ECOSYSTEM-BASED FISHERIES MANAGEMENT
IN CHESAPEAKE BAY

# Atlantic Menhaden

Atlantic menhaden, *Brevoortia tyrannus*, support the Chesapeake Bay's largest fishery. They are also key players in the Bay's food web — filtering plankton, cycling and recycling nutrients, and serving as prey for piscivores (Figure 1). In many ways, menhaden epitomize arguments in support of ecosystem-based fisheries management (EBFM). Precautionary management that minimizes risk of collapse of the species will contribute to the well-being of the Bay, its fisheries, and water quality.

## The Fishery and Uses

Some fishing for Atlantic menhaden has occurred since colonial times, but industrial scale harvest using purse-seine gear began in New England in the mid 1800s. Purse-seine landings of menhaden peaked in the 1950s when ~712,100 metric tons were taken (Figure 2). At this time over 20 menhaden factories — from northern Florida to southern Maine — processed the catch. In the 1960s, the Atlantic menhaden stock contracted geographically, and many of the factories, particularly north of Chesapeake Bay, closed because of a scarcity of fish.

A primary use for menhaden is in creating fishmeal and fish oil, so-called "reduction" products. By 1989 all shore-side reduction plants in New England had closed mainly because of odor abatement issues with local municipalities. In the late 90's remaining reduction plants began to shut down or consolidate due to declining populations. Since 2005, the only surviving plant is located in Reedville, VA (owned by Omega Protein, Inc.). In recent years (2005-08) landings at Reedville have averaged 154,980 metric tons. Total value of fisheries landings at the port of Reedville for this period averaged $26 million — an overwhelming proportion was menhaden for reduction purposes.

Purse-seine fishing for menhaden has been prohibited in Maryland waters, including Chesapeake Bay, since 1931. Within the geographic range of the current menhaden reduction fleet, Virginia and North Carolina are the only states that permit menhaden reduction purse-seine fishing in their state waters.

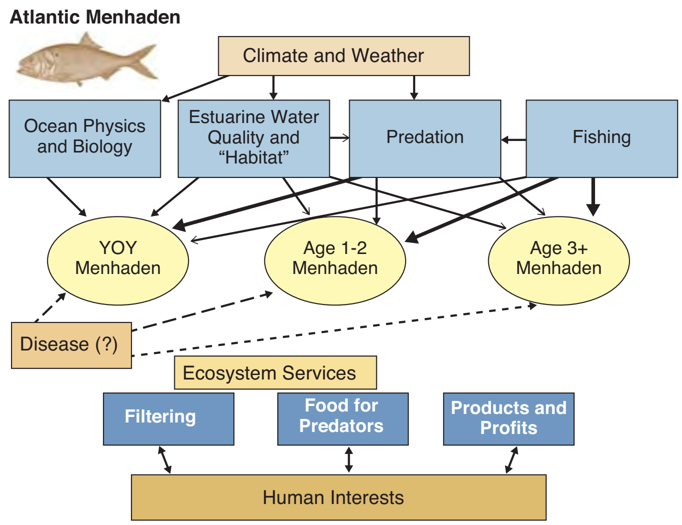


*Figure 1. Diagrammatic representation of factors affecting the ecology and dynamics of Atlantic menhaden, including fishing, and a depiction of its role in the Chesapeake Bay ecosystem. Source: EBFM Menhaden Background and Issue Briefs.*


*Figure 2. Historical Atlantic menhaden commercial coastwide landings. Source: EBFM Menhaden Background and Issue Briefs.*

The industrial reduction process for menhaden yields three main products: fish meal, fish oil, and fish soluble which are valuable ingredients in poultry, swine, equine, and aquaculture feeds. In recent years significant amounts of fish oil are also used domestically as edible oils since the Food and Drug Administration approved refined menhaden oil for general use in foods in 1997. Omega Protein, Inc. operates the only marine oil refinery in the U.S. and produces several grades of refined menhaden oil, rich in omega-3 oils and now incorporated into various human food products.

