal species and therefore reliant on cold spring bottom temperature for spawning (7–8°C). Spawning is followed by a multi-month larval development period, when egg capsules are anchored to hard structure on the bottom (**Figure 11**) (Borsetti et al. 2020).

Figure 11. Whelk egg clutches attached to empty clam valves on unconsolidated substrate
Image credit: Habcam online library, https://habcam.whoi.edu/

3.3.4.10 Squid*

Squid are an important ecological fishery resource within the NYB. Squid are a key forage item for many fishes, marine mammals, and birds, and as such are managed alongside Atlantic Mackerel and Butterfish (Hendrickson and Holmes 2004). Squids are a keystone fishery of the NYB, with almost all Mid-Atlantic squid landings being made in New Jersey and New York (National Marine Fisheries Service 2018). The two squid species of primary interest within the NYB are Longfin Inshore Squid (*Doryteuthis pealeii*, formerly *Loligo pealeiii*) and Northern Shortfin Squid (*Illex illecebrosus*). Both species live approximately one year and exhibit significant inshore-offshore and diel vertical migration (Hendrickson and Holmes 2004; Jacobson 2005). Northern Shortfin Squid are highly migratory and pelagic (Hendrickson and Holmes 2004) and mostly well offshore of the study area in water temperature >13ºC, especially in early stages.

Longfin Inshore Squid school in shallower waters than Northern Shortfin Squid and inside the NYB, but still outside of the study area, at depths of 50–100 m for juveniles and to 180 m for adults when inshore during March–October (Jacobson 2005). Adults remain close to silt and silty-sand bottom habitat within the 8–16ºC temperature range during the day before rising to feed in 9–21ºC waters at night. The shallower inshore range of juveniles puts them in warmer (10–26ºC) surface and near-surface water. Diet of *L. pealeii* changes with size and reflects the ontogenetic habitat shift. Near-surface juveniles consume planktonic copepods and euphausiids, while adults consume smaller forage fishes, crustaceans, and other squids (Jacobson 2005). Squid are managed by NMFS and MAFMC.

3.3.4.11 Spiny Dogfish*

Spiny Dogfish (*Squalus acanthias*, Fam. Squalidae) is by far the most abundant shark species in the NYB (Compagno 1984a). They are a small, elongate species named for sharp spines on the leading edge of their dorsal fins (Burgess 2002; Compagno 1984a). Spiny Dogfish are relatively slow swimming but agile (Compagno 1984a; Domenici et al. 2004; Stehlik 2007). Recent research challenges an earlier view of Spiny Dogfish as a benthic species, with telemetry showing water column use throughout the day (Carlson et al. 2014; Stehlik 2007; Sulikowski et al. 2010). Spiny Dogfish almost always occur in groups (Stehlik 2007). They consume fish and squid throughout their life and scallops when their range overlaps seasonally (Stehlik 2007). They occur from “shallows” to 900 m (Burgess 2002). Spiny Dogfish are widely distributed, including in the Pacific and eastern Atlantic (Europe), and from Greenland to northeastern Florida along the US Atlantic Coast (Burgess 2002). Here they exhibit both inshore-offshore and north-south seasonal migration. Compared to other Spiny Dogfish along the US Atlantic Coast, individuals within the MAB/NYB tend to remain more localized, with less population-wide synchronous movement patterns (Carlson et al. 2014). Spiny Dogfish within the MAB/NYB exhibit strong oscillatory diel behaviors, swimming deeper during the day than at night for bioenergetics optimization during hunting (Carlson et al. 2014). Spiny Dogfish are managed by NMFS, MAMFC, and the New England Fishery Management Council.

3.3.4.12 Smooth Dogfish (Smoothhound)*

Smooth Dogfish (*Mustelus canis,* Fam. Triakidae) is the second-most abundant shark species in the NYB (Compagno 1984a). Named for its lack of dorsal spines, it is not closely related but looks similar to Spiny Dogfish (Branstetter 2002). It is an active species that constantly scours the benthic environment for food, eating primarily large crustaceans such as crabs and American Lobsters, though it may also take small teleosts and other invertebrates such as squid, bivalves, gastropods, and annelid worms (Compagno 1984a). Reproductive maturity for this species is typically around 3 years of age for males and 5 years for females (Conrath and Musick 2002). In the NYB, parturition of 3–18 live young occurs in either estuaries or inshore marine environments from mid-May to July (Rountree and Able 1996). Young-of-the-year (YOY) remain in estuarine nursery habitat and rapidly grow to a size of 55–70 cm total length before emigrating in the fall of their first year (Rountree and Able 1996). Smooth Dogfish may segregate sexually, except during the spring mating and pupping season (Dell'Apa et al. 2018). Smooth Dogfish range from Bay of Fundy to Florida and in the Gulf of Mexico, but are most common between Cape Cod, MA, to Charelston, NC (Kiraly et al. 2003). It prefers muddy to sandy bottom usually at less than 20 m but as deep as 460 m of New York in winter. They are recorded at 5.3–27.7°C but most often between 10–22ºC (Kiraly et al. 2003). Smooth Dogfish are managed by NMFS under the 2006 Consolidated

Atlantic Highly Migratory Species (HMS) Fishery Management Plan (FMP) and its amendments and by states.

3.3.4.13 Sand Tiger Shark

Sand Tiger Sharks (*Carcharias taurus*) are found in coastal habitats throughout the world, including the US Atlantic and Gulf of Mexico coasts. They are most commonly found on or near the bottom on coral and rocky reefs, in shallow bays, and in the surf zone (Compagno 1984b). Sand Tigers are strong midwater swimmers and are highly migratory within the Western Atlantic portion of their range (Compagno 1984b; Teter et al. 2015). Sand Tigers on the US East Coast migrate, wintering in southern waters from Cape Hatteras to Florida and summering in the Mid-Atlantic and off New England (Gilmore 1993; Kneebone et al. 2014a; Teter et al. 2015). Southerly migration spans the end of summer to early autumn (Teter et al. 2015). Like Atlantic Sturgeon, at the mesoscale, Sand Tiger Sharks show an affinity for water characterized by low salinity, high chromatic dissolved organic material (CDOM), and proximity to shore, which is characteristic of coastally trapped estuarine plumes (Haulsee et al. 2015). Although they may be found at depths of up to 191 m, one study of Sand Tiger Sharks on the US East Coast found that all but the largest adults occupied depths shallower than 80 m (Compagno 1984b; Teter et al. 2015). Sand Tigers tolerate a wide range of temperatures but prefer a range 17–23ºC for adults and 12–20ºC for juveniles within the US East Coast (Kneebone et al. 2014a; Teter et al. 2015). However, temperature is not a good predictor of mesoscale habitat use (Haulsee et al. 2015). Sand Tiger Sharks are voracious feeders on a wide variety of teleost fishes, smaller sharks, rays, squid, crabs, and lobsters (Compagno 1984b). Although Sand Tiger Sharks are protected and commercial harvest is prohibited, they are bycatch in bottom longline and gillnet fisheries (Carlson et al. 2009) and are targeted by recreational anglers who must release them without landing them, but the sharks still risk mortality from gut hooking (Kilfoil et al. 2017). Sand Tiger Sharks are managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments and by states.

3.3.4.14 Requiem Sharks

Several species of requiem sharks (family Carcharhinidae) are found within the NYB: the Tiger Shark (*Galeocerdo cuvier*) (differs from Sand Tiger Shark), Blue Shark (*Prionace glauca*), Sandbar Shark (*Carcharhinus plumbeus*), Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*), and Dusky Shark (*Carcharhinus obscurus*). All are sleek active sharks lacking vascular heat preservation adaptations and thus are relegated to warmer water than lamnid sharks.

Tiger Sharks are a large, active, circumglobal species of temperate and tropical seas, ranging from Massachusetts to Uruguay in the Western Atlantic (Compagno 1984b). Adults occupy a wide range of habitats from the surface to depths of deeper than 1,000 m as tracked elsewhere in their range, but prefer turbid continental shelf water and estuaries especially as young (Afonso and Hazin 2015; Compagno 1984b). Tiger Sharks are among the least specialized feeders of all sharks; their diets include teleosts, elasmobranchs, invertebrates, marine reptiles, sea birds, marine mammals, and stray terrestrial vertebrates (Compagno 1984b). Blue Shark is a circumglobal offshore oceanic-epipelagic species that occasionally ventures inshore. They largely feed upon squid, though small teleost and invertebrate prey are also taken, as well as sea birds and marine carrion (Compagno 1984b). Although their extensive range includes the study area, neither of these species have known critical ties to sand features.

Sandbar Sharks (*Carcharhinus plumbeus*) are a medium-sized abundant coastal-pelagic shark of temperate and tropical waters (Compagno 1984b). They favor bottom habitat and may be found from extreme shallows to depths of 280 m including over the continental shelf and slope and oceanic banks; in bay and river mouths, and harbors; and within shallow muddy and sandy bays. Avoided habitats include the surf zone, sandy beaches, coral reefs, rough bottom, and the surface (Compagno 1984b). Sandbar sharks shift diet with ontogeny (Ellis and Musick 2007); small juveniles consume mostly crustaceans and small teleosts (higher boney fishes) such as Hogchokers (*Trinectes maculatus*) before transitioning to a diet predominated by teleosts and elasmobranchs (sharks, skates, and rays). Within the NYB, adult and large juvenile Sandbar Sharks consume mostly teleosts, followed by elasmobranchs, squid and octopus, and other miscellaneous organisms and detritus (Ellis and Musick 2007; Stillwell and Kohler 1993). Sandbar Sharks appear to prefer fresh fish prey they can swallow whole (Compagno 1984b). Only larger juveniles and adult sharks consume food that must be taken in bite-sized portions; prey eaten in this manner include larger skates, Goosefish, Bluefish, Smooth Dogfish, and Spiny Dogfish (Stillwell and Kohler 1993). Benthic and demersal fish prey species are preferred but not exclusive. Key teleost prey includes flatfishes (10% of diet by frequency of occurrence) and Goosefish (6%) (Stillwell and Kohler 1993). Skates (most likely Little Skate and Clearnose Skate) are the most important elasmobranch prey, possibly due to their abundance over the continental shelf. Other elasmobranch prey, notably Smooth and Spiny Dogfish within the NYB, are comparatively unimportant. Although cephalopods such as squid are relatively unimportant in the diets of Sandbar Sharks sampled in and near shore, they may be more important to the diet of sharks residing offshore (Stillwell and Kohler 1993).

The Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*) is a small, abundant species of warm-temperate to tropical waters of the western North Atlantic seaboard and Gulf of Mexico (Compagno 1984b). Within the Atlantic, it may be encountered on the continental shelf from New Brunswick, Canada, to Florida. It is usually found in shallow waters less than 10 m deep, with preferred habitats including the surf zone off of sandy beaches, harbors, bays, sounds, and brackish to marine estuaries. The species has been encountered in deeper waters and is documented from the intertidal zone to 280 m deep (Compagno 1984b). YOY feed upon a mix of small forage fish species and invertebrates, while juveniles and adults prey primarily upon larger species such as drum fishes (Bethea et al. 2006; Compagno 1984b).

Surveys of coastal Gulf of Mexico sharks by (Ward-Paige et al. 2015) and (Parsons et al. 2005) found evidence for sexual segregation, with adult female Atlantic Sharpnose Sharks preferring offshore areas (Pratt and Carrier 2001; Springer 1967; Ward-Paige et al. 2015) and males more inshore at least in summer (Parsons et al. 2005). However, that ecosystem differs from that of the NYB in patterns of productivity and temperature. Productivity and temperature are important drivers of bioenergetics optimization so extension of these findings to the NYB is cautioned until this is better understood.

Dusky Sharks (*Carcharhinus obscurus*) are a large, slender, common, coastal-pelagic species of warm-temperate and tropical waters (Compagno 1984b). They are a highly vagile and migratory, with a significant seasonal north-south migration and individual movement of about 10 km per day (Bangley et al. 2020; Carlson and Gulak 2012; Compagno 1984b). They may occur from inshore waters and the surf zone—avoiding areas near estuaries and those with reduced salinity—to offshore waters, where adults commonly trail ships. They eat a wide variety of bottom, reef, and pelagic teleosts, as well as invertebrates and elasmobranchs, including Spiny Dogfish, Smooth Dogfish, skates, rays, and other small *Carcharhinus* sharks (Compagno 1984b). Adult Dusky Sharks tracked off south Florida preferred water temperatures of 20–24ºC and spent most of their time in 0–40 m depths, but dove to 440 m (Carlson and Gulak 2012). Juvenile Dusky Sharks tagged within the NYB and MAB associate with two oceanic features: the Cold Pool and the Hatteras Bight (Bangley et al. 2020). Recent evidence collected by (Bangley et al. 2020) suggests that juvenile Dusky Sharks may reside just above the thermocline of the Cold Pool between May and June in order to access both cool-water and warm-water prey while minimizing cold exposure. This study also found that juveniles balance trade-offs between temperature preferences and foraging opportunities when selecting habitat similar to the strategy exhibited by the species in deeper water off Florida. During the summer, when overall water temperatures fall within the sharks' preferred range, the distribution patterns of juvenile's can largely be predicted along the lines of increased foraging opportunity (as proxied by Chlorophyll-*a* and depth). During the winter however, their distribution is constrained by sea surface temperatures (Bangley et al. 2020). Telemetry loggers from within the BOEM offshore wind lease areas for the proposed Delaware and Maryland leases (lease numbers OCS-A 0490 for US Wind, Inc.; OCS-A 0519 for Skipjack Offshore Energy, LLC; and OCS-A 0482 for GSOE I, LLC) logged frequent acoustic tag detections of juveniles (Bangley et al. 2020), showing an offshore range extent beyond the target depths for sand extraction. It should be noted that the detection array is unbalanced with regard to shallower loggers.

All of these sharks are managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments, and some are additionally managed by the Interstate Fishery Management Plan for Atlantic Coastal Sharks adopted by ASMFC in 2008 (http://www.asmfc.org/species/coastal-sharks).

3.3.4.15 Thresher Sharks

Of the family Alopidae, only the Common Thresher Shark (*Alopias vulpinus*) utilizes the shallow continental shelf of the NYB. With very small teeth and tails used as a whip to stun prey, thresher sharks specialize on small schooling fish and squid that they herd into balls (Compagno 1984b; Oliver et al. 2013b). The NYB, and particularly the inner continental shelf, is an important nursery habitat based on accumulated records of capture of juveniles in both recreational and commercial fisheries for spring, summer, and fall (Kneebone et al. 2020). Although adults were collected in the study area as part of a much wider range, YOY used the continental shelf north of 33.5ºN almost exclusively, and within that area, they were concentrated off New Jersey and Long Island and within a temperature range of 6–26ºC (Kneebone et al. 2020). However, this distribution is biased by distribution of fishing effort, and YOY may use areas that are not fished. Thresher sharks have no known ties to sand features, except as these might attract or concentrate small forage fish such as sand lance (see also Knowledge Gaps). The Common Thresher Shark is managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments, and is additionally managed by the ASMFC Interstate Fishery Management Plan for Atlantic Coastal Sharks.

3.3.4.16 Hammerhead Sharks

As a family, hammerhead sharks are defined on the basis of a characteristic flat wing-like head or cephalofoil that serves to spread apart the electroreception organs (Ampullae of Lorenzini) for greater search area and better triangulation in the detection of buried prey (Compagno 1984b; Kajiura 2001; Kajiura et al. 2010; Newton et al. 2019). This is especially useful for hunting over sand, and hammerhead sharks are known to specialize as stingray predators through the use of the cephalofoil to detect as well as pin them down (Kajiura et al. 2010; Strong et al. 1990). They appear to be immune to sting ray venom (Nair and James 1971). The Smooth Hammerhead Shark (*Sphyrna zygaena*) is the hammerhead species most regularly found within the NYB, despite the fact that the mature individuals are the most oceanic of the family Sphyraenid (Clarke et al. 2015; Compagno 1984b; Miller 2016). Individuals can range widely, with one study reporting an average daily distance of 33.4 km/day, and one female moving 6,600 km over 150 days (Santos and Coelho 2018). This makes it difficult to consider the NYB as critical to adults. However, within the larger MAB, tagged juvenile Smooth Hammerheads migrated between a core summer area within the coastal NYB to a core winter area off the coast of Cape Hatteras, suggesting that the NYB should be listed as EFH for juvenile Smooth Hammerhead (Logan et al. 2020). Smooth Hammerhead Sharks of all life stages appear to prefer shallow water, typically inhabiting surface waters to depths of 50 m (Compagno 1984b; Logan et al. 2020; Santos and Coelho 2018). In general, juveniles prefer coastal habitats to a greater degree than adults, leaving for the open ocean around 2–3 years of age (Clarke et al. 2015; Miller 2016). Juveniles exhibit a significantly greater range of vertical habitat than adults, and prefer deeper, cooler waters during nighttime than adults (Santos and Coelho 2018).

Preferred prey are small sharks, skates, and stingrays, particularly within inshore locations (Compagno 1984b; Miller 2016; Nair and James 1971), but their diet includes a wide variety of bony fishes, crustaceans, and cephalopods (Compagno 1984b; Miller 2016; Smale 1991). Juvenile Smooth

Hammerhead Sharks primarily prey upon cephalopods, particularly *Doryteuthis* squids, with teleosts being their secondary prey (Bornatowski et al. 2014; Smale 1991). Important teleost prey appear to include *Merluccius* hake, drum fishes, clupeids, mackerel, and ribbonfish (Bornatowski et al. 2014; Compagno 1984b; Smale 1991). Smooth Hammerhead Sharks opportunistically consume prey from fishery discards and drifting longlines, potentially bringing them into conflict with commercial fishing activities (Compagno 1984b; Smale 1991). As many dietary studies pertain only to juvenile sharks, not as much is known about the dietary habits of adult Smooth Hammerheads, though it appears as though teleosts such as Merluccius Hake continue to be important prey (Smale 1991).

The overharvesting of Smooth Hammerhead Sharks via commercial; artisanal; and illegal, unreported, and unregulated (IUU) fishing is perhaps the greatest threat to the species at a global level, with the shark fin trade appearing to drive this exploitation (Miller 2016). Juveniles are harvested at a greater rate than adults. Significant levels of incidental bycatch of Smooth Hammerhead Sharks in the course of longline fishing for other species contributes to overall exploitation rates. However, current fishing pressure is not sufficient to drive the Smooth Hammerhead Sharks to the brink of extinction (Miller 2016).

Hammerhead sharks are managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments and by additionally managed by the ASMFC Interstate Fishery Management Plan for Atlantic Coastal Sharks.

3.3.4.17 Lamnid (Mackerel) Sharks

The Lamnid or mackerel sharks (Family Lamnidae) are large, fast, active sharks with countercurrent heat exchange vessel beds (vascular plexus) in various tissues (muscle, eye, or brain) that allow at least temporary penetration of cold water to exploit prey that other active predators cannot (Andrzejaczek et al. 2019; Compagno 2002; Dickson and Graham 2004). As adults they are apex predators and exploit a wide variety of large prey.

The White Shark (*Carcharodon carcharias*) is found within the NYB as part of a wide variety of habitats that shifts with ontogeny and season. Along the US Atlantic Coast and MAB, they spend their summer months on Northeast Shelf waters between the Gulf of Maine and Cape Hatteras, followed by a staggered fall–late fall emigration to southeast shelf waters between North Carolina and Florida (Skomal et al. 2017). The return migration to the north is comparatively rapid and occurs during late spring and early summer. Prey availability is a major driver of White Shark migration patterns but is constrained by temperature. Migrating sharks spend the majority of their time within a 13–23ºC temperature range across seasons (Skomal et al. 2017). The usual depth range is 0–250 m (Weigmann 2016). Marine mammals such as seals and dolphins, as well as whale carcasses (Tucker et al. 2019), are important prey (Compagno 1984a). A wide range of teleost and condrichthyan prey are consumed as well, and sea turtles and seabirds are consumed on occasion. The overall abundance of these prey items on the Northeast Shelf draws White Sharks of all life stages there through the NYB when temperatures permit (Skomal et al. 2017).

The NYB is a nursery area for YOY White Sharks (Curtis et al. 2014a; Curtis et al. 2018). The YOY primarily reside within NYB waters less than 50 m deep for their first summer of life, with at least one focal area along the southeastern shore of Long Island, NY (Curtis et al. 2018). It is believed but difficult to verify that these waters provide refuge from potential predators (i.e., larger conspecifics, which do not frequent such habitat) while providing easy access to a high abundance and diversity of prey (believed to be demersal and pelagic teleosts and smaller elasmobranchs). YOY generally move out of the NYB in late fall to migrate to and overwinter just north of Cape Hatteras, before returning to the NYB in the late spring to early summer (Curtis et al. 2018).

Shortfin Mako (*Isurus oxyrinchus*) are also found within the NYB. They are a surface-oriented and focus on fast pelagic prey such as Bluefish, tunas, and billfish (Vaudo et al. 2017; Vaudo et al. 2016). There are no known critical ties to sand features. Although the NYB is a small part of the range of even individual Shortfin Mako, the MAB, inclusive of the NYB, appears to be a core area of distribution for the western North Atlantic subpopulation, particularly from the mid-shelf to the northern and western edges of the Gulf Stream (Vaudo et al. 2017).

The Porbeagle (*Lamna nasus*) occurs within the NYB, but its primary habitat is north and offshore. Aided by a heated eye, it focuses on deep, cold-water prey (Block and Carey 1985). Porbeagles prefer water temperatures of 5–10ºC, with a maximum temperature of 20ºC (Campana and Joyce 2004; Saunders et al. 2011).

These sharks are managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments.

3.3.4.18 Basking Shark

The large endangered Basking Shark *(Cetorhinus maximus*) occurs occasionally in the NYB, sometimes in schools. Basking Sharks filter feed on rich surface concentrations of plankton on the continental shelf waters of nearby New England during the summer before diving to deeper depths and migrating south during the autumn (Braun et al. 2018; Crowe et al. 2018; Skomal et al. 2004). It has no known ties to sand features, other than that bathymetric features such as ridges might concentrate plankton. Depletion was so rapid that assessments of habitat use and ranging under natural population pressures was never made (Gore et al. 2008; Hoelzel et al. 2006). Basking sharks are managed by NMFS under the 2006 Consolidated Atlantic HMS FMP and its amendments. It is illegal to possess, land, or trade them in the State of New Jersey.

3.3.4.19 Skates*

Skate species encountered within the NYB include the Barndoor (*Dipturus laevis*), Clearnose (*Raja eglanteria*), Little (*Leucoraja erinacea*), Rosette (*L. garmani virginica*), Smooth (*Malacoraja senta*), Thorny (*Amblyraja radiata*), and Winter (*L. ocellata*) Skate (Packer et al. 2003b; 2003c; 2003d; 2003e; 2003f; 2003g; 2003h). These seven species are managed as an aggregate complex. Skates are principally targeted for sale as lobster bait using otter trawl, though they are frequently caught as bycatch in groundfish trawls and scallop dredges. There is also an export market for the wings of Thorny and Winter Skate, which seems to be the most significant factor in the rise of skate landings up to 2003 (Packer et al. 2003g; 2003h).

Little Skate primarily occur over sandy or gravelly bottoms, but are found over mud bottoms as well (Packer et al. 2003d). They burrow in particular microhabitat features of the surface substrate during the day such as biogenic depressions and flat sand before becoming active and randomly dispersing at night (Packer et al. 2003d). Bottom type, rather than depth, may be a more significant driver of distribution, at least for Winter Skate on the Scotian shelf (Packer et al. 2003h). Little Skate are sympatric with Winter Skate (Packer et al. 2003d; 2003h). Little Skate migrate inshore and offshore with seasonal temperature changes, preferring shallow waters in the spring and deeper waters in the winter (Packer et al. 2003d). It is not clear if the Winter Skate do the same (Packer et al. 2003h). Little and Winter Skates of all life stages are generally found at depths shallower than 111 m, though they have been recorded as deep as 384 m off New Jersey (Packer et al. 2003d; 2003h). Little Skates are opportunistic predators with diet reflective of location; inshore individuals depend upon decapod crustaceans, amphipods, and polychaete worms (Packer et al. 2003d). Winter Skates depend more upon polychaetes and amphipods in terms of prey item occurrence, though amphipods, decapods, and fish are the most important prey by weight (Packer et al. 2003h).

Compared to other *Leucoraja* skates, Rosette Skates prefer deeper water but generally are found shallower than 366 m in the MAB (Packer et al. 2003e). Rosette Skates have been known to consume polychaetes, copepods, amphipods, the shrimp *Crangon septemspinosa*, and small fish, among other prey (Packer et al. 2003e).

Thorny Skate and Smooth Skate are sympatric within the skate management assemblage (Packer et al. 2003f; 2003g) and generally occur deeper than the potential extraction areas.

Clearnose Skate are most abundance at depths shallower than 111 m, though they have been known to occur to depths of 280–329 m during the winter within the NYB (Packer et al. 2003c). Clearnose Skate may be found on soft bottoms along the continental shelf and on rocky or gravel bottoms. The species-wide temperature range is 9–30ºC, with a preferred range of 9–20ºC within the northern portion of its range (which includes the NYB). Individuals within this northern range migrate inshore and northward along the continental shelf during the spring and early summer, and offshore and southward during the fall and early winter (Packer et al. 2003c). Prey species include polychaetes, amphipods, mysids, crabs, bivalves, squids, and small fish. Sandbar Sharks prey upon Clearnose Skate.

Barndoor Skates may be found on mud bottom types, as well as sand and gravel (Packer et al. 2003b). Juveniles are most abundant at depths of < 150 m, while adults prefer depths deeper than 70 m in the spring and deeper than 40 m in the fall. The overall species temperature range is 1.2–20ºC, with a preferred temperature range of 4–16ºC. Prey species include polychaetes, gastropods, bivalves, squids, crustaceans, and fishes, with larger skates eating larger and more active prey species. Barndoor Skate associate with Little and Winter Skate, though they have a wider substratum and depth tolerance and may occur independently of the aforementioned species (Packer et al. 2003b).

Most skates are managed by NMFS and the New England Fishery Management Council.

3.3.4.20 Rays

Rays are not generally of commercial or economic importance in the NYB but are interesting as quintessential benthic denizens that can grow very large (> 2 m wingspan) and may be important bioturbators, as they dig up prey by powerful wingbeats. Cownose Rays (*Rhinoptera bonasus*) are an increasingly common species within the NYB but are primarily confined to inshore and estuarine waters during their summer migration (McEachran 2002a). There is an interest in developing a fishery for them as a mitigation against the damage that they increasingly do to commercial shellfish beds in estuaries.

Three other ray species occurring within the NYB are the Roughtail Stingray (*Dasyatis centroura*), the Pelagic Stingray (*D. violacea*), and the Spiny Butterfly Ray (*Gymnura altavela*) (McEachran 2002c). The Roughtail Stingray occurs from the nearshore to 91 m, feeding upon polychaetes, cephalopods, crabs, and fishes such as Scup and Sand Lance. Pelagic Stingray are truly pelagic and oceanic as reflected in a diet of squids, shrimps, and pelagic fishes and their occurrence is generally seaward of the study area) (McEachran 2002c). Spiny Butterfly Ray can also exceed 2 m across the disk but have a very short tail (**Figure 12**). They are broadly distributed in warm shallow water from Massachusetts south to Argentina. They are critically endangered due to fishing for meat in parts of their range and are IUCN listed as Vulnerable, Least Concern in the US, where they are not fished (Kyne et al. 2012). There is little research on their life history specific to the NYB or MAB, but from studies elsewhere they are known to prey on small fish, which they stun with strong wing beats, and benthic invertebrates such as snails and crustaceans) (Daiber and Booth 1960; McEachran and Capepe 1984). They are potentially prey for hammerhead sharks (Myers et al. 2007), which specialize on rays.

Atlantic Torpedo (*Torpedo nobiliana*), an electric ray, is only distantly related to the whiptail-bearing species above (Nelson 2006). It is widely distributed along coasts of the Atlantic Ocean and "generally restricted to the continental shelf" (McEachran 2002b) but recorded to a depth of 800 m elsewhere. Torpedos are sluggish swimmers, with the pectoral disk muscles specialized for electricity production instead (Bennett et al. 1961; Bray and Hixon 1978; Macesic and Kajiura 2009), and Atlantic Torpedo can be captured incidentally by scallop dredge (Grothues et al. 2017a). They are hypothesized to spend a significant amount of time buried in soft sediments (McEachran 2002b). Like other electric rays, they may feed in the water column (McEachran 2002b; Newton et al. 2019). Their diet includes large demersal fishes such as adult Summer Flounder, which they stun by electrical discharge and eat with a greatly distensible mouth (McEachran 2002b).

Most rays are unmanaged.

Figure 12. Spiny Butterfly Ray
The ray was captured by the first author and crew with a small otter trawl while studying dredging impacts for the Army Corps of Engineers. The extent of the short tail is visible with the barb temporarily wrapped for safe handling. Image credit: Rutgers University Marine Field Station

3.3.4.21 Atlantic Sturgeon*

Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) are the largest bony fish in the NYB, historically achieving > 4 m in length and > 300 kg. They range from Canada to Florida (Smith and Clugston 1997). They were historically important for meat and caviar with the fishery centered in the NYB, especially around Delaware Bay and the Hudson River estuary, but the population crashed from overfishing in 1903 and is still recovering due to a late maturity and selective harvest of the largest, most fecund individuals (Johnson et al. 2005; Stevenson and Secor 1999). The US Endangered Species Act now affords protection to five distinct population segments (DPSs) (Department of Commerce 2012). One of these DPSs is the NYB DPS, which comprises two stocks: the Delaware Bay stock and the Hudson River stock, the latter of which is presently the largest US population of this species (Dunton et al. 2016; Kahnle et al. 2007). The stock is young when nominal species lifespan is taken into account, with a mean population age of 8.89 years and 84.7% of sturgeon being younger than the average age of maturity (12 years) (Dunton et al. 2016). The low age estimate may result from sampling bias towards subadult sturgeon due to life stage-differential habitat use, lower catchability of adult sturgeon, or a low abundance of adult sturgeon (Dunton et al. 2016). Genetic evidence of inbreeding suggests the latter (O'Leary et al. 2014).

Within the NYB, Atlantic Sturgeon migrate into the Hudson and Delaware Rivers to spawn between April to early July (Balazik and Musick 2015). Males move to riverine spawning grounds days to weeks ahead of females, which results in them being encountered in colder waters more frequently than females or sturgeon of unknown sex (Breece et al. 2018). The resulting young will remain in their natal rivers for several years before venturing into coastal waters.

Although take is prohibited, Atlantic Sturgeon are still encountered fairly regularly as bycatch. Within the NYB, most bycatch occurs in nearshore/state waters in the apex of the NYB, particularly within the gillnet and bottom otter trawl fisheries for species such as flounder and mid-shelf gillnet fishery for Goosefish (Dunton et al. 2015). Peak bycatch is during the seasonal migratory periods of April–June and October–November within the migratory corridor (Dunton et al. 2015). The migratory corridor was previously believed to range from the shoreline to about 20 m deep, but more recent estimates have expanded the corridor to waters up to 40 m deep within the NYB (Breece et al. 2018; Dunton et al. 2015; Erickson et al. 2011). Bycatch patterns suggest that migrating adult sturgeon are intercepted by gillnets, while juveniles are inadvertently harvested by trawls as they aggregate near river mouths (Dunton et al. 2015).

Atlantic Sturgeon are found in shallower waters in the spring, the mouths of estuaries during the summer, and deeper (between 20 to 40 m) offshore waters during the fall (Breece et al. 2018; Erickson et al. 2011). Adult Atlantic Sturgeon aggregate at two coastal points for following their departure from rivers: the south shore of Long Island, NY, at the apex of the NYB, and an area east to southeast of Cape May, NJ, near the mouth of the Delaware Bay (Erickson et al. 2011). Members of the Long Island aggregation point are frequently detected by a telemetry array associated with study of the proposed New York Wind Energy Lease Area (Frisk et al. 2019; Ingram et al. 2019). Sturgeon leave these inshore aggregations and disperse widely during the winter months, with some individuals being recorded over 40 km from shore (Frisk et al. 2019; Ingram et al. 2019).

Adult sturgeon are generally found within mean daily depths of 5 to 35 m but recorded as deep as 70 m deep (Erickson et al. 2011). Sturgeon appear to exhibit specific seascape preferences while inhabiting marine environments, with a preference for areas with high bottom temperature (Breece et al. 2016; Rothermel et al. 2020). (Breece et al. 2018) found a preferred temperature range of 12–25^{o}C with peak occurrence at 18^{o}C, while (Rothermel et al. 2020) found that sturgeon preferred 15–18^{o}C waters in the summer and > 11^{o}C waters in the winter and spring. Atlantic Sturgeon follow the plumes of estuarine water that generally constitute this seascape when these plumes are displaced offshore, disassociating distribution from specific benthic features (Breece et al. 2016; Oliver et al. 2013a).

Atlantic Sturgeon are opportunistic bottom feeders, as evidenced by their chemosensory barbels and inferior subterminal mouth (Musick 2002). They normally prey upon benthic infauna such as polychaetes, isopods, decapods, amphipods, gastropods, crustaceans, bivalves, and small benthic fishes such as Sand Lance. Within the NYB, polychaetes are particularly important as food (Musick 2002).

Atlantic Sturgeon were listed under the Endangered Species Act in 2012. They are managed by the NMFS, which put forth a recovery outline for the species.

3.3.4.22 Goosefish*

Goosefish (*Lophius americanus*) (also reported as "Monkfish" in NMFS fisheries data) are a commercially important species of anglerfish found within the NYB. Although primarily utilizing slope-and-canyon habitats (Briggs and Waldman 2002; Colvocoresses and Musick 1984; Gabriel 1992; Jean 1965; Overholtz and Tyler 1985; Ross et al. 2016), they occur across the entire shelf and even into estuaries (Caruso 2002). Reported depth range is 0–800 m ((Lophius americanus Valenciennes, 1837: American angler ; Murdy et al. 1997). They utilize open sandy, clay, and mud bottoms and prefer water temperatures between 6–14°C (Steimle et al. 1999a) with a total temperature range of 0–21C° (Scott and Scott 1988). These fish are solitary lie-in-wait ambush predators that at least partially bury themselves and use a modification of the dorsal fin (esca) as a lure (**Figure 13**). They take relatively frequent meals of invertebrates as juveniles before transitioning to sparser meals of teleost fishes as adults (Armstrong et al. 1996; Steimle et al. 1999a). Recent studies using archival tags provided evidence of extended excursions in the water column, contracting the sedentary ambush mode of predation, corroborating that birds are eaten as live prey, and supporting that migration is assisted by selective tidal stream transport (vertical movement between stratified water column layers with different flow velocity (Richards et al. 2012; Rountree et al. 2006). Goosefish have few natural predators as adults and are only occasionally preyed upon by Spiny Dogfish (*Squalus acanthias*) (which are common prey of Goosefish themselves), Smooth Dogfish (*Mustelus canis*), *Charcharhinus* sp. sharks, and other Goosefish. They are a frequent bycatch in scallop dredges, and this appears to often fatal due to their unscaled bodies and lack of escape response (Grothues et al. 2017a). Eggs are broadcast as a cohesive clutch into a mucilaginous pelagic "veil" resembling a jellyfish that may extend more than a meter across (Caruso 2002). Larvae also have a pelagic stage before metamorphosis (Able et al. 2007).

Goosefish are managed by the NMFS and the New England and Mid-Atlantic Fishery Management Councils.

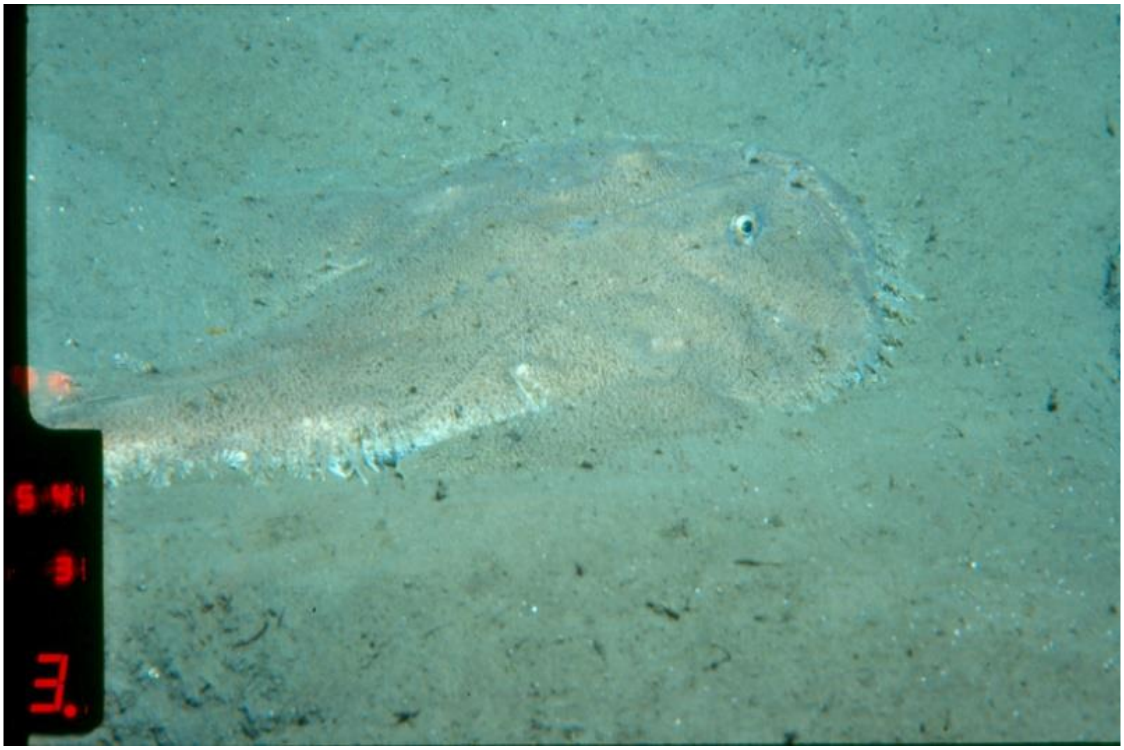


Figure 13. Partially buried Goosefish
Observed from Delta Submersible on the NYB OCS. Image credit: Rutgers University Marine Field Station

3.3.4.23 Atlantic Cod and Pollock

Atlantic Cod (*Gadus morhua*) and Pollock (*Polloachius virens*) are gadoid groundfishes of Georges Bank, the Gulf of Maine, and the Scotian Shelf. They are occasionally encountered in the NYB as adults and usually deeper than the study area (37–364 m for Pollock, 150–200 m and down to 600 m for Atlantic Cod) but come as far south as North Carolina (Cargnelli et al. 1999a; Lough 2004; Scott and Scott 1988). They are cold-water species, with temperature range of 0–15ºC (Fahay et al. 1999). However, larval Pollock dispersed from OCS or northern spawning sites recruit to estuaries of the NYB in winter and are captured as juveniles in traps and in spring by trawl surveys there, and juveniles may be found across the NYB (Able and Fahay 2010). Atlantic Cod prefer rocky, pebbly, and gravelly sediments within their range and avoid finer sediments, while Pollock are unselective outside of spawning. During spawning, Pollock prefer hard bottoms (Cargnelli et al. 1999a; Lough 2004).

