Forage Indicator Development Plan

Forage Action Team

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Chesapeake Bay Program
Science. Restoration. Partnership.

Purpose

The purpose of this plan is to provide an overview of the Forage Action Team's previous efforts leading toward indicator development as prescribed by the 2014 Chesapeake Bay Watershed Agreement's Forage Outcome, and to present a framework for developing forage indicators going forward. This document also identifies seven initial indicators to develop, potential data sources for indicator development, and approximate timelines for each proposed indicator.

Background

The Chesapeake Bay is the largest estuary in the United States, providing critical forage, nursery, and spawning habitat for many ecologically and economically important species along the East Coast, including blue crab (*Callinectes sapidus*), striped bass (*Morone saxatilis*), and even endangered species such as Atlantic sturgeon (*Acipenser oxyrhynchus*). The Chesapeake Bay has significant economic value, providing commercial, recreational, and subsistence fishing opportunities for the more than 18 million people living in the watershed, in addition to numerous visitors from outside the region, with more than 500 million pounds of seafood harvested from the Bay each year. To preserve this valuable ecosystem, resource managers use best management practices to ensure healthy habitat conditions (e.g., water quality, wetland restoration, aquatic vegetation), while fisheries managers use harvest regulations to prevent overfishing (e.g., size limits, creel limits, harvest seasons). Although managers are working on various aspects of ecosystem health, there are still challenges in making connections and implementing ecosystem-based management approaches.

In 2014, partners in the Chesapeake Bay Program signed the Chesapeake Bay Watershed Agreement, which aimed to improve effectiveness of restoration and management in the Bay by explicitly listing outcomes that would be carried out by designated Goal Implementation Teams (GITs). The goal of the Sustainable Fisheries GIT (SFGIT) takes an ecosystem-based approach, agreeing to "protect, restore, and enhance finfish, shellfish, and other living resources, their habitats, and ecological relationships to sustain all fisheries and provide for a balanced ecosystem in the watershed and Bay" (Chesapeake Bay Program 2014). The Forage Outcome in particular was developed with ecological relationships and ecosystem-based fisheries management (EBFM) in mind, striving to "continually improve the partnership's capacity to understand the role of forage fish populations in the Chesapeake Bay…and to develop a strategy for assessing the forage fish base available as food for predatory species."

To address the Forage Outcome, the Forage Action Team (FAT) was established and has since conducted workshops and studies focused on identifying important forage species and ways to evaluate their status based on abundance and predator-prey relationships. In 2014, the FAT conducted a workshop with the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) that determined the need for forage indicator development and identified a list of potential metrics to track forage status in the Bay over time (Ihde et al. 2015). In 2015, several members of the FAT conducted analyses to create four indicators of forage status in the Chesapeake Bay, including relative prey

abundance/biomass, diet-based indices, predator-prey ratios, and consumption-prey ratios (Buchheister & Houde 2016). A follow-up study was published, characterizing the temporal patterns and environmental effects on predator-prey relationships (Woodland et al. 2017). In a 2018 GIT-funded study, FAT members at the Virginia Institute of Marine Science (VIMS) developed thresholds at which hardened shoreline presence affects abundance of key forage species including juvenile blue crabs (Seitz et al. 2019). All of the information gathered from the STAC workshop and the following studies has laid the groundwork for developing a suite of indicators to track and assess the forage base in Chesapeake Bay.

Indicator Framework and Priorities

The FAT has agreed to continue building off of the recommendations of the STAC report and the previous research to develop an initial suite of indicators to assess the forage base in the Chesapeake Bay. This indicator suite is expected to operate as an assessment tool for tracking the health of the Bay and to eventually inform Chesapeake Bay Program (CBP) and fishery management. Each of these initial indicators addresses either CBP (e.g., water quality, habitat) or fisheries management interests (e.g., forage abundance, predator-prey relationships) identified previously by the FAT, and the information needed for development (e.g., data, preliminary analyses) are readily available. Ideally, these indicators will be developed within the next 18 months to two years.

Indicator development will be based on a tiered approach with increasing complexity. **Tier 1** is the most basic indicator and is a time series of abundance for a given forage species. **Tier 2** indicators use the relationships between environmental and/or habitat factors and forage abundance to track forage status over time. **Tier 3** is the most complex indicator, tracking changes in predator consumption of forage over time. Tier 1 and Tier 2 indicators are expected to be completed over the shorter term (within two years), whereas Tier 3 indicators will be completed in the longer term. Below are the seven priority indicators that will be developed to start the suite of forage indicators; note that these are just starting points and other indicators and species of interest will be considered in the future.