Atlantic menhaden are also harvested commercially as bait for crab pots, lobster pots, and hook-and-line fisheries. As reduction landings have declined in recent years, menhaden landings for bait have become relatively more important to the coastwide total landings of menhaden. Regional landings of menhaden for bait are dominated by catches in Chesapeake Bay and New Jersey (Figure 3). Recreational fishermen catch menhaden for bait when fishing for striped bass, bluefish, and sharks.

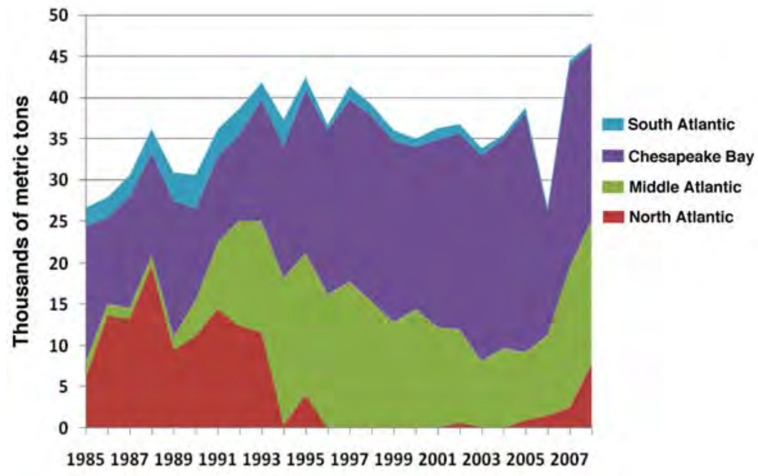


*Figure 3. Coastwide landings of Atlantic menhaden for bait, by region, 1985-2008. Source: EBFM Menhaden Background and Issue Briefs.*

## Management and Monitoring

According to the most recent menhaden stock assessment (2006), the fishery is not overfished, nor is overfishing occurring. The Atlantic menhaden is believed to be a single coastwide stock and the Atlantic States Marine Fisheries Commission (ASMFC) is responsible for oversight from Maine through the east coast of Florida. The Atlantic Menhaden Management Board (Board), part of ASMFC, directs management of the species. Individual states and jurisdictions are required to implement regulations consistent with ASMFC plans. The ASMFC approved the Interstate Fishery Management Plan (FMP) for menhaden in 1981. It has been amended twice and modified through a series of three addenda. The plan was revised in 1992, adopting several "management triggers" to annually evaluate the stock and fishery. The revision focused attention on a management approach that would assist in managing in a manner that is "biologically, economically, socially, and ecologically sound." It established biological reference points, instituted a five-year harvest cap for reduction landings from Chesapeake Bay, and initiated a research program to evaluate localized depletion.

There are no coastwide regulations in place to restrict menhaden harvest. Individual states have adopted a suite of regulations for the menhaden reduction and bait fisheries, including gear restrictions and seasonal closures. Fishery-independent monitoring of menhaden is conducted as part of several states' surveys, including striped bass young-of-the-year (YOY) seine surveys in Virginia and Maryland.

Fishery-dependent monitoring is conducted mostly on the reduction fishery. However, as bait landings have increased in recent years, they have become an important source of age and length data. In addition, a fishery-dependent index of abundance was developed from commercial pound net landings and effort in the Potomac River.

## Ecosystem Considerations

The Atlantic menhaden has a complex life history — accordingly there are various ecological factors that impact stock health. Survival of earliest life stages depends on environmental and hydrographic conditions on the continental shelf. Small changes in habitat suitability, climate effects (warming, pH changes, etc.), or predator-prey interactions can translate into order-of-magnitude differences in abundance or can force geographical shifts in spawning sites, nursery locations, and transport pathways of larvae. A suite of environmental and biological conditions are thought to impact successful recruitment and growth of YOY menhaden (a critical life phase that can regulate adult population abundance).

## Habitat Issues and Drivers

### *Oceanographic Factors*

Atlantic menhaden are distributed from the Gulf of Maine to the east coast of Florida. Larvae, juveniles, and sub-adults have been found throughout the year in Chesapeake Bay. Given the complex life cycle and the variability in habitats occupied by different life stages, it is not surprising that menhaden are found across a wide range of hydrographic and environmental conditions (Figure 4).