The NMFS and the New England Fishery Management Council collaborate with Canada to manage Atlantic Cod. Pollock are also managed by the NMFS and the New England Fishery Management Council.

3.3.4.24 Ocean Pout*

Ocean Pout (*Macrozoarces americanus*) are cool-water (< 10Cº), non-migratory, bottom-dwelling anguilliform fish encountered on the continental shelf from Labrador to Cape Hatteras, with the highest population density occurring in New England (Steimle 1999a). The species has been inconsistently exploited as a food fish within the US. Juvenile Ocean Pout are frequently consumed by Illex squid, Spiny Dogfish, Atlantic Cod, and Barndoor Skate (*Dipturus laevis*), but adults do not appear to be a key prey species (Cairns 1998; Froerman 1984; Scott and Scott 1988; Stillwell and Kohler 1993). Adults are found across most sediment types, though there is seasonal variability in microhabitat use (Auster et al. 1995; Auster et al. 1991; Bigelow and Schroeder 1953; Smith 1898). When occurring over soft sediment, individuals will burrow backwards using their eel-like tail. Adults may move seasonally to remain within their preferred temperature range (2–10Cº) and protected habitats—such as rocky crevices, large mollusk shells, and artificial structure—are used by spawning and nesting adults. Incubation is temperature dependent and takes 2–3 months in the Gulf of Maine but can be shorter in the MAB and NYB (Olsen and Merriman 1946). Juveniles prefer coastal waters around rocks with attached algae and water deeper than 90 m; they use bottom with shell cover (Auster et al. 1995; Sheehy et al. 1977).

Ocean Pout are managed by the NMFS and the New England Fishery Management Council.

3.3.4.25 Hakes*

Silver Hake (*Merluccius bilinearis*) and Offshore Hake (*Merluccius albidus*) are two commercially important gadid fish that are frequently caught together with the more distantly related physics hakes (Red Hake [*Urophycis chuss*], White Hake [*U. tenuis*], Squirrel Hake [*U. regia*]) (Colvocoresses and Musick 1984; Gabriel 1992; Steves and Cowen 2000). Larval and juvenile Silver Hake are found on the OCS, with larvae forming a significant portion of the area’s zooplankton before settling into silt-sand habitats with amphipod tubes at depths ≥ 60 m (Auster et al. 1997; Steves and Cowen 2000; Steves et al. 1999). Within the NYB, age-0 Silver Hake settle to the OCS during the summer and fall (Lock and Packer 2004; Steves and Cowen 2000). Adult Silver Hake may be found within the inner continental shelf and nearshore habitats from Newfoundland to South Carolina, where they seem to prefer sand wave habitats (Auster et al. 2003; Malek et al. 2014). Adult Offshore Hake range in depth from 80–1,170 m.

The physcid hakes also occur within the NYB (Briggs and Waldman 2002; Colvocoresses and Musick 1984; Gabriel 1992; Overholtz and Tyler 1985). Physcid hakes have been found within slope-and-canyon and shallow habitats within the NYB and seem to prefer microhabitats with shell (Auster et al. 1995;

Auster et al. 1991; Overholtz and Tyler 1985). These species have one or two prehensile free pelvic fin rays covered with chemosensitive taste buds, with which they probe the sediment ahead of them, as well as a barbell, demonstrating a close dependency on buried infauna as prey. Red Hake appear to be a common prey item of Goosefish where their ranges overlap (Armstrong et al. 1996). An affinity for cooler water means that Red Hake rely on the Cold Pool during summer migration (Nye et al. 2009).

Hakes are managed under NMFS and the New England Fishery Management Council.

3.3.4.26 Sand Lance*

Two species of Sand Lance are distributed within the NYB, the inshore American Sand Lance (*Ammodytes americanus*) (< 20 m depth) (Nizinski 2002) and the offshore Northern Sand Lance (*A. dubius*) (2–100 m depth) (Nizinski et al. 1990). Atlantic Sandlance have a narrower and more southern distribution, with a population range from Labrador to Delaware, while the Northern Sand Lance population range is Greenland to North Carolina and includes the northeast Atlantic (Robins and Ray 1986). Together, Sand Lance play a significant ecological role in the Northwest Atlantic and are considered the “quintessential forage fish,” supporting a range in predators, including seabirds, several fishes of high conservation concern such as Atlantic Sturgeon, and key species treated in this synthesis, such as skates, small sharks, jacks and tunas, Striped Bass, and also marine mammals (Robards et al. 1999; Staudinger et al. 2020). The two species exhibit different growth patterns due to temperature regimes of their respective habitats relative to both latitude and distance from shore (Robards et al. 2002). In the Mid-Atlantic, a small-scale bait fishery for forage species includes Sand Lance in Federal waters (Mid-Atlantic Fishery Management Council 2017). Spawning occurs in fall and winter months and eggs develop on sandy substrate. Bottom fishing gear can disturb demersal eggs and adults residing in the sediment (Staudinger et al. 2020). Egg development rate is highly temperature dependent (Smigielski et al. 1984). Larvae hatch into cold and cooling water and reside within the water column for 3–4 months prior to settling into demersal habitats (Auster and Stewart 1986). Projected warming in the NYB, particularly in the winter and spring, could have negative population implication (Staudinger et al. 2020). Adult Sand Lance have a strong association with coarse-grained sandy habitats that serves as burial refuge from predators (Nizinski 2002). Due to the tight association between various Sand Lance life stages and sandy demersal habitats, anthropogenic activities such as dredging, construction, and resource mining during periods of high abundance and spawning can disproportionately, relative to other forage fishes, result in decreased production (Staudinger et al. 2020). Lindeboom et al. (2011) suggest that the construction of artificial reefs as a side effect of wind power development could transform coarse-grain sediment habitats and alter the community composition. Conversely, some short-term studies from the North Sea showed short-term neutral or positive, but no long-term, effects on Sand Lance were detectable after the construction of wind turbines (Degraer et al. 2016; Stenberg et al. 2011; Stenberg et al. 2015; van Deurs et al. 2012). Sand Lance are managed by the Mid-Atlantic and New England Fishery Management Councils.

3.3.4.27 American Butterfish*

American Butterfish (*Peprilus triacanthus*) is a small (120–305 mm), short-lived pelagic forage fish that has a population range spanning from Newfoundland to the Gulf Coast of Florida and centering in the MAB (Cross et al. 1999). American Butterfish normally form loose schools near the surface, where they feed upon planktonic prey, such as pelagic tunicates, squids, copepods, amphipods, decapods, hydrozoans, polychaetes, small fishes, and ctenophores (Cross et al. 1999). Butterfish are eaten by numerous larger species, such as Longfin Inshore Squid, Silver Hake, Goosefish, Bluefish, Weakfish, hammerhead sharks, and Haddock.

Within the NYB, American Butterfish exhibit a seasonal inshore-offshore and north-south migration that is mainly driven by changes in water temperature (Cross et al. 1999). During the summer, butterfish may range throughout the entire NYB, from estuaries to offshore waters 200 m deep (Cross et al. 1999; Kohut et al. 2013). They begin to move offshore during the fall as temperatures cool and overwinter on the edge of the continental shelf. While overwintering, American Butterfish become epibenthic and may be found over sand, mud, and rock bottoms up to 200 m deep (Cross et al. 1999). Butterfish return to inshore waters when temperatures warm in the spring (Kohut et al. 2013). Within the NYB, butterfish spawning may occur during evenings and nights from February to October, with a peak in June and July (Cross et al. 1999). Temperature appears to regulate American Butterfish spawning, which is unlikely to happen below 15ºC.

American Butterfish are managed by the NMFS and the Mid-Atlantic Fishery Management Council.

3.3.4.28 Other Forage Species*

A number of species from the larger herring group (Clupeiformes) occur in the NYB, are extremely important as forage species, and may in turn be important predators of the pelagic larvae of all other species because they filter feed on plankton (Clay et al. 2014; Willson and Halupka 1995). Most are also fished for direct consumption, bait, or rendering into fish meal, oil, or protein products (Clay et al. 2014). These include Atlantic Menhaden (*Brevoortia tyrannus*), Atlantic Herring (*Clupea harengus*), Round Herring (*Etremus teres*), and the Alosine shads (river herrings): American Shad (*Alosa sapidissima*), Alewife (*A. psuedoharrengus*), Blueback (*A. aestivalis*). Three smaller filter feeding species, Bay Anchovy (*Anchoa mitchilli*), Striped Anchovy (*A. hepsetus*), and Silver Anchovy (*Engraulis euyostole*) also occur seasonally. Atlantic Menhaden are highly important as a fisheries species sold as a reduction product (fish meal, old, protein supplements) (SEDAR 2020). Atlantic Menhaden spawn continuously on the inner and OCS over a wide range of the SEUSCS, MAB, and Gulf of Maine (Warlen et al. 2002), which should make them resilient to local perturbation through the portfolio effect (Secor 2007), but the YOY are estuarine dependent (Able and Fahay 1998; 2010). The river herrings are anadromous and in decline, possibly from dams and other degradation (Ellis and Vokoun 2009; Hall et al. 2011; 2012b; Tommasi et al.), although other evidence implicates bycatch in offshore pelagic fisheries (Bethoney et al. 2014; Hall et al. 2012a; Hasselman et al. 2016; Turner et al. 2016).

Many of the forage species are managed by the ASMFC and sometimes in collaboration with the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council.

3.3.4.29 Striped Bass*

Striped Bass (*Morone saxatilis*) are an economically important species throughout their range from Nova Scotia to Florida (Atlantic States Marine Fisheries Commission 2019b; Westin and Rogers 1978), and especially so in the Mid-Atlantic States, where they contribute to both commercial and recreational fisheries (Atlantic States Marine Fisheries Commission 2019b). In New Jersey and New York, their importance as an economic leveraging factor through spending by anglers during fishing trips is so great (Southwick Associates 2018) that the species is protected from commercial take as a gamefish (https://www.njfishandwildlife.com/pdf/2021/comregs21.pdf, https://www.dec.ny.gov/outdoor/113797.html). Approximately 90% of angler-caught Striped Bass are released alive (Atlantic States Marine Fisheries Commission 2019b).

Striped Bass are anadromous and juveniles stay in rivers and estuaries for the first several years (Able et al. 2012a; Morris et al. 2003; Secor and Piccoli 1996) and may even remain there as non-migratory adults (Secor et al. 2001). Ocean migration participation is learned and plastic and contingents may be riverine, move between but principally utilize estuaries, or stay marine except to spawn and have different extents and desinations within that migration (Clark 1968; Grothues et al. 2009; Secor et al. 2001; Secor 1999; Secor and Piccoli 2007). Marine dwellers tend to be the larger individuals and migrate at least between Maine in summer and North Carolina to overwinter in the Caroline Capes area, but they also use estuaries and rivers to overwinter (Dorazio et al. 1994; Welsh et al. 2007). Based on telemetry of 315 Striped Bass through a hydrophone array offshore Delaware Bay just south of the study area, ocean migrants were detected in highest incidence in spring (April) and again, although lower, in winter (December through February) and preferred the middle or outer shelf to the inner shelf (Rothermel et al. 2020). In doing so, they avoided water temperature > 15ºC in fall and occupied a range of 9–13ºC, with a tolerance down to 7ºC (Rothermel et al. 2020).

Striped Bass are ecological generalists, able to exploit a wide variety of habitats (including land-locked reservoirs) over rock, cobble, sand, or mud and prey on a wide variety of invertebrates and fishes. Individuals can develop feeding and ranging habit "personalities" (Able and Grothues 2007; Grothues et al. 2009; Kneebone et al. 2014b). Although this diversity in life history creates a "portfolio effect" (Secor and Piccoli 2007) that proffers resilience against environmental dynamics, the stock has undergone great fluctuations due to recruitment variation that was not historically anticipated, allowing lagged recruitment overfishing (Atlantic States Marine Fisheries Commission 2019b). Based on work in the Chesapeake Bay, a major source of NYB Striped Bass, high volume of fresh riverine input from watershed precipitation enhances the extent and nutrient load of estuaries to promote and concentrate the prey of Striped Bass larvae, while droughts cause the recruitment bottleneck (Martino and Houde 2010). However, coastal storms can also cause cold mortality through shock (Rutherford and Houde 1995) or though starvation due to torpor (Hurst 2007; Hurst and Conover 2002).

Striped Bass are managed by the ASMFC.

3.3.4.30 Drumfishes (Atlantic Croaker*, Spot, Weakfish*, Black Drum, Northern Kingfish*)

Drumfishes (Family Scaenidae), collectively named for the ability to vocalize by stridulating the resonant swimbladder, are well represented in the NYB by five species and incidentally by at least three more (Able and Fahay 2010). All five common species are estuarine dependent or estuarine facultative for juvenile nursery habitat and all are concentrated inshore along beaches or in estuaries as adults also, but all can occur well out onto the continental shelf as adults. Additionally, the YOY can be found on the inner continental shelf in different seasons (**Table 2**) (Able and Fahay 2010), but it is unclear if those contribute much to the population in most years (see Knowledge Gaps). All are centered to the south, with ranges to North Carolina or even Florida. and most enter the NYB in spring while Atlantic Croaker enter later (**Table 2**). All retreat south or onto the shelf by October (Able and Fahay 2010). Recruitment strength of the smaller species can vary greatly on interannual scales, and for Atlantic Croaker this has been related to winter temperature (Able and Fahay 2010; Hare and Able 2007).

Black Drum (*Pogonias cromis*), Atlantic Croaker, and Northern Kingfish (*Menticirrhus saxatilus*) have subterminal inferior mouths and barbels with tastebuds, which they use to find infaunal prey in sediments; the difference in barbell presence and mouth morphology reflects diet differences (Able and Fahay 2010; Bowman et al. 2000; Chao and Musick 1977; Mercer 1983) (**Table 2**). All are described as using habitat over sand and mud, but the literature treats mostly estuarine distribution and feeding (Able and Fahay 2010; Collette and Klein-MacPhee 2002). The largest species, Black Drum reach greater than 50 kg and are specialist predators on bivalves, including large adult clams and oysters (Grubich 2000). Black Drum use the continental shelf south of the NYB but stay along the beach or in estuaries while in the NYB (Collette and Klein-MacPhee 2002), see also Data Synthesis). The potential for this to change with warming of the NYB should be considered (See Knowledge Gaps). Weakfish and Atlantic Croaker spawn on the NYC continental shelf, including at a shoreface sand ridge off New Jersey based on recordings of the spawning calls (Mann and Grothues 2009). A recent low in the population of Weakfish (Atlantic States Marine Fisheries Commission 2016) is ascribed to increased predation by Striped Bass and dolphins during periods of growth for these predator populations (Krause et al. 2020).

Most species of the drumfish family are managed by the ASMFC.

Table 2. Life history diversification among five common drumfishes in the NYB

Species	Barbel	Principle Adult Diet	Spawning Season And Location	Nursery Habitat	Lower Depth Limit (m)
Atlantic Croaker	Yes	crustaceans, annelids, mollusks, ascidians, brittle stars, fish	October-December, inner shelf in NYB	Estuary, inner shelf (fall)	273
Black Drum	Yes	clams, oysters crabs	Spring, estuaries	Estuary	Do not use shelf in NYB
Northern Kingfish	Yes	Benthic infauna	Spring-summer, shelf in NYB	Estuary, inner continental shelf	76
Spot	No	Benthic infauna	Winter, outer shelf south of NYB	Estuary, inner shelf (fall)	240
Weakfish	No	Forage fishes, flatfishes, other drumfishes, natant decapods	Spring, summer	Estuary, continental shelf	40

Note: Upper depth limits approach the shoreline for all species.

3.3.4.31 Black Sea Bass*

Black Sea Bass (*Centropristis striata*) are distributed over the entire MAB continental shelf, where they support highly valuable commercial and recreational fisheries. The US population range is reported from Maine to northeastern Florida and disjunct in the eastern Gulf of Mexico; it may extend to southern Florida during cold winters (Scott and Scott 1988). Black Sea Bass are protogynous hermaphrodites (Mercer 1978), with sex change thought to be stimulated by social signaling(Benton and Berlinsky 2006) and therefore vulnerable to threats from selective overfishing of larger males. Although they frequently occur over sand (Fabrizio et al. 2013; Jensen and Zemeckis 2019) and forage there (Steimle and Figley 1996), they are closely associated with reefs, wrecks, or even minor projections from an otherwise soft bottom of unconsolidated sediments (Drohan et al. 2007; Moser and Shepherd 2009). Their diet indicates exploitation of a wide range of foraging opportunities, including sediment infauna such as worms and mollusks, but also soft bottom, benthic-oriented, and water column species such as mysids, Windowpane (Flounder), Cusk Eel, Sand Lance, and nekton such as euphausid shrimps, anchovies, and herrings (**Appendix A**) (Bowman et al. 2000; Sedberry 1988; Steimle and Ogren 1982). Though Black Sea Bass diet analysis indicates consumption of soft bottom species, the extent to which they forage in soft bottom habitat is unclear. Telemetry from two different studies that were combined with side scan sonar show that Black Sea Bass are closely tied to the location of a reef, but not individual reef pieces, and that the sand between reef elements covers more ground than reef (Fabrizio et al. 2014; Jensen and Grothues 2015).

Juvenile Black Sea Bass use estuaries as well as the inner continental shelf (Diaz et al. 2003; Drohan et al. 2007; Moser and Shepherd 2009; Musick and Mercer 1977). Spawning occurs at aggregations focused on reefs and wrecks beginning in May over a wide range of depths. The sex-biased fishery in conjunction with protogyny and especially reef-association all challenge stock assessment of this species, the fishery independent part of which is based on a trawl survey (Jensen and Zemeckis 2019; Miller et al. 2009). Black Sea Bass migrate so that the center of distribution shifts onshore in warmer months and offshore towards winter, but they are present on the region of interest at all times of the year (Moser and Shepherd 2009; Musick and Mercer 1977).

A trap survey of Black Sea Bass on sand and different reef types failed to find a consistent pattern in the Black Sea Bass CPUE (Jensen and Zemeckis 2019). Dependent on general reef location, Black Sea Bass CPUE was highest on concrete (Little Egg Inlet Reef), sand (on Sea Girt Reef), and metal (on Manasquan Inlet Reef). Black Sea Bass catch was lowest on sand on both Little Egg Inlet Reef and Manasquan Inlet Reef and lowest on metal on Sea Girt Reef. In the same survey, Tautog CPUE was never higher on sand than on structure. In another experiment of the same survey, traps were deployed on sand before artificial reef construction and subsequently on the constructed reef, and the change was compared to the change across the same years on two existing reefs in a Before-After-Control-Impact (BACI) design. There was a net mean CPUE increase of 1.07 Black Sea Bass per trap per day attributable to the deployment of reef materials. The difference in reef quality, including substrate type and patch density, may have accounted for consistent differences in the response of fishes among reefs. There are more than 4,000 artificial reef patches (individual wrecks, concrete structures, train cars, etc.) in 15 federally permitted reef sites (Resciniti et al. 2009) (**Figure 14**). The possibility that a high density of artificial reefs (such as wind power pylon) can effect use of adjacent sand habitat has been tested in the North Sea, where no strong effect was found on fish distribution (Lindeboom et al. 2011), but has not been examined in the NYB, which has a much richer species assemblage (see Section 5.1 Scaling).

Black Sea Bass are managed jointly by the ASMFC and by the Mid-Atlantic Fishery Management Council.

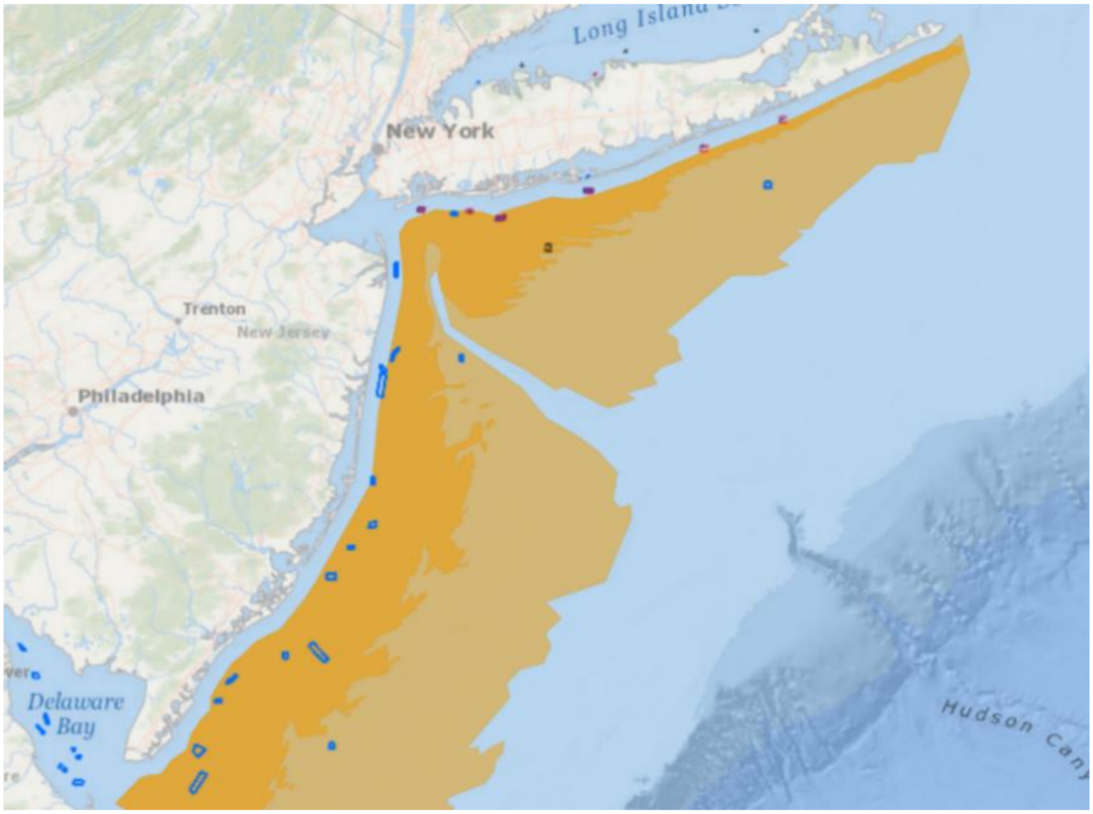


Figure 14. Chart of existing (blue) and planned (red) permitted artificial reef sites
Dark orange polygon is waters less than 30-m depth, light orange polygon is waters less than 50-m depth within the Federal waters of the study area. Generated by https://portal.midatlanticocean.org/visualize

3.3.4.32 Scup*

Scup (*Stenotomus crysops*) (also known locally as "porgy") are a temperate demersal species found from the Bay of Fundy to Florida, with a center of population between Massachusetts and South Carolina (Steimle 1999b). Adults use a wide variety of benthic habitats across seasons, including soft sandy bottoms, hard structure (e.g., artificial reefs, wrecks, and rocky ledges), and mussel beds. Juveniles are estuarine dependent (Able and Fahay 1998; 2010). Scup YOY utilize both estuarine and continental shelf nursery habitat and are common in survey trawls on the inner continental shelf in fall and on the mid-to-outer shelf in winter and spring (Able and Fahay 2010). Scup feed primarily on benthic invertebrates, such as small crustaceans, polychaetes, mollusks, small squid, and sand dollars; small fish, vegetable detritus, insect larvae, and hydroids may also be consumed (Bowman and Michaels 1984; Steimle 1999b). This focus on benthic invertebrate prey makes Scup's diet largely similar to other soft bottom fishes, such as the small mouthed plueronectid flounders (Garrison and Link 2000) (see Sections 3.2.4.6 and 3.2.4.8). Both juvenile and adult Scup exhibit an inshore-offshore seasonal migration and depart inshore habitats when water temperatures decline to < 8–9ºC during the winter, overwintering on the OCS at depths ranging from 75 to 185 m (Steimle 1999b). They return to inshore habitats when waters warm in the spring, with larger fish arriving first. Within the NYB, Scup are targeted by commercial trawl fisheries and recreational hook-and-line anglers (Atlantic States Marine Fisheries Commission 2015c).

Scup are managed jointly by the ASMFC and the Mid-Atlantic Fishery Management Council.

3.3.4.33 Tautog (Blackfish)

Tautog *(Tautoga onitis*) is one of only two wrasses within the NYB and a species of considerable recreational and commercial value. The population range is from Halifax, Nova Scotia, to South Carolina, but it is most abundant between Cape Cod and Delaware Bay. Tautog populate reefs between 1- and 75-m depth and sleep at night by wedging themselves into crevices (Olla et al. 1974; Olla and Studholme 1978), going into an extended torpor during cold winter months (Cooper 1966). Their dentition and jaw morphology reflects a reliance on hard shelled prey—particularly mussels and crabs taken off reefs—although their diet also includes also sand dwelling organisms such as sand dollars and scallops (Olla et al. 1974; 1975). The only habitat-scale telemetry studies of tautog are estuarine (Arendt et al. 2001a; Arendt et al. 2001b; Olla et al. 1975) but show dispersal away from cover. Tautog juveniles are only rarely found on the shelf even though adults spawn there (Able and Fahay 2010). Like Black Sea Bass and Scup, Tautog make an ontogenetic shift towards continental shelf habitat, seasonally migrating towards deeper habitat in fall/winter and shoal habitat in spring and summer (Able and Fahay 2010; Adams 1993; Cooper 1966; Olla et al. 1974; Olla and Studholme 1978; Olla et al. 1980; Steimle and Shaheen 1999). Tautog are managed by the ASMFC.

3.3.4.34 Bluefish*, Jacks, and Tunas

Bluefish (*Pomatomus saltatrix*) exemplify the distribution dynamics for a number of NYB fish species because of divergence or plasticity in early and adult life history and habitat use. They respond to environmental forcing through many of the mechanisms that act on other fishes. They are important commercially, recreationally, as predators, and as prey. They disperse through a planktonic larval stage, and over a protracted spawning season, they migrate, are highly vagile, and are not reef resident but are attracted to benthic features that concentrate resources (Shepherd and Packer 2006). Fisheries managers assess US East Coast Bluefish as a single stock (Shepherd and Nieland 2010; Shepherd and Packer 2006). Among Bluefish, non-migrant individuals maintain a presence south of the NYB, while migrants push north into and often well past it beginning in May and retreating through November. A contingent of NYB resident Bluefish is postulated on the basis of catch in infrequent exploratory surveys but has not been verified through tagging, perhaps because coastal migrants are disproportionately represented by this mark and recapture methodology (Shepherd and Packer 2006). The postulated resident contingent is thought to mix with migrants in the inner to OCS or Hudson Valley Canyon in May through November but retreat seaward to the slope break in winter. Out of 1,539 tag returns between1963 and 2003, releases were primarily (56%) from recreational angler-caught fishes. Because angler distribution (both in initial tagging effort and recapture) is biased towards nearshore, the NMFS addressed this by tagging offshore. Return rates were low overall at 4.3%, and of these, the tags from fish captured offshore were underrepresented, suggesting that they were less likely to be recaptured than Bluefish tagged in nearshore waters. This could be explained by a lack of mixing with the nearshore population. Further, tag returns were generally from fish at liberty for less than a year after tagging (and most less than one month), suggesting high mortality of tagged fish or at least a high tag shedding rate. Of the fish at liberty over more than two years, all were recaptured from New Jersey or northward. Although many small fish tagged in the south were recaptured to the north, all captures of large fish were from the northern area (MA to DE). Together, this demonstrated the likelihood that fish restricted their ranging behavior and their individual migration routes to the north as they grew. An ontogenetic shift favors ocean water, including well offshore. FishBase reports their depth range from 0–200 m. In the NYB, Bluefish diet for young and adults is dominated by squid and fish, especially forage species Bay Anchovy (*Anchoa mitchilli*), Striped Anchovy (*Anchoa hepsetus*), Butterfish (*Peprilus triacanthus*), and herrings but includes a variety of benthic species such as flounder, crabs, worms, amphipods and even whelk, a heavily armored benthic gastropod from which they bite off the foot and operculum (Buckel et al. 1999). Bluefish are unique among other NYB bony fishes in that they sever pieces of large prey rather than eat them whole; this allows exploitation of a much larger size range of potential prey (Scharf et al. 1998).

Bluefish share aspects of their migration and larval dispersal phase with a number of other southern transient species that use the NYB shelf habitat seasonally, including jacks (Carangidae)—for example Horse Eye Jack (*Caranx hippos*) (McBride 1995)—and scombrids—for example King Mackerel (*Scomberomorus regal*is*)*, Spanish Mackerel (*S. maculatus*), and Little Tunny (*Euthynnus alletteratus*)—although these utilize coastal or ocean nurseries rather than estuaries (Studholme 1999). Although none of these highly vagile species appear to rely directly on sand as a resource and are highly opportunistic, all take benthic prey and aggregate and are targeted by anglers around shoreface sand ridges, where they prey on Sand Lance (*Ammodytes sp*.); they also aggregate around other bathymetric breaks that steer currents and concentrate forage fish (Manooch et al. 1985; National Marine Fisheries Service 2011; Schultz 2004). Bluefish are managed by the NMFS, the Mid-Atlantic Fishery Management Council, and the ASMFC.

Bluefin Tuna (*Thunnus thynnus*) also utilize the breadth of the NYB continental shelf, and a study from the Gulf of Maine and into the NYB showed that diet was location sensitive in that it was broad overall, including even sessile sponges, but locally focused on whatever was abundant (Chase 2002). In contrast to Bluefish, however, spawning is more regionally restricted, and these very large fish range farther and deeper, penetrate colder water; Bluefish is an important part of their diet. Depth range is reported by FishBase from 0–985 m, usually 0–100 m. They tolerate temperature between 3 and 30ºC (Block 2001).

Other large scombrids tend to stay beyond the shelf break in Slope Sea and Gulf Stream or deeps of the Hudson Valley where it intersects the shelf, and so they do not intersect with sand extraction activities. Ecologically similar species in the NYB include transient Cobia (*Rachycentron canadum*), Blue Runner (*Caranx crysos*), and other Carangids.

3.3.4.35 Atlantic Chub Mackerel and Atlantic Mackerel*

Atlantic Mackerel (*Scomber scombrus*) and Atlantic Chub Mackerel (*S. colias*, but until recently reported as *S. japonica colias*, a subspecies of Pacific Mackerel) are very similar and are true tunas but differ in ecology from the species discussed above in that they are small (to about 0.3-m length) and primarily planktivorous filter feeders that form large shoals throughout the Atlantic Ocean (Castro-Hernández and Santana-Ortega 2000). They are important prey for many species—including the tunas, jacks, billfishes, Bluefish, sharks, and birds—and can be treated ecologically as forage fishes rather than game fish or predator, though they are a managed species that are commercially and recreationally fished in the NYB. As a group, the so-called Blue Mackerels of this genus are hugely important as a fisheries species and subsistence species worldwide (Castro-Hernández and Santana-Ortega 2000). In the US and Canada, they are currently listed as overfished (but remain abundant in their wide distributions) and listed of least concern (Canada 2019; Mid-Atlantic Fishery Management Council 2019; Mid-Atlantic Fishery Management Council and National Marine Fisheries Service 2019). They are managed together with American Butterfish and Longfin Squid because they are caught together in similar gear, especially paired trawls. Atlantic Mackerel are abundant occur across the continental shelf in the study area but are not "directly dependent either on the coastline or on the bottom in any way at any stage of their lives" and occur well out to sea, while Atlantic Chub Mackerel are more coastal and tend towards warmer water (Collette 2002). FishBase reports Atlantic Mackerel depths range of 0–1,000m, but usually less than 200 m.

Atlantic Mackerel and Atlantic Chub Mackerel are managed under NMFS and the Mid-Atlantic Fishery Management Council.

3.3.4.36 Summer Flounder*

Several economically important species of flatfish are found within the NYB but as widely as Maine to Southern Florida (Auster et al. 1991; Briggs and Waldman 2002; Colvocoresses and Musick 1984; Gabriel 1992; Overholtz and Tyler 1985). Of these, there is an interesting life history contrast between Summer Flounder *Paralichthys dentatus* and Winter Flounder *Pseudopleuronectes americanus* in that both utilize and migrate between the OCS and estuary as adults and both utilize estuarine nursey habitat beginning in winter, but larvae reach this through different means. In the NYB, both species spend the first years of their lives within shallow estuarine habitats before moving to deeper offshore habitats at around two to three years old (Klein-MacPhee 1978; McCraken 1963; Methratta and Link 2007; Sackett et al. 2007). Similarities end there. Summer Flounder spawn pelagic eggs on the continental shelf during an offshore fall migration (Able and Kaiser 1994; Able et al. 1990). Based on studies of DNA and otolith mineral signature, the estuarine-dependent juveniles (Able and Fahay 2010; Packer et al. 1999) are sourced from a widely dispersed larval pool, which is sufficient to mix the stock (Hoey et al. 2020). Adults loosely segregate with females tending towards estuarine residency in spring and summer while the smaller males tend to remain on the continental shelf (Morson et al. 2012; Morson et al. 2015). Early out migration of estuarine individuals can be stimulated by low atmospheric pressure indicative of approaching tropical storms and storm timing may thus bias to the fall assessment surveys on the continental shelf (Sackett et al. 2007). However, as they grow, larger females also tend towards shelf residency and shift northwards within the NYB (Morson et al. 2015). The population center has shifted from Cape Hatteras into the NYB over the last two decades (Able et al. 2011b; Bell et al. 2014; Nye et al. 2009). Summer Flounder bury in the sand (Yergey et al. 2012) and can match their coloration pattern to the substrate. They have large mouths and teeth and are important predators of active fish and squid and are eaten by sharks and Goosefish on the OCS (Able and Kaiser 1994).

The NMFS, the Mid-Atlantic Fishery Management Council, and the ASMFC manage Summer Flounder.

3.3.4.37 Fourspot Flounder*

Fourspot flounder (*Paralicthys oblongus*) are congeners and similar in appearance to Summer Flounder but complete their lifecycle entirely on the continental shelf (Klein-MacPhee 2002b). Unlike Summer Flounder, Fourspot Flounder begin spawning in May in the NYB and spawn through summer. Larvae settle beginning at 8–12 mm and will thus be vulnerable to bottom disturbance. An early study identified a center of larval distribution midway out on the continental shelf off New Jersey (Smith et al. 1975). This needs to be re-evaluated due to a fast rate of climate change in this region. They are smaller than Summer

Flounder and therefore less valuable in fisheries. They move seasonally across the shelf from shoal summer depths of 27 m to of the shelf in winter in response to temperature but remain resident in the NYB (Miller et al. 1991; Wilk et al. 1975). Their distribution is centered deeper than that targeted for sand extraction (Guthertz 1967). The population range is reported by FishBase from Georges Bank to southern Florida. Diet changes with size and shifts from crustaceans and bony fishes towards cepahalopods. They are less active and more commonly captured in bottom trawls at night. They are eaten by sharks, Goosefish, and a variety of fish including other flounders as juveniles (Klein-MacPhee 2002b). Fourspot Flounder are unmanaged.

3.3.4.38 Winter Flounder*

Winter Flounder has long been a highly valuable commercial and recreational species (Perlmutter 1947) and has seen drastic declines in estimated stock size in the NYB in recent years, leading to full closure of the fishery on the Mid-Atlantic stock (essentially defined by the NYB) in 2014 (Atlantic States Marine Fisheries Commission 2013; Collie et al. 2008). The population range is from Labrador to Georgia, but they are becoming increasingly uncommon south of central New Jersey (Able et al. 2014). Winter Flounder lay adhesive demersal egg clutches in estuaries in winter, but the larvae that hatch from them are planktonic for periods of 8 days to weeks (Chambers and Leggett 1987; Chambers and Leggett 1992; Manderson et al. 2003; Pereira et al. 1999). Most of these larvae probably stay and settle in the natal estuary for periods of months and potentially longer (Manderson et al. 2003; Stoner et al. 2001), but they also appear on the inner continental shelf. Some evidence points towards permanent continental shelf residence and thus also spawning for a subgroup (contingent) of this species in the NYB (Burton and Burton 1989). For example, Chant et al. (1996) and Chant et al. (2000) found estuarine settlement consistent with both retention and ingress. Winter Flounder collected on the inner continental shelf of the NYB in January had ripe gonads, suggesting that they would spawn there or that migration to an estuary would have to be very rapid (Wuenschel et al. 2009). Individuals that were tagged and telemetered at the HARS were detected there (but moving) as late as December (Coleman 2015). OCS residence is consistent with the physiological capability of the eggs and larvae in terms of temperature and salinity tolerance (Chambers and Leggett 1987; Chambers and Leggett 1992) and the fact that conspecific populations to the north spawn on Georges Bank and inner Gulf of Maine, as well as along the inner continental shelf there (DeCelles and Cadrin 2010; Fairchild et al. 2013). The potential for these spawners to contribute to the total population is unknown and appears to be overlooked or recently changing as a result of climate change and a shrinking estuarine occupation (Able et al. 2014; Coleman 2015; Grothues et al. 2011). Tagging shows that Winter Flounder tagged in an estuary return to that estuary to spawn but mix with other Winter Flounder on the continental shelf in summer (Phelan 1992). Winter Flounder bury in sediment, at least during estuarine residency, and in winter; this could be for a period of more than a week (Grothues et al. 2012; Grothues et al. 2011; Olla et al. 1969). They are small mouthed, and adults eat primarily benthic invertebrates, including worms, crustaceans, and small clams (Pereira et al. 1999), although diet study is based heavily on estuarine collections. As adults, when they are on the OCS, they are eaten by Goosefish, sharks, seals, and osprey (Klein-MacPhee 2002a).

Winter Flounder are managed by the NMFS and the New England Fishery Management Council in Federal waters. In state waters, they are managed by the ASMFC.

3.3.4.39 Windowpane*

Windowpane (or Windowpane Flounder) (*Scopthalmus aquosos*) are thin-bodied, left-eyed flounder (Chang 1999). They are most abundant from depths of 1–56 m but found as deep as 200 m (Wenner and Sedberry 1989); they may be found in bays, estuaries, nearshore, and continental shelf waters within the NYB (Chang 1999; Thorpe 1991). The population range is reported by FishBase to extend from the Gulf of Saint Lawrence to northern Florida. Both juvenile and adult windowpane are typically found nearshore (< 40 m depths) throughout the year, with additional migration to nearshore and estuarine habitats in the spring through autumn (Chang 1999). Windowpane prefer sand to sand-silt substrates within the MAB but have been known to occur over mud bottoms as well, particularly within the Gulf of Maine (Chang 1999; Langton et al. 1994). Both life stages primarily feed upon small crustaceans—particularly mysids—and small fish larvae, and are in turn predated upon by Spiny Dogfish, thorny skate, Goosefish, Atlantic Cod, Black Sea Bass, Weakfish, and Summer Flounder (**Appendix A**) (Chang 1999). They have two spawning phases in the NYB coinciding with the beginning (spring) and end (fall) of a protracted spawning season, the mode of which happens to the north of the NYB (Morse and Able 1995; Wilk et al. 1990). The eggs and smallest larvae (especially of the fall cohort) in the NYB are most abundant in the center of the continental shelf coincident with the region of interest, and, therefore, putative spawning grounds.