Tier 1: Forage Abundance

The forage abundance indicators will consist of time series of abundance or biomass for key forage species including benthic invertebrates, demersal finfishes, and pelagic finfishes to determine the status and trends of forage availability in the Chesapeake Bay. Baseline abundance, such as the mean or median of the time series, must be established, and anomalies must be defined to determine any significant changes in abundance trends over time. Standard deviation or standard error will likely be used to define expected variability and identify anomalies. Note that these abundance indicators will be developed using the best available data, which may be limited for some species. The FAT will continue to discuss options for addressing sampling challenges and consequent data gaps to develop more-refined indicators in the future.

Benthic Invertebrates

Abundance indicators for benthic invertebrates will use existing long-term benthic data to examine temporal variability of key benthic taxa in the Bay. The 2014 STAC workshop determined that benthic invertebrates were important components of predator diets in addition to finfish prey (Ihde et al. 2015). Polychaetes were the most common and abundant benthic taxa found in predator diets and will therefore be the initial focus of this indicator. Forage abundance indicators for other benthic

invertebrates, such as crustaceans (mysids are of particular interest to the FAT) and bivalves, will be developed in the future.

Data source: Chesapeake Bay Long-Term Benthic Monitoring and Assessment Program

Demersal Finfishes

Abundance indicators for demersal finfishes will focus on the temporal variability of critical finfish prey associated with structured and unstructured bottom habitats such as sand/mud flats, seagrass beds, marshes, and oyster reefs. Atlantic croaker (*Micropogonias undulatus*) is a demersal species, the juvenile stages of which are a key prey item for many larger fishes in the Bay (Ihde et al. 2015). Given its importance as forage and as a species of interest to fisheries managers, juvenile Atlantic croaker will be the initial focus of this indicator. Future indicators of demersal finfish abundance may include mummichog (*Fundulus heteroclitus*), spot (*Leiostomus xanthurus*), silver perch (*Bairdiella chrysoura*), and white perch (*Morone americana*).

Data sources:

Chesapeake Bay Fishery-Independent Multispecies Survey
Chesapeake Bay Multispecies Monitoring and Assessment Program
MDNR Juvenile Striped Bass Seine Survey
MDNR Upper Bay Winter Trawl Survey
VIMS Juvenile Fish and Blue Crab Trawl Survey
VIMS Juvenile Striped Bass Seine Survey

Pelagic Finfishes

Abundance indicators for pelagic finfishes will focus on the temporal variability of critical finfish prey associated with the water column in the Chesapeake Bay. Bay anchovy (*Anchoa mitchilli*) are the primary finfish prey in the Bay and are therefore the initial focus of this indicator (Ihde et al. 2015). Atlantic menhaden (*Brevoortia tyrannus*) is another good candidate for a future pelagic finfish abundance indicator.

Data sources:

ASMFC Species Stock Assessments—Data Manager: Pat Campfield, pcampfield@asmfc.org
Chesapeake Bay Fishery-Independent Multispecies Survey
Chesapeake Bay Multispecies Monitoring and Assessment Program
MDNR Juvenile Striped Bass Seine Survey
MDNR Upper Bay Winter Trawl Survey
VIMS Juvenile Fish and Blue Crab Trawl Survey
VIMS Juvenile Striped Bass Seine Survey

Tier 2: Habitat and Environmental Factors

Habitat and environmental indicators will include time series of suitable habitat availability and of other environmental conditions that have demonstrated impacts on forage abundance, such as water quality and hardened shorelines. These indicators are meant to make connections between forage abundance and habitat characteristics to improve our understanding of ecological relationships and to eventually inform EBFM. The FAT will also work with CBP partners (e.g., Water Quality GIT) to develop these indicators by making connections between forage habitat requirements and Chesapeake Bay conditions through existing monitoring and assessment efforts such as the Chesapeake Bay Total Maximum Daily Load (TMDL).

Springtime Warming

The springtime warming indicator will build off the work done by Woodland et al. (2017) and will use a phenological temperature index to determine the timing of warming water temperatures in the Chesapeake Bay. Woodland et al. (2017) determined that the rate of springtime warming (i.e., how quickly water temperatures reached a threshold in spring) has a negative relationship with summer forage abundance. That is, the earlier in the year that water temperature warms up, the less forage are available as prey in the Bay. The indicator will consist of a time series of the integer day each year at which 500 degree-days (DD) was achieved using 5°C as a threshold and will provide insight into the effects of climate change on the forage base. Bay anchovy are a key forage species that exhibited a significant negative relationship with the rate of springtime warming and will therefore be the initial focus of this indicator. Other finfish (e.g., YOY weakfish) and invertebrates (e.g., polychaetes, crustaceans) that exhibited a relationship can be used to develop indicators in the future.