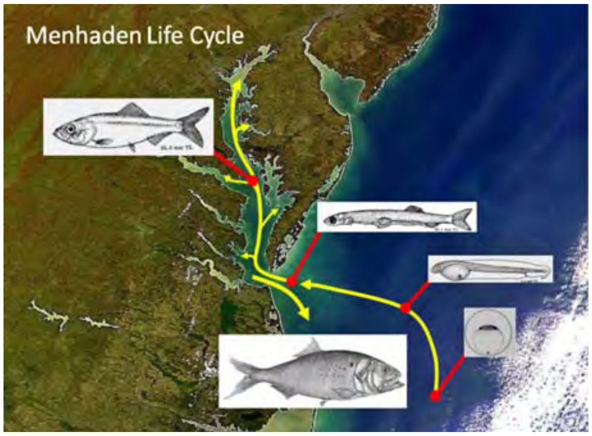


*Figure 4. Life cycle of Atlantic menhaden with respect to the Mid-Atlantic region and Chesapeake Bay. Source: EBFM Menhaden Background and Issue Briefs.*

### Hydrography and Circulation Features and Biological Oceanography

Hydrography and circulation patterns are thought to heavily influence menhaden distribution throughout their life cycle. Temperature exerts the primary hydrographic control over seasonal migration patterns, areas of abundance, and reproductive activities. Ocean circulation also plays an important role in cueing reproduction and in controlling dispersal of larval stages, assuring that some larvae are transported to juvenile nurseries in coastal estuaries and embayments. Winds and tides are thought to play a prominent role here as well. Larval behavior, tuned and responsive to ocean conditions, ensures connectivity between shelf and estuary/embayment ecosystems. Juvenile YOY menhaden in the estuary feed primarily on phytoplankton and they appear to use gradient search behaviors to find plankton food resources in estuaries, resulting in highly patterned distributions. It is believed that interannual variability in recruitment is at least partly controlled by these oceanographic conditions.

### Water Quality and Habitat Considerations

The Bay has experienced profound changes due to agriculture, recreational use, and development — all may impact menhaden productivity either directly or indirectly. Deforestation, nutrient loading, urbanization, and runoff have exacerbated eutrophication and expanded anoxic zones. Wetlands have been drained and buffer zones have been reduced. Areas without adequate buffer are not protected from stormwater runoff, which results in further erosion and increased sediment into the Bay.

Diminished water quality in the Chesapeake Bay is thought to be a factor in the decline of populations of filter-feeding animals, including menhaden. Because menhaden diet changes ontogenetically with changes in their morphology, removal of phytoplankton, zooplankton, and detrital particles could significantly affect the species. Quantity and quality of phytoplankton and zooplankton affect growth and recruitment of juvenile menhaden. Plankton populations also vary in abundance and taxonomic composition from year to year in response to variable climatic and environmental factors in Chesapeake Bay.

Habitat degradation impacts habitat use and productivity of menhaden in the coastal ocean, estuaries, and embayments. Hypoxic volume has expanded in Chesapeake Bay since the1950s and has resulted in loss of available habitat. Localized hypoxia results in habitat squeeze if the cooler, deeper waters of the Bay are unavailable due to anoxia. Turbidity and other water quality problems are significant in the Bay and may be factors affecting recruitment and production. Loss of wetlands and increases in impervious surfaces due to human construction activity may impact menhaden adversely as well. Wetlands act as natural filters between land and water and are a source of detrital particles. Impervious surfaces increase the rate at which nutrients, sediment, and contaminants are delivered to tributaries, exacerbating eutrophication and expansion of anoxic zones.

### Climate Change

Although climate change is a major issue for the Bay ecosystem, relatively little is known about its potential effects on specific fisheries populations. The effects of climate change are projected to include: increased water temperatures, sea-level rise, change in precipitation patterns, changes in climate variability that includes increased storm and drought events, and ocean acidification. These changes will influence salinity, temperature, and nutrients in menhaden nursery grounds in Chesapeake Bay. Shifting oceanographic and hydrographic conditions in the coastal ocean would affect adult menhaden spawning areas and times, as well as dispersal and transport pathways that deliver larvae to the mouth of Chesapeake Bay. Increased severity of droughts and flood events would affect primary productivity and zooplankton production and could compromise larval menhaden feeding and survival. The most immediate concern with respect to menhaden would be stressors that affect early life stages in the open ocean and the impact of a highly altered community of primary and secondary producers on menhaden feeding.