Windowpane are managed by the NMFS and the New England Fishery Management Council.

3.3.4.40 Other Managed Flounders

Witch (*Glypotcephalus cynoglossus*) and Yellowtail Flounder (*Pleuronectes* [formerly *Limanda*] *ferruginae*) are two additional economically important flatfish species that occur in the NYB. Both utilize OCS nursery grounds, but an affiliation with cold water means that the bulk of the distribution is often deeper than the projected sand extraction area, is in winter, or is restricted to the Cold Pool (Auster et al. 1991; Briggs and Waldman 2002; Colvocoresses and Musick 1984; Gabriel 1992; Overholtz and Tyler 1985). They have planktonic larvae that settle on the shelf. Both are small mouthed species that eat primarily sediment epi- or infauna, such as gammarid amphipods and polychaete worms (Bowman et al. 2000; Cargnelli et al. 1999b; Link et al. 2002). In a comparison between habitat use and its ontogenetic shift, Yellowtail Flounder was least strongly associated with its preferred habitat type of coarser sediment than Flourspot Flounder, American Plaice (not a significant contributor to NYB fish fauna), and Winter Flounder because it was more likely to shift with season than the others, probably due to a temperature sensitivity (a correlate of season) (Methratta and Link 2007).

Other flatfishes that utilize the NYB have no commercial value but may be important due to their occurrence in the diet of other species and their reliance on sand. These include Smallmouth Flounder (*Etropus microsotomus*) and Gulf Stream Flounder (*Citharichthys arctifrons*). These also complete their life cycle on the OCS. Little is known about their nursey needs because nets that sample these depths are typically of large mesh (see Knowledge Gaps). The exceptions are several studies that used 2-m beam trawls with 1-mm cod end mesh or submersible observations (Steves et al. 1999; Sullivan et al. 2003; Sullivan et al. 2000; Sullivan et al. 2005).

These flounders are managed by the NMFS and the New England Fishery Management Council.

3.3.4.41 Northern Puffer*

Northern Puffer (*Sphoeroides maculate*) are estuarine spawners, and adults are found mostly in estuaries and nearshore coastal waters from Newfoundland to Florida to a maximum of 60-m depth, but YOY are common out to the middle continental shelf in the NYB (Able and Fahay 2010). Most of the literature on life history and diet comes from estuarine studies. They utilize many habitats, including hard and soft bottom, in which they can bury. Adults spawn May to August, but both adults and YOY have to retreat south by the end of fall as they are subject to cold mortality (Richards and Castagna 1970; Wicklund 1970). Cold also slows growth (Able and Fahay 1998), which is important given that these are small (< 30 cm total length), but they need to migrate within their first year (Shipp 1974). Northern Puffer have fused beak-like teeth that allow them to bite of pieces of prey and break through hard-shelled prey, including large crabs, barnacles, shelled mollusks, bryzoans; they also eat soft invertebrates such as worms (Nichols and Breeder 1927). They are eaten by tunas, Bluefish, sharks (Collette and Klein-MacPhee 2002), and recreational anglers (Hammer 1972). Abundance in NYB nearshore water and estuaries varies greatly among years from absence to dominance (Murawski and Festa 1979). A depleted local population can be quickly reestablished by larvae spawned south of Cape Hatteras and transported to the MAB as larvae (Able and Fahay 2010). Northern Puffer are managed by the states.

3.4 Assemblages

Several persistent assemblages form among the sand-dependent species of the NYB (Colvocoresses and Musick 1984; Gabriel 1992; Overholtz and Tyler 1985). These assemblages do not segregate along strictly benthic and demersally oriented gradients, or even sand feature-dependent or -independent gradients. For example, Summer Flounder have been found to aggregate with Scup and Black Sea Bass in two separate studies, even though the latter two species are more dependent on hard structure than sand features (Colvocoresses and Musick 1984; Gabriel 1992; Steimle 1999b; Steimle et al. 1999b). This particular assemblage seems to hold across both annual and seasonal scales. A second assemblage of note is that of Silver Hake, Red Hake, and Goosefish, with the occasional addition of White Hake (Colvocoresses and Musick 1984; Gabriel 1992; Overholtz and Tyler 1985). This particular assemblage seems to hold across annual, seasonal, and major habitat lines, occurring in slope-and-canyon, intermediate, and shallow habitats in the latter case. These species assemblages remain stable during migration and are likely due to shared thermal preferences (Colvocoresses and Musick 1984; Friedland et al. 2018; Gabriel 1992). Where assemblage segregation by habitat does occur, it seems to be on the basis of macrohabitat type—i.e., slope-and-canyon, shallow, deep—or by the formation of sub-assemblages by microhabitat use (Malek et al. 2014; Overholtz and Tyler 1985). This demonstrates spatial scale dependence. Shifts in species assemblages primarily occur on long time scales, with factors such as multi-decadal and climate change-driven shifts in thermal habitat having the greatest impacts on species ranges and assemblages (Gabriel 1992; Nye et al. 2009). There are indicators that assemblages are further influenced by the presence of keystone predators (Gabriel 1992). Within the MAB, the Spiny Dogfish are such a keystone species (Morgan and Sulikowski 2015).

3.5 Mechanisms of Disruption

In the sections above, natural and anthropogenic disturbances known to drive abundance and distribution were treated for individual species. Here, disturbance is summarized on the basis of mechanism. These include natural abiotic, natural biotic, and anthropogenic forces, as well as temporal and spatial changes to habitat. Changes on spatial scales can be viewed as perturbations in time: a fish traveling through habitats will encounter habitat changes as temporal disruptions. These are features of geology and bathymetry (Section 2.2), circulation (Section 2.3), seasonality (Section 2.4), migration, dispersal, ranging (Section 3.2.2), spawning success and mortality, ontogeny, and predation. Additionally, much of the area within these bathymetric boundaries is regularly disturbed by bottom-tending fishing trawl nets, clam dredges, and scallop dredges; and the upper sediment layer is naturally re-suspended and turned over by frequent seasonal storms, including hurricanes (Sullivan et al. 2003). Features that require additional attention include disease, storms, upwelling, specific bathymetric features, and climate change effects on acidification and water temperature.

3.5.1 Disease and Parasitism

Parasites are common to fishes and arise in many forms from many clades, including those living inside the gut lumen (roundworms), or boring from the gut into skeletal or cardiac muscle, or into other organs including liver and swimbladder (flatworms and roundworms). Ectoparasites, such as certain copepods, attach to the skin or gill filaments. Disease, including parasite load, covaries with environmental stress or fish and terrestrial animals as a rule—stressed fish become sick or sick fish are more easily stressed (Anderson and May 1978; Harvell et al. 2002; Hurst 2007; May and Anderson 1978) and more easily eaten by predators so that they are not frequently encountered by researcher (Packer et al. 2003a). Mortality can therefore rarely be disambiguated as a result of environmental or disease stress except under the relatively controlled and monitored conditions in aquaculture; much of the literature comes from application to that industry. Disease and parasitism documented to affect fisheries is generally the result of escape from aquaculture but remains controversial (Lafferty et al. 2015). Notable examples of disease from the NYB include:

1) Shell disease outbreak in American Lobster or epizootic shell disease causes pitting and erosion of lobster shells leading to secondary infections, decreased reproductive capacity, and death. A complex culture of bacteria infects the lesions, but the exact cause or instigator is unknown. By 2010, 35% of lobsters in the Southern New England area and Long Island Sound were affected (Castro et al. 2012; Gomez-Chiarri and Cobb 2012).
2) Gray-meat disease in Atlantic Sea Scallop results from infection by organisms of the Phylum Apicomplexa (a type of protozoan). Infection turns the edible adductor muscle gray and stringy. Apicomplexan infection led to rapid death in 92% of sick scallops in a laboratory (Levesque et al. 2016) and mass mortality in the wild (Stokesbury et al. 2019; Stokesbury et al. 2007).
3) A roundworm parasite also effects the adductor muscle of Atlantic Sea Scallops. It is visible as a lesion but is less virulent than gray-meat (Rudders et al. 2019)
4) Mycobacteriosis is a chronic wasting disease of Striped Bass, Atlantic Menhaden, and other fishes in Chesapeake Bay (an important source of NYB migrants). Excess mortality (calculated death rate over what would be expected in the absence of the disease) of Striped Bass was detectable through novel statistical methods (Gauthier et al. 2008; Stine et al. 2010).

3.5.2 Storms

Storms in the NYB include atmospheric disturbances from squalls to hurricanes and nor’easters, or in the case of Superstorm Sandy (2012), a combined post-tropical storm and Nor’easter. Sandy was large enough to cover the NYB synoptically as it made landfall in Tuckerton, NJ (Blake et al. 2013). Because this storm was so centered on the NYB and was large, powerful, and slow moving (Miles et al. 2017), it is useful to understand as an upper limit of storm perturbation. The storm forced a downwelling event by piling up water against the shore. This pushed the Cold Pool off the continental shelf. With the Cold Pool missing and replaced with warmer downwelled surface water, it could not be mixed upward to cool the surface (Miles et al. 2017). Upward mixing of cold nutrient rich water, known as “cold wake”, can stimulate phytoplankton blooms, which Sandy did not, making it differ from previous hurricanes in the area. The storm crossed the NYB on October 29, a period after which many NYB fish would have been migrating. Additionally, it suspended continental shelf sediment (0.1 mm and 0.4 mm sand) in amounts equal to a 3 cm layer over the bight throughout the entire water column (Miles et al. 2015). Similar resuspension was measured during a lesser storm in the same area along the 40-m isobath (Miles et al. 2013b).

Based on a synthesis of the life history traits discussed above and the contrasts between this storm and lesser storms such as Hurricane Irene (Tropical Storm as it made landfall in the NYB) and Hurricane Floyd, the size, strength, and timing of storms have the means for impacting NYB fishes. Storm-induced, abrupt change can affect metabolic demand and cues from temperature change, clog gills or reduce vision from sediment suspension, agitate infaunal prey beds that may result in noncommittal facilitation or hindrance of foraging, create positive or adverse advection of larvae, and reshape benthic structural features from sand waves to shell hash beds. Unfortunately, there are few empirical studies of these effects on the continental shelf (see Knowledge Gaps) but there are some. Additionally, there are a number of such studies from estuaries, including from New Jersey and New York, that can are revealing and also relevant because estuarine fish populations are connected to shelf populations as nursery, feeding, and transient habitat, and many of the shelf species treated above were represented as juveniles in these studies (Able and Fahay 2010; Olin et al. 2020; Valenti et al. 2020). **Table 3** provides a summary of findings for estuarine and reef locations.

A single study just south of the study area (off Delaware) provides a unique view of behavioral response to storm passage. Black Sea Bass on scattered reef structure over sand bottom were telemetered cumulatively over three years, allowing for the passage of numerous storms (Wiernicki et al. 2020). Storm passage reduced activity of individuals and late season storms led to evacuation of seasonal home sites for this cross-shelf migrating species. Temperature disruption, more than turbulence and current velocity, explained variance in activity (Wiernicki et al. 2020).

Table 3. Summary of storm effects on fish and fish habitat

Location	Effect	Implication	Reference
New York estuary	Barrier island breach by Sandy increased salinity and recruitment of marine fishes	Storm effects in estuary relate to marine species	Olin et al. (2020)
New Jersey estuary	Barometric pressure of late summer storm cued Summer Flounder estuarine emigration	Redistributes fish, trophic linkages; biases fall trawl survey through timing of availability on shelf	Sackett et al. (2007)
	Moderate change in juvenile fish assemblage and abundance in year following Sandy relative to year before and 2 years after	Storm was well after recruitment period for most species; a change in circulation from inlet alteration suspected in causing lag effect, change fits within high interannual variance	Valenti et al. (2020)
	No hypoxia or salinity change, no infauna change from Sandy	Storm came from seaward; rain and nutrient load from watershed not strong	Taghon et al. (2017)
	No apparent immediate fish mortality from qualitative observation after Sandy	Resilience to strong storms by coastal and estuarine fish in NJ	Bilinski J et al. (2015)
Chesapeake Bay estuary	Storm cools estuarine nursery water, increases mortality of Striped Bass	Recruitment depression of anadromous species	Rutherford and Houde (1995)
	Storms displaced meso- and euryhaline estuarine fish assemblage shelfward due to freshwater influx and hypoxia	Effects from freshwater inputs are short lived	Hoagman and Wilson (1977); Hoagman and Merriner (1977); Ritchie Jr. (1977); Houde et al. (2005)
	Increasingly frequent storms have diverse effects on nutrient cycling and plankton ecology	Effects of scale are evident	Paerl et al. (2001); Paerl et al. (2006)
	Isabelle brought short-term reduction in hypoxia, plankton; lagged increase in hypoxia; change in zooplankton; increased Atlantic Croaker recruitment	Lagged, mixed effects on an estuarine-dependent shelf species	Montane and Austin (2005); Roman et al. (2005)
South Carolina estuary	Massive fish kills from hypoxia from nutrient influx brought by storm Fran, Hugo inflow to estuary killed fish; vs. Dennis, Floyd, Irene, changed fishing effort, scouring of noxious algae	Frequent hurricanes in a hurricane-prone estuary have short-term negative and positive (cleansing) effects, no long-term effects	Burkholder et al. (2004); Knott (1991)

Location	Effect	Implication	Reference
Gulf of Mexico estuary	Flight behavior of five shark species to approaching storms was species and site-dependent	Redistributes fish, trophic linkages, short-lived	Heupel et al. (2003); Udyawer et al. (2013)
	Seatrout (drumfish) continued spawning vocalizations through and after Harvey, slight time shift	Species is resilient to storm disturbance	Biggs et al. (2018)
	Passage of Charley displaced marine fishes from estuary due to hypoxia and freshening	Mostly short-term (annual) effects within high interannual variance	Greenwood et al. (2006); Stevens et al. (2006)
Puerto Rico reefs	Abundance of a genus of parochial reef fishes restored	Storm restored fish community after long decline by lowering temperature, shifting sediments	Meléndez-Vazquez et al. (2019)
Brazil estuary	Frequent storms of El Nino caused freshwater outflow increase, decreased marine species representation in estuarine assemblage	Frequency of storms drives population dynamics of estuarine-dependent marine species; effect depends on proximity to fresh water	Garcia (2001)
Jamaica coral reef	Destruction of sessile fauna, redistribution of territorial fish	-	Kaufman (1983); Woodley et al. (1981)

Note: Named storms are Category 3 or higher.

3.5.3 Shoreface Sand Ridges

Shoreface sand ridges are dynamic on geological time but stable on the scale of seasonal fish occupation of the NYB and longer (Hayes and Nairn 2004; Stahl et al. 1974). They are treated here as a spatial sale disruption in that they form high relief structure unique to the southern part of the study area, and their approximate 10-m relief above the surrounding seabed is remarkable within the NYB. The vertical relief is sufficient to penetrate the seasonal thermocline so that a strong temperature gradient is possible within a short stretch of benthos; it can steer currents (notably upwelling), has an effect on fish behavior, and results in a sediment size and sorting gradient (Glenn et al. 2004; Mann and Grothues 2009). The tops of these ridges have coarser sand, which is the preferred substrate for burial of the highly important forage fish Sand Lance (Staudinger et al. 2020).

A study by Vasslides and Able (2008) found that the Beach Haven Ridge, a shoreface sand ridge off Little Egg Inlet, NJ, had structured fish assemblages. In a repeated transect of 11 trawl stations perpendicular to shore, there was significantly increased abundance and richness on both the inshore and offshore flanks of the ridge compared to inshore and offshore and top of the ridge. The total assemblage comprised 61 species, many of them represented as juveniles or belonging to small species such as gobies, pipefishes, seahorse, and Smallmouth Flounder (which are not treated here in detail), as well as Scup, skates, and several drumfishes. This size distribution was a result of the small nets used, but those small nets allowed for much finer sampling than the habitat integration of kilometer-long trawls that happens with larger nets and vessels. The differentiation of three assemblages across the transect was stable across seasons despite some species turnover. The near-ridge assemblages were dominated by forage fishes (Bay Anchovy and American Butterfish) and, in some years, Bluefish, Weakfish, and Northern Puffer. Temperature, dissolved oxygen, and benthic structure such as shell hash density and sediment type were important correlates of the assemblage overturn.

3.5.4 Water Temperature Change

Because fish and invertebrates are poikilothermic (cold blooded), their metabolic rates are intimately dependent on ambient temperature. This dictates activity level and, therefore, both food demand and foraging ability, growth rate, growth potential, size and age at maturity, fecundity, phenology of seasonal maturity or onset of spawning, and onset of migration (Asch et al. 2019; Chambers et al. 2001; Kennedy 1990; Rijnsdorp et al. 2009). Because regional temperature ranges favor one or another species in competition, temperature also has secondary effects on assemblage (Attrill and Power 2002; Bell et al. 2014; Hurst 2007). Passing upper and lower temperature tolerances is fatal, but metabolism in itself will not always be the proximal cause of death as predators; parasites, and disease can claim compromised fish before then (see review by (Hurst 2007)).

Cold stress occurs when poikilotherms such as fish cannot sustain metabolism because the chemical kinetics are too slow, or because they cannot be fueled (Hurst 2007). In the first case, enzymes that are optimized for a higher temperature (especially pumps that counteract salt diffusions) stop being reactive with their metabolic substrates (osmotic stress), or blood literally freezes. Some cold-adapted fishes, such as Winter Flounder, have antifreeze proteins in their blood to prevent this (Haymet et al. 1999). In the second case, where fishes are not fueled, fishes are in torpor and cannot forage, so that they must live off fat stores (Hurst 2007). If stores are insufficient, they die, as demonstrated for overwintering Striped Bass in the Hudson River estuary (Hurst and Conover 2002). Overwintering in isosmotic salinity ranges of estuaries can reduce the metabolic load side of this budge equation, but at the risk of tidal and discharge-induced salinity changes (Hurst and Conover 2002).

Cold mortality in the ocean can be avoided by mobile animals by moving, which may be one of the primary drivers of migration in the NYB. Striped Bass balance a caloric budget between using stored fat to migrate or living through winter in torpor (Hurst and Conover 2002). Larger Bluefish may similarly balance a shorter cross-shelf migration against a longer southern migration (Shepherd et al. 2006). Cold shock occurs when temperature drops too quickly and can happen at temperatures higher than minimum survivable temperatures (Buhariwalla et al. 2016; Hurst 2007). The occurrence of cold shock is demonstrated when power plants that draw cooling water from rivers or estuaries shut down in winter, and their warm effluent stops providing a refuge for fish gathered there (Buhariwalla et al. 2016). These mass mortality events are easily noticed because they happen in urban settings. Despite the fact that they are estuarine, they can impact populations of fish that use the shelf at another time. Natural events are documented for Scup (Morse 1978; Smith and Norcross 1968), Bluefish (Slater et al. 2007), and Northern Puffer (Wicklund 1970) in the MAB and NYB as a result of upwelling of cold bottom water, and for Golden Tilefish on the OCS from eastward flow of the Cold Pool (Fisher et al. 2014). Such events are difficult to detect and quantify because they are episodic, because they could happen in winter when there are few observers, or because they leave dead animals on the bottom instead of floating (Fisher et al. 2014) so that they are only detected incidentally by trawler (e.g., Woodhead (1964)).

The opposite, protein denaturation from heat is not known from the NYB. Instead, upper limits to warmth are bioenergetic challenges (called “scope of growth”), where increased metabolism requires increased food in the face of decreased oxygen concentration (oxygen residence time and saturation are inversely related to water temperature) (see review by Lugert et al. (2016)). Because marine fish are able to move, range contractions and expansions, or latitudinal range shifts, are the primary manifestation of a response to temperature change in the highly dynamic NYB. Range shifts are also evident for immobile animals such as clams, but this is the result of shifts in spatially explicit mortality and recruitment success (Hare et al. 2016) (see also **Volume 2**).This is seen seasonally as migration and is the most similar, at an annual scale, to that of disturbance by dredging (**Figure 10**). However, the MAB, the NYB at the center of it, and the adjacent and connected Gulf of Maine is also experiencing rapid warming due to climatic change at a rate higher than most regions worldwide (Zhu and Liu 2020), and fishers are experiencing effects within their lifetimes (Rogers et al. 2019). Although there are many recent papers on this important issue to examine the mechanisms and projections of global climate impact on fishes and fisheries (e.g., Free et al. (2019) and Hollowed et al. (2013)), an emerging synthetic view for the NYB is summarized as four points:

1) There is a general northeastward shift in the center of mass for Mid-Atlantic coastal warm-water-affiliated species corresponding to northward progression of both the northern and southern range limits. These shifts are happening faster than elsewhere and track climate velocity (the speed at which a point on a map would have to move to keep its average temperature static among years) (Kleisner et al. 2016; Pinsky et al. 2013). Species in this group include Atlantic Croaker, Blueback Herring, Bluefish, Clearnose Skate, Little Skate, Northern Kingfish, Spot, Striped Bass, Tautog, Weakfish, Windowpane Flounder, Winter Flounder, and Winter Skate (see individual species accounts) (Kleisner et al. 2016). The analyses were sensitive however, to how the stocks were defined, and regionally managed stocks, as a rule, break into two different groups at the apex of the NYB (Nye et al. 2009). These shifts are modeled to accommodate a neutral thermal habitat index only until 2030 (Shackell et al. 2014). Specifically, 17 of 36 had significant poleward shifts ranging between 0.61-8.53 km/yr while four had significant southward shifts between 0.83 and 3.82 km/yr (Nye et al. 2009). Shifts in larval distribution did not generally match shifts in adult distribution (Walsh et al. 2015).
2) There is a cross-shelf shift to deeper water in the center of mass for a group of cool-water affiliated Mid-Atlantic species: American Lobster, Barndoor Skate, Black Sea Bass, American Butterfish, Fourspot Flounder, Gulf Stream Flounder, Longfin Squid, Red Hake, Spiny Dogfish, Thorny Skate, Roseate Skate, White Hake (Kleisner et al. 2016).
3) The shift in mass changes the relative extent or depth of different static habitats (sand, cobble, rock, estuaries, shelf breadth) within the new range (Nye et al. 2009).
4) Counter intuitive and non-linear effects occur. For example, the new northern range may contain little suitable habitat so that a population shrinks and centers on patches of suitable habitat remaining in the southern part of their range (Kleisner et al. 2016; Nye et al. 2009). Also, the thermal tolerance of predators may encompass the range shift of prey and buffer it as warm-water predators replace cold-water predators (Fuchs et al. 2020; Selden et al. 2018).

Water temperature is also a critical factor of water density governing mixing and circulation (Pickard and Emery 1990). Warming has the capacity to change circulation in the NYB, especially through mixing rates with the Gulf Stream and through total heat transport by the Gulf Stream (Zhu and Liu 2020).

3.5.5 Fishing

Commercial and recreational fishing remove large amounts of marine biomass (target species and bycatch) at a global scale, with an estimated global marine harvest (including permitted bycatch) of 84.4 million tonnes in 2018 (FAO 2020). Bycatch, incidentally captured non-target species that may not legally be landed (e.g., protected, over bag limit, undersized), are “discards” and represent an additional 9.1 million tonnes per year that are frequently dead or injured but are returned to the water (Roda et al. 2019). Currently, there are no NYB-specific estimates of overall fishing effort, harvest, bycatch, and revenue (but see accompanying Data Synthesis for estimates). However, a review of stock assessments for stocks that are open to fishing in this region as part of a larger range, estimate instantaneous fishing mortality rates generally around 0.2 to 0.4 of a given stock annually. Targets for instantaneous fishing mortality vary greatly depending on estimates of recruitment success, fish size, fecundity, stock age structure, and age at first reproduction. Instantaneous fish mortality is additive with natural mortality as total mortality in the logistic growth equation but natural sources cannot easily be disambiguated because fishing may catch a fish that would have died anyway. Natural mortality rates are largely unmeasured or unknown in the absence of fishing.

In addition to the removal of biomass and discard mortality, fishing can trigger density-dependent compensation and depensation in a population. Depensation is the reduced effectiveness (recruit per adult) of recruitment under low spawning stock size (e.g., adults are less likely to encounter each other or to eat the predators of their young) (Rose et al. 2001; Walters and Kitchell 2001). A particularly well-known example of this phenomenon is the failure of Atlantic Cod to recover following their collapse in the North Atlantic (Walters and Kitchell 2001). Conversely, compensation increases recruit-per-adult ratios at low stock density and leads to fast population growth rate (Rose et al. 2001). These departures from linearity in stock-recruit relationships are known mechanistically but are very difficult to assess empirically or to predict on a regular basis except in simple systems.

Fishing can skew population sex ratios and thereby reduce reproductive capacity by the selective retention of larger fishes (Alonzo and Mangel 2004). Current recreational fishing regulations within the NYB favor the harvest of female Summer Flounder via large minimum length limits, but this is partially balanced by a male bias in the commercial trawl fishery (Morson et al. 2012; Morson et al. 2015). Similarly, there is a bias toward the selective harvesting of male Black Sea Bass within the recreational fishery due to minimum length limits and the fact that females became males as they grow (Provost et al. 2017).

Excessive fishing pressure on one particular trophic level may lead to a phenomenon known as a trophic cascade (Frank 2005; Pinnegar et al. 2000). Trophic cascades occur when the removal of one organism from a given trophic level lead to inverse patterns of abundance or biomass across other trophic links (Pace et al. 1999). Trophic cascades are typically described as being either “top-down” -- such as when a predator regulates the lower food web -- or “bottom-up” -- such as when primary producers regulate higher trophic levels. Within the MAB and NYB, fishing is responsible for the removal of fishes from nearly all trophic levels: primary consumers (e.g., bivalves), secondary consumers (e.g., forage fish, especially Atlantic Menhaden), and higher level consumers (e.g., Summer Flounder, sharks) (National Marine Fisheries Service 2020). Regime shifts precipitated by trophic cascades are known for the adjacent Gulf of Maine. Atlantic Cod stocks that crashed there due to overfishing failed to recover because the abundance of remaining adults was too low to keep the predators of their own young in check. The increase in abundance of those predatory species, such as Spiny Dogfish and skates, extended into the NYB (Dulvy et al. 2000; Fogarty and Murawski 1998; Myers et al. 2007).

Fishing gear may physically damage habitat. Within the context of this synthesis, bottom-tending gear disturbs sediment-dependent fish and invertebrate communities’ habitat (Dayton et al. 1995; Jennings and Kaiser 1998; Martín et al. 2014). Bottom fishing methods used within the NYB include bottom trawls, bottom-fixed gillnets, pots and traps, scallop dredges, and clam dredges. The effects of trawls are the most understood. Bottom trawling suspends sediment that has been sorted and stratified by biological and physical processes, and leads to the homogenization of seafloor texture when practiced extensively (Hewitt et al. 2010; Lucchetti and Sala 2012; Puig et al. 2012; Thrush et al. 2006; Watling and Norse 1998). It can also lead to instability of sediment systems from increased benthic chemical flux between oxic and anoxic carbon compartments (Kaiser et al. 2002). Bottom trawling may also cause direct impacts to benthic communities themselves by directly killing benthic organisms through strikes, breaking shells, destroying habitat components such as sponge or worm tubes, altering food web dynamics, and altering biogeochemical processes (Clark et al. 2016; Collie et al. 2017; Duplisea et al. 2001; Hiddink et al. 2017; Puig et al. 2012; Sciberras et al. 2018). The unobserved mortality is analogous to uncounted discards.

3.5.6 Ocean Acidification

Ocean acidification (OA), driven by the ocean's uptake of increasing atmospheric carbon dioxide (CO_2) is occurring globally and has decreased the average global surface water pH by about 0.1 unit since the beginning of the industrial revolution (Sabine et al. 2004). This rate of OA is unprecedented and optimistic model projection scenarios show an additional 0.2-0.3 drop in pH by the end of the century (Caldeira and Wickett 2005; Hönisch et al. 2012). Related coastal acidification is more variable and has greater extremes due to a combination of anthropogenic biogeochemical and physical processes (Chen et al. 2012). There is uncertainty regarding the scale of ecological and biogeochemical impacts of coastal acidification; however, efforts are underway to examine possible effects (e.g., (Saba et al. 2019)). Ecological consequences associated with OA are expected to have economic implications (Poe et al. 2014). Similar to the ecological effects, the economic implications of OA are presently not well understood.

Within the Mid-Atlantic region, pH can be modified by OA or influenced by coastal acidification (plume water may reach across the OCS, see Circulation)). Coastal water chemistry can be more complex than that of the open or deep ocean as it is affected by both freshwater and atmospheric inputs and a supply of both organic matter and nutrients from land (National Research Council 2010). Many additional drivers can cause estuarine and coastal waters to have a decrease in pH. In coastal environments, dissolution or weathering of carbonate sediments could partially buffer the effects of OA. However, the faster dissolution rates could lead to the reduction of calcium carbonate reef structures (National Research Council 2010) though these are relict in the NYB. The extent to which coastal acidification reaches seaward onto the OCS is not yet studied.

Co-occurring environmental phenomena, such as rainfall, runoff, temperature, salinity, circulation, wind direction and intensity, can have profound effects on the degree of acidification events (Abril and Borges 2004; Cai et al. 2017; Gobler et al. 2014; Johnson et al. 2013; Salisbury et al. 2008; Waldbusser and Salisbury 2014). Therefore, there is a need to monitor OA along with other environmental stressors (Goldsmith et al. 2019). The Atlantic Coast faces unique risks, such as sea level rise, storm surges, rising water temperatures, which can all impact OA (USGCRP 2018). Localized seasonal upwelling can result in the surfacing of deep water which is CO_2 rich with a low pH exacerbating coastal acidification (Feely et al. 2008). Events such as coastal storms and hurricanes can cause significant short-term impacts, such as decreased pH and increased dissolved organic carbon, due to terrestrial water inputs (Johnson et al. 2013). Terrestrial organic carbon or the resuspension of buried organic matter in ocean sediments can increase the biologically sourced CO_2 burden due to increased microbial activity in coastal waters (Bauer et al. 2013; Cai et al. 2011; Cai et al. 2017). These co-occurring processes can cause substantial daily, seasonal, and interannual variability in pH.

The CO_2 concentration in the surface ocean tracks that of the atmosphere, but the CO_2 which penetrates into deep water is dependent on slow vertical mixing due to wind-driven circulation (Sarmiento and Gruber 2006). Half of the anthropogenic CO_2 is found in the upper ocean (400 meters) and the other half has penetrated to deeper water (Feely 2004). Due to this slow penetration of CO_2 into the deep ocean, there is a slower decrease in pH at depth as compared to surface (epipelagic) and neritic water. Yet, some regions experience faster vertical migration allowing for a reduction in time scales for diffusion of anthropogenic CO_2 to the deep ocean to the order of decades instead of centuries (Sabine et al. 2004).

There is significant variability in the pH sensitivity of a number of different benthic groups with the potential to affect biological processes including calcification, photosynthesis, nutrient acquisition, growth, reproduction, and survival (Orr et al. 2009). Single species acidification studies in the Mid-Atlantic have determined responses to changes in survival, hatching success, larval development and growth, metabolic rates, immune response, etc. on a range of organisms (including crustaceans, mollusks, finfish, submerged aquatic vegetation, and some phytoplankton) (reviewed in (Saba et al. 2019)). Resulting responses to acidification are highly variable within and among species. These responses can also vary with the addition of other environmental stressor (i.e., temperature, low dissolved oxygen) (Gobler and Baumann 2016). These variations in response to acidification suggests the potential for OA "winners" and "losers" in a future more acidified ocean (Cooley et al. 2015). Further research which better represent the natural variability of the environment is needed to address acclimation and adaptation of these species.

4 Human uses of NYB Fish Resources

4.1 Fisheries

Fisheries represent one of the greatest—if not the greatest—current human uses of the NYB. Fisheries statistics are not published for the NYB as a statistical area, but instead are included within the larger Mid-Atlantic region, and landings statistics for individual states are available. According to the most recent data (2016), commercial landings included 597.5 million pounds of finfish and shellfish in the larger Mid-Atlantic region. This was down 20% from 2007 and 8% from 2015 (National Marine Fisheries Service 2018). However, overall commercial landings revenue increased 30% from 2007 and 7% from 2015, for a 2016 value of $550.3 million. Shellfish accounted for 80% of commercial landings revenue. Of particular note are Atlantic Sea Scallop and Blue Crab (*Callinectes sappidus*), which accounted for 54% of commercial landings revenue overall ($180.1 million and $117.5 million, respectively). Note that most of the Sea Scallop and all of the Blue Crab fishing happens outside of the study area (offshore and inshore, respectively).

Recreational fisheries expenditures across the Mid-Atlantic region totaled approximately $3.9 billion in 2016, of which an estimated $670.9 million were trip expenditures and $3.3 billion were durable goods expenditures (National Marine Fisheries Service 2018). Approximately 14 million fishing trips were taken within the region, primarily by private vessel (55%) and by shore (41%). There were approximately 2.4 million recreational anglers active in the Mid-Atlantic region at this time, of whom 93% were residents of a Mid-Atlantic coastal county. Summer Flounder (12.2 million fish), Black Sea Bass (9.3 million fish), and Striped Bass (8.6 million fish) were the most frequently caught finfish by recreational anglers within the region. The majority Striped Bass and Summer Flounder are caught inshore and many inside estuaries, but both, and especially Summer Flounder, have life history connections to the continental shelf. Black Sea Bass of legal size are almost all taken on the continental shelf in and beyond the study area. Bluefish, Striped Bass, Mackerel, and other scombrids are frequently targeted by trolling lure from small private boats (rather than charter or head boats) at the shoreface sand ridges and other high relief features, and thus probably represent a much higher fuel investment per fish than fishes targeted by bait, such as hakes, Tautog, and Black Sea Bass. The seaward side of sand ridges are identified in fishing guides as fish aggregation points that allow an intercept strategy for fishers to concentrate effort (Grosslein and Azarovitz 1982).

4.2 Diving

SCUBA diving is another human use that is based in part on fish resources. There are a number of dive charter operations running out of New York and New Jersey. Divers value clear water, which may be disturbed by sediment plumes, as well as fish and invertebrates for photography or spearfishing. Most diving, however, is focused on reef and wreck sites rather than sand. NJSCUBA.net estimates between 4,000–7,000 wrecks and artificial reef complexes in the NYB (**Figure 14, Figure 15**); coordinates for 727 of these are included in the **Volume 2**. As discussed in Section 6 (Gaps), and 6.3 (Scaling) specifically, the extent to which these affect or are affected by fish response to sand extraction is probably affected by scale in density and proximity (see discussion in Lindeboom et al. (2011)).

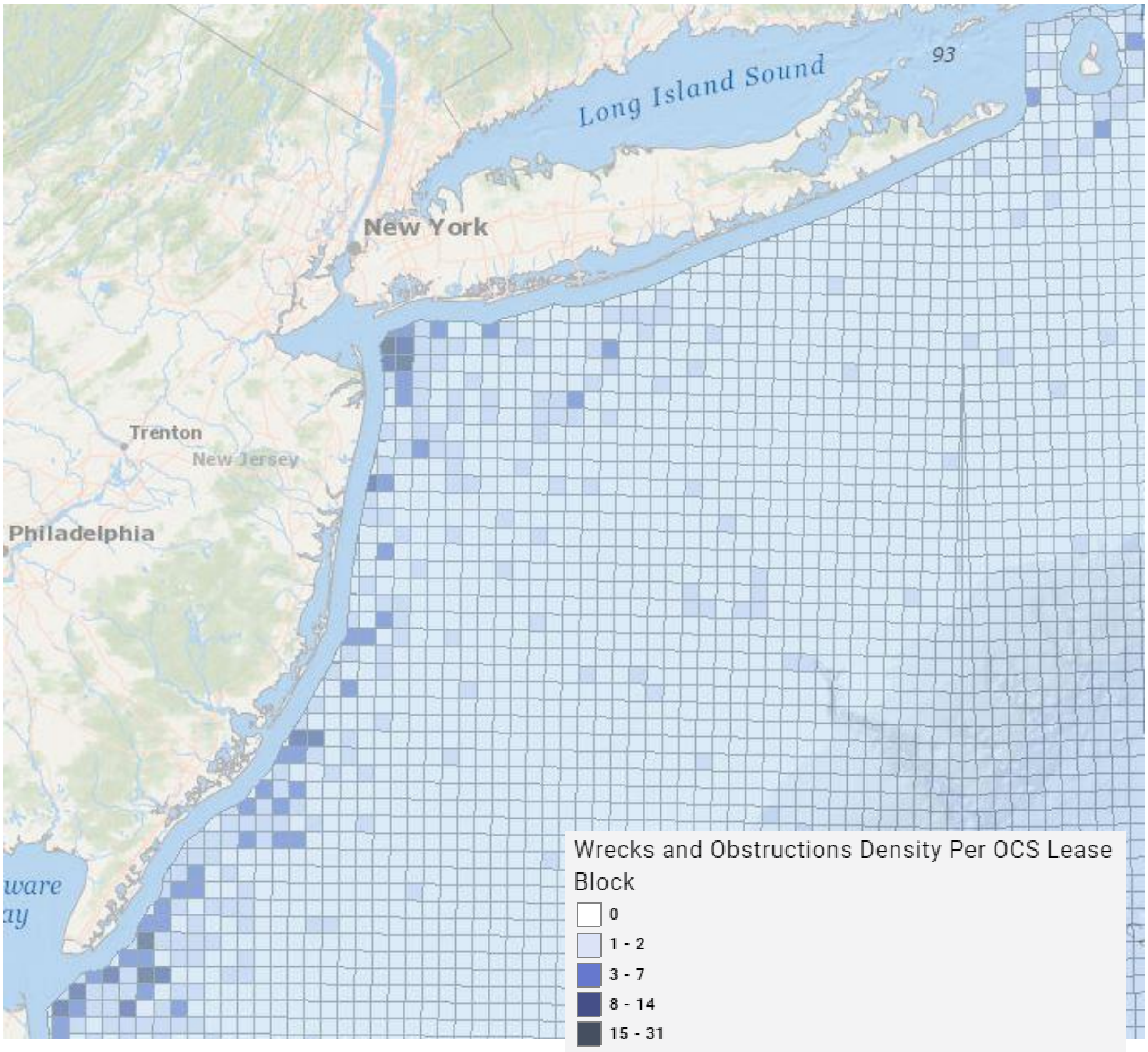


Figure 15. Estimated number of wrecks and obstructions within OCS Lease Blocks in the study area

Data is a density map calculating the reported wrecks and obstructions per OCS Lease Block, and aggregated into five categories from NOAO’s National Ocean Service Automated Wreck and Obstruction Information system. From MARCO portal.https://portal.midatlanticocean.org/visualize/#x=-73.36&y=39.83&z=8&logo=true&controls=true&dls%5B%5D=true&dls%5B%5D=0.5&dls%5B%5D=1348&basemap=ocean&themes%5Bids%5D%5B%5D=8&tab=legend&legends=false&layers=true

5 Conclusions

Conclusions about the vulnerability and resilience of economically and ecologically important fish and invertebrate species in the NYB emerge as six general themes from this literature synthesis. They should be considered together with those of the companion data synthesis, which focuses explicitly on distribution of these living resources in the narrowly defined study area. A comparison with the data synthesis may, for example, resolve differences in offshore vs. depth extent that come from or are confounded by literature that draws observations from a wider range than the NYB. Knowledge gaps that erode confidence or quantifiable limits to these conclusions are addressed in Section 6.