Data sources:

Chesapeake Bay Fishery-Independent Multispecies Survey
Chesapeake Bay Long-Term Benthic Monitoring and Assessment Program
Chesapeake Bay Multispecies Monitoring and Assessment Program
Chesapeake Bay Program Water Quality Data
MDNR Juvenile Striped Bass Seine Survey
MDNR Upper Bay Winter Trawl Survey
NOAA Physical Sciences Laboratory Climate Data
VIMS Juvenile Fish and Blue Crab Trawl Survey
VIMS Juvenile Striped Bass Seine Survey

Habitat Suitability Index

The habitat suitability index will consist of a time series of area (or percent area of the Bay) available as suitable habitat for various forage species in the Chesapeake Bay. This indicator will be developed from the results of a habitat suitability modeling project being conducted by researchers at VIMS and AnchorQEA, which uses hydrodynamic models and water quality parameters (e.g., salinity, dissolved oxygen) to assess the extent of suitable habitat for four key forage species: bay anchovy, juvenile spot, juvenile weakfish (*Cynoscion regalis*), and juvenile spotted hake (*Urophycis regius*). The project, funded by the NOAA Chesapeake Bay Office, is expected to be finalized by December 2020, at which point the FAT can begin to develop a time series of available suitable habitat for the initial indicator species, bay anchovy.

Data sources:

MDNR Upper Bay Winter Trawl Survey
VIMS Juvenile Fish and Blue Crab Trawl Survey

Hardened Shorelines

The hardened shorelines indicator will build off of previous work done by Seitz et al. (2019), which examined relationships between forage abundance and percent hardened shoreline in a given area. The study results identified thresholds between 10-30% at which hardened shorelines began to affect forage abundance. For juvenile blue crabs, there was a 0.4% decrease in abundance with every 1% increase in shoreline development. The CBP GIS Team is also currently mapping out shoreline status throughout the Bay, which can be used in combination with the shoreline threshold study results to identify high-risk areas for forage that may be suffering from habitat loss. This indicator would ideally identify shoreline

development trends to help target restoration and conservation efforts throughout the Bay that will help maintain habitat for the forage base.

Data sources:

MDNR Juvenile Striped Bass Seine Survey
MDNR Upper Bay Winter Trawl Survey
VIMS Blue Crab Surveys – Data Manager: Rom Lipcius, rom@vims.edu
VIMS CCRM Shoreline and Tidal Marsh Inventory
VIMS Juvenile Fish and Blue Crab Trawl Survey
VIMS Juvenile Striped Bass Seine Survey

Tier 3: Predator Consumption

Diet Profiles

Predator consumption indicators will build off of previous work done by Buchheister and Houde (2016), consisting of time series of diet profiles (i.e., prey ratios in diets) of key predator species in the Bay. These indicators will improve understanding of how prey consumption changes over time and the relationship between prey preference and availability. The initial focus of this indicator will be striped bass (*Morone saxatilis*), a top fish predator and a species with significant management interest in Chesapeake Bay. In the future, these indicators will include both top pelagic (e.g., weakfish) and demersal (e.g., Atlantic croaker, blue catfish) finfish predators to encompass all feeding guilds. A new project led by VIMS and the University of Maryland Center for Environmental Science will estimate the abundance of two iconic species in the Bay, striped bass and Atlantic menhaden, which will provide more data for this and future indicator development. The FAT may also explore the potential to tie these indicators into bioenergetics models and indicators to assess the energy available to support predator fish populations in the Bay.

Data sources:

ASMFC Species Stock Assessments—Data Manager: Pat Campfield, pcampfield@asmfc.org
Chesapeake Bay Fishery-Independent Multispecies Survey
Chesapeake Bay Multispecies Monitoring and Assessment Program
MDNR Juvenile Striped Bass Seine Survey
MDNR Upper Bay Winter Trawl Survey
VIMS Juvenile Fish and Blue Crab Trawl Survey
VIMS Juvenile Striped Bass Seine Survey

Tier 1: Abundance	Species of Interest
Benthic Invertebrates	Polychaetes
Demersal Finfishes	Atlantic croaker
Pelagic Finfishes	Bay anchovy Atlantic menhaden
Tier 2: Habitat and Environmental Factors	**Species of Interest**
Springtime Warming	Bay anchovy Polychaetes
Habitat Suitability Index	Bay anchovy
Hardened Shorelines	Juvenile blue crabs
Tier 3: Predator Consumption	**Species of Interest**
Diet Profiles	Striped bass

Figure 1. The seven proposed priority indicators in their respective tiers and suggested focal species for each.

References

Buchheister A, Houde ED (2016) Forage indicators and nutritional profiles for Chesapeake Bay fishes. Final report to Chesapeake Bay Trust, Ref No [UMCES]CBL 2016-001. https://cbtrust.org/wp-content/uploads/FY14-Forage-fish-indicator-metric-development-1.pdf

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Woodland R, Buchheister A, Latour R, Lozano C, Fabrizio M, Tuckey T, Sweetman C (2017) Environmental, spatial, and temporal patterns in Chesapeake Bay forage population distributions and predator consumption. Final report to Chesapeake Bay Trust, Ref No CBL2016-043CBT. https://cbtrust.org/wp-content/uploads/Scope-1-Drivers-of-Forage-Population-Trends-and-Consumption-patterns-PDF2.pdf