## Foodweb Issues and Drivers

### Foods, Foraging, and Productivity of Menhaden

Atlantic menhaden occupy two distinct feeding niches during their lifetime. Menhaden are size-selective zooplankton feeders as larvae and filter feeders as juveniles and adults. Juvenile and adult menhaden strain phytoplankton, zooplankton, and detritus on their sieve-like gill rakers. Because of their abundance, rapid growth, and seasonal migrations, menhaden annually consume and redistribute large amounts of energy and materials throughout estuaries and continental shelf waters. Because of their significant herbivorous role along the Atlantic coast, menhaden may contribute significantly to top-down control of the Chesapeake Bay ecosystem (Figure 5). In recent years, recruitment of YOY menhaden has been positively correlated with primary production (via chl-α levels). This relationship is observed during the critical time period when menhaden larvae transform to juveniles and make a transition from selective zooplankton feeding to filter feeding primarily on phytoplankton. This relationship suggests that reductions in phytoplankton biomass would negatively affect menhaden growth.

### *Predation*

Atlantic menhaden are important forage for many fish, bird, and mammalian predators along the Atlantic Coast. Menhaden are also prey for several economically important recreational and commercial fisheries in Chesapeake Bay, including striped bass, weakfish, and bluefish. Of these, striped bass are most likely to have a large impact on menhaden abundance. Reduced fishing mortality and higher minimum size limits that restored the coastal striped bass population during the 1980s and 1990s led to more abundant and larger striped bass, increasing their predatory demand for Atlantic menhaden. Piscivorous bird populations (bald eagle, osprey, terns, gannet, loons, great blue heron, double-crested cormorant, brown pelican, and sea gulls) have also grown exponentially throughout the tidal reaches of Chesapeake Bay since the close of the DDT era. Increases in bird populations leads to greater predation pressure on menhaden stocks.

### *Competition*

Because Atlantic menhaden are pelagic planktivores in all life stages, the potential for competitive interactions rests primarily on availability of planktonic food resources. There is evidence that intra-specific competition may be important in controlling or regulating growth and recruitment levels. Growth, productivity, and recruitment levels of the menhaden stock may be limited by both quantity and quality of planktonic food resources, increasing the potential for competitive interaction in cases where food is limiting. Specific competitors of larval-stage Atlantic menhaden are not known although other fish larvae and invertebrate carnivores are likely competitors. After ingress into Chesapeake Bay, late-stage larvae may compete with larvae of anadromous and estuarine fishes (striped bass, white perch, shads, and river herrings) as well as other planktivorous juvenile and adult fishes (bay anchovy, silversides, juvenile alosines, and gizzard shad).