5.1 Range Buffers Local Impacts

One important conclusion is that most fishes utilizing the NYB have population and individual ranges far greater than the spatial extent of the study area. Sand resource areas are small in terms of temporal and spatial extent relative to many other factors that force populations in this particularly dynamic region. Of those fish species mentioned in the individual accounts sections or treated in the compiled data, 77% are seasonally migratory; 31% shift south in winter, while 7% shift into the NYB in winter from more northern locations. The remaining may be found in the NYB in any season, but their population range extends beyond it. Additionally, 36% utilize a cross-shelf and depth extent wider and/or deeper than the study area's 50-m bathymetric limit or additionally utilize inshore regions as their principal or extended range. Mobile invertebrates (squid, Atlantic Horseshoe Crab, American Lobster, crabs, and whelks) are also migratory. Scallops are centered deeper and farther to the north. Of the treated species, Surfclams are the most quintessential residents of the NYB study area in that their population is centered and largely bounded by it in latitude and depth, and they are immotile and buried in the sand for the duration of their post-settlement life.

There are a number of implications of this pattern. One is that there will exist a seasonal period of relative absence from the NYB for groups of species together, and this provides a window of opportunity to avoid direct effects of sand extraction activity on them through seasonal restrictions. (Indirect effects, such as infaunal forage base depletion, should still be considered.) A second implication is that range breadth and population size provide a buffer of resilience against local impacts from extraction, in that habitat resources such as forage patches may be found elsewhere. A negative implication is inverse to this; effects of natural and anthropogenic disturbances outside of the NYB could have cumulative or interactive impacts with those of sand extraction in the NYB. Local detrimental effects may be dispersed through the migrations to other regions. Another consideration is that, despite temporary occupancy, NYB-local disruptions could be critical to migrating species that cannot avoid it. This consideration is analogous to that of the Atlantic Horseshoe Crab spawning in the Delaware Bay providing eggs as a critical fuel for migrating birds.

Wide individual range and commonality within the NYB means co-occurrence at some scale, and this is borne out at the scale at which trawls integrate samples (~2 km long) in the surveys cited above and in the accompanying **Volume 2**. That means that habitat is either homogenous at that scale, or patchy, so that fish are constantly moving through habitat to find patchy resources, or that the habitat occupant comes to it stochastically when niche is not specialized (following the Lottery Hypothesis, Sale (1977)). In any case, this differs from reef occupancy and territoriality, with the implication that individual sand extraction operation scales are small compared to that of fish habitat continuity. But what “small” means, or the ability to quantify the scale of continuity or patchiness, is an important Knowledge Gap.

5.2 Connections to Estuaries Are Important in the NYB

What happens in estuaries does not stay in estuaries. The NYB is uniquely influenced by estuaries compared to other regions. The Hudson River plume merges with that of smaller estuaries to the sout,h and sometimes that of the Delaware Bay, and can be driven well out onto the OCS to provide nutrients and drive currents. Life histories of species synthesized above are frequently connected to estuaries through nursery or adult feeding habitat or simply through continuity of broad habitat niche or resource patchiness. Dynamics of estuaries should be considered in decisions about continental shelf fish and invertebrate resources in terms of driving factors and consequences.

5.3 Nursery and Adult Habitat Is Frequently Decoupled

Nursery habitat of many species that use the NYB as adults is spatially decoupled and isolated from dredging effects until subadult or adult stages. Of the treated species, 17 have estuarine or riverine nurseries, 18 have nurseries centered to the south, 11 to the north, while 44 have nurseries inclusive of the study area. An implication of this is that conceivable mitigation or prevention actions that are focused on species-specific behavioral avoidance (see Knowledge Gaps) would not need to consider abilities (such as reaction distance and swim speed) of multiple life stages. Furthermore, some of the species for which the study area does provide a primary nursey ground (particularly the larger shark species) might be treated as small adults with respect to these abilities, while others remain entirely pelagic (e.g., some anchovies and jacks) and have less of a reliance on benthic features than epibenthic species. Many benthic invertebrates (including small and economically unimportant forms, such as worms, which are not treated here) are the exceptions, even though they have a dispersal phase similar to that of fishes. Juveniles do not segregate from adults into nursery habitat upon settlement and are vulnerable to similar disruptions as adults.

5.4 Species of Concern Frequent the NYB

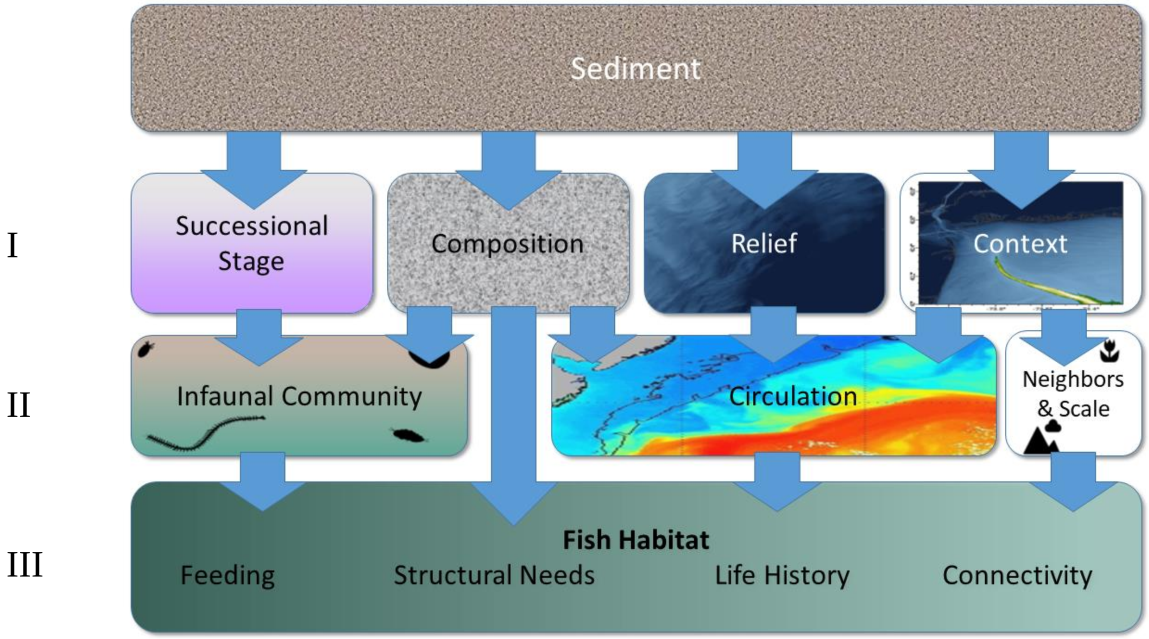
The NYB is the center of distribution for adults of the largest remaining population of endangered Atlantic Sturgeon, with subunits focused on the Hudson River and Delaware River breeding stocks. It is also used to some degree by 25 other species of concern listed above. This number owes to the heavy representation of elasmobranchs (40% of the 61 taxa treated), especially skates and rays, that utilize sand habitat in this area (**Appendix A**). All of these are considered to be of concern because of late maturity and low fecundity, but the population of some, especially skates, is healthy and possibly larger than they would be if their predators or competitors were not exploited; they have expanded into niches previously filled by fished species, such as cod, or species released from the predatory control of larger sharks (Dulvy et al. 2000; Fogarty and Murawski 1998; Myers et al. 2007). However, skates are also among the species that are most directly dependent on sand habitat. Note that large shark species are treated in the literature synthesis, but these are never or rarely caught in the trawl survey used in the accompanying Data Synthesis (Volume 2). That Data Synthesis considers relative abundance, as well as many species that are not considered to be resource species and were not treated in the literature synthesis, and both of these factors change the weight of representation by elasmobranchs.

5.5 Climate Change Is Changing Habitat Suitability

Thermal characteristics of habitat in the NYB are changing fast. Niche parameters describing species distributions, including depth, latitudinal range, relative abundance, diet, and phenology—described above and in the accompanying **Volume 2**—will change in the coming decades. Population ranges are shifting north and deeper (although not exclusively), and new species are entering or expanding their abundance and influence in the local ecosystems, while others are vacating it as a function of individual physiology and interactions with current residents and physical dynamics.

5.6 Sand Is a Structural Habitat Component for Fishes Beyond Foraging Substrate

Although some fish—especially skates, rays, and flounders and many invertebrates—rely on aggregates directly as a substrate for shelter, the connection for many others is indirect (**Figure 16**). Fish, juveniles, and whelk use structures made by sand fauna, such as worm tube reef and shell hash, as shelter or spawning substrate. They forage on infauna as food and this extends to water column residents. In contrast to continental shelf or escarpment zones elsewhere, in which parochial reef species are well represented, the NYB study region is typified by at having 51% species that utilize sand bottom for refuge and foraging, while about 24% are water column/pelagic foragers (as based on the sample of taxa and species complexes treated above); the remainder use a variety of habitats as generalists, including reef. Even reef species such as Black Sea Bass use sand bottom as part of a habitat mosaic. Some fish and invertebrates rely on hydrographic features, such as the Cold Pool, and upwelling, which are influenced in part by topographic steering and roughness (drag) of particular features. The relationships to sand are reflected in the representation of feeding guilds. Sand features may also aggregate pelagic planktivores or pelagic piscivores by concentration of prey in eddies (see Gaps) or over the prey's preferred habitat, as is certain in the case of the highly important forage fish American Sand Lance. That species prefers the coarse sand on shoreface sand ridges and, in turn, attracts pelagic predators such as scombrids, seals, and even whales to those features.



mm Spatial Scale 100 km

Figure 16. Summary of sand influences on fish habitat
Characters (I) of sediment, including the successional stage and oxygenation horizons resulting from disturbance; composition in size, sorting, and organic content; vertical relief and rugosity; and the context of larval supply and position relative to other structures influences the (II) infaunal community, surrounding circulation, and scale (size, density, and dynamics) of features that delineate (III) fish habitat including, in decreasing order of impact and immediacy, short and small feeding opportunities, diurnal scale shelter needs, life scale selection pressures, and intergenerational scale population connectivity.

6 Knowledge Gaps

Knowledge gaps are evident as missing detailed information on life history and behavior, but also as broader themes that encompass generalities about marine fauna response to sand dredging. These themes emerge from repeated conclusion statements from the authors of the papers reviewed here, as well as by asking and trying to answer the questions posed in the Introduction. Key among these themes are the following:

1. Details on the basic life history and ecology of NYB fishes and invertebrates, including on the quantification of the dynamic distribution of YOY
2. The role of bathymetric, bedform, and benthic features on the distribution of fishes, including water column piscivorous and planktivorous fishes
3. Behavioral responses to dredging activity and subsequent environmental change
4. The effect of scale on our understanding of habitat use and function

Beyond the uncovering of facts, patterns, and mechanisms, the quantification of response strength and variance is important in order to be able to apply knowledge to predict and potentially mitigate effects of dredging. This last point is integral to understanding effects of scale as well. These gaps, specific examples, and approaches to addressing them are detailed below.

6.1 Life History

All aspects of life history—from egg placement or place of parturition through foraging, resting, and sleeping patterns, to adult mortality—need continuing addressing, revision, and especially quantification. The direct mechanisms by which fishes and invertebrates interact, utilize, and rely on sand substrate is needed in order to understand critical life history aspects. This reflects an overall plea for basic observation and results from a publication and funding culture that is heavily focused on hypothesis-driven testing of very specific questions as opposed to exploration (Able 2016). The necessary types of explorations are expensive and technically challenging in the ocean and therefore risky for funding given uncertainty about return on the investment. This challenge can be integrated with continued question-driven exploration of co-occurrence/segregation as a result of competition, niche specialization, predatory exclusion, mutualism, or stochastic processes (all the basics of ecology).

A basic principle of ecology is that sympatric speciation is driven by competition for resources, resulting in more specialization or, in very dynamic environments, more generalization. For example, the various skates that share the NYB OCS, all of which feed primarily on bottom invertebrates, should have niches in which they outcompete each other. These would manifest in particular depth/light regimes, digging depth or speed to excavate different prey to certain depths (possibly as a cost to swimming speed), dentition for capturing and holding certain prey, swimming speed or spines to avoid predation and compete in more predator dense areas, or segregation and tolerance to a particular temperature or season or even time of day that lessens direct competition. These are the features that make species look different and the basis on which they are classified. The differences in range and preferred center of depth, temperature, diet, and seasonality noted in the species accounts above and especially in the analysis in the accompanying **Volume 2**, allude to these “realized” niches, but these are empirical and incomplete. There is also some broad overlap among their habitat niches, indicating that specialization may be at the microhabitat level or the way they forage. The empirically derived distributions do not reveal the mechanisms that structure them, or what the “ideal” niche is.

An ideal niche is that multivariate environmental space that an organism populates when it is free of competition or predatory exclusion. Studies that tackle niche partitioning in terrestrial ecosystems are common, especially for immobile and observable plants, but there are also many marine examples. These ae typically done on small, well-structured and defined reef spaces where all of one species can be removed (e.g., through spearfishing) and the extent of spread of a competitor into the released niche can be observed. For example, see Schmitt and Holbrook (1990), where two reef surfperch species with similar diet but different feeding habits (bite selection vs winnowing) divided vertical reef space but expanded to reciprocally move into the other's space upon competitor removal. Such experiments are challenging in the NYB and in general when spaces and individual movements are large and when the underlying gradients are not readily apparent to humans (for example, when the underlying structure is buried, such as some kinds of prey patches). Nevertheless, they are worthwhile to pursue because they address the underlying reasons for distributions and dynamics and can lead to predictions that are counterintuitive based on observation of realized niche. For example, a disturbance that is superficially detrimental to two species may result in a competitive resource release for one that is more tolerant to its ultimate benefit. Empirical retrospective studies of fisheries and survey trawl data have revealed that these situations can be extremely consequential, to the point of regime change, resulting in major shifts in biomass storage and energy flow and economic. For example, overfishing of New England cod changed the OCS regime there when the cod no longer ate the predators of their (and others') young, so that the fishery did not recover (Walters and Kitchell 2001).

A potential approach to these kinds of studies in the more dynamically and sediment-structured NYB is in the establishment of underwater observatories. Observatories support numerous sensors at once, with sufficient power and bandwidth for high density, high frequency sampling. These are typically set up for physical/chemical or biological oceanography (Glenn et al. 2004; Hay and Mudge 2005) but have precedents for the study of fish behavior. One such study in the NYB included observation on the acoustic space partitioning of soniferous fish and their response to upwelling (Mann and Grothues 2009). The continuous measurement by observatories allows the capture of data on episodic events that are too unpredictable or infrequent (such as competitor social interactions)—or even unknown—to capture in targeted experiments. An observatory for understanding fish ecology on open sand habitat would include cameras, telemetry receivers, passive acoustic receivers, water quality sondes and current meters, and fixed or turreted side-looking sonar to map and document bedforms dynamics to see if such small features change competition or occupation. Ultimately, such an observatory should allow configuration for manipulation, including mechanical altering of bedform, dredging, addition or removal (e.g., sifting) of materials such as shell hash or cobble. As an example, an ongoing experiment in Little Egg Harbor, NJ, is testing the efficacy of spreading broken shall hash in high density over estuarine clam farms as a deterrent to depredation by Cownose Rays (Daphne Munroe and Thomas Grothues, unpublished data). The experiment includes randomized plots of traditional bottom netting, shell hash, or no treatment (controls). Response measurements follow seed clam survival through sequential coring and follows ray occupation, path, and residence time by high precision sub-meter-scale acoustic telemetry (see Section 6.4 for further treatment of telemetry). Such an observatory would necessarily be cabled to meet the broadband data transfer and power requirements. The first-ever cabled observatory, LEO-15, was established on Beach Haven Ridge, a sand ridge in 15-m depth off Little Egg Harbor, NJ, by 9-km electro-fiber-optic cable running underground from the Rutgers University Marine Field Station in 1996 (Forrester et al. 1997). Synergism with wind power infrastructure offers an opportunity to greatly reduce the costs of such an observatory compared to stand-alone.

Another important life history phase—settlement by YOY (and especially flatfish)—has only rarely been studied in the NYB with small nets suitable to catch them (Diaz et al. 2003; Diaz et al. 2004; Steves et al. 1999; Sullivan et al. 2003; Sullivan et al. 2000; Sullivan et al. 2005). Large vessels pulling large nets do not adequately sample newly settled fish, because the codend mesh is too large, and the nets can skip them while bouncing over sand ripples and sand wave troughs or cobble, as observed by video (e.g., Grothues et al. (2017a)). Studies on settlement would be leveraged by synchronous sampling of planktonic late stage larvae to differentiate the effect of larva supply and patchiness from that of differential mortality into settlement habitat. For example, a study series was done in the LEO-15 observatory for Atlantic Surfclam using a plankton pump map pelagic larval density and compare it to benthic settlement and revealed that delivery set cross-shelf patterns, but patchiness within that was set by predation post-settlement (Ma et al. 2006; Quijón et al. 2007). As in those studies, models that include drift and other oceanographic variables provide context. All seasons should be considered given the diversity of fishes and invertebrates that use the NYB OCS.

Camera sleds are one way to make direct observations (Clarke et al. 2010), but they do not recover samples for identification, which can be important for small flatfishes. Habcam is the evolving Habitat Mapping Camera System of Woods Hole Oceanographic Institution used for scallop and benthic survey and has applied both towed sleds and more recently autonomous underwater vehicles (AUVs) (https://habcam.whoi.edu/about/habcam-6/) (Taylor et al. 2008). Habcam optics have improved greatly compared to those of earlier trials, and AUVs decouple the cameras from jerking tow cables and can proceed slowly (Wilber and Clarke 2001). Habcam deployments, which are focused on scallop survey, have stayed largely seaward of the study area the study area (**Figure 17**).

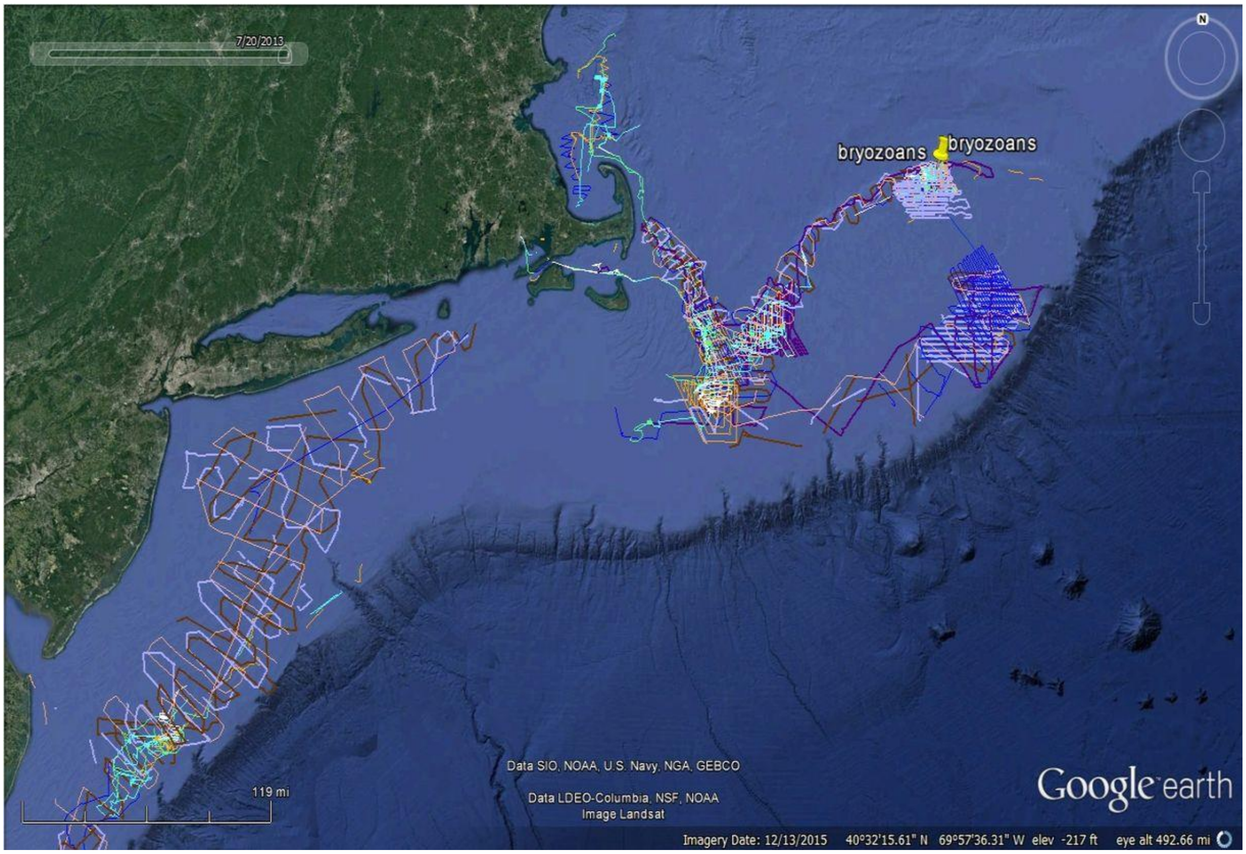


Figure 17. Path of all Habcam deployments to date
Previous deployments approach but stop near the 50-m outer boundary of the study area. Image created by visualization app with data from the Woods Hole Oceanographic Institution's Habcam program https://habcam.whoi.edu/data-and-visualization/

Finally, divers and submersibles offer the best opportunity to directly observe fine scale patterns of microhabitat use and the behaviors that drive that selection in nature (**Figure 18**) (Sullivan et al. 2006). In that study, m^2 habitat microhabitat differences were resolvable in preferences for flatfish, physcid hakes, and other species for shell hash, sand wave trough vs. crest and worm tubes, and furthermore could do so on the basis of used vs. available habitat. Divers and submersibles can capture of specimens for verification and can find and stay with individuals for extended observations. For example, divers were essential to the understanding of Giant Sea Bass (*Stereolepis gigas*) recruitment to drift algae along Californian sandy beaches and the role that the juveniles form and coloration played in this (Benseman and Allen 2018; Benseman et al. 2019)

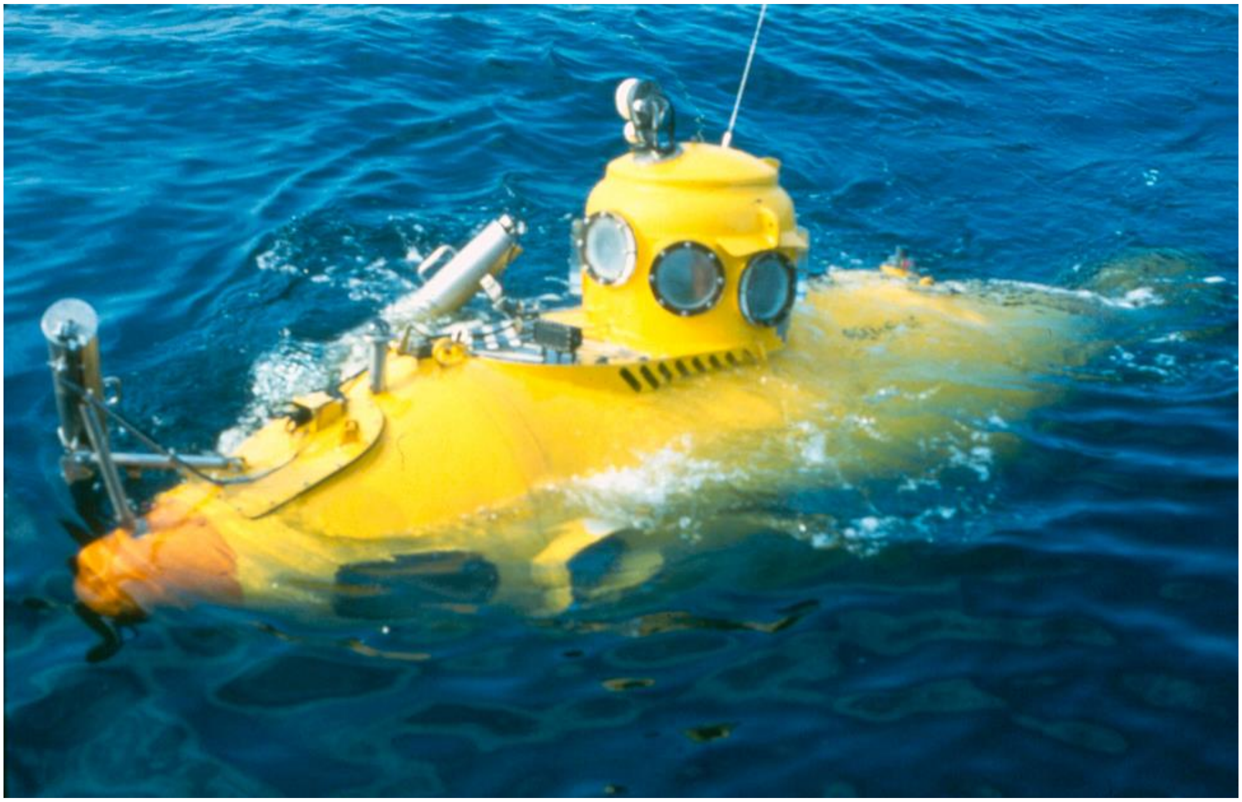


Figure 18. Delta submersible prepares to dive on a NYB study site
Direct observations by small submersibles remain an indispensable method for collecting information about the life history and habitat use of fishes. This small submersible is nimble enough to hover just above the bottom with minimal disturbance and holds an observer lying prone in the pressure hull with a view just inches above the benthos while a single pilot straddles them to view out the conning tower ports. Image credit: Rutgers University Marine Field Station

6.2 The Role of Sand Ridge Topography as Fish Habitat

Sand ridges are much larger features than the microhabitats addressed in the previous section, but they appear to help structure microhabitat for both benthic and water column fishes by steering water flow. A repeated observation of the species accounts in Section 3.3.4 was that a connection with sand was unknown for species that stayed in or foraged in the water column, in particular the piscivorous jacks, tunas, and sharks, but also planktivores. However, pelagic and planktivorous fishes were among those that exhibited significant spatial distribution differences relative to the Beach Haven Ridge (Vasslides and Able 2008), and variation in distribution of planktivorous and forage fish was significantly explained by proximity to sand shoals in the accompanying data synthesis of trawl samples (**Volume 2**). The attraction to much larger structural features such as seamounts and islands, but also smaller ones such as oil rigs, over sand are well known. Attraction to wrecks and floating objects is also known and exploited as fish aggregating devices (FADS), which are thought to simply be orientation and meeting points since they do not produce or aggregate food in balance to the number of predators that frequent them, e.g., Sinopoli et al. (2019). Shoreface sand ridges are the most prominent bathymetric features within the 50-m isobath south of the Hudson Shelf Valley, with 77 off New Jersey). They are known to steer currents that produce upwellings and eddies (Glenn et al. 2004). Sand ridges thus might structure habitat for fishes that have habitat much greater than the extent of the ridge itself.

One way to address how sand ridges structure habitat for larger, more mobile fish for which trawling is not appropriate is to use towed cameras and AUVs as self-baited camera traps (Grothues et al. 2017b) (**Figure 19**). Camera traps are known to be effective for rare predators in terrestrial applications and have a growing marine analog as baited remote underwater video surveys (BRUVS). BRUVS, including AUVs acting as BRUVS (without the addition of any actual bait), have a limited attraction range; a subject must be within a sensing/reaction distance. Therefore, surveys rapidly crossing and extending well beyond sand ridges can tally and find the decorrelation scale between sightings and benthic features. From repeated surveys made at short (hourly) to long (monthly) repeat intervals, co-classified contacts by sonar (**Figure 20**) or camera (**Figure 19**) can be mapped to topographic layers and calculated and plotted as probability density functions (or kernels) (Grothues et al. 2017b; Worton 1989) because AUVs and ships have timestamped records of their positions to meter-scale accuracy. Calculations made from telemetry of sentinel individuals can be supported by the same AUV, or towed platforms can resolve bias from multiple resightings of individuals (Grothues et al. 2017b) (see also section on telemetry in Section 6.3) and can also support oceanographic sensors for hydrographic context. As above, these observations can be used to populate bioenergetics models that further test our understanding of any such associations.

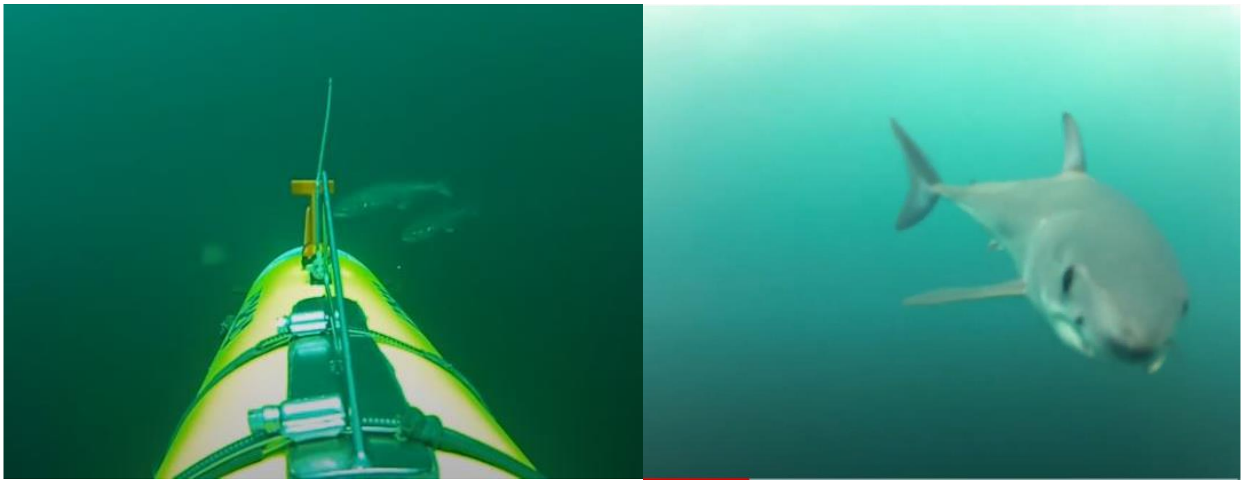


Figure 19. Pelagic fish following AUV and towed camera
Both images are screen grabs from GoPro video. *Left:* two Bluefish turn away after a period of closely following an AUV with rear-facing camera offshore Sandy Hook, NJ. *Right:* a juvenile Shortfin Mako Shark approaches a camera towed behind a research vessel off Virginia. Predators are attracted to the AUV and camera housing, and follow or sometimes hit them, as this shark did. Image credits: Thomas Grothues

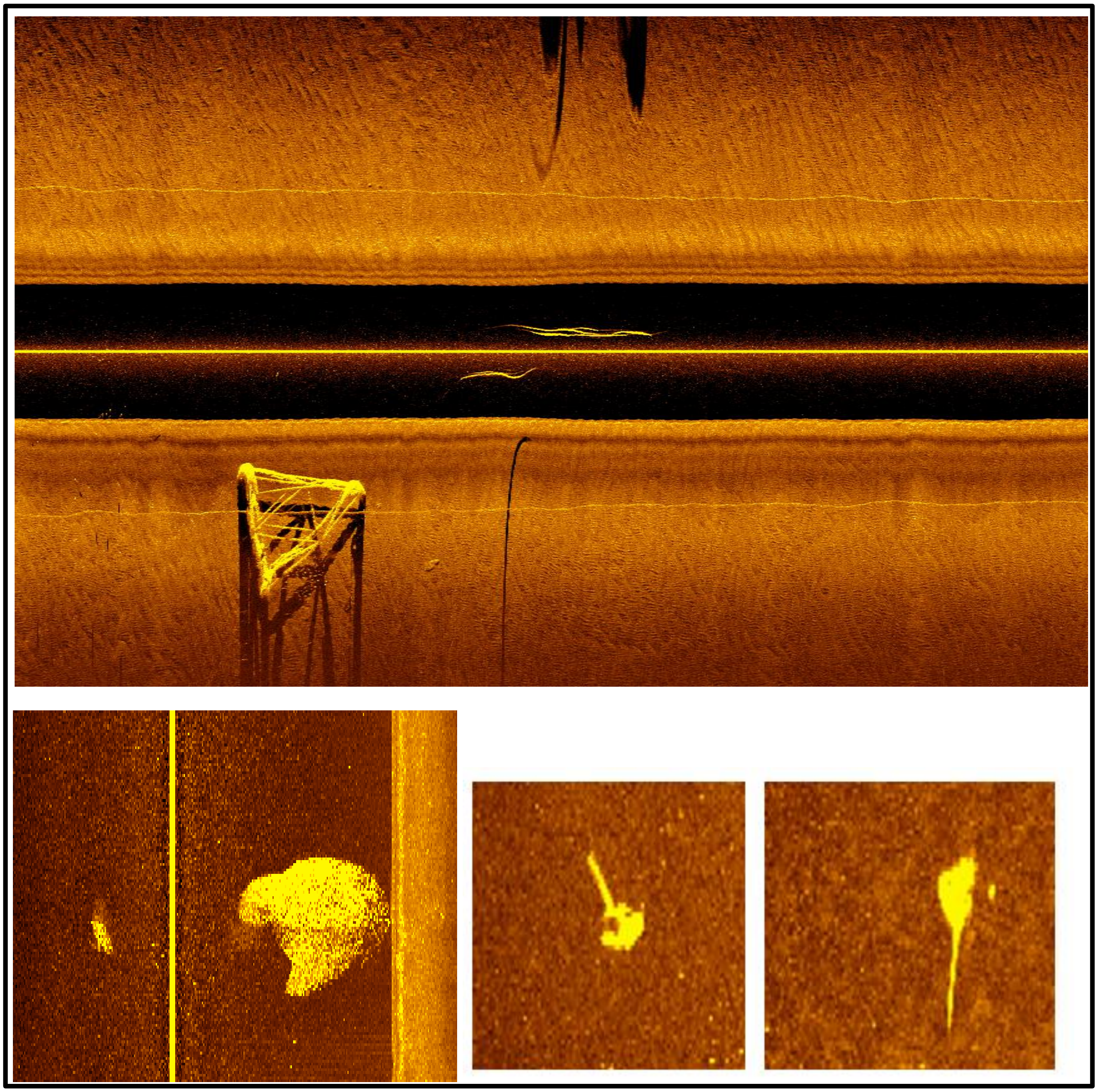


Figure 20. Fish targets imaged by side scan sonar (600 or 900 khz) from REMUS-100 AUV
Top: elongated midwater sonar reflectors are a school of Greater Amberjack pacing the AUV as it passes a radar tower over flat sand bottom off Virginia (verified by camera imaging). A school of Blue Runner are also evident below the tower. AUV traverse is left to right along the center line and swath is approximately 30 m to each side starting from nadir. *Lower right:* Dasyatid stingrays, also near Virginia. *Lower left:* a school of forage fish near the HARS, NJ. AUV travers is bottom to top along centerline. Cross range scale is 30 m. Larger targets may be smaller predators such as Bluefish, which were prevalent in the camera footage during the deployment. Image credit Rutgers University Marine Field Station

6.3 Response to Dredging Activity

The distance at which fish react to dredging, the nature of the response, and duration or period to inurement of a response to the direct dredging activity (rather than the longer term of effect of alteration to the benthos or forage base) for fishes and invertebrates in the NYB and by species and season is unknown. Can or do clams dig deeper in response to vibration from dredges? Are fish attracted to and do they benefit from opportunistic feeding on exposed infauna? Do they flee? Do they react at all, and does this change during the day or night as a factor of sleep or diurnal activity? Do they bury themselves to escape threat and thus make themselves more vulnerable to entrainment? These questions are summarized in Pickens et al. (2020).

These questions can be addressed through the same methods of direct observation discussed above as useful for making behavioral observations about the mechanisms of life history intersection with sand. Their broader affects can be anticipated by modeling bioenergetics through the parameterization of response variables in models such as EcoPath/EcoSIM.

Approaches must utilize different methods for the different scales (e.g., reaction distance for attraction or avoidance, possibly on the scale of kilometers, vs. a buried fish emerging to get out of the way of approaching a cutterhead). Behavioral observations could lead to innovations in the dredge equipment, such as ticklers or rakes that precede the dredge head. Thus, solutions range from cameras to observe close field response to telemetry to reveal far field (100s of meters) response. In an observatory setting (see Section 6.1), these would be able to control some conditions while varying dredge operation parameters or equipment. Experiments in large aquaria, such as that at the NOAA Magruder Laboratory in Sandy Hook, NJ, could address some of the basics such as day vs. night difference in response to acoustic, mechanical agitation, or tactile stimulus. These lead directly to actionable recommendations on dredge operation.

6.4 Scaling

An important gap in our knowledge is the temporal and spatial extent to which individual species use non-reef habitat, and what the scale of features that make up a reef or any home use area means to understanding fidelity or residency. “Scale bias” is the extent to which the temporal or spatial scale at which an experiment or survey is conducted influences the results (Levin 1992; Mashintonio et al. 2014) (**Figure 21**), as captured in the phrase seeing the “forest or the trees” (Shrader et al. 2012). Scale bias is a recurring theme in the current synthesis. When we examine the scale at which a disturbance is measured relative to the scale at which fish distribution/abundance is measured, we find a mismatch. Scale bias is relevant to disturbance/response but also to factors influencing distribution measures as a base state. For example, a survey trawl integrates fish distribution and microhabitat differences within a single 2-km long path. The importance of scale extends from coastwide down to concentration of shell hash and the size and sorting of sand grain (Bartholomew et al. 2000; Diaz et al. 2003; Diaz et al. 2004; Fabrizio et al. 2014; Fogarty and Murawski 1998; Friedland et al. 2018; Holland et al. 2004; Scharf et al. 2006).

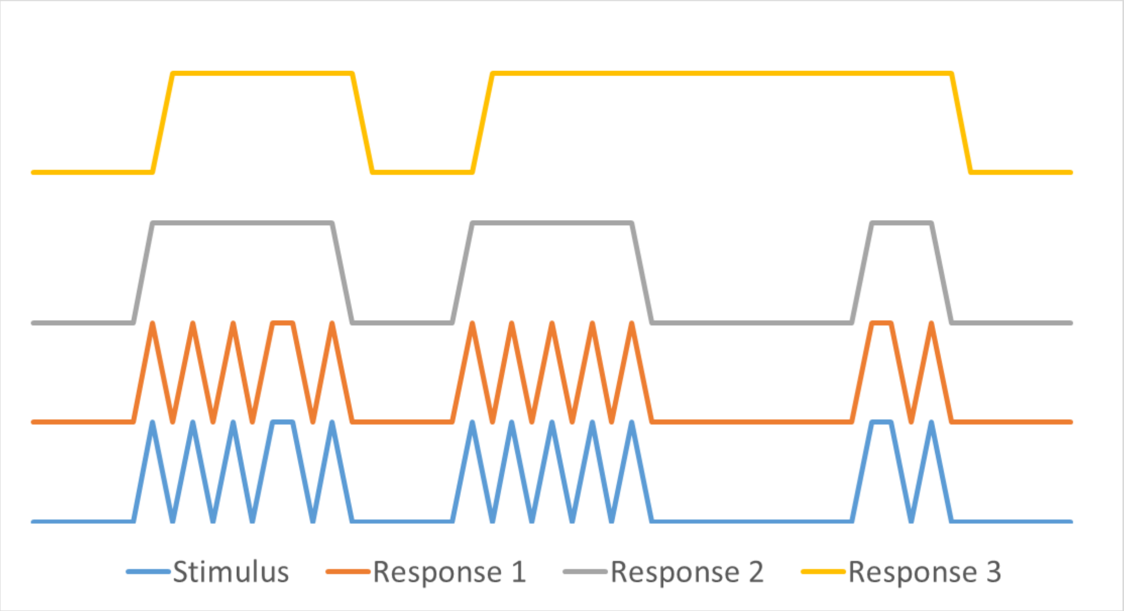


Figure 21. Diagrammatic representation scaled response
In the figure above, a hypothetical perturbation (e.g., storm, dredging, trawling) is represented as an oscillating state (lower blue line, up is disturbance, down is no disturbance) along a time line (x-axis). Three possible response patterns (upper three curves) show the effect of scale in eliciting or detecting a response. The uppermost hypothetical response is least correlated to the stimulus unless the stimulus signal is resampled to a lower resolution and also lagged, but remains plausible as a response, for instance if fish evacuate an area on the basis of frequent disturbance, rather than in response to just one event. The same pattern holds true if the x-axis is understood to depict a spatial measurement (e.g., meters). In that case, fish may vacate a wide area that has a high density of habitat disruptions even if they do not avoid any individually disturbed area. The conceptual figure also holds for attractor stimuli (e.g., concentration of shell hash), in which case the response is positive.

Scaling is quantified by producing the finest possible or practical maps of possible underlying variables—in this case bathymetry, bedform, surficial sediment properties (from side scan sonar), infauna distribution (from core samples and extrapolation to bedform and surficial reflectance, but also sidescan sonar identification and classification of biogenic habitat such as tube worm reefs)—and then obtaining and overlaying fine-scale (meter-scale) tracks or space use maps of animals (typically from acoustic telemetry positioning systems) (**Table 4** and explanation below), and finally sequentially and iteratively downsampling or degrading the resolution of either or both the animal map and the underlying maps and testing the correlative fit between the map features at each step (Mashintonio et al. 2014). The scale of the response is identified as that at which the fit is best. In **Figure 21** above, if Response 2 had been the measured path of a fish, the stimulus would have been needed to be subsample at half of its original resolution to make a good fit, thus pointing to resolution of the whole patch, rather than variation within the patch, as the scale of importance to the fish.

The importance of understanding scale is exemplified in a trap survey on sand and reef (Jensen and Zemeckis 2019) and by the telemetry experiment of Black Sea Bass by Jensen and Grothues (2015) reported in Section 3.3.4.31. In the former, it is recognized that traps placed on otherwise bare sand may be reefs at the scale identified by the fish themselves. This conundrum is important to address. Most telemetry studies are confounded by limits and costs of the necessary technology for sub-meter resolution to the larger (between-reef or between-reef-element) scale, but telemetry solutions exist for many different scales (**Table 4**). However, they all have constraints. For example, acoustic transmitter/receiver technologies that do positioning well (sub-meter precision and 3-second temporal resolution) are sufficient to show even spawning, death, and burial behavior and can be applied to the same fish as telemetry technology that that is commonly used to “gate” passage or detect presence, but they are twice as expensive to purchase, deploy, and process (Grothues 2009; Grothues et al. 2012; Yergey et al. 2012). Because they are less commonly used and not compatible for detection on other receivers, they lack the ability to synergize with and utilize already tagged fish (for other projects) that may come through the area (Grothues 2009).

Table 4. Telemetry technologies, constraints, and applications

Class	Technology	Constraint	Niche
Acoustic PPM	High frequency acoustic, simple code, inexpensive, widely accessible, small	600 m–1 km range Needs to be in range of moored or mobile receiver	Fish and invertebrates down to 0.25 kg, wide buy-in promotes unified and synergistic listening arrays
Acoustic Spread Spectrum	High frequency acoustic, small	600 m–1 km range Needs to be in range of moored or mobile receiver, more expensive than PPM, not as much buy-in	Fish and invertebrates down to 0.25 kg, performs very well for high precision time and space virtual positioning array, useful for behavior, social interaction studies
Archival Tags	Collect information about habitat and animal from sensors	Do not transmit. Tag must be recovered and data downloaded. No true positions. Paths, if important, must be modeled from most parsimonious Markov walk or sunup/sundown relative to GMT from light sensor.	Good for fishes that have high fishing mortality, so that tags are likely to be recovered by massive “free” fishing effort. Provide habitat and even physiological history. Fish and invertebrates down to 0.25 kg
Pop-off Archival Satellite Tag	Similar to archival tag, but after sampling period, pop off and float to surface and download data to satellite	Paths, if important must be modeled as for archival tags. Satellite transmitter, wire burner, battery for those features, float, and antenna make these very large. Must be externally attached to allow pop-off.	Only for very large fish, such as tunas, billfish, sharks, have been fitted to smaller fish but risk changing behavior. Method of positioning makes them useful only for basin scale studies (100–1,000 km)
GPS Satellite Tag	GPS receiver acquires satellite signal, calculates position, reports position back to satellite and then to reader	Receive/send antenna only works out of the water.	Basin and smaller scale realtime position reports, but only animals that regularly break water for extended periods to breath (mammals, turtles), bask, or hunt (certain sharks)

Instructive results have come from a pilot project seeking to understand social structure on a reef relative to spawning patterns and social signaling. Positioning of tagged Black Sea Bass from signal time-of-arrival-differencing (also called multilateration) was accomplished between June and September 2011 on six mature males and four mature females in a polygon array with six hydrophones with 5-s temporal resolution on a popular artificial reef off southern New Jersey set over a reef complex that was mapped at night with 600 kHz side scan sonar (**Figure 22**). The sonar map showed a scatter of small elements, meter-scale reef ball to military vehicles, in a “figure 8” spread over rippled sand. Ranging behavior covered the sand but favored the reef elements; scaling of element spacing, reef element sizes, and cumulative effect of elements is clearly warranted for further study.

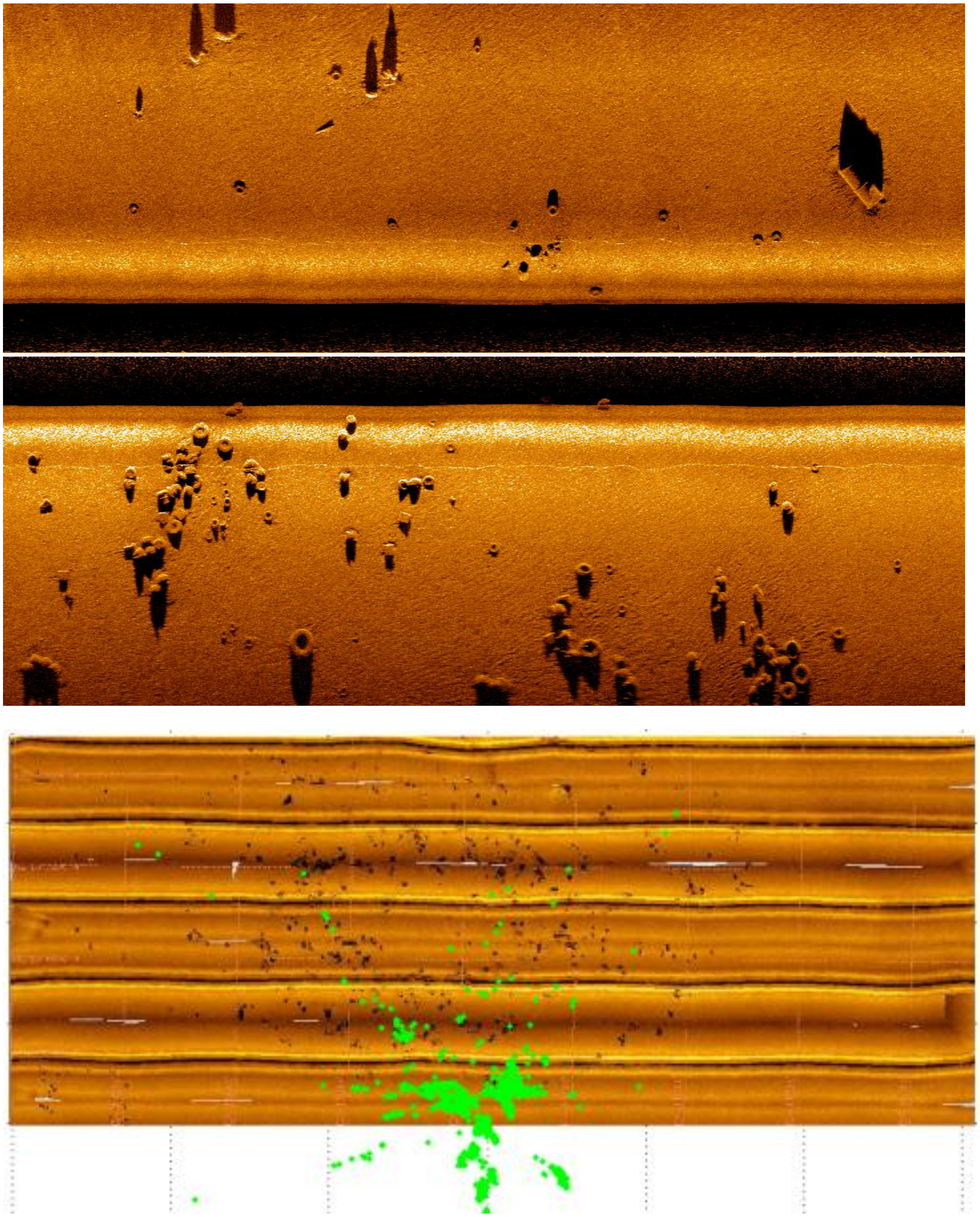


Figure 22. Detail of side scan sonar imagery of Black Sea Bass habitat and telemetry track overlay
Upper: This tile from a more extensive 600 kHz side scan sonar survey of a Black Sea Bass telemetry study site details scattered artificial reef elements over rippled sand on the Little Egg Harbor Reef on the NYB off New Jersey. Track span is approximately 60 m (top to bottom), not counting the water column (black stripe). *Lower:* georectified position of 1 of 10 tagged Black Sea Bass over the course of 2 months shows high localization to a specific cluster of reef elements in the lower center of scanned area and beyond, with occasional forays (Jensen and Grothues 2015).

One very important gap is a lack of understanding of how soft bottom demersal fish such as flounders form home territories the way that reef fish do. Sand habitat is often considered by humans to be transient in its features or homogenous at the scale of fish range, but fish may be orienting to features that are not visible to us. A number of studies have found varying periods of fidelity of pelagic fishes to floating objects, and this knowledge is used in pelagic fisheries to localize tunas. For flatfish on sand habitat, however, there are only two telemetry studies that examine site fidelity and territorial range; one is for Senegelese Sole (*Solea senegalensis*) from the Portuguese coast (Gandra et al. 2018) and the other in the UK in an estuary for European Flounder (*Platichthys flesus*) (Dando 2011), although numerous studies have approached habitat use of flatfishes in estuaries. Studies scaling home range information is especially critical to understanding the sizing and siting of potential marine protected areas (MPAs) or extraction-free zones (Abecasis et al. 2014). Similar studies to that on reef use by Black Sea Bass need to be repeated and expanded for numerous species, preferably together, on sand and sand/reef habitat. The methodology again returns to that of an observatory focused on a fine scale positioning array and repeatedly mapped at high spatial resolution, such as by the 600 kHz side scan sonar shown above and augmented by mobile telemetry systems that can find and position tagged fish beyond the study area (Eiler et al. 2019; Haulsee et al. 2015; Oliver et al. 2013a).

7 Literature Inventory

7.1 Literature Search Methods

Initial literature collection by the principal investigators was assisted by multiple technicians of the Rutgers University Marine Field Station, with additional input from Rutgers-based SMEs and BOEM partners. Search results were combined and collated. Initial collection was conducted with topic and keyword searches. Topic and keyword searches used included: benthic fauna/communities, habitat interaction, food web flow, and seasonality; Mid-Atlantic Bight; dredging; sediment transport; and continental shelf/slope. A second round of literature collection efforts was then conducted via snowball sampling of literature collected in the initial literature search and literature already known to Rutgers SMEs. Snowball sampling was conducted by reviewing the sources cited by other pieces of literature and checking for connected papers via the Connectedpapers.com web tool.

7.2 Literature Inventory

Approximately 1,500 sources were collected during the literature search. Of these ~1,500 sources, 640 were cited within this review. An overview of the general topics addressed by these 640 sources may be found in **Table 5**.

Table 5. An overview of the literature cited for this review

Category	Pieces of Literature
NYB/MAB	313
Other Atlantic	193
Other Regional	56
Fish	444
Invertebrates	139
Birds	3
Human Dimensions	126
Life History	370
Assemblages	38
Other Ecology	388
Methods	66
Oceanography	89

8 Companion Data Review and Synthesis

This literature synthesis is accompanied by a synthesis of data (**Volume 2: Data Synthesis**).

9 References

Abbot RT. 1974. American seashells. New York: van Nostrand Reinhold.

Abecasis D, Afonso P, Erzini K. 2014. Combining multispecies home range and distribution models aids assessment of MPA effectiveness. Marine Ecology Progress Series. 513:155-169.

Able KW. 2016. Natural history: an approach whose time has come, passed, and needs to be resurrected†. ICES Journal of Marine Science. 73(9):2150-2155.

Able KW, Clarke PJ, Chambers RC, Witting DA. 2007. Transitions in the morphological features, habitat use, and diet of young-of-the-year goosefish (Lophius americanus). Fishery Bulletin. 105:457-469.

Able KW, Fahay MP. 1998. The first year in the life of estuarine fishes in the Middle Atlantic Bight. New Brunswick, NJ: Rutgers University Press.

Able KW, Fahay MP. 2010. Ecology of Estuarine Fishes: Temperate Waters of the Western North Atlantic. Baltimore, MD: John Hopkins University Press.

Able KW, Grothues TM. 2007. Diversity of estuarine movements of striped bass (Morone saxatilis): a synoptic examination of an estuarine system in southern New Jersey. Fishery Bulletin. 105:426-435.

Able KW, Grothues TM, Morson JM, Coleman KE. 2014. Temporal variation in winter flounder recruitment at the southern margin of their range: is the decline due to increasing temperatures? ICES Journal of Marine Science. 71(8):2186-2197.

Able KW, Grothues TM, Rowe PM, Wuenschel MJ, Vasslides JM. 2011a. Near-Surface Larval and Juvenile Fish in Coastal Habitats: Comparisons Between the Inner Shelf and an Estuary in the New York Bight During Summer and Fall. Estuaries and Coasts. 34(4):726-738.

Able KW, Grothues TM, Turnure J, Byrne D, Clerkin P. 2012a. Distribution, movements, and habitat use of small striped bass (Morone saxatilis) across multiple spatial scales. Fishery Bulletin. 110:176-192.

Able KW, Kaiser SC. 1994. Synthesis of summer flounder habitat parameters. Silver Spring, MD: NOAA Coastal Ocean Office. Report No.: 1. 68 pp + biblio + 63 app p.

Able KW, López-Duarte PC, Grothues TM, Barry L, Petrecca R, Fredricks J, Navara C, Hanson A. 2019. Limulus polyphemus (Atlantic Horseshoe Crab) Habitats in a Small Estuary and the Adjacent Inner Continental Shelf: Linkages Across Mid-Atlantic Bight Seascapes. Northeastern Naturalist. 26(2):287.

Able KW, Matheson RE, Morse WW, Fahay MP, Shepard GR. 1990. Patterns of summer flounder Paralicthys dentatus early life history in the Mid-Atlantic Bight and New Jersey estuaries. Fishery Bulletin. 88(1):1-12.

Able KW, Sullivan MC, Hare JA, Bath-Martin B, Taylor JC, Hagan R. 2011b. Larval abundance of summer flounder (Paralichthys dentatus) as a measure of recruitment and stock status. Fishery Bulletin. 109:68-78.

Able KW, Valenti JL, Grothues TM. 2017. Fish larval supply to and within a lagoonal estuary: multiple sources for Barnegat Bay, New Jersey. Environmental Biology of Fishes. 100(6):663-683.

Able KW, Wilber DH, Muzeni-Corino A, Clarke DG. 2009. Spring and Summer Larval Fish Assemblages in the Surf Zone and Nearshore off Northern New Jersey, USA. Estuaries and Coasts. 33(1):211-222.

Able KW, Wuenschel MJ, Grothues TM, Vasslides JM, Rowe PM. 2012b. Do surf zones in New Jersey provide "nursery" habitat for southern fishes? Environmental Biology of Fishes. 96(5):661-675.

Abril G, Borges AV. 2004. Carbon Dioxide and Methane Emissions from Estuaries. In: Tremblay A, Varfalvy L, Roehm C, Garneau M, editors. Greenhouse Gases Emissions from Natural Environments and Hydroelectric Reservoirs: Fluxes and Processes. Berlin: p. 187-207.

Adams AJ. 1993. Dynamics of Fish Assemblages Associated with an offshore Artificial Reef in the Southern Mid-Atlantic Bight. [Williamsburg, VA]: College of William & Mary.

Afonso AS, Hazin FH. 2015. Vertical movement patterns and ontogenetic niche expansion in the tiger shark, Galeocerdo cuvier. PLoS One. 10(1):e0116720.

Aikman F, Posmentier ES. 1985. Stratification and shelf-slope interaction in the Middle Atlantic Bight: A numerical study. Journal of Geophysical Research. 90(C3).

Alonzo SH, Mangel M. 2004. The effects of size-selective fisheries on the stock dynamics of and sperm limitation in sex-changing fish. Fishery Bulletin. 102:1-13.

Anderson RL, Watson WH, Chabot CC. 2013. Sublethal Behavioral and Physiological Effects of the Biomedical Bleeding Process on the American Horseshoe Crab,Limulus polyphemus. The Biological Bulletin. 225(3):137-151.

Anderson RM, May RM. 1978. Regulation and Stability of Host-Parasite Population Interactions: I. Regulatory Processes. Journal of Animal Ecology. 47(1):219-247.

Andrzejaczek S, Gleiss AC, Pattiaratchi CB, Meekan MG. 2019. Patterns and drivers of vertical movements of the large fishes of the epipelagic. Reviews in Fish Biology and Fisheries. 29(2):335-354.

Anne Richards R. 1992. Habitat selection and predator avoidance: ontogenetic shifts in habitat use by the Jonah crab Cancer borealis (Stimpson). Journal of Experimental Marine Biology and Ecology. 156(2):187-197.

Ansell AD, Gibson RN. 1993. The effect of sand and light on predation of juvenile plaice (Pleuronectes platessa) by fishes and crustaceans. Journal of Fish Biology. 43(6):837-845.

Arendt MD, Lucy JA, Evans DA. 2001a. Diel and seasonal activity patterns of adult tautog, Tautoga onitis, in lower Chesapeake Bay, inferred from ultrasonic telemetry. Environmental Biology ofFishes. 62:379–391.

Arendt MD, Lucy JA, Munroe TA. 2001b. Seasonal occurrence and site-utilization patterns of adult tautog, Tautoga onitis (Labridae), at manmade and natural structures in lower Chesapeake Bay. Fishery Bulletin. 99:519-527.

Armstrong MP, Musick JA, Colvocoresses JA. 1996. Food and Ontogenetic shifts in feeding of the goosefish, Lophius Americanus. Journal of Northwest Atlantic Fishery Science. 18:99-103.

Asch RG, Stock CA, Sarmiento JL. 2019. Climate change impacts on mismatches between phytoplankton blooms and fish spawning phenology. Global Change Biology. 25(8):2544-2559.

Atlantic States Marine Fisheries Commission. 2013. Addendum III to Amendment I to the interstate fishery management plan for the inshore stocks of winter flounder: commercial & recreational specification process for Gulf of Maine and Southern New England/Mid-Atlantic stocks. Atlantic States Marine Fisheries Commission. 3 p.

Atlantic States Marine Fisheries Commission. 2015a. American Lobster Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission. 493 p.

Atlantic States Marine Fisheries Commission. 2015b. Interstate Fishery Management Plan for Jonah Crab. Atlantic States Marine Fisheries Commission. 73 p.

Atlantic States Marine Fisheries Commission. 2015c. Scup benchmark assessment for 2015.

Atlantic States Marine Fisheries Commission. 2016. Weakfish Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission. 270 p.

Atlantic States Marine Fisheries Commission. 2018a. 2018 Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for Jonah Crab (Cancer borealis): 2017 fishing year. Atlantic States Marine Fisheries Commission. 19 p.

Atlantic States Marine Fisheries Commission. 2018b. Addendum XXVI to amendment 3 to the American Lobster fishery management plan; addendum III to the Jonah Crab fishery management plan: Harvester reporting and biological data collection. Atlantic States Marine Fisheries Commission. 30 p.

Atlantic States Marine Fisheries Commission. 2019a. 2019 Horseshoe Crab Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission.

Atlantic States Marine Fisheries Commission. 2019b. Summary of the 2019 Benchmark Stock Assessment for Atlantic Striped Bass. Atlantic States Marine Fisheries Commission. 24 p.

Attrill MJ, Power M. 2002. Climatic influence on a marine fish assemblage. Nature. 417(6886):275-278.

Auster PJ, Lindholm J, Schaub S, Funnell G, Kaufman LS, Valentine PC. 2003. Use of sand wave habitats by silver hake. Journal of Fish Biology. 62(1):143-152.

Auster PJ, Malatesta RJ, Donaldson CLS. 1997. Distributional responses to small-scale habitat variability by early juvenile silver hake, Merluccius bilinearis. Environmental Biology of Fishes. 50:195-200.

Auster PJ, Malatesta RJ, LaRosa SC. 1995. Patterns of microhabitat utilization by mobile megafauna on the southern New England (USA) continental shelf and slope. Marine Ecology Progress Series. 127:77-85.

Auster PJ, Malatesta RJ, LaRosa SC, Cooper RA, Stewart LR. 1991. Microhabitat utilization by the megafaunal assemblage at a low relief outer continental shelf site - Middle Atlantic Bight, USA. Journal of Northwest Atlantic Fishery Science. 11:59-69.

Auster PJ, Stewart LL. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic): Sand Lance. Report No.: Biological Report 82 (11.66).

Balazik MT, Musick JA. 2015. Dual Annual Spawning Races in Atlantic Sturgeon. PLOS ONE. 10(5):e0128234.

Bangley CW, Curtis TH, Secor DH, Latour RJ, Ogburn MB. 2020. Identifying Important Juvenile Dusky Shark Habitat in the Northwest Atlantic Ocean Using Acoustic Telemetry and Spatial Modeling. Marine and Coastal Fisheries. 12(5):348-363.

Bartholomew A, Diaz R, Cicchetti G. 2000. New dimensionless indices of structural habitat complexity: predicted and actual effects on a predator's foraging success. Marine Ecology Progress Series. 206:45-58.

Bauer JE, Cai W-J, Raymond PA, Bianchi TS, Hopkinson CS, Regnier PAG. 2013. The changing carbon cycle of the coastal ocean. Nature. 504(7478):61-70.

Bayne BL. 1976. Marine mussels: their ecology and physiology. Bayne BL, editor. New York: Cambridge University Press. 506 p.

Beardsley RC, Boicourt WC. 1981. On estuarine and continental shelf circulation in the Middle Atlantic Bight. In: Warren BA, Wunsch C, editors. Evolution of Physical Oceanography. Cambridge, MA: M.I.T. Press. p. 198-234.

Bell RJ, Hare JA, Manderson JP, Richardson DE. 2014. Externally driven changes in the abundance of summer and winter flounder. ICES Journal of Marine Science. 71(9):2416-2428.

Bennett MVL, Wurzel M, Grundfest H. 1961. The Electrophysiology of Electric Organs of Marine Electric Fishes. Journal of General Physiology. 44(4):757-804.

Benseman SA, Allen LG. 2018. Distribution and Recruitment of Young-of-the-Year Giant Sea Bass,Stereolepis gigas, off Southern California. Copeia. 106(2):312-320.

Benseman SA, Couffer MC, Allen LG. 2019. Behavior of young-of-the-year Giant Sea Bass, Stereolepis gigas, off the sandy beaches of Southern California. Bulletin of the Southern California Academy of Sciences. 118(2):79-86.

Benton CB, Berlinsky DL. 2006. Induced sex change in black sea bass. Journal of Fish Biology. 69(5):1491-1503.

Berkson J, Carl N. Shuster J. 1999. The Horseshoe Crab: The Battle for a True Multiple-use Resource. FisherieS. 24(11):6-10.

Bethea DM, John K. Carlson, Buckel JA, Satterwhite M. 2006. Ontogenetic and site-related trends in the diet of the Atlantic sharpnose shark rhizoprionodon terraenovae from the Northeast Gulf of Mexico. Bulletin of Marine Science. 78(2):287-307.

Bethoney ND, Stokesbury KDE, Schondelmeier BP, Hoffman WS, Armstrong MP. 2014. Characterization of River Herring Bycatch in the Northwest Atlantic Midwater Trawl Fisheries. North American Journal of Fisheries Management. 34(4):828-838.

Bigelow HB, Schroeder WC. 1953. Fishes of the Gulf of Maine. Fishery Bulletin. 53:1-577.

Biggs CR, Lowerre-Barbieri SK, Erisman B. 2018. Reproductive resilience of an estuarine fish in the eye of a hurricane. Biol Lett. 14(11).

Bilinski J, G B, D F, R H, Lippincott L, Procopio N, Ruppel B, Tucker T. 2015. Damage assessment report on the effects of Hurricane Sandy on the state of New Jersey's natural resources: final report. . Trenton, NJ.

Bizzarro JJ, Peterson AN, Blaine JM, Balaban JP, Greene HG, Summers AP. 2016. Burrowing behavior, habitat, and functional morphology of the Pacific sand lance (Ammodytes personatus). Fishery Bulletin. 114(4):445-460.

Blake ES, Kimberlain TB, Berg RJ, Cangialosi JP, II JLB. 2013. Tropical Cyclone Report Hurricane Sandy.157.

Block BA. 2001. Migratory Movements, Depth Preferences, and Thermal Biology of Atlantic Bluefin Tuna. Science. 293(5533):1310-1314.

Block BA, Carey FG. 1985. Warm brain and eye temperatures in sharks. Journal of Comparative Physiology B. 156:229-236.

Boehlert GW, Mundy BC. 1988. Roles of Behavioral and Physical Factors in Larval and Juvenile Fish Recruitment to Estuarine Nursery Areas. American Fisheries Science Symposium. 3:51-67.

Bornatowski H, Braga RR, Abilhoa V, Corrêa MFM. 2014. Feeding ecology and trophic comparisons of six shark species in a coastal ecosystem off southern Brazil. Journal of Fish Biology. 85(2):246-263.

Borsetti S, Munroe D, Rudders D, Chang J-H. 2020. Timing of the reproductive cycle of waved whelk, Buccinum undatum, on the U.S. Mid-Atlantic Bight. Helgoland Marine Research. 74(1).

Borsetti S, Munroe D, Rudders DB, Dobson C, Bochenek EA. 2018. Spatial variation in life history characteristics of waved whelk (Buccinum undatum L.) on the U.S. Mid-Atlantic continental shelf. Fisheries Research. 198:129-137.

Botton ML. 2009. The ecological important of horseshoe crabs in estuarine and coastal communities: A review and speculative summary. In: Tanacredi JT, Botton ML, Smith DR, editors. Biology and Conservation of Horseshoe Crabs. New York: Springer. p. 43-63.

Botton ML, Haskin HH. 1984. Distribution and feeding of the Horseshoe Crab, Limulus polyphemus, on the continental shelf off New Jersey. Fishery Bulletin. 82(2):383-389.

Botton ML, Ropes JW. 1987. Populations of horseshoe crabs, (Limulus polyphemus), on the Northwestern Atlantic continental shelf. Fishery Bulletin. 85(4):808-812.

Botton ML, Tankersley RA, Loveland RE. 2010. Developmental ecology of the American horseshoe crab Limulus polyphemus. Current Zoology. 56(5):550-562.

Bowman RE, Michaels WL. 1984. Food of seventeen species of Northwest Atlantic fish. Woods Hole, MA: National Oceanic and Atmospheric Administration National Marine Fisheries Service Northeast Fisheries Center. Report No.: NMFS-F/NEC-28. 187 p.

Bowman RE, Stillwell CE, Michaels WL, Grosslein MD. 2000. Food of Northwest Atlantic Fishes and Two Common Species of Squid. Woods Hole, MA: National Oceanic and Atmospheric Administration National Marine Fisheries Service Northeast Fisheries Science Center. Report No.: NMFS-NE-155. 134 p.

Bradt G, Kashef N, Wilding S. 2016. Monterey Bay Aquarium Seafood Watch: Atlantic rock crab, Jonah crab. Monterey Bay Aquarium Seafood Watch. 81 p.

Branstetter S. 2002. Smooth Dogfishes. Family Triakidae. In: Colette BB, G. K-M, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 37-38.

Braun CD, Skomal GB, Thorrold SR. 2018. Integrating Archival Tag Data and a High-Resolution Oceanographic Model to Estimate Basking Shark (Cetorhinus maximus) Movements in the Western Atlantic. Frontiers in Marine Science. 5.

Bray RN, Hixon MA. 1978. Night-Shocker: Predatory Behavior of the Pacific Electric Ray (Torpedo californica). Science. 200(4339):333-334.

Breece MW, Fox DA, Dunton KJ, Frisk MG, Jordaan A, Oliver MJ, Kurle C. 2016. Dynamic seascapes predict the marine occurrence of an endangered species: Atlantic Sturgeon Acipenser oxyrinchus oxyrinchus. Methods in Ecology and Evolution. 7(6):725-733.

Breece MW, Fox DA, Haulsee DE, Wirgin II, Oliver MJ, Hidalgo M. 2018. Satellite driven distribution models of endangered Atlantic sturgeon occurrence in the mid-Atlantic Bight. ICES Journal of Marine Science. 75(2):562-571.

Briggs PT, Waldman JR. 2002. Annotated List of Fishes Reported from the Marine Waters of New York. Northeastern Naturalist. 9(1):47-80.

Bruce DG. 2006. The whelk dredge fishery of Delaware. Journal of Shellfish Research. 25(1):1-13.

Brusca RC, Moore W, Schuster SM. 2016. Invertebrates. New York: Oxford University Press. 1104 p.

Buckel JA, Fogarty MJ, Conover DO. 1999. Foraging habits of bluefish, Pomatomus saltatrix, on the U.S. east coast continental shelf. Fishery Bulletin. 97:758-775.

Buhariwalla CF, MacMillan JL, Gregoire MJ, Dadswell MJ, Stokesbury MJW. 2016. Population Characteristics of Striped Bass Killed by Cold Shock during Winter Shutdown of a Power Plant in Nova Scotia. Northeastern Naturalist. 23:163-173.

Burgess GH. 2002. Spiny Dogfishes. Family Squalidae. In: Colette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, Dc: Smithsonian Institution Press. p. 48-57.

Burkholder J, Eggleston D, Glasgow H, Brownie C, Reed R, Janowitz G, Posey M, Melia G, Kinder C, Corbett R, et al. 2004. Comparative impacts of two major hurricane seasons on the Neuse River and western Pamlico Sound ecosystems. PNAS. 101(25):9291–9296.

Burton D, Burton MPM. 1989. Epidermal characteristics of reproductive subsets in an inshore population of winter flounder,Pseudopleuronectes americanus. Journal of Zoology. 218(4):637-647.

Burton WH, Kelley FS, Franks EA. 2009. Distribution of Juvenile Horseshoe Crabs in Subtidal Habitats of Delaware Bay Using a Suction-Dredge Sampling Device. In: Tanacredi JT, editor. Biology and Conservation of Horseshoe Crabs. Springer.

Butler PG, Richardson CA, Scourse JD, Wanamaker AD, Shammon TM, Bennell JD. 2010. Marine climate in the Irish Sea: analysis of a 489-year marine master chronology derived from growth increments in the shell of the clam Arctica islandica. Quaternary Science Reviews. 29(13-14):1614-1632.

Butler PG, Wanamaker AD, Scourse JD, Richardson CA, Reynolds DJ. 2013. Variability of marine climate on the North Icelandic Shelf in a 1357-year proxy archive based on growth increments in the bivalve Arctica islandica. Palaeogeography, Palaeoclimatology, Palaeoecology. 373:141-151.

Butman B. 1987. Physical processes causing surficial-sediment movement. . In: Backus RH, editor. Georges Bank. M.I.T. Press: Cambridge, MA. 13; p. 147-162.

Byrnes MR, Hammer RM, Thibaut TD, Snyder DB. 2004. Effects of Sand Mining on Physical Processes and Biological Communities Offshore New Jersey, U.S.A. Journal of Coastal Research. 201:25-43.

C. L. MacKenzie J, Radosh DJ, Reid RN. 1985. Densities, growth, and mortalities of juveniles of the surf clam (Spisula solidissima)(Dillwyn) in the New York Bight. Journal of Shellfish Research. 5:81-84.

C. N. Shuster J. 1950. Observations on the natural history of the American horseshoe crab, Limulus polyphemus. Woods Hole Oceanographic Institution. 18–23 p.

C. N. Shuster J. 1982. A pictorial review of the natural history and ecology of the Horseshoe Crab Limulus polyphemus, with reference to other Limulidae. In: Bonaventura J, Bonaventura C, Tesh S, editors. Physiology and Biology of Horseshoe Crabs. New Yourk: Alan R. Liss. p. 1-52.

C. N. Shuster J, Botton ML. 1985. A contribution to the population of Horseshoe Crabs, Limulus polyphemus (L.), in Delaware Bay. Estuaries. 8:363-372.

Cai W-J, Hu X, Huang W-J, Murrell MC, Lehrter JC, Lohrenz SE, Chou W-C, Zhai W, Hollibaugh JT, Wang Y, et al. 2011. Acidification of subsurface coastal waters enhanced by eutrophication. Nature Geoscience. 4(11):766-770.

Cai W-J, Huang W-J, Luther GW, Pierrot D, Li M, Testa J, Xue M, Joesoef A, Mann R, Brodeur J, et al. 2017. Redox reactions and weak buffering capacity lead to acidification in the Chesapeake Bay. Nature Communications. 8(1).

Cairns DK. 1998. Diets of cormorants, mergansers, and kingfishers in the northeastern North Atlantic. Canadian Technical Report of Fisheries and Aquatic Sciences. 2225:32.

Caldeira K, Wickett ME. 2005. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. Journal of Geophysical Research. 110(C9).

Campana SE, Joyce WN. 2004. Temperature and depth associations of porbeagle shark (Lamna nasus) in the northwest Atlantic. Fisheries Oceanography. 13(1):52-64.

Canada DoFaO. 2019. Assessment of the atlantic mackerel stock for the northwest atlantic (subareas 3 and 4) in 2018.

Cargnelli LM, Griesbach SJ, Packer DB, Berrien PL, Johnson DL, Morse WW. 1999a. Essential fish habitat source document. Pollock, Pollachius virens, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE -131. 30 p.

Cargnelli LM, Griesbach SJ, Packer DB, Berrien PL, Morse WW, Johnson DL. 1999b. Essential fish habitat source document. Witch flounder, Glyptocephalus cynoglossus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-139. 29 p.

Cargnelli LM, Griesbach SJ, Packer DB, Weissberger E. 1999c. Essential Fish Habitat Source Document: Atlantic surfclam, *Spisula solidissima*, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-142. 13 p.

Cargnelli LM, Griesbach SJ, Packer DB, Weissberger E. 1999d. Essential Fish Habitat Source Document: Ocean quahog, *Arctica islandica*, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-148. 12 p.

Carlson AE, Hoffmayer ER, Tribuzio CA, Sulikowski JA. 2014. The Use of Satellite Tags to Redefine Movement Patterns of Spiny Dogfish (Squalus acanthias) along the U.S. East Coast: Implications for Fisheries Management. 9(7):e103384.

Carlson JK, Gulak SJB. 2012. Habitat use and movements patterns of oceanic whitetip, bigeye thresher and dusky sharks based on archival satellite tags. ICCAT Collective Volume of Scientific Papers 68(5):1922-1932.

Carlson Jk, McCandless CT, Cortés E, Grubbs RD, Andrews KI, MacNeil MA, Musick JA. 2009. An update on the status of the sand tiger shark, carcharias taurus in the northwest atlantic ocean. Report No.: NOAA Technical Memorandum NMFS-SEFSC-585. 23 p.

Carpenter RK. 1978. Aspects of growth, reproduction, distribution and abundance of the Jonah crab, (Cancer borealis) Stimpson, in Norfolk Canyon and the adjacent slope [MA Thesis]. [Charlottesville, VA]: University of Virginia.

Carrier JC, Musick JA, Heithaus MR. 2012. Biology of Sharks and Their Relatives. Boca Raton, FL: CRC Press.

Caruso JH. 2002. Goosefishes or Monkfishes. Family Lophidae. In: Collette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 264-270.

Casey JG, Pratt HL, Stillwell CE. 1985. Age and growth of the sandbar shark (Carcharhinus plumbeus) from the western North Atlantic. Canadian Journal of Fisheries and Aquatic Sciences. 42:963-975.

Castelao R, Glenn S, Schofield O. 2010. Temperature, salinity, and density variability in the central Middle Atlantic Bight. Journal of Geophysical Research. 115(C10).