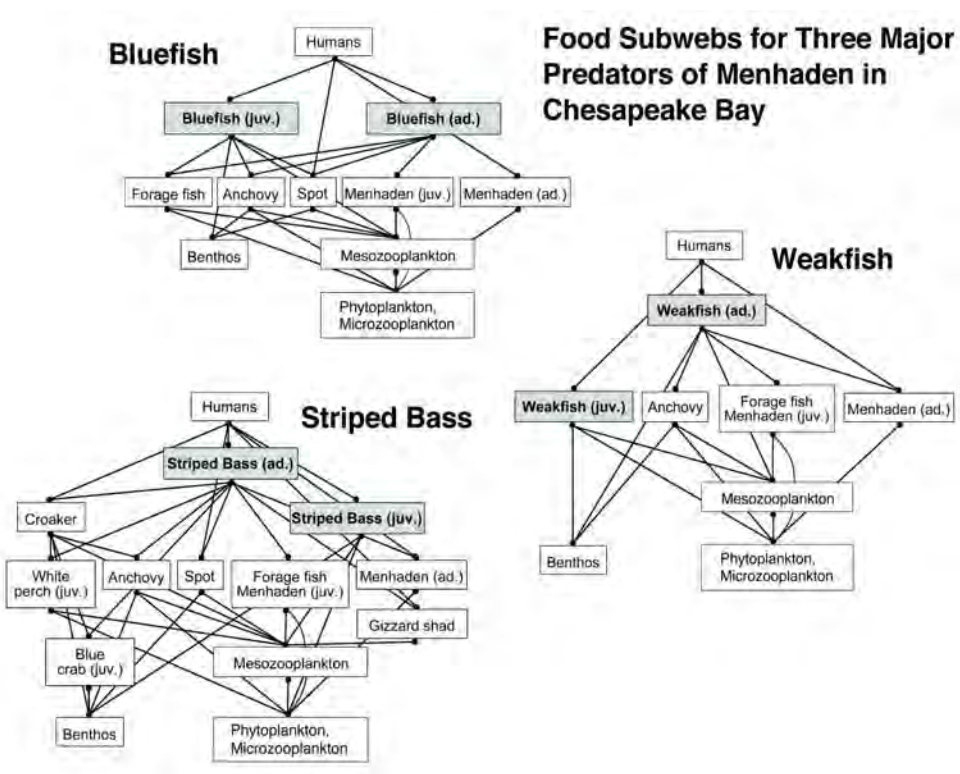


*Figure 5. Conceptual models of food subwebs for bluefish, striped bass, and weakfish — three major predators of Atlantic menhaden in Chesapeake Bay. Note the prominent position of menhaden in the subwebs. Source: Modified from figures in CBFEAP (2006).*

## Stock Dynamics Issues and Drivers

Based on results from YOY survey abundance estimates in the Chesapeake Bay, menhaden recruitment levels have been low for nearly two decades. Most eggs are spawned over the continental shelf in the coastal ocean from Florida to the Gulf of Maine. The relatively short stage duration of eggs suggests that this life stage may not control recruitment levels. In the estuary, YOY menhaden experience critical transitions in habitat, morphology, and diet. Recruitment to the adult population and growth during this period is dependent on favorable environmental and water quality conditions. Although different temporal spawning cohorts of menhaden exist, they appear to mix rapidly as a result of their extensive migratory movements and are virtually inseparable in the commercial fishery. Based on size-frequency information and tagging studies, the menhaden resource is believed to consist of a single unit stock and recent genetic studies support this.

### *Connectivity and Regional Abundance*

Research has shown that Atlantic menhaden distribute and move along the coast during late spring and summer, separated and aggregated by size and age (Figure 6). During the warm season (April — October) menhaden are distributed along the coast from Florida to Maine. The larger and older the fish are, the farther North they are found. By the end of fall, fish of all ages migrate to the South Atlantic (south of Cape Hatteras) forming a mixed overwintering population. At the end of winter, menhaden begin a northward migration, repopulating coastal areas on their way, including Chesapeake Bay, and stratifying by size and age. Thus, the Chesapeake Bay is repopulated each year by menhaden of variable ages (primarily age-1 through age-3).

### *Recruitment Variability*

Recruitment is a function of population fecundity (eggs produced by mature females) and subsequent survival through

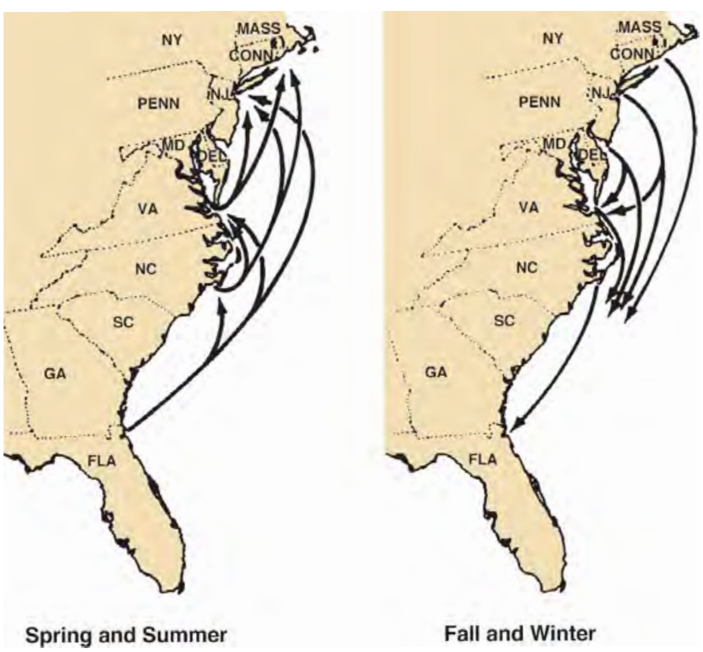


*Figure 6. Generalized movements of tagged adult Atlantic menhaden. Source: Dryfoos et al. 1973.*