Castro-Hernández JJ, Santana-Ortega AT. 2000. Synopsis of biological data on the chub mackerel (Scomberjaponicus Houttuyn, 1782). Rome, Italy: Food and agriculture organization of the united nations. 84 p.

Castro G, Myers JP. 1993. Shorebird Predation on Eggs of Horseshoe Crabs During Spring Stopover on Delaware Bay. The Auk. 110(4):927-930.

Castro KM, Cobb JS, Gomez-Chiarri M, Tlusty M. 2012. Epizootic shell disease in American lobsters Homarus americanus in southern New England: past, present and future. Dis Aquat Organ. 100(2):149-158.

Chambers R, Leggett WC. 1987. Size and age at metamorphosis in marine fishes: an analysis of laboratory-reared winter flounder (Psuedopleuronectes americanus) with a review of variation in other species. Canadian Journal of Fisheries and Aquatic Sciences. 44:1936-1947.

Chambers RC, Leggett WC. 1992. Possible causes and consequences of variation in age and size at metamorphosis in flatfishes (pleuronectiformes): An analysis at the individual, population, and species levels. Netherlands Journal of Sea Research. 29(1-3):7-24.

Chambers RC, Witting DA, Lewis SJ. 2001. Detecting critical periods in larval flatfish populations. Journal of Sea Research. 45(3-4):231-242.

Chang S. 1999. Essential fish habitat source document. Windowpane, Scophthalmus aquosus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-137. (U.S.). 32 p.

Chant R, Curran MC, Able KW, Glenn S. 1996. 6. Circulation patterns in Little Egg Harbor and its role in larval winter flounder distribution: Preliminary results. In: Barnegat Bay Ecosystem Workshop; Nov 14, 1996; Rutgers Cooperative Extension of Ocean County, Toms River, NJ.

Chant RJ, Curran MC, Able KW, Glenn SM. 2000. Delivery of Winter Flounder (Pseudopleuronectes americanus) Larvae to Settlement Habitats in Coves Near Tidal Inlets. Estuarine, Coastal and Shelf Science. 51(5):529-541.

Chao LN, Musick JA. 1977. Life-History, Feeding-Habits, And Functional-Morphology Of Juvenile Sciaenid Fishes In York River Estuary, Virginia. Fishery Bulletin. 75(4):657-702.

Chase BC. 2002. Differences in diet of Atlantic bluefin tuna (Thunnus thynnus) at five seasonal feeding grounds on the New England continental shelf. Fishery Bulletin. 100:168-180.

Checkley DM, Raman S, Maillet GL, Mason KM. 1988. Winter storm effects on the spawning and larval drift of a pelagic fish. Nature. 335(6188):346-348.

Chen C-TA, Huang T-H, Fu Y-H, Bai Y, He X. 2012. Strong sources of CO2 in upper estuaries become sinks of CO2 in large river plumes. Current Opinion in Environmental Sustainability. 4(2):179-185.

Chen Z. 2018. Dynamics and Spatio-temporal Variability of the Mid-Atlantic Bight Cold Pool. Rutgers, The State University of New Jersey.

Chen Z, Curchitser E, Chant R, Kang D. 2018. Seasonal Variability of the Cold Pool Over the Mid-Atlantic Bight Continental Shelf. Journal of Geophysical Research: Oceans. 123(11):8203-8226.

Cheung WWL, Watson R, Pauly D. 2013. Signature of ocean warming in global fisheries catch. Nature. 497(7449):365-368.

Churchill JH, Cornillon PC. 1991a. Gulf Stream water on the shelf and upper slope north of Cape Hatteras. Continental Shelf Research. 11(5):409-431.

Churchill JH, Cornillon PC. 1991b. Water discharged from the Gulf Stream north of Cape Hatteras. Journal of Geophysical Research. 96(C12):22227.

Clark J. 1968. Seasonal Movements of Striped Bass Contingents of Long Island Sound and the New York Bight. Transactions of the American Fisheries Society. 97(4):320-343.

Clark MR, Althaus F, Schlacher TA, Williams A, Bowden DA, Rowden AA. 2016. The impacts of deep-sea fisheries on benthic communities: a review. ICES Journal of Marine Science. 73(suppl_1):i51-i69.

Clarke ME, Whitmire C, Fruh E, Anderson J, Taylor J, Rooney J, Ferguson S, Singh H. 2010. Developing the SeaBED AUV as a tool for conducting routine surveys of fish and their habitat in the Pacific. In: Symposium on Autonomous Underwater Vehicle Technology (AUV); 2010; Monterey, California. IEEE.

Clarke S, Coelho R, Francis M, Kai M, Kohin S, Liu KM, Simpfendorfer C, Tovar-Avila J, Rigby C, Smart J. 2015. Report of the Pacific shark life history expert panel workshop, 28-30 April 2015. Pohnpei, Federated States of Micronesia: Western & Central Pacific Fisheries Commission. 111 p.

Clay PM, DePiper G, Gaichas S, Hare J, Houde E, Seagraves R. 2014. Managing Forage Fishes in the Mid-Atlantic Region: A White Paper to Inform the Mid-Atlantic Fishery Management Council.

Coen LD, Grizzle RE. 2007. The Importance of Habitat Created by Molluscan Shellfish to Managed Species along the Atlantic Coast of the United States. Atlantic States Marine Fisheries Commission. Report No.: Habitat Management Series #8. 108 p.

Coleman K. 2015. Understanding the winter flounder (Pseudopleuronectes americans) Southern New England/Mid-Atlantic stock through historical trawls surveys and monitoring cross continental shelf movement. [New Brunswick, NJ]: Rutgers university.

Collette BB. 2002. Mackerels. Family Scombridae. In: Collette BB, Klein-MacPhee G, editors. Biglow and Schroeder's Fishes of the Gulf of Maine. Washington, DC: Smithsonian Institution Press. p. 516-536.

Collette BB, Klein-MacPhee G. 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Washington, DC: Smithsonian Institution Press.

Collie J, Hiddink JG, Van Kooten T, Rijnsdorp AD, Kaiser MJ, Jennings S, Hilborn R. 2017. Indirect effects of bottom fishing on the productivity of marine fish. Fish and Fisheries. 18(4):619-637.

Collie JS, Wood AD, Jeffries HP. 2008. Long-term shifts in the species composition of a coastal fish community. Canadian Journal of Fisheries and Aquatic Sciences. 65(7):1352-1365.

Colvocoresses JA, Musick JA. 1984. Species associations and community composition of Middle Atlantic Bight continental shelf demersal fishes. Fishery Bulletin. 82(2):295-313.

Compagno LJV. 1984a. FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1 - Hexanchiformes to Lamniformes. Rome, Italy: FAO.

Compagno LJV. 1984b. FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 - Carcharhiniformes. Rome, Italy: FAO.

Compagno LJV. 2002. Volume 2. Bullhead, mackerel and carpet sharks (Heterodontformes, Lamniformes and Orectolobiformes). Sharks of the World: An annotated and illustrated catalogue of Shark species known to date. Rome: Food and Agriculture Organization of the United Nations.

Conrath CL, Musick JA. 2002. Reproductive biology of the smooth dogfish, Mustelus canis, in the northwest Atlantic Ocean. Environmental Biology of Fishes. 64(4):367-377.

Cooley SR, Rheuban JE, Hart DR, Luu V, Glover DM, Hare JA, Doney SC. 2015. An Integrated Assessment Model for Helping the United States Sea Scallop (Placopecten magellanicus) Fishery Plan Ahead for Ocean Acidification and Warming. PLOS ONE. 10(5):e0124145.

Cooper RA. 1966. Migration and Population Estimation of the Tautog, Tautoga onitis (Linnaeus), from Rhode Island. Transactions of the American Fisheries Society. 95(3):239-247.

Corn KA, Farina SC, Summers AP, Gibb AC. 2018. Effects of organism and substrate size on burial mechanics of English sole, Parophrys vetulus. The Journal of Experimental Biology. 221(18):jeb176131.

Cross JN, Zetlin CA, Berrien PL, Johnson DL, McBride C. 1999. Essential Fish Habitat Source Document: Butterfish, Peprilus triacanthus, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-145. 42 p.

Crowe LM, O'Brien O, Curtis TH, Leiter SM, Kenney RD, Duley P, Kraus SD. 2018. Characterization of large basking shark Cetorhinus maximus aggregations in the western North Atlantic Ocean. Journal of Fish Biology. 92(5):1371-1384.

Curtis TH, McCandless CT, Carlson JK, Skomal GB, Kohler NE, Natanson LJ, Burgess GH, Hoey JJ, Pratt HL. 2014a. Seasonal Distribution and Historic Trends in Abundance of White Sharks, Carcharodon carcharias, in the Western North Atlantic Ocean. PLoS ONE. 9(6):e99240.

Curtis TH, Metzger G, Fischer C, McBride B, McCallister M, Winn LJ, Quinlan J, Ajemian MJ. 2018. First insights into the movements of young-of-the-year white sharks (Carcharodon carcharias) in the western North Atlantic Ocean. Scientific Reports. 8(1).

Curtis TH, Zeeman SI, Summers EL, Cadrin SX, Skomal GB. 2014b. Eyes in the sky: linking satellite oceanography and biotelemetry to explore habitat selection by basking sharks. Animal Biotelemetry. 2(1):12.

Daiber FC, Booth RA. 1960. Notes on the biology of the butterfly rays, Gymnura altavela and Gymnura micrura. Copeia. 1960(2):137-139.

Dalyander PS, Butman B, Sherwood CR, Signell RP, Wilkin JL. 2013. Characterizing wave- and current-induced bottom shear stress: U.S. middle Atlantic continental shelf. Continental Shelf Research. 52:73-86.

Dando P. 2011. Site fidelity, homing and spawning migrations of flounder Platichthys flesus in the Tamar estuary, South West England. Marine Ecology Progress Series. 430:183-196.

Dayton PK, Thrush SF, Agardy MT, Hofman RJ. 1995. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems. 5(3):205-232.

DeCelles GR, Cadrin SX. 2010. Movement patterns of winter flounder (Pseudopleuronectes americanus) in the southern Gulf of Maine: observations with the use of passive acoustic telemetry. Fishery Bulletin. 108:408-419.

Degraer S, Brabant R, Rumes B, Vigin L. 2016. Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Environmental impact monitoring reloaded.: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section. 287 p.

Dell'Apa A, Pennino MG, Bangley CW, Bonzek C. 2018. A Hierarchical Bayesian Modeling Approach for the Habitat Distribution of Smooth Dogfish by Sex and Season in Inshore Coastal Waters of the U.S. Northwest Atlantic. Marine and Coastal Fisheries. 10(6):590-605.

Department of Commerce. 2012. Endangered and Threatened Wildlife and Plants; Threatened and Endangered Status for Distinct Population Segments of Atlantic Sturgeon in the Northeast Region; Final Rule. Federal Register National Oceanic and Atmospheric Administration.

Diaz RJ, Cutter GR, Able KW. 2003. The Importance of Physical and Biogenic Structure to Juvenile Fishes on the Shallow Inner Continental Shelf. Estuaries. 26(1):12-20.

Diaz RJ, Cutter GR, Hobbs CH. 2004. Potential Impacts of Sand Mining Offshore of Maryland and Delaware: Part 2—Biological Considerations. Journal of Coastal Research. 201:61-69.

Dickson KA, Graham JB. 2004. Evolution and Consequences of Endothermy in Fishes. Physiological and Biochemical Zoology. 77(6):998-1018.

Dingle H. 2006. Animal migration: is there a common migratory syndrome? Journal of Ornithology. 147(2):212-220.

Domenici P, Standen EM, Levine RP. 2004. Escape manoeuvers in the spiny dogfish (Squalus acanthias). The Journal of Experimental Biology. 207:2339-2349.

Dorazio RM, Hattala KA, McCollough CB, Skjeveland JE. 1994. Tag Recovery Estimates of Migration of Striped Bass from Spawning Areas of the Chesapeake Bay. Transactions of the American Fisheries Society. 123(6):950-963.

Drohan AF, Manderson JP, Packer DB. 2007. Essential Fish Habitat Source Document: Black sea bass, Centropristis striata, Life History and Habitat Characteristics: Second Edition. Woods Hole, Massachusetts: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-200. 78 p.

Dulvy NK, Metcalfe JD, Glanville J, Pawson MG, Reynolds JD. 2000. Fishery Stability, Local Extinctions, and Shifts in Community Structure in Skates. Conservation Biology. 14(1):283-293.

Dunton KJ, Jordaan A, Conover DO, McKown KA, Bonacci LA, Frisk MG. 2015. Marine Distribution and Habitat Use of Atlantic Sturgeon in New York Lead to Fisheries Interactions and Bycatch. Marine and Coastal Fisheries. 7(1):18-32.

Dunton KJ, Jordaan A, Secor DH, Martinez CM, Kehler T, Hattala KA, Van Eenennaam JP, T. Fisher M, McKown KA, Conover DO, et al. 2016. Age and Growth of Atlantic Sturgeon in the New York Bight. North American Journal of Fisheries Management. 36(1):62-73.

DuPaul WD, Kirkley JE, Schmitzer AC. 1989. Evidence of a semiannual reproductive cycle for the sea scallop, Placopecten magellanicus (gmelin, 1791), in the Mid-Atlantic region. Journal of Shellfish Research. 8(1):173-178.

Duplisea DE, Jennings S, Malcolm SJ, Parker R, Sivyer DB. 2001. Modelling potential impacts of bottom trawl fisheries on soft sediment biogeochemistry in the North Sea†. Geochemical Transactions. 2(1).

Durbin E, Kane J. 2007. Seasonal and spatial dynamics of Centropages typicus and C. hamatus in the western North Atlantic. Progress in Oceanography. 72(2-3):249-258.

Edwards AL, Harasewych MG. 1988. Biology of the recent species of the subfamily Busyconinae. Journal of Shellfish Research. 7:467-472.

Eiler JH, Grothues TM, Dobarro JA, Shome R. 2019. Tracking the Movements of Juvenile Chinook Salmon using an Autonomous Underwater Vehicle under Payload Control. Applied Sciences. 9.

Ellis D, Vokoun JC. 2009. Earlier Spring Warming of Coastal Streams and Implications for Alewife Migration Timing. North American Journal of Fisheries Management. 29(6):1584-1589.

Ellis JC, Shulman MJ, Wood M, Witman JD, Lozyniak S. 2007. Regulation of intertidal food webs by avian predators on New England rocky shores. Ecology. 88(4):853-863.

Ellis JK, Musick JA. 2007. Ontogenetic changes in the diet of the sandbar shark, Carcharhinus plumbeus, in lower Chesapeake Bay and Virginia (USA) coastal waters. Environmental Biology of Fishes. 80(1):51-67.

Ellis T, Hoowell BR, Hughes RN. 1997. The cryptic responses of hatchery-reared sole to a natural sand substratum. Journal of Fish Biology. 51(2):389-401.

Epifanio CE, Garvine RW. 2001. Larval Transport on the Atlantic Continental Shelf of North America: a Review. Estuarine, Coastal and Shelf Science. 52(1):51-77.

Erickson DL, Kahnle A, Millard MJ, Mora EA, Bryja M, Higgs A, Mohler J, Dufour M, Kenney G, Sweka J, et al. 2011. Use of pop-up satellite archival tags to identify oceanic-migratory patterns for adult Atlantic Sturgeon, Acipenser oxyrinchus oxyrinchus Mitchell, 1815. Journal of Applied Ichthyology. 27(2):356-365.

Fabrizio MC, Manderson JP, Pessutti JP. 2013. Habitat associations and dispersal of black sea bass from a mid-Atlantic Bight reef. Marine Ecology Progress Series. 482:241-253.

Fabrizio MC, Manderson JP, Pessutti JP. 2014. Home range and seasonal movements of Black Sea Bass (Centropristis striata) during their inshore residency at a reef in the mid-Atlantic Bight. Fishery Bulletin. 112:82-97.

Fahay MP, Berrien PL, Johnson DL, Morse WW. 1999. Essential Fish Habitat Source Document: Atlantic Cod, Gadus morhua, Life History and Habitat Characteristics. Woods Hole, Massachusetts: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-124. 41 p.

Fairchild EA, Siceloff L, Howell WH, Hoffman B, Armstrong MP. 2013. Coastal spawning by winter flounder and a reassessment of Essential Fish Habitat in the Gulf of Maine. Fisheries Research. 141:118-129.

FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome: FAO.

Fay CW, Neves RJ, Pardue GB. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic): Surf Clam. U.S. Department of the Interior, Fish and Wildlife Service, U.S. Army Corps of Engineers, Coastal Ecology Group, Waterways Experiment Station. Report No.: FWS/OBS-82/11.13 TR EL-82-4. 23 p.

Feely RA. 2004. Impact of Anthropogenic CO2 on the CaCO3 System in the Oceans. Science. 305(5682):362-366.

Feely RA, Sabine CL, Hernandez-Ayon JM, Ianson D, Hales B. 2008. Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf. Science. 320(5882):1490-1492.

Fisher JAD, Frank KT, Petrie B, Leggett WC. 2014. Life on the edge: environmental determinants of tilefish (Lopholatilus chamaeleonticeps) abundance since its virtual extinction in 1882. ICES Journal of Marine Science. 71(9):2371-2378.

Fisher RA, Rudders DB. 2017. Population and Reproductive Biology of the Channeled Whelk, Busycotypus canaliculatus, in the US Mid-Atlantic. Journal of Shellfish Research. 36:427-444.

Flagg CN, Dunn M, Wang D-P, Rossby HT, Benway RL. 2006. A study of the currents of the outer shelf and upper slope from a decade of shipboard ADCP observations in the Middle Atlantic Bight. Journal of Geophysical Research. 111(C6).

Fogarty MJ, Murawski SA. 1998. Large-scale disturbance and the structure of marine systems: Fishery impacts on georges bank. Ecological Applications. 8(sp1):S6-S22.

Forrester NC, Stokey RP, Von Alt C, Allen BG, Goldsborough RG, Purcell MJ, Austin TC. 1997. The LEO-15 Long-term Ecosystem Observatory: design and installation. In: Oceans '97 Halifax, Canada. IEEE.

Frank KT. 2005. Trophic Cascades in a Formerly Cod-Dominated Ecosystem. Science. 308(5728):1621-1623.

Free CM, Thorson JT, Pinsky ML, Oken KL, Wiedenmann J, Jensen OP. 2019. Impacts of historical warming on marine fisheries production. Science. 363(6430):979-983.

Friedland KD, Hare JA, Wood GB, Col LA, Buckley LJ, Mountain DG, Kane J, Brodziak J, Lough RG, Pilskaln CH. 2008. Does the fall phytoplankton bloom control recruitment of Georges Bank haddock, Melanogrammus aeglefinus, through parental condition? Canadian Journal of Fisheries and Aquatic Sciences. 65(6):1076-1086.

Friedland KD, Leaf RT, Kane J, Tommasi D, Asch RG, Rebuck N, Ji R, Large SI, Stock C, Saba VS. 2015. Spring bloom dynamics and zooplankton biomass response on the US Northeast Continental Shelf. Continental Shelf Research. 102:47-61.

Friedland KD, McManus MC, Morse RE, Link JS, Ojaveer H. 2018. Event scale and persistent drivers of fish and macroinvertebrate distributions on the Northeast US Shelf. ICES Journal of Marine Science.

Frisk MG, Ingram EC, Dunton K. 2019. Monitoring Endangered Atlantic Sturgeon and Commercial Finfish Habitat Use in the New York Lease Area. Report No.: OCS Study BOEM 2019-074. 88 p.

Froerman YM. 1984. Feeding Spectrum and Trophic Relationships of Short-finned Squid (II/ex illecebrosus) in the Northwest Atlantic. NAFO Scientific Council Studies. 7:67-75.

Fuchs HL, Chant RJ, Hunter EJ, Curchitser EN, Gerbi GP, Chen EY. 2020. Wrong-way migrations of benthic species driven by ocean warming and larval transport. Nature Climate Change. 10(11):1052-1056.

Gabriel WL. 1992. Persistence of demersal fish assemblages Between Cape Hatteras and Nova Scotia, Northwest Atlantic. Journal of Northwest Atlantic Fishery Science. 14:29-46.

Gandra M, Erzini K, Abecasis D. 2018. Diel and seasonal changes in the spatial behaviour of a soft-sediment fish (Solea senegalensis) inside a marine reserve. Marine Environmental Research. 135:82-92.

Garcia A. 2001. Dynamics of the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes. Journal of Fish Biology. 59(5):1218-1238.

Garlo EV. 1982. Increase in a surf clam population after hypoxic water conditions off Little Egg Inlet, New Jersey [Spisula solidissima]. Journal of Shellfish Research. 2(1):59-64.

Garrison L, Link J. 2000. Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. Marine Ecology Progress Series. 202:231-240.

Gauthier DT, Latour RJ, Heisey DM, Bonzek CF, Gartland J, Burge EJ, Vogelbein WK. 2008. Mycobacteriosis-associated mortality in wild striped bass (morone saxatilis) from chesapeake bay, USA. Ecological Applications. 18(7):1718-1727.

German AW. 1987. History of the early fisheries: 1720−1930. Cambridge: Massachusetts Institute of Technology Press. 409−424 p.

Gibson RN, Batty RS. 1990. Lack of substratum effect on the growth and metamorphosis of larval plaice Pleuronectes platessa. Marine Ecology Progress Series. 66:219-223.

Gibson RN, Robb L. 2000. Sediment selection in juvenile plaice and its behavioural basis. Journal of Fish Biology. 56(5):1258-1275.

Gilmore R. 1993. Reproductive biology of lamnoid sharks. Environmental Biology of Fishes. 38:95-114.

Glenn S, Arone R, Bergmann T, Bissett WP, Crowley M, Cullen J, Gryzmski J, Haidvogel D, Kohut J, Mollin M, et al. 2004. Biogeochemical impacts of summertime coastal upwelling on the New Jersey Shelf. Journal of Geophysical Research. 109:C12S02.

Gobler CJ, Baumann H. 2016. Hypoxia and acidification in ocean ecosystems: coupled dynamics and effects on marine life. Biology Letters. 12(5):20150976.

Gobler CJ, Depasquale EL, Griffith AW, Baumann H. 2014. Hypoxia and Acidification Have Additive and Synergistic Negative Effects on the Growth, Survival, and Metamorphosis of Early Life Stage Bivalves. PLoS ONE. 9(1):e83648.

Goff JA, Swift DJP, Duncan CS, Mayer LA, Hughes-Clarke J. 1999. High-resolution swath sonar investigation of sand ridge, dune and ribbon morphology in the offshore environment of the New Jersey margin. Marine Geology. 161(2-4):307-337.

Goldsmith KA, Lau S, Poach ME, Sakowicz GP, Trice TM, Ono CR, Nye J, Shadwick EH, Stlaurent KA, Saba GK. 2019. Scientific considerations for acidification monitoring in the U.S. Mid-Atlantic Region. Estuarine, Coastal and Shelf Science. 225:106189.

Gomez-Chiarri M, Cobb JS. 2012. Shell Disease in the American Lobster, Homarus americanus: A Synthesis of Research from the New England Lobster Research Initiative: Lobster Shell Disease. Journal of Shellfish Research. 31(2):583-590.

Gore MA, Rowat D, Hall J, Gell FR, Ormond RF. 2008. Transatlantic migration and deep mid-ocean diving by basking shark. Biol Lett. 4(4):395-398.

Grassle JF, Sanders HL. 1973. Life histories and the role of disturbance. Deep Sea Research and Oceanographic Abstracts. 20(7):643-659.

Greenwood MFD, Stevens PW, Jr. REM. 2006. Effects of the 2004 Hurricanes on the Fish Assemblages in Two Proximate Southwest Florida Estuaries: Change in the Context of Interannual Variability. Estuaries and Coasts. 29(6a):985-996.

Grosslein MD, Azarovitz TR. 1982. MESA New York Bight Atlas Monograph No. 15: Fish Distribution. Albany, NY: New York Sea Grant Institution.

Grothues TM. 2009. A review of acoustic telemetry technology and a perspective on its diversification relative to coastal tracking arrays. In: Nielsen JL, Arrizabalaga H, Fragoso N, Hobday A, Lutcavage M, Sibert J, editors. Tagging and Tracking of marine Animals with Electronic Devices. Springer. p. 77-90.

Grothues TM, Able KW, Carter J, Arienti TW. 2009. Migration Patterns of Striped Bass through Nonnatal Estuaries of the U.S. Atlantic Coast. American Fisheries Society Symposium. 69:135-150.

Grothues TM, Able KW, Pravatiner JH. 2012. Winter flounder (Pseudopleuronectes americanus Walbaum) burial in estuaries: Acoustic telemetry triumph and tribulation. Journal of Experimental Marine Biology and Ecology. 438:125-136.

Grothues TM, Bochenek EA, Martin S. 2017a. Reducing Discards of Flatfish in the Sea Scallop Dredge Fishery by Dredge Pause. Journal of Shellfish Research. 36(3):627-631.

Grothues TM, Cowen RK. 1999. Larval fish assemblages and water mass history in a major faunal transition zone. Continental Shelf Research. 19(9):1171-1198.

Grothues TM, Cowen RK, Pietrafesa LJ, Bignami F, Weatherly GL, Flagg CN. 2002. Flux of larval fish around Cape Hatteras. Limnology and Oceanography. 47(1):165-175.

Grothues TM, Newhall AE, Lynch JF, Vogel KS, Gawarkiewicz GG. 2017b. High-frequency side-scan sonar fish reconnaissance by autonomous underwater vehicles. Canadian Journal of Fisheries and Aquatic Sciences. 74(2):240-255.

Grothues TM, Phelan BA, Bochenek EA. 2011. Telemetry of spawning winter flounder, Pseudopleuronectes americanus, in a New Jersey estuary: Final Report to the I Boat New Jersey Grant Program of the New Jersey Department of Transportation Office of Maritime Resources.

Grubich JR. 2000. Crushing motor patterns in drum (teleostei: Sciaenidae): Functional novelties associated with molluscivory. The Journal of Experimental Biology 203:3161–3176

Guthertz E. 1967. Field Guide to the Flatfishes of the Family Bothidae in the Western North Atlantic. Washington, D.C.: United States Department of the Interior. Report No.: Circular 623. 48 p.

Gutiérrez JL, Jones CG, Strayer DL, Iribarne OO. 2003. Mollusks as ecosystem engineers: the role of shell production in aquatic habitats. Oikos. 101(1):79-90.

Haefner Pa. 1977. Aspects of the biology of the Jonah crab, Cancer borealis Stimpson, 1859 in the mid-Atlantic Bight. Journal of Natural History. 11:303-320.

Hall AR, Miller AD, Leggett HC, Roxburgh SH, Buckling A, Shea K. 2012a. Diversity–disturbance relationships: frequency and intensity interact. Biology Letters. 8(5):768-771.

Hall CJ, Jordaan A, Frisk MG. 2011. The historic influence of dams on diadromous fish habitat with a focus on river herring and hydrologic longitudinal connectivity. Landscape Ecology. 26(1):95-107.

Hall CJ, Jordaan A, Frisk MG. 2012b. Centuries of Anadromous Forage Fish Loss: Consequences for Ecosystem Connectivity and Productivity. BioScience. 62(8):723-731.

Hall SJ. 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanography and Marine Biology: an Annual Review. 32:179-239.

Hammer PE. 1972. Studies of the Mullica River-Great Bay Estuary. Report No.: Miscellaneous Report No. 6M-1 115-141 p.

Hanson JM, Comeau M, Rondeau A. 2014. Atlantic Rock Crab, unlike American Lobster, Is Important to Ecosystem Functioning in Northumberland Strait. Transactions of the American Fisheries Society. 143(5):1266-1279.

Harden-Jones FR. 1968. Fish Migration. London: Edward Arnold Publisher.

Hardin G. 1960. The competitive exclusion principle. Science. 131:1292–1297.

Harding JM. 2011. Observations on the Early Life History and Growth Rates of Juvenile Channel Whelks Busycotypus canaliculatus (Linnaeus, 1758). Journal of Shellfish Research. 30(3):901-903.

Hare J, Cowen R. 1993. Ecological and evolutionary implications of the larval transport and reproductive strategy of bluefish Pomatomus saltatrix. Marine Ecology Progress Series. 98:1-16.

Hare J, Thorrold S, Walsh H, Reiss C, Valle-Levinson A, Jones C. 2005. Biophysical mechanisms of larval fish ingress into Chesapeake Bay. Marine Ecology Progress Series. 303:295-310.

Hare JA, Able KW. 2007. Mechanistic links between climate and fisheries along the east coast of the United States: explaining population outbursts of Atlantic croaker (Micropogonias undulatus). Fisheries Oceanography. 16(1):31-45.

Hare JA, Cowen RK. 1991. Expatriation of Xyrichtys novacula (Pisces: Labridae) larvae: Evidence of rapid cross-slope exchange. Journal of Marine Research. 49(4):801-823.

Hare JA, Cowen RK. 1996. Transport mechanisms of larval and pelagic juvenile bluefish (Pomatomus saltatrix) from South Atlantic Bight spawning grounds to Middle Atlantic Bight nursery habitats. Limnology and Oceanography. 41(6):1264-1280.

Hare JA, Cowen RK. 1997. Size, growth, development, and survival of the planktonic larvae of Pomatomus saltatrix (Pisces: Pomatomidae). Ecology. 78(8):2415-2431.

Hare JA, Morrison WE, Nelson MW, Stachura MM, Teeters EJ, Griffis RB, Alexander MA, Scott JD, Alade L, Bell RJ, et al. 2016. A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLOS ONE. 11(2):e0146756.

Hart DR, Chute AS. 2004. Essential fish habitat source document. Sea scallop, Placopecten magellanicus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-189. (U.S.). 21 p.

Hart DR, Munroe DM, Caracappa JC, Haidvogel D, Shank BV, Rudders DB, Klinck JM, Hofmann EE, Powell EN. 2020. Spillover of sea scallops from rotational closures in the Mid-Atlantic Bight (United States). ICES Journal of Marine Science. 77(5):1992-2002.

Harvell CD, Mitchell CE, Ward JR, Altizer S, Dobson AP, Ostfeld RS, Samuel MD. 2002. Climate Warming and Disease Risks for Terrestrial and Marine Biota. Science. 296:2158-2162.

Hasselman DJ, Anderson EC, Argo EE, Bethoney ND, Gephard SR, Post DM, Schondelmeier BP, Schultz TF, Willis TV, Palkovacs EP. 2016. Genetic stock composition of marine bycatch reveals disproportional impacts on depleted river herring genetic stocks. Canadian Journal of Fisheries and Aquatic Sciences. 73(6):951-963.

Haulsee D, Breece M, Miller D, Wetherbee B, Fox D, Oliver M. 2015. Habitat selection of a coastal shark species estimated from an autonomous underwater vehicle. Marine Ecology Progress Series. 528:277-288.

Hay AE, Mudge T. 2005. Principal bed states during SandyDuck97: Occurrence, spectral anisotropy, and the bed state storm cycle. Journal of Geophysical Research: Oceans. 110(C3).

Hayes MO, Nairn RB. 2004. Natural Maintenance of Sand Ridges and Linear Shoals on the U.S. Gulf and Atlantic Continental Shelves and the Potential Impacts of Dredging. Journal of Coastal Research. 201:138-148.

Haymet ADJ, Ward LG, Harding MM. 1999. Winter Flounder “Antifreeze” Proteins: Synthesis and Ice Growth Inhibition of Analogues that Probe the Relative Importance of Hydrophobic and Hydrogen-Bonding Interactions. Journal of the American Chemical Society. 121(5):941-948.

Hendrickson LC, Holmes EM. 2004. Essential fish habitat source document. Northern shortfin squid, Illex illecebrosus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-191. (U.S.). 36 p.

Heupel M, Carlson J, Simpfendorfer C. 2007. Shark nursery areas: concepts, definition, characterization and assumptions. Marine Ecology Progress Series. 337:287-297.

Heupel MR, Simpfendorfer CA, Hueter RE. 2003. Running before the storm: blacktip sharks respond to falling barometric pressure associated with Tropical Storm Gabrielle. Journal of Fish Biology. 63(5):1357-1363.

Hewitt J, Thrush S, Lohrer A, Townsend M. 2010. A latent threat to biodiversity: consequences of small-scale heterogeneity loss. Biodiversity and Conservation. 19(5):1315-1323.

Hiddink JG, Jennings S, Sciberras M, Szostek CL, Hughes KM, Ellis N, Rijnsdorp AD, McConnaughey RA, Mazor T, Hilborn R, et al. 2017. Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. Proceedings of the National Academy of Sciences. 114(31):8301-8306.

Hoagman WJ, Merriner JV. 1977. The displacement and loss of larval fishes from the Rappahannock and James Rivers, Virginia, following a major tropical storm. In: Ruzecki EP, Schubel JR, Huggett RJ, Anderson AM, Wass ML, Marasco RJ, Lynch MP, editors. The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system. Baltimore, MD: The Johns Hopkins University Press. p. 591-593.

Hoagman WJ, Wilson WL. 1977. The effects of Tropical Storm Agnes on fishes in the James, York, and Rappahannock Rivers of Virginia. In: Ruzecki EP, Schubel JR, Huggett RJ, Anderson AM, Wass ML, Marasco RJ, Lynch MP, editors. The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system. Baltimore, MD: The Johns Hopkins University Press. p. 464-477.

Hoelzel AR, Shivji MS, Magnussen J, Francis MP. 2006. Low worldwide genetic diversity in the basking shark (Cetorhinus maximus). Biol Lett. 2(4):639-642.

Hoenig JM, Gruber SH. 1990. Life-history patterns in the elasmobranchs: Implications for fisheries management. In: H.L. Pratt J, Gruber SH, Taniuchi T, editors. Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries.

Hoey JA, Fodrie FJ, Walker QA, Hilton EJ, Kellison GT, Targett TE, Taylor JC, Able KW, Pinsky ML. 2020. Using multiple natural tags provides evidence for extensive larval dispersal across space and through time in summer flounder. Mol Ecol. 29(8):1421-1435.

Hofmann EE, Powell EN, Klinck JM, Munroe DM, Mann R, Haidvogel DB, Narváez DA, Zhang X, Kuykendall KM. 2018. An Overview of Factors Affecting Distribution of the Atlantic Surfclam (Spisula solidissima), a Continental Shelf Biomass Dominant, During a Period of Climate Change. Journal of Shellfish Research. 37(821-831).

Holland JD, Bert DG, Fahrig L. 2004. Determining the Spatial Scale of Species' Response to Habitat. BioScience. 54(3):227.

Hollowed AB, Barange M, Beamish RJ, Brander K, Cochrane K, Drinkwater K, Foreman MGG, Hare JA, Holt J, Ito S-I, et al. 2013. Projected impacts of climate change on marine fish and fisheries. ICES Journal of Marine Science. 70(5):1023-1037.

Hönisch B, Ridgwell A, Schmidt DN, Thomas E, Gibbs SJ, Sluijs A, Zeebe R, Kump L, Martindale RC, Greene SE, et al. 2012. The Geological Record of Ocean Acidification. Science. 335(6072):1058-1063.

Houde E. 1987. Fish early life Dynamics and Recruitment Variability. American Fisheries Society Symposium. 2:17-29.

Houde ED. 2006. Subtleties and episodes in the early life of fishes. Journal of Fish Biology. 35:29-38.

Houde ED, Bichy J, Jung S. 2005. Effects of hurricane Isabel on fish populations and communities in Chesapeake Bay. In: Sellner KG, editor. Hurricane Isabel in Perspective. Edgewater, MD: Chesapeake Research Consortium. p. 193-199.

Houghton RW, Schlitz R, Beardsley RC, Butman B, Chamberlin JL. 1982. The Middle Atlantic Bight Cold Pool: Evolution of the Temperature Structure During Summer 1979. Journal of Physical Oceanography. 12(10):1019-1029.

Hurst TP. 2007. Causes and consequences of winter mortality in fishes. Journal of Fish Biology. 71(2):315-345.

Hurst TP, Conover DO. 2002. Effects of temperature and salinity on survival of young-of-the-year Hudson River striped bass (Morone saxatilis): implications for optimal overwintering habitats. Canadian Journal of Fisheries and Aquatic Sciences. 59(5):787-795.

Hutchison ZL, Hendrick VJ, Burrows MT, Wilson B, Last KS. 2016. Buried Alive: The Behavioural Response of the Mussels, Modiolus modiolus and Mytilus edulis to Sudden Burial by Sediment. PLOS ONE. 11(3):e0151471.

Ingram EC, Cerrato RM, Dunton KJ, Frisk MG. 2019. Endangered Atlantic Sturgeon in the New York Wind Energy Area: implications of future development in an offshore wind energy site. Scientific Reports. 9(1).

Jacobson LD. 2005. Essential fish habitat source document. Longfin inshore squid, Loligo pealeii, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-193. (U.S.). 42 p.

Jean Y. 1965. Seasonal distribution of Monkfish along the Canadian Atlantic Mainland. Journal of the Fisheries Research Board of Canada. 22(2):621-624.

Jeffries HP. 1966. Partitioning of the Estuarine Environment by Two Species of Cancer. Ecology. 47(3):477-481.

Jennings S, Kaiser MJ. 1998. The Effects of Fishing on Marine Ecosystems. Advances in Marine Biology. 34:201-212.

Jensen OP, Grothues TM. 2015. Understanding the effects of fishing on the size, age, and sex distribution of black sea bass (Centropristis striata) during the spawning season. Rutgers Univerity. 24 p.

Jensen OP, Zemeckis D. 2019. A Pilot Trap Survey of Artificial Reefs in New Jersey for Monitoring of Black Sea Bass, Tautog, and Lobster. Final Report to the New Jersey Department of Environmental Protection.

Johnson JH, McKenna JE, Dropkin DS, Andrews WD. 2005. A Novel Approach to Fitting the Von Bertalanffy Relationship to a Mixed Stock of Atlantic Sturgeon Harvested Off the New Jersey Coast. Northeastern Naturalist. 12(2):195-202.

Johnson ZI, Wheeler BJ, Blinebry SK, Carlson CM, Ward CS, Hunt DE. 2013. Dramatic Variability of the Carbonate System at a Temperate Coastal Ocean Site (Beaufort, North Carolina, USA) Is Regulated by Physical and Biogeochemical Processes on Multiple Timescales. PLoS ONE. 8(12):e85117.

Juanes F, Buckel JA, Conover DO. 1994. Accelerating the onset of piscivory: intersection of predator and prey phenologies. Journal of Fish Biology. 45(sa):41-54.

Kahnle AW, Hattala KA, McKown K. 2007. Status of Atlantic Sturgeon of the Hudson River estuary, New York, USA. In: Munro J, editor. Anadromous sturgeons: habitats, threats, and management. Bethesda, MD: American Fisheries Society. p. 347-363.