the early portion of life. Early life stage survival is typically controlled by the environmental factors discussed earlier (both biological and physical). How reproductive health is distributed along the coast of the U.S. is fundamental to stock assessments and is related to annual migration patterns as well as maturation and fecundity of adult females. Inter-annual variability in migration schedules and fecundity are not well described and could contribute to coastwide and Chesapeake Bay recruitment success. Excessive fishing mortality also reduces spawning biomass, shortens average lifespan, and potentially erodes stock productivity and recruitment potential. Mean population abundance, size, and age of menhaden in the Bay are important indicators of age structure, growth, recruitment success, and production in the Bay and must be considered when developing ecosystem-based management approaches.

The present, two-decade period of low recruitment to Chesapeake Bay is an issue of concern and has fueled the debate over "localized depletion," and management of the fishery in the Bay. The primary concern is our poor understanding of how environmental factors affect recruitment of young menhaden to the adult stock. Additionally, it is not known how reproductive strength (spawning stock) interacts with environmental factors to regulate recruitment success, either coastwide or in Chesapeake Bay. This issue has coastwide implications because of the weight given to the recruitment contribution from the Bay to the coastwide stock during stock assessments.

### *Stock Assessment*

The latest stock assessment of Atlantic menhaden was conducted in 2006 at the coastwide level, and suggests a general decline in fishing mortality from a peak in 1965 (Figure 7). This decline is largely attributable to the consolidation of the reduction industry and closure of plants along the coast. An explicit strategy for allocating menhaden among competing sectors in Chesapeake Bay has not been developed. This deficiency is largely because only a portion of the stock is found within the Bay, and estimates of standing stock within the Bay are unavailable. Consequently, metrics for exploitation that are representative of Chesapeake Bay presently cannot be determined.

### *Localized Depletion*

"Localized depletion" in Chesapeake Bay is defined as a "reduction in menhaden population size or density below the level of abundance that is sufficient to maintain its basic ecological (e.g., forage base, grazer of plankton), economic, and social/cultural functions." It can occur as a result of fishing pressure, environmental conditions, and predation pressures on a limited spatial and temporal scale. The argument


*Figure 7. Atlantic menhaden fishing mortality rate (F). Source: Coastwide model, 1955-2005.*

for "localized depletion" arises from the concern that Atlantic menhaden removals from Chesapeake Bay are excessive and compromise the ability of menhaden to fulfill their ecosystem services, namely their forage and nutrient-cycling roles. At this time, the definition does not allow for quantification of level or severity but it is an issue of concern because it could lead to compromised predator-prey relationships, reduction in nutrient cycling, and chronic low recruitment via larval ingress of menhaden to the Chesapeake system.

### *Disease/Fish Kills*

Reports of fish kills involving Atlantic menhaden have historically been associated with low oxygen levels. However in recent years, fish kills have attracted a more intense interest because of an exhibited spinning behavior caused by a viral agent. Fish kills resulting from skin lesions, reported in menhaden since 1984, are identical to other ulcerative diseases seen across the world, and now are collectively termed epizootic ulcerative syndrome (EUS). Research is needed to address the causes of disease and fish kills, effects on menhaden populations, and effects of reduced menhaden population size on other species and water quality.

## Socioeconomics Issues and Drivers

### *Trophic Importance*

As discussed, menhaden are a dominant planktivore in Chesapeake Bay and provide important links in the foodweb through efficiently transforming primary productivity into biomass, which is then consumed by numerous predators. Menhaden are also an important vector for energy transfer through converting and exchanging energy and organic matter via sequestering, cycling, and transporting nutrients within, to, and from Chesapeake Bay.