Kaiser MJ, Collie JS, Hall SJ, Jennings S, Poiner IR. 2002. Modification of marine habitats by trawling activities: prognosis and solutions. Fish and Fisheries. 3(2):114-136.

Kajiura SM. 2001. Head Morphology and Electrosensory Pore Distribution of Carcharhinid and Sphyrnid Sharks. Environmental Biology of Fishes. 61(2):125-133.

Kajiura SM, Cornett AD, Yopak KE. 2010. Sensory adaptations to the environment: Electroreceptors as a case study. In: Carrier J, Musick J, Heithaus M, editors. Biology of Sharks and Their Relatives II. Boca Raton, FL: CRC Press. p. 393-434.

Kaufman LS. 1983. Effects of Hurricane Allen on reef fish assemblages near Discovery Bay, Jamaica. Coral Reefs. 2:43-47.

Kelman EJ, PalapTiptus, Osorio D. 2006. Juvenile plaice (Pleuronectes platessa) produce camouflage by flexibly combining two separate patterns. The Journal of Experimental Biology. 209:3288-3292.

Kennedy VS. 1990. Anticipated effects of climate change on estuarine and coastal fisheries. Fisheries. 15(6):16-24.

Kennett J. 1982. Marine Geology. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kennish MJ. 1992. Ecology of Estuaries: Anthropogenic Effects. Boca Raton, FL: CRC Press.

Kilfoil JP, Wetherbee BM, Carlson JK, Fox DA. 2017. Targeted Catch-and-Release of Prohibited Sharks: Sand Tigers in Coastal Delaware Waters. Fisheries. 42(5):281-287.

Kiraly SJ, Moore JA, Jaskinski PH. 2003. Deepwater and Other Sharks of the U.S. Atlantic Ocean Exclusive Economic Zone. Marine Fisheries Review. 65(4):1-20.

Klein-MacPhee G. 1978. Synopsis of Biological Data for the Winter Flounder Psuedopleuronectes americanus (Walbaum). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Report No.: NMFS Circular 414 No. 117. 43 p.

Klein-MacPhee G. 2002a. Righteye flounders. Family Plueronectidae. In: Collette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington DC: Smithsonian Institution Press. p. 560-587.

Klein-MacPhee G. 2002b. Sand flounders. Family Paralichthyidae. In: Collette BB, Klein-MacPhee G, editors. Biglow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 551-560.

Kleisner KM, Fogarty MJ, McGee S, Barnett A, Fratantoni P, Greene J, Hare JA, Lucey SM, McGuire C, Odell J, et al. 2016. The Effects of Sub-Regional Climate Velocity on the Distribution and Spatial Extent of Marine Species Assemblages. PLoS One. 11(2):e0149220.

Kneebone J, Bowlby H, Mello JJ, McCandless CT, Natanson LJ, Gervelis B, Skomal GB, Kohler N, Bernal D. 2020. Seasonal distribution and habitat use of the common thresher shark (Alopias vulpinus) in the western North Atlantic Ocean inferred from fishery-dependent data. Fishery Bulletin. 118(4):399-394`391.

Kneebone J, Chisholm J, Skomal G. 2014a. Movement patterns of juvenile sand tigers (Carcharias taurus) along the east coast of the USA. Marine Biology. 161(5):1149-1163.

Kneebone J, Hoffman WS, Dean MJ, Fox DA, Armstrong MP. 2014b. Movement Patterns and Stock Composition of Adult Striped Bass Tagged in Massachusetts Coastal Waters. Transactions of the American Fisheries Society. 143(5):1115-1129.

Knott DM. 1991. The Short-term Effects of Hurricane Hugo on Fishes and Decapod Crustaceans in the Ashley River and Adjacent Marsh Creeks, South Carolina. Journal of Coastal Research. (SI 8):335-356.

Kohut J, Palamara L, Curchitser E, Manderson J, DiDomenico G, Oliver MJ. 2013. Toward dynamic marine spatial planning tools: An example with butterfish assessment in the Mid-Atlantic Bight. In: 2013 MTS/IEEE OCEANS - Bergen; Bergen. p. 1-6.

Krause JR, Hightower JE, Buckel JA, Turnure JT, Grothues TM, Manderson JP, Rosendale JE, Pessutti JP. 2020. Using Acoustic Telemetry to Estimate Weakfish Survival Rates along the U.S. East Coast. Marine and Coastal Fisheries. 12(5):241-257.

Krouse JS. 1980. Distribution and catch composition of Jonah crab, Cancer borealis, and rock crab, Cancer irroratus, near Boothbay Harbor, Maine. Fishery Bulletin. 77:685-693.

Kunzig R. 1995. Twilight of the Cod. Discover Magazine.

Kyne PM, Carlson JK, Ebert DA, Fordham SV, Bizzarro JJ, Graham RT, Kulka DW, Tewes EE, Harrison LR, Dulvy NK. 2012. The Conservation Status of North American, Central American, and Caribbean Chondrichthyans. Vancouver, Canada: IUCN Species Survival Commission Shark Specialist Group.

Lafferty KD, Harvell CD, Conrad JM, Friedman CS, Kent ML, Kuris AM, Powell EN, Rondeau D, Saksida SM. 2015. Infectious diseases affect marine fisheries and aquaculture economics. Ann Rev Mar Sci. 7:471-496.

Langton RW, Pearce JB, Gibson JA. 1994. Selected Living Resources, Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management. Woods Hole, MA: NOAA NMFS NEFSC. Report No.: NMFS-NE-106. 70 p.

Langton RW, Robinson WE, Schick D. 1987. Fecundity and reproductive effort of sea scallops Placopecten magellanicus from the Gulf of Maine. Marine Ecology Progress Series. 37:19-25.

Lathrop RG, Cole M, Senyk N, Butman B. 2006. Seafloor habitat mapping of the New York Bight incorporating sidescan sonar data. Estuarine, Coastal and Shelf Science. 68(1-2):221-230.

Leis J. 1991. The pelagic stage of reef fishes: the biology of coral reef fishes. In: Sale PF, editor. Ecology of Fishes on Coral Reefs. San Diego: Academic Press. p. 183-230.

Lentz SJ. 2017. Seasonal warming of the Middle Atlantic Bight Cold Pool. Journal of Geophysical Research: Oceans. 122(2):941-954.

Levesque MM, Inglis SD, Shumway SE, Stokesbury KDE. 2016. Mortality Assessment of Atlantic Sea Scallops (Placopecten magellanicus) from Gray-Meat Disease. Journal of Shellfish Research. 35(2):295-305.

Levin J, Wilkin J, Fleming N, Zavala-Garay J. 2018. Mean circulation of the Mid-Atlantic Bight from a climatological data assimilative model. Ocean Modelling. 128:1-14.

Levin SA. 1992. The Problem of Pattern and Scale in Ecology: The Robert H. MacArthur Award Lecture. Ecology. 73(6):1943-1967.

Lindeboom HJ, Kouwenhoven HJ, Bergman MJN, Bouma S, Brasseur S, Daan R, Fijn RC, de Haan D, Dirksen S, van Hal R, et al. 2011. Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environmental Research Letters. 6(3):035101.

Link JS, Bolles K, Milliken CG. 2002. The Feeding Ecology of Flatfish in the Northwest Atlantic. Journal of Northwest Atlantic Fishery Science. 30:1-17.

Lock MC, Packer DB. 2004. Essential Fish Habitat Source Document. Silver Hake, Merluccius Bilinearis, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-186. 68 p.

Logan RK, Vaudo JJ, Sousa LL, Sampson M, Wetherbee BM, Shivji MS. 2020. Seasonal Movements and Habitat Use of Juvenile Smooth Hammerhead Sharks in the Western North Atlantic Ocean and Significance for Management. Frontiers in Marine Science. 7.

Lophius americanus Valenciennes, 1837: American angler. FishBase; [accessed 2021]. https://www.fishbase.de/summary/Lophius-americanus.html.

Lough RG. 2004. Essential fish habitat source document. Atlantic cod, Gadus morhua, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-190. (U.S.). 94 p.

Lucchetti A, Sala A. 2012. Impact and performance of Mediterranean fishing gear by side-scan sonar technology. Canadian Journal of Fisheries and Aquatic Sciences. 69(11):1806-1816.

Lugert V, Thaller G, Tetens J, Schulz C, Krieter J. 2016. A review on fish growth calculation: multiple functions in fish production and their specific application. Reviews in Aquaculture. 8(1):30-42.

Ma H, Grassle JP, Chant RJ. 2006. Vertical distribution of bivalve larvae along a cross-shelf transect during summer upwelling and downwelling. Marine Biology. 149(5):1123-1138.

Macesic LJ, Kajiura SM. 2009. Electric organ morphology and function in the lesser electric ray, Narcine brasiliensis. Zoology (Jena). 112(6):442-450.

Magalhaes H. 1948. An Ecological Study of Snails of the Genus Busycon at Beaufort, North Carolina. Ecological Monographs. 18(3):377-409.

Mahon R, Brown SK, Zwanenburg KCT, Atkinson DB, Buja KR, Claflin L, Howell GD, Monaco ME, O’Boyle RN, Sinclair M. 1998. Assemblages and biogeography of demersal fishes of the east coast of North America. Canadian Journal of Fisheries and Aquatic Sciences. 55:1704–1738.

Malek AJ, Collie JS, Gartland J. 2014. Fine-scale spatial patterns in the demersal fish and invertebrate community in a northwest Atlantic ecosystem. Estuarine, Coastal and Shelf Science. 147:1-10.

Manderson J, Kohut J, Oliver M, Palamara L, Gray S, Goff J. 2009. Developing Ecological Indicators for Spatial Fisheries Management using Ocean Observatory Defined Habitat Characteristics in the Mid-Atlantic Bight.

Manderson J, Palamara L, Kohut J, Oliver MJ. 2011. Ocean observatory data are useful for regional habitat modeling of species with different vertical habitat preferences. Marine Ecology Progress Series. 438:1-17.

Manderson J, Pessutti J, Meise C, Johnson D, Shaheen P. 2003. Winter flounder settlement dynamics and the modification of settlement patterns by post-settlement processes in a NW Atlantic estuary. Marine Ecology Progress Series. 253:253-267.

Mann DA, Grothues TM. 2009. Short-term upwelling events modulate fish sound production at a mid-Atlantic Ocean observatory. Marine Ecology Progress Series. 375:65-71.

Manooch CS, Mason DL, Nelson RS. 1985. Foods of little tunny Euthynnus alletteratus collected along the Southeastern and Gulf Coasts of the United States. NIPPON SUISAN GAKKAISHI. 51(8):1207-1218.

Martel A, Larrivée DH, Himmelman JH. 1986. Behaviour and timing of copulation and egg-laying in the neogastropod Buccinum undatum L. Journal of Experimental Marine Biology and Ecology. 96(1):27-42.

Martín J, Puig P, Palanques A, Giamportone A. 2014. Commercial bottom trawling as a driver of sediment dynamics and deep seascape evolution in the Anthropocene. Anthropocene. 7:1-15.

Martino EJ, Houde ED. 2010. Recruitment of striped bass in Chesapeake Bay: spatial and temporal environmental variability and availability of zooplankton prey. Marine Ecology Progress Series. 409:213-228.

Mashintonio AF, Pimm SL, Harris GM, Van Aarde RJ, Russell GJ. 2014. Data-driven discovery of the spatial scales of habitat choice by elephants. PeerJ. 2:e504.

May RM, Anderson RM. 1978. Regulation and Stability of Host-Parasite Population Interactions: II. Destabilizing Processes. The Journal of Animal Ecology. 47(1):249.

McBride RS. 1995. Perennial occurrence and fast growth rates by Crevalle Jacks (Carangidae: Caranx hippos) in the Hudson River Estuary. In: Blair EA, Waldmann JR, editors. Reports of the Tibor T Polgar Fellowship Program, 1994. New York: Hudson River Foundation. p. VI1-VI29.

McBride RS, Able KW. 1998. Ecology and Fate of Butterflyfishes, Chaetodon spp., in the Temperate, Western North Atlantic. Bulletin of Marine Science. 63(2):401-416.

McConnaughey RA, Smith KR. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences. 57:2410-2419.

McCraken FD. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus, on the Atlantic coast. Journal of the Fisheries Research Board of Canada. 20(2):551-586.

McEachran JD. 2002a. Cownose Rays. Family Rhinopteridae. In: Collette BB, Klein-MacPhee G, editors. Bigelowe and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 78-80.

McEachran JD. 2002b. Torpedoes or Electric Rays. Family Torpedinidae. In: Collette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 59-60.

McEachran JD. 2002c. Whip-tail Stingrays. Family Dasyatidae. In: Collette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 75-78.

McEachran JD, Capepe C. 1984. Gymnuridae. In: Whitehead PJP, Bauchot M-L, Hureau J-C, Nielsen J, Tortonese E, editors. Fishes of the North-eastern Atlantic and Mediterranean. Paris: UNESCO. p. 203-204.

McKay K, Heck K. 2008. Presence of the Jonah crab Cancer borealis significantly reduces kelp consumption by the green sea urchin Strongylocentrotus droebachiensis. Marine Ecology Progress Series. 356:295-298.

Meléndez-Vazquez F, Olmeda-Saldaña M, Cruz J, Arcila D, Betancur R. 2019. Effects of Hurricane Maria in hamlet communities (Serranidae: Hypoplectrus spp.) in Puerto Rico. Ecological Indicators. 107:105591.

Mercer LP. 1978. The reproductive biology and population dynamics of black sea bass, Centropristis striata. The College of William and Mary in Virginia.

Mercer LP. 1983. A biological and fisheries profile of weakfish, Cynoscion regalis. Morehead City, NC: Report No.: Division of Marine Fisheries Species Scientific Report No. 39.

Methratta ET, Link JS. 2007. Ontogenetic variation in habitat associations for four flatfish species in the Gulf of Maine-Georges Bank region. Journal of Fish Biology. 70(6):1669-1688.

Meyer TL, Anderson EL, Ropes JW, Phoel WC. 1987. Underwater Observations of a Surf Clam, Spisula soJidissima (Dillwyn), Community and the Relative Efficiency of a Prototype Airlift Clam Sampler. Marine Fisheries Review. 49(4):23-33.

Michel J, Bejarano AC, Peterson CH, Voss C. 2013. Review of Biological and Biophysical Impacts from Dredging and Handling of Offshore Sand. Herndon, VA: Bureau of Ocean Energy Management. Report No.: BOEM 2013-0119. 258 p.

Mid-Atlantic Fishery Management Council. 2017. Unmanaged Forage Omnibus Amendment. Mid-Atlantic Fishery Management Council. 223 p.

Mid-Atlantic Fishery Management Council. 2019. Mackerel Rebuilding Framework: Atlantic mackerel, squid, and butterfish fishery management plan. Mid-Atlantic Fishery Management Council. 167 p.

Mid-Atlantic Fishery Management Council, National Marine Fisheries Service. 2019. Amendment 21 to the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan: Measures to Manage Atlantic Chub Mackerel (Scomber colias). Mid-Atlantic Fishery Management Council, National Marine Fisheries Service. 192 p.

Miles T, Glenn S, Kohut J, Seroka G, Xu Y. 2013a. Observations of Hurricane Sandy from a glider mounted aquadopp profiler. In: 2013 OCEANS - San Diego; San Diego, CA, USA. IEEE.

Miles T, Glenn SM, Schofield O. 2013b. Temporal and spatial variability in fall storm induced sediment resuspension on the Mid-Atlantic Bight. Continental Shelf Research. 63:S36-S49.

Miles T, Seroka G, Glenn S. 2017. Coastal ocean circulation during Hurricane Sandy. Journal of Geophysical Research: Oceans. 122(9):7095-7114.

Miles T, Seroka G, Kohut J, Schofield O, Glenn S. 2015. Glider observations and modeling of sediment transport in Hurricane Sandy. Journal of Geophysical Research: Oceans. 120(3):1771-1791.

Miller JM, Burke JS, Fitzhugh GR. 1991. Early life history patterns of Atlantic North American flatfish: Likely (and unlikely) factors controlling recruitment. Netherlands Journal of Sea Research. 27(3-4):261-275.

Miller MH. 2016. Endangered Species Act status Review Report: Smooth Hammerhead Shark (Sphyrna zygaena). Silver Spring, MD: NOAA NMFS.

Miller TJ, Muller R, O'Boyle B, Rosenberg A. 2009. Report by the peer review panel for the Northeast data poor stocks working group. 34 p.

Montane MM, Austin HM. 2005. Effects of hurricanes on Atlantic croaker (Micropogonias undulatus) recruitment to Chesapeake Bay. In: Sellner KG, editor. Hurricane Isabel in perspective. Edgewater, MD: Chesapeake Research Consortium. p. 185-192.

Morgan AC, Sulikowski JA. 2015. The role of spiny dogfish in the northeast United States continental shelf ecosystem: How it has changed over time and potential interspecific competition for resources. Fisheries Research. 167:260-277.

Morris JA, Rulifson RA, Toburen LH. 2003. Life history strategies of striped bass, Morone saxatilis, populations inferred from otolith microchemistry. Fisheries Research. 62(1):53-63.

Morse WW. 1978. Biological and Fisheries Data on scup, Stenotomus chrysops (Linnaeus). Highlands, NJ: Sandy Hook Laboratory Northeast Fisheries Science Center. 41 p.

Morse WW, Able KW. 1995. Distribution and life history of windowpane, Scophthalmus aquosus, off the northeastern United States. Fishery Bulletin. 93:675-693.

Morson JM, Bochenek EA, Powell EN, Gius JE. 2012. Sex at Length of Summer Flounder Landed in the New Jersey Recreational Party Boat Fishery. North American Journal of Fisheries Management. 32(6):1201-1210.

Morson JM, Bochenek EA, Powell EN, Hasbrouck EC, Gius JE, Cotton CF, Gerbino K, Froehlich T. 2015. Estimating the Sex Composition of the Summer Flounder Catch using Fishery-Independent Data. Marine and Coastal Fisheries. 7(1):393-408.

Morson JM, Grothues T, Able KW. 2019. Change in larval fish assemblage in a USA east coast estuary estimated from twenty-six years of fixed weekly sampling. PLOS ONE. 14(10):e0224157.

Moser H. 1984. Ontogeny and systematics of fishes: based on an international symposium dedicated to the memory of Elbert Halvor Ahlstrom. American Society of Icthyologists and Herpatologists. 760 p.

Moser J, Shepherd GR. 2009. Seasonal Distribution and Movement of Black Sea Bass (Centropristis striata) in the Northwest Atlantic as Determined from a Mark-Recapture Experiment. Journal of Northwest Atlantic Fishery Science. 40:17-28.

Munroe DM, Haidvogel D, Caracappa JC, Klinck JM, Powell EN, Hofmann EE, Shank BV, Hart DR. 2018. Modeling larval dispersal and connectivity for Atlantic sea scallop (Placopecten magellanicus) in the Middle Atlantic Bight. Fisheries Research. 208:7-15.

Murawski WS, Festa PJ. 1979. Creel census of the summer flounder Paralichthys dentatus sportfishery in Great Bay, New Jersey. Nacote Creek, NJ.

Murdy EO, Birdsong RS, Musick JA. 1997. Fishes of Chesapeake Bay. Washington and London: Smithsonian Institution Press. 324 p.

Musick JA. 2002. Sturgeons. Family Acipenseridae. In: Collette BB, Klein-MacPhee G, editors. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 83-88.

Musick JA, McEachran JA. 1972. Autumn and winter occurrence of decapod crustaceans in Chesapeake Bight, U.S.A. . Crustaceana. 22:190-200.

Musick JA, Mercer LP. 1977. Seasonal Distribution of Black Sea Bass, Centropristis striata, in the Mid-Atlantic Bight with Comments on the Ecology and Fisheries of the Species. Transactions of the American Fisheries Society. 106:12-25.

Myers RA, Baum JK, Shepherd TD, Powers SP, Peterson CH. 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. Science. 315:1846-1850.

Nair RV, James DB. 1971. On the occurrence of sting-ray spines in the jaws and gills of the hammerhead shark Syphrna zygaena (Linnaeus). Journal of the Bombay Natural History Society. 69(2):432-434.

Nairn R, Johnson JA, Hardin D, Michel J. 2004. A Biological and Physical Monitoring Program to Evaluate Long-term Impacts from Sand Dredging Operations in the United States Outer Continental Shelf. Journal of Coastal Research. 201:126-137.

Narváez DA, Munroe DM, Hofmann EE, Klinck JM, Powell EN, Mann R, Curchitser E. 2015. Long-term dynamics in Atlantic surfclam (Spisula solidissima) populations: The role of bottom water temperature. Journal of Marine Systems. 141:136-148.

Nasir NA, Poxton MG. 2001. Substratum preferences of juvenile flatfish. Cybium. 25(2):109-117.

National Marine Fisheries Service. 2011. 2011 Atlantic Mackerel, Squid, and Butterfish Specifications Environmental Assessment (EA). 185 p.

National Marine Fisheries Service. 2018. Fisheries Economics of the United States 2016. Report No.: NMFS-F/SPO-187a. 243 p.

National Marine Fisheries Service. 2020. Fisheries of the United States, 2018. Report No.: No. 2018. 167 p.

National Research Council 2010. Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean. Washington, DC: The National Academies Press. 200 p.

Nehls G, Thiel M. 1993. Large-scale distribution patterns of the mussel Mytilus edulis in the Wadden Sea of Schleswig-Holstein: Do storms structure the ecosystem? Netherlands Journal of Sea Research. 31(2):181-187.

Nelson GA, Wilcox SH, Glenn R, Pugh TL. 2018. A Stock Assessment of Channeled Whelk (Busycotypus canaliculatus) in Nantucket Sound, Massachusetts. Massachusetts Division of Marine Fisheries. Report No.: TR-66. 43 p.

Nelson JS. 2006. Fishes of the World. Hoboken, NJ: John Wiley & Sons. 601 p.

Nemerson D, Able K. 2004. Spatial patterns in diet and distribution of juveniles of four fish species in Delaware Bay marsh creeks: factors influencing fish abundance. Marine Ecology Progress Series. 276:249-262.

Nemerson DM. 2001. Trophic dynamics and habitat ecology of the dominant fish of Delaware Bay (USA) marsh creeks [Dissertation]. [New Brunswick, NJ]: Rutgers, The State University of New Jersey.

Neuman MJ, Able KW. 1998. Experimental evidence of sediment preference by early life history stages of windowpane (Scophthalmus aquosus). Journal of Sea Research. 40:33-41.

Newell RIE. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (north and mid-Atlantic): blue mussel. Slidell, LA: Report No.: Report No. FWS/OBS-82/11.102.

Newton KC, Gill AB, Kajiura SM. 2019. Electroreception in marine fishes: chondrichthyans. J Fish Biol. 95(1):135-154.

Nichols JT, Breeder CM. 1927. The marine fishes of New York and southern New England. Zoologica. 9:1-192.

Nielsen C. 1975. Observations on Buccinum undatum attacking bivalves and on prey responses, with a short review on attack methods of other prosobranchs. Ophelia. 13(1-2):87-108.

Nizinski MS. 2002. Sand Lances. Family Ammodytidae. In: Collette BB, editor. Bigelow and Schroeder's Fishes of the Gulf of Maine. 3 ed. Washington, DC: Smithsonian Institution Press. p. 496-505.

Nizinski MS, Collette BB, Washington BB. 1990. Separation of Two Species of Sand Lances, Ammodytes americanus and A. dubius, in the Western North Atlantic. Fishery Bulletin. 88:241-255.

Northeast Fisheries Science Center. 2014. 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Summary Report. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: Northeast Fisheries Science Center Reference Document 14-07. 44 p.

Northeast Fisheries Science Center. 2017. 61st Northeast Regional Stock Assessment Workshop (61st SAW) Assessment Report. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: Northeast Fish Sci Cent Ref Doc. 17-05. 466 p.

Northeast Fisheries Science Center. 2020 (in press). Stock Assessment of the Ocean Quahog for 2020. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric

Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: Northeast Fisheries Science Center Reference Document 20-XXXX. 213 p.

Novitsky TJ. 2009. Biomedical applications of Limulus Amebocyte Lysate. In: Tanacredi JT, Botton ML, Smith D, editors. Biology and Conservation of Horseshoe Crabs. New York: Springer. p. 315-329.

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

O'Leary SJ, Dunton KJ, King TL, Frisk MG, Chapman DD. 2014. Genetic diversity and effective size of Atlantic sturgeon, Acipenser oxyrhinchus oxyrhinchus river spawning populations estimated from the microsatellite genotypes of marine-captured juveniles. Conservation Genetics. 15(5):1173-1181.

Olin JA, Cerrato RM, Nye JA, Sagarese SR, Sclafani M, Zacharias JP, Frisk MG. 2020. Evidence for Ecosystem Changes Within a Temperate Lagoon Following a Hurricane-Induced Barrier Island Breach. Estuaries and Coasts. 43(7):1625-1639.

Oliver MJ, Breece MW, Fox DA, Haulsee DE, Kohut JT, Manderson J, Savoy T. 2013a. Shrinking the Haystack: Using an AUV in an Integrated Ocean Observatory to Map Atlantic Sturgeon in the Coastal Ocean. Fisheries. 38(5):210-216.

Oliver SP, Turner JR, Gann K, Silvosa M, D'Urban Jackson T. 2013b. Thresher Sharks Use Tail-Slaps as a Hunting Strategy. PLoS ONE. 8(7):e67380.

Olla BL, Bejda AJ, Martin AD. 1974. Daily activity, movements, feeding, and seasonal occurrence in the tautog, Tautoga onitis. Fishery Bulletin. 72:27-35.

Olla BL, Bejda AJ, Martin AD. 1975. Activity, movements, and feeding behavior of the cunner, Tautogolabrus adspersus, and comparison of food habits with young tautog, Tautoga onitis, off Long Island, New York. Fishery Bulletin. 73(4):895-900.

Olla BL, Samet CE, Studholme AL. 1972. Activity and feeding behavior of the summer flounder (Paralichthys dentatus) under controlled laboratory conditions. Fishery Bulletin. 70(4):1127-1136.

Olla BL, Studholme AL. 1978. Comparative aspects of the activity rhythms of tautog, Tautoga onitis, bluefish, Pomatomous saltatrix, and Atlantic mackerel, Scomber scombrus, as related to their life habits. In: Thorpe JE, editor. Rhythmic Activity of Fishes. London: Academic Press. p. 131-151.

Olla BL, Studholme AL, Bejda AJ, Samet C. 1980. Role of temperature in triggering migratory behavior of the adult tautog Tautoga onitis under laboratory conditions. Marine Biology. 59:23-30.

Olla BL, Wicklund R, Wilk S. 1969. Behavior of winter flounder in a natural habitat. Transactions of the American Fisheries Society. 4:717-720.

Olsen YN, Merriman D. 1946. Studies of the marine resources of southern New England. IV. The biology and economic importance of the ocean pout, Macrozoarces americanus (Bloch and Schneider). Bulletin of the Bingham Oceanographic Collection. 9(4):1-184.

Orr JC, Caldeira K, Fabry V, Gattuso JP, Haugan P, Lehodey P, Pantoja S, Pörtner HO, Riebesell U, Trull T, et al. 2009. Research priorities for understanding ocean acidification. Oceanography. 22:182189.

Overholtz WJ, Tyler AV. 1985. Long-term responses of the demersal fish assemblages of Georges Bank. Fishery Bulletin. 88(4):507-520.

Owen D. 2017. The End of Sand. The New Yorker. New York, New York. p. 28-33.

Pace ML, Cole JJ, Carpenter SR, Kitchell JF. 1999. Trophic cascades revealed in diverse ecosystems. Trends in Ecology & Evolution. 14(12):483-488.

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

Pace SM, Powell EN, Mann R, Long MC. 2017. Comparison of age-frequency distributions for ocean quahogs Arctica islandica on the western Atlantic US continental shelf. Marine Ecology Progress Series. 585:81-98.

Packer C, Holt RD, Hudson PJ, Lafferty KD, Dobson AP. 2003a. Keeping the herds healthy and alert: implications of predator control for infectious disease. Ecology Letters. 6(9):797-802.

Packer DB, Griesbach SJ, Berrien PL, Zetlin CA, Johnson DL, Morse WW. 1999. Essential Fish Habitat Source Document: Summer Flounder, Paralichthys dentatus, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-151. 88 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003b. Essential fish habitat source document. Barndoor skate, Dipturus laevis, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-173. (U.S.). 23 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003c. Essential fish habitat source document. Clearnose skate, Raja eglanteria, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-174. (U.S.). 50 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003d. Essential fish habitat source document. Little skate, Leucoraja erinacea, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-175. (U.S.). 66 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003e. Essential fish habitat source document. Rosette skate, Leucoraja garmani virginica, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-176. (U.S.). 17 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003f. Essential fish habitat source document. Smooth skate, Malacoraja senta, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-177. (U.S.). 26 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003g. Essential fish habitat source document. Thorny skate, Amblyraja radiata, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-178. (U.S.). 39 p.

Packer DB, Zetlin CA, Vitaliano JJ. 2003h. Essential fish habitat source document. Winter skate, Leucoraja ocellata, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-179. (U.S.). 57 p.

Paerl HW, Bales JD, Ausley LW, Buzzelli CP, Crowder LB, Eby LA, Fear JM, Go M, Peierls BL, Richardson TL, et al. 2001. Ecosystem impacts of three sequential hurricanes (Dennis, Floyd, and Irene) on the United States' largest lagoonal estuary, Pamlico Sound, NC. Proceedings of the National Academy of Sciences. 98(10):5655-5660.

Paerl HW, Valdes LM, Joyner AR, Peierls BL, Piehler MF, Riggs SR, Christian RR, Eby LA, Crowder LB, Ramus JS, et al. 2006. Ecological response to hurricane events in the Pamlico Sound system, North Carolina, and implications for assessment and management in a regime of increased frequency. Estuaries and Coasts. 29(6):1033-1045.

Palma A, Wahle R, Steneck R. 1998. Different early post-settlement strategies between American lobsters Homarus americanus and rock crabs Cancer irroratus in the Gulf of Maine. Marine Ecology Progress Series. 162:215-225.

Parsons GR, Hoffmayer ER, Taylor CM. 2005. Seasonal Changes in the Distribution and Relative Abundance of the Atlantic Sharpnose SharkRhizoprionodon Terraenovaein the North Central Gulf of Mexico. Copeia. 2005(4):914-920.

Pearce CM, Manuel JL, Gallager SM, Manning DA, O'Dor RK, Bourget E. 2004. Depth and timing of settlement of veligers from different populations of giant scallop, Placopecten magellanicus (Gmelin), in thermally stratified mesocosms. Journal of Experimental Marine Biology and Ecology. 312(1):187-214.

Pereira JJ, Goldberg R, Ziskowski JJ, Berrien PL, Morse WW, Johnson DL. 1999. Essential fish habitat source document. Winter flounder, Pseudopleuronectes americanus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-138. (U.S.). 39 p.

Perez KO, Carlson RL, Shulman MJ, Ellis JC. 2009. Why are intertidal snails rare in the subtidal? Predation, growth and the vertical distribution of Littorina littorea (L.) in the Gulf of Maine. Journal of Experimental Marine Biology and Ecology. 369(2):79-86.

Perlmutter A. 1947. The blackback flounder and its fishery in New England and New York. Bulletin of the Bingham Oceanographic Collection. 11:1-92.

Phelan BA. 1992. Winter Flounder Movements in the Inner New York Bight. Transactions of the American Fisheries Society. 121:777-784.

Pickard GL, Emery WJ. 1990. Descriptive Physical Oceanography: An Introduction. Oxford: Pergamon Press.

Pickens BA, Taylor JC. 2020. Regional Essential Fish Habitat Geospatial Assessment and Framework for Offshore Sand Features. Sterling, VA: US Department of the Interior, Bureau of Ocean Energy Management. Report No.: OCS Study BOEM 2020-002 and NOAA NCCOS Technical Memorandum 270. 362 p.

Pickens BA, Taylor JC, Hansen D. 2020. Fish Habitat Associations and the Potential Effects of Dredging on Fish of the Atlantic and Gulf of Mexico Outer Continental Shelf, Literature Synthesis and Gap Analysis. Sterling, VA: Bureau of Ocean Energy Management Headquarters. 134 p.

Pickett STA, White PS. 1985. The Ecology of Natural Disturbance and Patch Dynamics. London: Academic Press.

Pinnegar JK, Polunin NVC, Francour P, Badalamenti F, Chemello R, Harmelin-Vivien ML, Hereu B, Milazzo M, Zabala M, D'Anna G, et al. 2000. Trophic cascades in benthic marine ecosystems: lessons for fisheries and protected-area management. Environmental Conservation. 27(2):179-200.

Pinsky ML, Worm B, Fogarty MJ, Sarmiento JL, Levin SA. 2013. Marine Taxa Track Local Climate Velocities. Science. 341(6151):1239-1242.

Poe MR, Norman KC, Levin PS. 2014. Cultural Dimensions of Socioecological Systems: Key Connections and Guiding Principles for Conservation in Coastal Environments. Conservation Letters. 7(3):166-175.

Polacheck T, Mountain D, McMillan D, Smith W, Berrien P. 1992. Recruitment of the 1987 year class of haddock (Melanogrammus aeglefinus): the influence of unusual larval transport. Canadian Journal of Fisheries and Aquatic Sciences. 49(3):484-496.

Powers SP, Kittinger JN. 2002. Hydrodynamic mediation of predator–prey interactions: differential patterns of prey susceptibility and predator success explained by variation in water flow. Journal of Experimental Marine Biology and Ecology. 273(2):171-187.

Pratt HL, Carrier JC. 2001. A Review of Elasmobranch Reproductive Behavior with a Case Study on the Nurse Shark, Ginglymostoma Cirratum. Environmental Biology of Fishes. 60(1-3):157-188.

Provost MM, Jensen OP, Berlinsky DL. 2017. Influence of Size, Age, and Spawning Season on Sex Change in Black Sea Bass. Marine and Coastal Fisheries. 9(1):126-138.

Puig P, Canals M, Company JB, Martín J, Amblas D, Lastras G, Palanques A, Calafat AM. 2012. Ploughing the deep sea floor. Nature. 489(7415):286-289.

Quijón PA, Grassle JP, Rosario JM. 2007. Naticid snail predation on early post-settlement surfclams (Spisula solidissima) on the inner continental shelf of New Jersey, USA. Marine Biology. 150(5):873-882.

Ramenofsky M, Wingfield JC. 2007. Regulation of Migration. BioScience. 57(2):135-143.

Resciniti J, Handel C, FitzSimmons C, Carberry H. 2009. A guide to fishing and diving New Jersey reefs. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Bureau of Marine Fisheries, Reef Program. 11 p.

Richards CE, Castagna M. 1970. Marine fishes of Virginia's eastern shore (inlet and marsh, seaside waters). Cheasapeake Science. 11(4):235-248.

Richards RA, Graboswski J, Sherwood G, Alade L, Bank C. 2012. Archival tagging study of Monkfish, Lophius americanus. Final Report to the Northeast Consortium, Award No. 09- 042.

Richards WJ. 2006. Early Stages of Atlantic Fishes. An Identification Guide for the Central North Atlantic. Richards WJ, editor. Boca Raton, FL: Taylor and Francis.

Rijnsdorp AD, Peck MA, Engelhard GH, Möllmann C, Pinnegar JK. 2009. Resolving the effect of climate change on fish populations. ICES Journal of Marine Science. 66(7):1570-1583.

Ritchie Jr. DE. 1977. Short-term response of fish to Tropical Storm Agnes in the mid-Chesapeake Bay. In: Ruzecki EP, Schubel JR, Huggett RJ, Anderson AM, Wass ML, Marasco RJ, Lynch MP, editors. The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system. Baltimore, MD: The Johns Hopkins University Press. p. 460-463.

Robards MD, Rose GA, Piatt JF. 2002. Growth and Abundance of Pacific Sand Lance, Ammodytes hexapterus, under differing Oceanographic Regimes. Environmental Biology of Fishes. 64(4):429-441.

Robards MD, Willson MF, Armstrong RH, Piatt JF. 1999. Sand Lance: A Review of Biology and Predator Relations and Annotated Bibliography. Portland, OR: Report No.: Research Paper PNW-RP-521. 327 p.

Robichaud DA, Frail C. 2006. Development of the Jonah Crab, Cancer borealis, and Rock Crab, Cancer irroratus, Fisheries in the Bay of Fundy (LFAs 35-38) and off Southwest Nova Scotia (LFA 34): Exploratory to Commercial Status (1995-2004). Report No.: 2775. 48 p.

Robins CR, Ray GC. 1986. A field guide to Atlantic coast fishes of North America. Boston, USA: Houghton Mifflin Company.

Roda MAP, Gilman E, Huntington T, Kennelly SJ, Suuronen P, Chaloupka M, Medley PAH. 2019. A third assessment of global marine fisheries discards. Rome, Italy: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. 78 p.

Rogers LA, Griffin R, Young T, Fuller E, St. Martin K, Pinsky ML. 2019. Shifting habitats expose fishing communities to risk under climate change. Nature Climate Change. 9(7):512-516.

Roman MR, Boicourt WC, Kimmel DG, Miller WD, Adolf JE, Bichy J, Harding LW, Houde ED, Jung S, Zhang X. 2005. Chesapeake Bay plankton and fish abundance enhanced by Hurricane Isabel. Eos, Transactions American Geophysical Union. 86(28):261.

Ropes JW. 1980. Biological and Fisheries Data on Surfclam Spisula solidissima (Dillwyn). Woods Hole: Woods Hole Laboratory, Northeast Fisheries Center.

Ropes JW, Merrill AS. 1973. To what extent do Surfclams move? The Nautilus. 87(1):19-21.

Rose KA, Cowan JH, Winemiller KO, Myers RA, Hilborn R. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries. 2:293-327.

Ross SW, Rhode M, Viada ST, Mather R. 2016. Fish species associated with shipwreck and natural hard-bottom habitats from the middle to outer continental shelf of the Middle Atlantic Bight near Norfolk Canyon. Fishery Bulletin. 114(1):45-57.

Rothermel ER, Balazik MT, Best JE, Breece MW, Fox DA, Gahagan BI, Haulsee DE, Higgs AL, O'Brien MHP, Oliver MJ, et al. 2020. Comparative migration ecology of striped bass and Atlantic sturgeon in the US Southern mid-Atlantic bight flyway. PLoS One. 15(6):e0234442.

Rountree RA, Able KW. 1996. Seasonal abundance, growth, and foraging habits of juvenile smooth dogfish, Mustelus canis, in a New Jersey estuary. Fishery Bulletin. 94(3):522-534.

Rountree RA, Gröger JP, D.Martins. 2006. Extraction of daily activity pattern and vertical migration behavior from the benthic fish, Lophius americanus, based on depth analysis from data storage tags.

Rowe PM, Epifanio CE. 1994a. Flux and transport of larval weakfish in Delaware Bay, USA. Marine Ecology Progress Series. 110:115-120.