### *User Conflicts*

Disputes with respect to user conflicts over the menhaden resource normally include five core issues: fishing operations and distance from shore, by-catch, forage base, water quality, and management. Purse-seine fishing operations for menhaden are highly visible. Vessels are large (up to 200 feet long) catching tens of thousands of pounds of menhaden per net set. Attendant spotter aircraft often herald the arrival of the fleet. Moreover, vessels often operate at times of peak tourism and waterfront usage. As use of public waters has increased in recent decades, competition for space and resources among menhaden vessels, recreational fishermen, and waterfront property owners has escalated into conflict. The regulatory trend of Atlantic coastal states relative to menhaden purse-seining has been one of progressive area closures, often based on societal decisions unrelated to the status of the menhaden resource. Many coastal communities are not fond of menhaden reduction factories, because of aesthetic and odor abatement issues. Areas for fishing for menhaden are getting smaller and smaller, with ever greater fishing effort concentrated in Chesapeake Bay. Not surprisingly, such fishing effort by large commercial operators in a relatively small portion of Chesapeake Bay has been the source of considerable friction.

### *Industry and Economics*

The fish factory at Reedville (northeastern Virginia) is an important local industry and employs about 250 people. Landings of Atlantic menhaden for reduction in recent years (2005-08) have averaged 154,980 metric tons. In 2007, menhaden landings for reduction in Virginia represented 27% of all fisheries landings on the U.S. East coast. That year, Reedville ranked second among U.S. ports in terms of total weight of fisheries landings, and 28th in terms of value. The reduction process for menhaden yields three main products used in agriculture and for human consumption: fish meal, fish oil, and fish solubles. Over the past decade, a transformation of the industry has been occurring, with larger quantities of menhaden meal now being milled into aquaculture feeds, and there are concerns that this shift in demand for menhaden has the potential to spur unsustainable fishing on these resources. The bait fishery for menhaden is also significant, harvested commercially for crab pots, lobster pots, and hook-and-line fisheries in almost all U.S. East Coast states, amounting to 25% of the total Atlantic menhaden landings (in 2008). Significant quantities of menhaden are also packed and frozen as bait or ground chum for recreational and charter fishermen, thus linking the commercial and recreational fishing industries.

Table 1. Critical ecosystem considerations for Atlantic menhaden in Chesapeake Bay.

| Ecosystem Stressor | | Issues/Drivers/Stressors |
|---|---|---|
| 1. Habitat | a. Oceanographic Factors | • Interannual variability in hydrography and circulation impact survival, production, and dispersal of menhaden eggs and larvae.<br>• Oceanographic regime shifts can shift spawning patterns, larval production, dispersal pathways, and distribution of larval ingress along the coast. |
| | b. Water Quality | • Nutrient loading and resulting increases in turbidity impact menhaden filtering capacity.<br>• Water quality directly impacts the structure and extent of the plankton community thereby impacting menhaden diets.<br>• Hypoxia impacts menhaden behavior, distribution patterns, and availability of suitable habitat in the Bay. |
| | c. Historic Changes over Time | • Land use and watershed development impact buffer zones integral for providing protection and filtration to the Bay ecosystem.<br>• Increasing runoff from urbanization yields debris and pollutants, increasing sediment load and turbidity, which impacts the distribution and abundance of phytoplankton and degrades the health of the ecosystem. |
| | d. Climate Change | • Increasing temperature, freshwater input, changes in pH, nutrient, and salinity levels resulting from climate change may impact menhaden temporal and spatial spawning patterns, stock productivity, and available juvenile habitat. |
| 2. Foodwebs | a. Community and Forage | • Natural and anthropogenic forcing factors directly impact plankton community structure, affecting menhaden food quality and quantity. |
| | b. Predation | • Changes in predator populations (humans, birds, and other fish) and behavioral patterns impact predation pressure on menhaden. |
| | c. Competition | • Because both intra- and inter-specific competition occurs within menhaden populations and among other species that share similar prey size and type, any changes in competitor populations will impact competition pressure. |
| 3. Stock Dynamics | a. Recruitment Variability | • Steadily decreasing recruitment levels over the past twenty years requires a clearer understanding of the physical and biological drivers of recruitment, especially in the context of the contribution of recruits to the coastwide menhaden stock.<br>• A clearer picture of stock health (including new modeling efforts regarding juvenile abundance within and outside of the Bay) is needed to inform management decisions. |
| | b. Exploitation | • Spatially explicit and reliable monitoring programs are needed to obtain accurate estimates for fishing mortality (F), natural mortality (M), and environmental factors used in stock assessment models and subsequent management decisions. |
| | c. Disease/Fish Kills | • Increased eutrophic events, nutrient loading, hypoxia, and pollution may cause increased natural mortality.<br>• Epizootic ulcerative syndrome (EUS: fish kills resulting from skin lesions) may be increasing in Bay populations. |
| | d. Connectivity and Abundance | • The Bay contribution to coastwide menhaden recruitment is significant; therefore, suitable Bay habitat must be maintained for the health of the entire menhaden population stock. |
| 4. Socioeconomics | a. Ecosystem Services and User Conflicts | • To better understand the quantity and quality of the ecosystem services menhaden provide (forage, filtration, and prey base), ingress and egress rates between the coastal and Chesapeake Bay menhaden stocks must be better described.<br>• Because menhaden commercial vessels are large and visible from shore, and because peak fishing times coincide with tourist seasons, conflicts may arise between communities and the menhaden industry. |
| | b. Regional and National Economic Importance | • The fish factory at Reedville (northeastern Virginia — the lone surviving menhaden reduction factory) is important to the local economy, employing about 250 people. The reduction process for menhaden yields three main products used in agriculture and human health products: fish meal, fish oil, and fish solubles. Since the 1960s, all but the Reedville factory have closed; demographic changes resulting from these closures are poorly understood.<br>• Landings of Atlantic menhaden for reduction in recent years represent a large percentage of all fisheries landings on the U.S. East Coast (among U.S. ports in terms of total weight of fisheries landings, and in terms of value).<br>• Menhaden provide an important bait fishery and are harvested commercially for crab pots, lobster pots, and hook-and-line fisheries in almost all U.S. East Coast states. |