Rowe PM, Epifanio CE. 1994b. Tidal stream transport of weakfish larvae in Delaware Bay, USA. Marine Ecology Progress Series. 110:105-114.

Rudders D, Roman S, Fisher RA, Bushek D, Munroe D, Bochenek EA, McGurk E, Borsetti S. 2019. An Investigation into the Scallop Parasite Outbreak on the Mid-Atlantic Shelf: Transmission Pathways, Spatio-Temporal Variation of Infection and Consequences to Marketability : Final Report. Virginia Institute of Marine Science, William & Mary. 53 p.

Rudloe A. 1981. Aspects of the biology of juvenile horseshoe crabs, Limulus polyphemus. Bulletin of Marine Science. 31(1):125-133.

Rutecki D, Dellapenna T, Nestler E, Scharf F, Rooker J, Glass C, Pembroke A. 2014. Understanding the Habitat Value and Function of Shoals and Shoal Complexes to Fish and Fisheries on the Atlantic and Gulf of Mexico Outer Continental Shelf. Literature Synthesis and Gap Analysis. U.S. Department of the Interior, Bureau of Ocean Energy Management. 176 p.

Rutherford ES, Houde ED. 1995. The influence of temperature on cohort-specific growth, survival, and recruitment of striped bass, Marone saxatilis, larvae in Chesapeake Bay. Fishery Bulletin. 93:315-332.

Ryer CH, Stoner AW, Titgen RH. 2004. Behavioral mechanisms underlying the refuge value of benthic habitat structure for two flatfishes with differing anti-predator strategies. MARINE ECOLOGY PROGRESS SERIES. 268:231-243.

Saba GK, Goldsmith KA, Cooley SR, Grosse D, Meseck SL, Miller AW, Phelan B, Poach M, Rheault R, St.Laurent K, et al. 2019. Recommended priorities for research on ecological impacts of ocean and coastal acidification in the U.S. Mid-Atlantic. Estuarine, Coastal and Shelf Science. 225:106188.

Sabine CL, Feely RA, Gruber N, Robert M. Key, Kitack Lee, Bullister JL, Rik Wanninkhof, Wong CS, Wallace DWR, Tilbrook B, et al. 2004. The Oceanic Sink for Anthropogenic CO2. Science. 305(5682):367-371.

Sackett DK, Able KW, Grothues TM. 2007. Dynamics of summer flounder, Paralichthys dentatus, seasonal migrations based on ultrasonic telemetry. Estuarine, Coastal and Shelf Science. 74(1-2):119-130.

Safina C. 1990. Bluefish Mediation of Foraging Competition between Roseate and Common Terns. Ecology. 71(5):1804-1809.

Sagarese SR, Frisk MG. 2011. Movement Patterns and Residence of Adult Winter Flounder within a Long Island Estuary. Marine and Coastal Fisheries. 3(1):295-306.

Sale PF. 1977. Maintenance of High Diversity in Coral Reef Fish Communities. The American Naturalist. 111(978):337-359.

Salisbury J, Green M, Hunt C, Campbell J. 2008. Coastal Acidification by Rivers: A Threat to Shellfish? Eos, Transactions American Geophysical Union. 89(50):513-513.

Santos CC, Coelho R. 2018. Migrations and habitat use of the smooth hammerhead shark (Sphyrna zygaena) in the Atlantic Ocean. PLOS ONE. 13(6):e0198664.

Sarmiento JL, Gruber N. 2006. Ocean biogeochemical dynamics. Princeton, NJ: Princeton University Press.

Saunders RA, Royer F, Clarke MW. 2011. Winter migration and diving behaviour of porbeagle shark, Lamna nasus, in the Northeast Atlantic. ICES Journal of Marine Science. 68(1):166-174.

Savage NB. 1976. Burrowing activity in Mercenaria mercenaria (L.) and Spisula solidissima (Dillwyn) as a function of temperature and dissolved oxygen. Marine Behaviour and Physiology. 3(4):221-234.

Scharf FS, Buckel JA, Juanes F, Conover DO. 1998. Predation by juvenile piscivorous bluefish (Pomatomus saltatrix) : the influence of prey to predator size ratio and prey type on predator capture success and prey profitability. Canadian Journal of Fisheries and Aquatic Sciences. 55:1695-1703.

Scharf FS, Manderson JP, Fabrizio MC. 2006. The effects of seafloor habitat complexity on survival of juvenile fishes: Species-specific interactions with structural refuge. Journal of Experimental Marine Biology and Ecology. 335(2):167-176.

Schmitt RJ, Holbrook SJ. 1990. Population Responses of Surfperch Released from Competition. Ecology. 71(5):1653-1665.

Schultz K. 2004. Little Tunny. Ken Schultz's Field Guide to Saltwater Fish. Hoboken, NJ: John Wiley and Sons, Inc. p. 259.

Sciberras M, Hiddink JG, Jennings S, Szostek CL, Hughes KM, Kneafsey B, Clarke LJ, Ellis N, Rijnsdorp AD, McConnaughey RA, et al. 2018. Response of benthic fauna to experimental bottom fishing: A global meta-analysis. Fish and Fisheries. 19(4):698-715.

Scolding JWS, Richardson CA, Luckenbach MJ. 2007. Predation of cockles (Cerastoderma edule) by the whelk (Buccinum undatum) under laboratory conditions. Journal of Molluscan Studies. 73(4):333-337.

Scott WB, Scott MG. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fish and Aquatic Sciences. 219:731.

Sebunka JD, Silverman MJ. 1989. MARMAP Surveys of the Continental Shelf from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia (1984-1987) Woods Hole (MA): U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center. 208 p.

Secor D. 2000. Spawning in the nick of time? Effect of adult demographics on spawning behaviour and recruitment in Chesapeake Bay striped bass. ICES Journal of Marine Science. 57(2):403-411.

Secor D, Rooker, Jr., Zlokovitz E, Zdanowicz V. 2001. Identification of riverine, estuarine, and coastal contingents of Hudson River striped bass based upon otolith elemental fingerprints. Marine Ecology Progress Series. 211:245-253.

Secor DH. 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries Research. 43(1-3):13-34.

Secor DH. 2007. The year-class phenomenon and the storage effect in marine fishes. Journal of Sea Research. 57(2-3):91-103.

Secor DH, Piccoli PM. 1996. Age- and sex-dependent migrations of the Hudson River striped bass population determined from otolith microanalysis. Estuaries. 19:778-793.

Secor DH, Piccoli PM. 2007. Oceanic migration rates of Upper Chesapeake Bay striped bass (Morone saxatilis), determined by otolith microchemical analysis. Fishery Bulletin. 105:62-73.

SEDAR. 2020. SEDAR 69 – Atlantic Menhaden Benchmark Stock Assessment Report. North Charleston SC: Southeast Data, Assessment, and Review. 691 p.

Sedberry G. 1988. Food and feeding of the black sea, Centropristis striata, in live bottom habitats of the South Atlantic Bight. Journal of the Elisha Mitchell Scientific Society. 104(2):35-50.

Seed R, Suchanek TH. 1992. Population and community ecology of Mytilus. In: Gosling M, editor. The mussel Mytilus: ecology, physiology, genetics and culture. Amsterdam: Elsevier Science.

Selden RL, Batt RD, Saba VS, Pinsky ML. 2018. Diversity in thermal affinity among key piscivores buffers impacts of ocean warming on predator-prey interactions. Global Change Biology. 24(1):117-131.

Shackell NL, Ricard D, Stortini C. 2014. Thermal habitat index of many northwest Atlantic temperate species stays neutral under warming projected for 2030 but changes radically by 2060. PLoS One. 9(3):e90662.

Sheehy DJ, Shenouda SYK, Alton AJ, Saila SB, Constantinides SM. 1977. The Ocean Pout: An Example of Underutilized Fisheries Resource Development. Marine Fisheries Review. 39(6).

Shepherd GR, Moser J, Deuel D, Carlsen P. 2006. The migration patterns of bluefish (Pomatomus saltatrix) along the Atlantic coast determined from tag recoveries. Fishery Bulletin. 104:559-570.

Shepherd GR, Nieland J. 2010. Bluefish 2010 Stock Assessment Update. Woods Hole, Massachusetts: Report No.: 10-15. 33 p.

Shepherd GR, Packer DB. 2006. Essential fish habitat source document. Bluefish, Pomatomus saltatrix, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-198. 89 p.

Shipp RL. 1974. The puffer fishes (Tetraodontidae) of the Atlantic Ocean. Ocean Springs, MS: Gulf Coast Research Laboratory.

Shrader AM, Bell C, Bertolli L, Ward D. 2012. Forest or the trees: At what scale do elephants make foraging decisions? Acta Oecologica. 42:3-10.

Shumway SE, Parsons GJ. 2006. Scallops: Biology, Ecology and Aquaculture. Boston, MA: Elsevier.

Sinopoli M, Lauria V, Garofalo G, Maggio T, Cillari T. 2019. Extensive use of Fish Aggregating Devices together with environmental change influenced the spatial distribution of a tropical affinity fish. Scientific Reports. 9(1).

Skomal G, Braun C, Chisholm J, Thorrold, Sr. 2017. Movements of the white shark Carcharodon carcharias in the North Atlantic Ocean. Marine Ecology Progress Series. 580:1-16.

Skomal GB, Wood G, Caloyianis N. 2004. Archival tagging of a basking shark, Cetorhinus maximus, in the western North Atlantic. Journal of the Marine Biological Association of the United Kingdom. 84:795-799.

Slater J, Lankford T, Buckel J. 2007. Overwintering ability of young-of-the-year bluefish Pomatomus saltatrix: effect of ration and cohort of origin on survival. Marine Ecology Progress Series. 339:259-269.

Smale MJ. 1991. Occurrence and feeding of three shark species, Carcharhinus brachyurus, C. obscurus and Sphyrna zygaena , on the Eastern Cape coast of South Africa. 11(1):31-42.

Smigielski AS, Halavik TA, Buckley LJ, Drew SM, Laurence GC. 1984. Spawning, embryo development and growth of the American sand lance Ammodytes americanus in the laboratory. Marine Ecology Progress Series. 14:287-292.

Smith DR, Beekey MA, Brockmann HJ, King TL, Millard MJ, Zaldívar-Rae JA. 2016. Limulus ployphemus. The IUCN Red List of Threatened Species; [accessed 2021]. https://www.iucnredlist.org/species/11987/80159830.

Smith HM. 1898. The Fishes Found in the Vicinity of Woods Hole. Bulletin of the United States Fish Commission. 17:85-111.

Smith TIJ, Clugston JP. 1997. Status and management of Atlantic sturgeon, Acipenser oxyrinchus, in North America. Environmental Biology of Fishes. 48(1-4):335-346.

Smith WG, Norcross JJ. 1968. The Status of the Scup (Stenotomus chrysops) in Winter Trawl Fishery. Cheasapeake Science. 9(4):207-216.

Smith WG, Sibunka JD, Wells A. 1975. Seasonal distributions of flatfishes (Plearonectiformes) on the contnental shelf between Cape Cod, Massachusetts, and Cape Lookout, North Carolina, 1965-66. Report No.: NMFS SSRF-691. 75 p.

Southwick Associates. 2018. The Economic Contributions of Recreational and Commercial Striped Bass Fishing. Fernandina Beach, FL.

Springer S. 1967. Social organization of shark populations. In: Gilbert PW, Mathewson RW, Rall DP, editors. Sharks, skates and rays. Baltimore, MD: John Hopkins Press. p. 149-174.

Stahl L, Koczan J, Swift D. 1974. Anatomy of a Shoreface-Connected Sand Ridge on the New Jersey Shelf: Implications for the Genesis of the Shelf Surficial Sand Sheet. Geology. 2:117-120.

Staudinger MD, Goyert H, Suca JJ, Coleman K, Welch L, Llopiz JK, Wiley D, Altman I, Applegate A, Auster P, et al. 2020. The role of sand lances (Ammodytes sp.) in the Northwest Atlantic Ecosystem: A synthesis of current knowledge with implications for conservation and management. Fish and Fisheries. 21(3):522-556.

Stehlik LL. 1993. Diets of the brachyuran crabs Cancer irroratus, Cancer borealis, and Ovalipes ocellatus in the New York Bight. Journal of Crustacean Biology. 13:723-735.

Stehlik LL. 2007. Essential Fish Habitat Source Document: Spiny Dogfish, Squalus acanthias, Life History and Habitat Characteristics: Second Edition. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-203. 44 p.

Stehlik LL, MacKenzie Jr. CL, Morse WW. 1991. Distribution and Abundance of Four Brachyuran Crabs on the Northwest Atlantic Shelf. Fishery Bulletin. 89:473-492.

Stehlik LL, Pikanowski RA, McMillan DG. 2004. The Hudson-Raritan Estuary as a crossroads for distribution of blue (Callinectes sapidus), lady (Ovalipes ocellatus), and Atlantic rock (Cancer irroratus) crabs. Fishery Bulletin. 102:693-710.

Steimle FW. 1999a. Essential fish habitat source document. Ocean pout, Macrozoarces americanus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-129. (U.S.). 26 p.

Steimle FW. 1999b. Essential fish habitat source document. Scup, Stenotomus chrysops, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-149. (U.S.). 39 p.

Steimle FW, Figley W. 1996. The Importance of Artificial Reef Epifauna to Black Sea Bass Diets in the Middle Atlantic Bight. North American Journal of Fisheries Management. 16:433-439.

Steimle FW, Morse WW, Johnson DL. 1999a. Essential Fish Habitat Source Document: Goosefish, Lophius americanus, Life History and Habitat Characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-127. 40 p.

Steimle FW, Ogren L. 1982. Food of Fish Collected on Artificial Reefs in the New York Bight and Off Charleston, South Carolina. Marine Fisheries Review. 44:49-52.

Steimle FW, Shaheen P. 1999. Tautog (Tautoga onitis) life history and habitat requirements.

Steimle FW, Zetlin C. 2000. Reef Habitats in the Middle Atlantic Bight: Abundance, Distribution, Associated Biological Communities, and Fishery Resource Use. Marine Fisheries Review. 62(2):24-42.

Steimle FW, Zetlin C, Berrien PL, Chang S. 1999b. Essential Fish Habitat Source Document: Black Sea Bass, Centropristis striata, Life History and Habitat Characteristics. Woods Hole, Massachusetts: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-143. 42 p.

Stenberg C, Deurs MV, Støttrup J, Mosegaard H, Grome T, Dinesen GE, Christensen A, Jensen H, Kaspersen M, Berg CW, et al. 2011. Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities: Follow-up Seven Years after Construction. DTU Aqua. 66 p.

Stenberg C, Støttrup JG, van Deurs M, Berg CW, Dinesen GE, Mosegaard H, Grome TM, Leonhard SB. 2015. Long-term effects of an offshore wind farm in the North Sea on fish communities. Marine Ecology Progress Series. 528:257-265.

Stephens WM. 1964. The Increadible Horseshoe Crab. Sea Frontiers. 10(3):131-138.

Stevens PW, Blewett DA, Casey JP. 2006. Short-term effects of a low dissolved oxygen event on estuarine fish assemblages following the passage of hurricane Charley. Estuaries and Coasts. 29(6):997-1003.

Stevenson JT, Secor DH. 1999. Age determination and growth of Hudson River Atlantic sturgeon, Acipenser oxyrinchus. Fishery Bulletin. 97:153-166.

Steves BP, Cowen RK. 2000. Settlement, growth, and movement of silver hake Merluccius bilinearis in nursery habitat on the New York Bight continental shelf. Marine Ecology Progress Series. 196:279-290.

Steves BP, Cowen RK, Malchoff MH. 1999. Settlement and nursery habitats for demersal fishes on the continental shelf of the New York Bight. Fishery Bulletin. 98:167–188

Stillwell CE, Kohler NE. 1993. Food habits of the sandbar shark Carcharhinus plumbeus off the U.S. northeast coast, with estimates of daily ration. Fishery Bulletin. 91:138-150.

Stine CB, Kane AS, Baya AM. 2010. Mycobacteria isolated from Chesapeake Bay fish. Journal of Fish Diseases. 33(1):39-46.

Stokesbury KDE, Bethoney ND, Georgianna D, Inglis S, Keiley E. 2019. Convergence of a Disease and Litigation Leading to Increased Scallop Discard Mortality and Economic Loss in the Georges Bank Fishery. North American Journal of Fisheries Management. 39(2):299-306.

Stokesbury KDE, Harris BP, Marino MC, Nogueira JI. 2007. Sea scallop mass mortality in a Marine Protected Area. Marine Ecology Progress Series. 349:151-158.

Stoner A, Manderson J, Pessutti J. 2001. Spatially explicit analysis of estuarine habitat for juvenile winter flounder: combining generalized additive models and geographic information systems. Marine Ecology Progress Series. 213:253-271.

Stoner AW, Ottmar ML. 2003. Relationships between size-specific sediment preferences and burial capabilities in juveniles of two Alaska flatfishes. Journal of Experimental Marine Biology and Ecology. 282(1-2):85-101.

Strong W, Snelson F, Gruber S. 1990. Hammerhead Shark Predation on Stingrays: An Observation of Prey Handling by Sphyrna mokarran. Copeia. 1990(3):836-840.

Studholme AL. 1999. Essential fish habitat source document. Atlantic mackerel, Scomber scombrus, life history and habitat characteristics. Woods Hole, MA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Report No.: NOAA Technical Memorandum NMFS-NE-141. (U.S.). 35 p.

Sulikowski J, Galuardi B, Bubley W, Furey N, Driggers W, Ingram G, Tsang P. 2010. Use of satellite tags to reveal the movements of spiny dogfish Squalus acanthias in the western North Atlantic Ocean. 418:249-254.

Sulikowski JA, Tsang PCW, Huntting Howell W. 2004. An annual cycle of steroid hormone concentrations and gonad development in the winter skate, Leucoraja ocellata , from the western Gulf of Maine. Marine Biology. 144(5):845-853.

Sullivan M, Cowen R, Able K, Fahay M. 2003. Effects of anthropogenic and natural disturbance on a recently settled continental shelf flatfish. Marine Ecology Progress Series. 260:237-253.

Sullivan MC, Cowen RK, Able KW, Fahay MP. 2000. Spatial scaling of recruitment in four continental shelf fishes. Marine Ecology Progress Series. 207:141-154.

Sullivan MC, Cowen RK, Able KW, Fahay MP. 2006. Applying the basin model: Assessing habitat suitability of young-of-the-year demersal fishes on the New York Bight continental shelf. Continental Shelf Research. 26(14):1551-1570.

Sullivan MC, Cowen RK, Steves BP. 2005. Evidence for atmosphere-ocean forcing of yellowtail flounder (Limanda ferruginea) recruitment in the Middle Atlantic Bight. Fisheries Oceanography. 14(5):386-399.

Sutherland WJ. 1996. From individual to population biology. New York: Oxford University Press.

Swan BL. 2005. Migrations of adult horseshoe crabs,Limulus polyphemus, in the Middle Atlantic Bight: A 17-year tagging study. Estuaries. 28(1):28-40.

Swift DJP, Duane DB, McKinney TF. 1973. Ridge and swale topography of the Middle Atlantic Bight, North America: Secular response to the Holocene hydraulic regime. Marine Geology. 15(4):227-247.

Taghon GL, Ramey PA, Fuller CM, Petrecca RF, Grassle JP. 2017. Benthic Community Structure and Sediment Properties in Barnegat Bay, New Jersey, Before and After Hurricane Sandy. Estuaries and Coasts. 40(1):160-172.

Taylor AC. 1976. Burrowing behaviour and anaerobiosis in the bivalve Arctica islandica (L.). Journal of the Marine Biological Association of the United Kingdom. 56(1):95-109.

Taylor R, Vine N, York A, Lerner S, Hart D, Howland J, Prasad L, Mayer L, Gallager S. 2008. Evolution of a benthic imaging system from a towed camera to an automated habitat characterization system. In: Oceans'08; Kobe, Japan.

Teter SM, Wetherbee BM, Fox DA, Lam CH, Kiefer DA, Shivji M. 2015. Migratory patterns and habitat use of the sand tiger shark (Carcharias taurus) in the western North Atlantic. 66(2):158.

Thompson KJ, Inglis SD, Stokesbury KDE. 2014. Identifying Spawning Events of the Sea Scallop Placopecten magellanicus on Georges Bank. Journal of Shellfish Research. 33(1):77-87.

Thorpe EA. 1991. Aspects of the biology of windowpane flounder Scophthalmus aquosus, in the northwest Atlantic Ocean [M.S. Thesis]. [Amherst, MA]: University of Massachusetts.

Thouzeau G, Robert G, Smith SJ. 1991. Spatial variability in distribution and growth of juvenile and adult sea scallops Placopecten magellanicus (Gmelin) on eastern Georges Bank (Northwest Atlantic). Marine Ecology Progress Series. 74(2/3):205-218.

Thrush SF, Gray JS, Hewitt JE, Ugland KI. 2006. Predicting the effects of habitat homogenization on marine biodiversity. Ecological Applications. 16(5):1636-1642.

Tommasi D, Nye J, Stock C, Hare JA, Alexander M, Drew K. Effect of environmental conditions on juvenile recruitment of alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis) in fresh water: a coastwide perspective. Canadian Journal of Fisheries and Aquatic Sciences. 72:1037-1047.

Tucker JP, Vercoe B, Santos IR, Dujmovic M, Butcher PA. 2019. Whale carcass scavenging by sharks. Global Ecology and Conservation. 19:e00655.

Turner SM, Manderson JP, Richardson DE, Hoey JJ, Hare JA. 2016. Using habitat association models to predict Alewife and Blueback Herring marine distributions and overlap with Atlantic Herring and Atlantic Mackerel: can incidental catches be reduced? ICES Journal of Marine Science. 73(7):1912-1924.

Twichell DC, McClennen CE, Butman B. 1981. Morphology and Processes Associated with the Accumulation of the Fine-Grained Sediment Deposit on the Southern New England Shelf. Journal of Sedimentary Research. 51:269-280.

U.S. Fish and Wildlife Service. 2004. Changes Affecting Import and Export of Seahorses and Other Tropical Fish. U.S. Fish and Wildlife Service Office of Law Enforcement. 1 p.

Udyawer V, Chin A, Knip D, Simpfendorfer C, Heupel M. 2013. Variable response of coastal sharks to severe tropical storms: environmental cues and changes in space use. Marine Ecology Progress Series. 480:171-183.

United Nations Environmental Programme. 2015. UNEP 2014 Annual Report. 66 p.

United States Army Corps of Engineers. 2015. Dredging and Dredged Material Management. Washington, DC: U.S. Army Corps of Engineers. Report No.: EM 1110-2-5025.

USGCRP. 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC: U.S. Global Change Research Program. 1515 p.

Valenti JL, Grothues TM, Able KW. 2020. Juvenile fish assemblage recruitment dynamics in a mid-Atlantic estuary: before and after Hurricane Sandy. Marine Ecology Progress Series. 641:177-193.

van Deurs M, Grome TM, Kaspersen M, Jensen H, Stenberg C, Sørensen TK, Støttrup J, Warnar T, Mosegaard H. 2012. Short- and long-term effects of an offshore wind farm on three species of sandeel and their sand habitat. Marine Ecology Progress Series. 458:169-180.

Vanblaricom GR. 1982. Experimental Analyses of Structural Regulation in a Marine Sand Community Exposed to Oceanic Swell. Ecological Monographs. 52(3):283-305.

Vasslides JM, Able KW. 2008. Importance of shoreface sand ridges as habitat for fishes off the northeast coast of the United States. Fishery Bulletin. 106:93-107.

Vaudo JJ, Byrne ME, Wetherbee BM, Harvey GM, Shivji MS. 2017. Long-term satellite tracking reveals region-specific movements of a large pelagic predator, the shortfin mako shark, in the western North Atlantic Ocean. Journal of Applied Ecology. 54(6):1765-1775.

Vaudo JJ, Wetherbee BM, Wood AD, Weng K, Howey-Jordan LA, Harvey GM, Shivji MS. 2016. Vertical movements of shortfin mako sharks Isurus oxyrinchus in the western North Atlantic Ocean are strongly influenced by temperature. Marine Ecology Progress Series. 547:163-175.

Vogel S. 1994. Life in Moving Fluids. Princeton, NJ: Princeton University Press.

Vosatka ED. 1970. Observations on the swimming, righting, and burrowing movements of young horseshoe crabs, limulus polyphemus. The Ohio Journal of Science. 70(5):276-283.

Waldbusser GG, Salisbury JE. 2014. Ocean Acidification in the Coastal Zone from an Organism's Perspective: Multiple System Parameters, Frequency Domains, and Habitats. Annual Review of Marine Science. 6(1):221-247.

Walker R. 1988. Observations on intertidal whelk (Busycon and Busycotypus) populations in Wassaw Sound, Georgia. Journal of Shellfish Research. 7:476-478.

Walsh HJ, Marancik KE, Hare JA. 2006. Juvenile fish assemblages collected on unconsolidated sediments of the southeast United States continental shelf. Fishery Bulletin. 104:256-277.

Walsh HJ, Richardson DE, Marancik KE, Hare JA. 2015. Long-Term Changes in the Distributions of Larval and Adult Fish in the Northeast U.S. Shelf Ecosystem. PLoS One. 10(9):e0137382.

Walters C, Kitchell JF. 2001. Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. Canadian Journal of Fisheries and Aquatic Sciences. 58(1):39-50.

Ward-Paige CA, Britten GL, Bethea DM, Carlson JK. 2015. Characterizing and predicting essential habitat features for juvenile coastal sharks. Marine Ecology. 36(3):419-431.

Warlen SM, Able KW, Laban EH. 2002. Recruitment of larval Atlantic menhaden (Brevoortia tyrannus) to North Carolina and New Jersey estuaries: evidence for larval transport northward along the east coast of the United States. Fishery Bulletin. 100(3):609-623.

Watling L, Norse EA. 1998. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. Conservation Biology. 12(6):1180-1197.

Watson 3rd WH, Schaller SY, Chabot CC. 2009. The relationship between small- and large-scale movements of horseshoe crabs in the Great Bay Estuary and Limulus behavior in the laboratory. In: Tanacredi JT, Botton ML, Smith DR, editors. Biology and Conservation of Horseshoe Crabs. New York: Springer. p. 131-147.

Waye-Barker GA, McIlwaine P, Lozach S, Cooper KM. 2015. The effects of marine sand and gravel extraction on the sediment composition and macrofaunal community of a commercial dredging site (15 years post-dredging). Mar Pollut Bull. 99(1-2):207-215.

Weigmann S. 2016. Annotated checklist of the living sharks, batoids and chimaeras (Chondrichthyes) of the world, with a focus on biogeographical diversity. Journal of Fish Biology. 88(3):837-1037.

Weissberger EJ, Grassle JP. 2003. Settlement, first-year growth, and mortality of surfclams, Spisula solidissima. Estuarine, Coastal and Shelf Science. 56(3-4):669-684.

Welsh SA, Smith DR, Laney RW, Tipton RC. 2007. Tag-Based Estimates of Annual Fishing Mortality of a Mixed Atlantic Coastal Stock of Striped Bass. Transactions of the American Fisheries Society. 136(1):34-42.

Wenger AS, Harvey E, Wilson S, Rawson C, Newman SJ, Clarke D, Saunders BJ, Browne N, Travers MJ, McIlwain JL, et al. 2017. A critical analysis of the direct effects of dredging on fish. Fish and Fisheries. 18(5):967-985.

Wenner CA, Sedberry GR. 1989. Species Composition, Distribution, and Relative Abundance of Fishes in the Coastal Habitat off the Southeastern United States. Report No.: NMFS 79. 49 p.

Westin DT, Rogers BA. 1978. Synopsis of the biological data on the striped bass Morone saxatilis (Walbaum 1792). . Kingston, RI: University of Rhode Island.

Wicklund R. 1970. A puffer kill related to nocturnal behavior and adverse environmental changes. Underwater Naturalist. 6(3):28-29.

Wiernicki CJ, O'Brien MHP, Zhang F, Lyubchich V, Li M, Secor DH. 2020. The recurring impact of storm disturbance on black sea bass (Centropristis striata) movement behaviors in the Mid-Atlantic Bight. PLoS One. 15(12):e0239919.

Wijsman J, Dedert M, Schellekens T, Teal L, Kruchten Yv. 2012. Case Study Mussels – Modeling the effect of dredging on filter-feeding bivalves. IMARES. 52 p.

Wilber DH, Clarke DG. 2001. Biological Effects of Suspended Sediments: A Review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management. 21(4):855-875.

Wilk SJ, Morse WW, Ralph DE, Steady EJ. 1975. Life history aspects of New York Bight finfishes. Report No.: Lab. Ref. SHL 75-1. 265 p.

Wilk SJ, Morse WW, Stehlik LL. 1990. Annual cycles of gonad-somatic indices as indicators of spawning activity for selected species of finfish collected from the New York Bight. Fishery Bulletin. 88(4):775-786.

Willson MF, Halupka KC. 1995. Anadromous Fish as Keystone Species in Vertebrate Communities. Conservation Biology. 9(3):489-497.

Wood A, Wood H. 1927. A quantitative study of the marine mollusks of Cape May County, New Jersey. Nautilus. 41:8-18.

Woodhead PMJ. 1964. The death of north sea fish during the winter of 1962/63, particularly with reference to the sole,Solea vulgaris. Helgoländer Wissenschaftliche Meeresuntersuchungen. 10(1-4):283-300.

Woodley JD, Chornesky EA, Clifford PA, Jackson JBC, Kaufman LS, Knowlton N, Lang JC, Pearson MP, Porter JW, Rooney MC, et al. 1981. Hurricane Allen's Impact on Jamaican Coral Reefs. Science. 214(4522):749-755.

Worton BJ. 1989. Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies. Ecology. 70(1):164-168.

Wright PJ, Jensen H, Tuck I. 2000. The influence of sediment type on the distribution of the lesser sandeel, Ammodytes marinus. Journal of Sea Research. 44(3-4):243-256.

Wuenschel MJ, Able KW, Byrne D. 2009. Seasonal patterns of winter flounder Pseudopleuronectes americanus abundance and reproductive condition on the New York Bight continental shelf. J Fish Biol. 74(7):1508-1524.

Xu Y, Miles T, Schofield O. 2020. Physical processes controlling chlorophyll-a variability on the Mid-Atlantic Bight along northeast United States. Journal of Marine Systems. 212:103433.

Yergey ME, Grothues TM, Able KW, Crawford C, Decristofer K. 2012. Evaluating discard mortality of summer flounder (Paralichthys dentatus) in the commercial trawl fishery: Developing acoustic telemetry techniques. Fisheries Research. 115-116:72-81.

Zhang X, Haidvogel D, Munroe D, Powell EN, Klinck J, Mann R, Castruccio FS. 2015. Modeling larval connectivity of the Atlantic surfclams within the Middle Atlantic Bight: Model development, larval dispersal and metapopulation connectivity. Estuarine, Coastal and Shelf Science. 153:38-53.

Zhang X, Munroe D, Haidvogel D, Powell EN. 2016. Atlantic surfclam connectivity within the Middle Atlantic Bight: Mechanisms underlying variation in larval transport and settlement. Estuarine, Coastal and Shelf Science. 173:65-78.

Zhu C, Liu Z. 2020. Weakening Atlantic overturning circulation causes South Atlantic salinity pile-up. Nature Climate Change. 10(11):998-1003.

Appendix A: Trophic and Life History Guilds

Table A.1 presents a summary of trophic and spawning life history for economically or ecologically important macro-invertebrates and fishes of the New York Bight. A "Yes" in columns 2–5 indicates that these classes are common prey of the predator named in column 1. "Clutch" in the spawning guild column indicates that eggs are cohesive, either by way of sticky demersal or buried deposition, or carrying by the females independent of subsequent dispersal form.

Table A.1. Simplified crosstab of species feeding and reproductive guild

Predators	Fishes and Squids	Plankton	Infauna	Epifauna	Feeding Guild	Spawning Guild
Atl. Horseshoe Crab	-	-	Yes	Yes	Benthivore	Estuarine clutch
American Lobster	-	-	Yes	Yes	Benthivore	Clutch, planktonic
Rock and Jonah Crab	-	-	Yes	Yes	Benthivore	Clutch, planktonic
Squid	Yes	Yes	-	-	Piscivore	Clutch, planktonic
Atlantic Hagfish	Yes	-	Yes	Yes	Generalist	Unknown
Sea lamprey	Yes	-	-	-	Piscivore	Anadromous
Sand Tiger	Yes	-	Yes	Yes	Generalist	Live birth
White Shark	Yes	-	-	-	Piscivore	Live Birth
Shortfin Mako	Yes	-	-	-	Piscivore	Live Birth
Porbeagle	Yes	-	-	-	Piscivore	Live Birth
Basking Shark	-	Yes	-	-	Planktivore	Live Birth
Common Thresher	Yes	-	-	-	Piscivore	Live Birth
Smooth Dogfish	Yes	-	Yes	Yes	Generalist	Live Birth
Tiger Shark	Yes	-	Yes	Yes	Generalist	Live Birth
Atlantic Sharpnose Shark	Yes	-	-	-	Piscivore	Live Birth
Dusky Shark	Yes	-	-	-	Piscivore	Live Birth
Sandbar Shark	Yes	-	Yes	Yes	Piscivore	Live Birth
blacktip shark	Yes	-	-	-	Piscivore	Live Birth
Bonnethead	Yes	-	-	-	Piscivore	Live Birth
Smooth Hammerhead	Yes	-	-	-	Piscivore	Live Birth
Spiny Dogfish	Yes	-	Yes	Yes	Piscivore	Live Birth
Atlantic Torpedo	Yes	-	-	-	Piscivore	Live Birth
Thorny Skate	-	-	Yes	Yes	Benthivore	Capsule
Barndoor Skate	-	-	Yes	Yes	Benthivore	Capsule
Little Skate	-	-	Yes	Yes	Benthivore	Capsule
Rosette Skate	-	-	Yes	Yes	Benthivore	Capsule
Winter Skate	Yes	-	Yes	Yes	Benthivore	Capsule
Smooth Skate	-	-	Yes	Yes	Benthivore	Capsule
Clearnose Skate	Yes	-	Yes	Yes	Benthivore	Capsule

Predators	Fishes and Squids	Plankton	Infauna	Epifauna	Feeding Guild	Spawning Guild
Roughtail Stingray	-	-	Yes	Yes	Benthivore	Capsule
Bullnose Ray	-	-	Yes	Yes	Benthivore	Live birth
Cownose Ray	-	-	Yes	Yes	Benthivore	Live birth
Spiny Butterfly Ray	-	-	Yes	Yes	Benthivore	Live birth
Atlantic Sturgeon	Yes	-	Yes	Yes	Benthivore	Anadromous
Striped Anchovy	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Bay Anchovy	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Blueback Herring	-	Yes	-	-	Planktivore	Anadromous
Alewife	-	Yes	-	-	Planktivore	Anadromous
American Shad	-	Yes	-	-	Planktivore	Anadromous
Hickory Shad	-	Yes	-	-	Planktivore	Estuarine/Planktonic
Atlantic Menhaden	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Atlantic Herring	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Round Herring	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Atlantic Thread Herring	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Fawn Cusk-Eel	-	-	-	-	-	Broadcast/Planktonic
Striped Cusk-Eel	-	-	-	-	-	Broadcast/Planktonic
Silver Hake	-	-	-	-	-	Broadcast/Planktonic
Cusk	-	-	Yes	-	Generalist	Broadcast/Planktonic
Atlantic Cod	-	-	Yes	-	Generalist	Broadcast/Planktonic
Haddock	-	-	Yes	-	Generalist	Broadcast/Planktonic
Pollock	-	-	Yes	-	Generalist	Broadcast/Planktonic
Red Hake	-	-	Yes	-	Generalist	Broadcast/Planktonic
Spotted Hake	-	-	Yes	-	Generalist	Broadcast/Planktonic
White Hake	-	-	Yes	-	Generalist	Broadcast/Planktonic
Goosefish	Yes	-	-	-	Piscivore	Veil/Planktonic
Atlantic Silverside	-	Yes	-	-	Planktivore	Estuarine clutch
Atlantic Flyingfish	-	Yes	-	-	Planktivore	Adhesive eggs, planktonic larvae
Northern Searobin	-	Yes	-	-	Generalist	Broadcast/Planktonic
Striped Searobin	-	-	-	-	Generalist	Broadcast/Planktonic
Striped Bass	Yes	-	Yes	-	Generalist	Anadromous
Black Sea Bass	Yes	Yes	Yes	Yes	Generalist	Broadcast/Planktonic
Bluefish	Yes	-	-	-	Generalist	Broadcast/Planktonic
Small Jacks	Yes	Yes	-	-	Generalist	Broadcast/Planktonic
Scup	Yes	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Weakfish	Yes	-	-	-	Generalist	Broadcast/Planktonic
Spot	-	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Northern Kingfish	-	-	Yes	-	Benthivore	Broadcast/Planktonic

Predators	Fishes and Squids	Plankton	Infauna	Epifauna	Feeding Guild	Spawning Guild
Tautog	-	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Cunner	-	Yes	Yes	Yes	Generalist	Broadcast/Planktonic
Ocean Pout	-	-	-	Yes	Benthivore	Clutch/Brood
Sandlance	-	Yes	-	-	Planktivore	Adhesive eggs, planktonic larvae
Little Tunny	Yes	Yes	-	-	Piscivore	Broadcast/Planktonic
Atlantic Bonito	Yes	Yes	-	-	Piscivore	Broadcast/Planktonic
Atlantic Chub Mackerel	-	Yes	-	-	Planktivore	Broadcast/Planktonic
Atlantic Mackerel	-	Yes	-	-	Planktivore	Broadcast/Planktonic
King Mackerel	Yes	-	-	-	Piscivore	Broadcast/Planktonic
Spanish Mackerel	Yes	-	-	-	Piscivore	Broadcast/Planktonic
Bluefin Tuna	Yes	-	-	-	Piscivore	Broadcast/Planktonic
Butterfish	Yes	Yes	-	-	Planktivore	Broadcast/Planktonic
Windowpane	Yes	-	-	-	Benthivore	Broadcast/Planktonic
Gulf Stream Flounder	-	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Smallmouth Flounder	-	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Summer Flounder	Yes	-	-	-	Piscivore	Broadcast/Planktonic
Fourspot Flounder	Yes	-	-	-	-	Broadcast/Planktonic
Yellowtail Flounder	Yes	-	Yes	Yes	Benthivore	Broadcast/Planktonic
Winter Flounder	Yes	-	Yes	Yes	Benthivore	Adhesive eggs, planktonic larvae
Gray Triggerfish	-	Yes	Yes	Yes	Benthivore	Broadcast/Planktonic
Ocean Sunfish	Yes	Yes	-	-	Planktivore	Broadcast/Planktonic

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM’s Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).