**The Ecosystem-Based Fisheries Management (EBFM) Project for Chesapeake Bay** *has been developed and coordinated by Maryland Sea Grant, working in partnership with the scientific community and the region's state and federal agencies (the Virginia Marine Resources Commission, Maryland Department of Natural Resources, Potomac River Fisheries Commission, Atlantic States Marine Fisheries Commission, District of Columbia Department of the Environment, NOAA, and EPA). The EBFM Project targets five key species identified in the Ecosystem Planning for Chesapeake Bay document, including striped bass, menhaden, blue crab, alosines, and oysters. The goals of the EBFM project are to build a sustainable mechanism for addressing ecosystem issues for fisheries within Chesapeake Bay and to develop ecosystem tools for use in ecosystem-based fishery management plans for the five key species (or group of species in the case of alosines). Currently the project involves 85 scientists, managers, and stakeholders from within and beyond the Chesapeake Bay region. For more information on Maryland Sea Grant's Ecosystem-Based Fishery Management Project please visit: www.mdsg.umd.edu/ebfm.*

## Authors and Editors

The information in this summary brief was adapted from the EBFM for Chesapeake Bay Menhaden Background and Issue Briefs authored by the Menhaden Species Team members: Ed Houde (UMCES-CBL, Chair), Eric Annis (Hood College), Kevin Friedland (NMFS Narragansett), Cynthia Jones (Old Dominion University), Raemarie Johnson (VIMS), Alexei Sharov (MD DNR), Joe Smith (NMFS Beaufort), Braddock Spear (ASMFC), Jim Uphoff (MD DNR), Doug Vaughan (NMFS Beaufort), Marek Topolski (MD DNR). Alesia Read, Jonathan Kramer, Shannon Green, and Jessica Smits served as editors.

## For More Information and References

Please visit our website for more information on the Menhaden Species Team and all other information related to the Ecosystem-Based Fisheries Management Program at Maryland Sea Grant: www.mdsg.umd.edu/programs/policy/ebfm/

Further information and all references for primary literature can be found within the species briefs here: www.mdsg.umd.edu/programs/policy/ebfm/bioteam/menhaden/

This publication was prepared by Alesia Read and produced by Maryland Sea Grant.

Publication Number
UM-SG-TS-2011-03

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**A Maryland Sea Grant Publication**
**College Park, Maryland**