INCORPORATING HABITAT INTO ECOSYSTEM-BASED FISHERIES MANAGEMENT: HABITAT MATTERS!

Habitat consists of the physical, chemical, and biological components that are necessary for the survival and growth of organisms in an ecosystem. In an estuary, habitat provides food and shelter for invertebrates, shellfish, and fish. Habitat is an integral part of an ecosystem, and assessing habitats is important in determining ecosystem health. This newsletter describes the steps in determining optimal habitat conditions, discusses the practical reality of measuring habitats in complex ecosystems, and provides an example of a habitat suitability model.

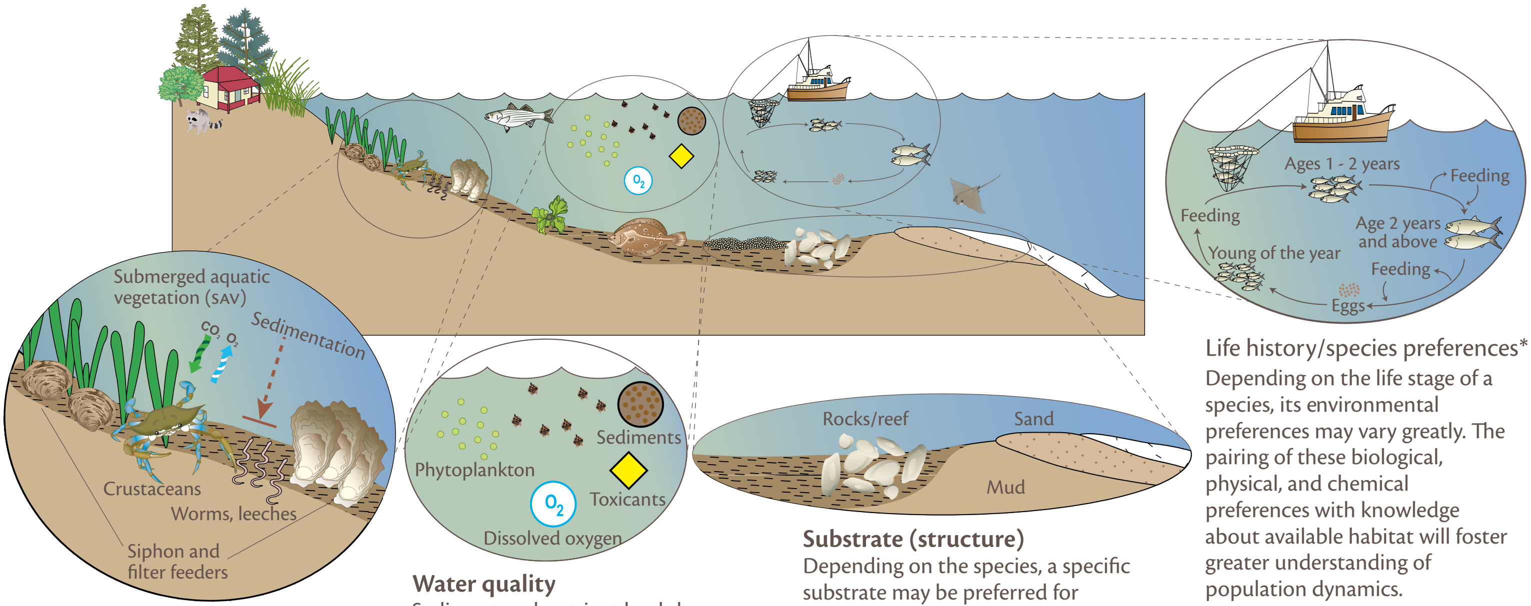
WHY FOCUS ON HABITAT?

Ecosystem-based fisheries management (EBFM) includes not only the stock assessment and prey items of a single species, but also addresses the relationships between habitat, land use, water quality, and multiple species. Tools used in EBFM include models that link living resources and habitat characteristics, integrative ecosystem committees, and habitat restoration.

One key component of ecosystem-based fisheries management is fisheries habitat. Habitat destruction is a major issue because it has contributed to 75% of fish extinctions in the past 75 years[1]. Habitat may be defined in a variety of ways, but usually includes the physical, chemical, and biological parameters that living resources need to survive and grow (Figure 1). The habitat that is being managed varies based on the type of ecosystem (e.g., estuarine versus oceanic). In estuarine ecosystems, habitat encompasses a wide range of factors, such as salinity, dissolved oxygen, sediment type, and prey availability and distribution. To manage these ecosystems, habitat also needs to include other aspects of EBFM, such as living resources' use of habitat as refuge, habitat unsuitability due to poor water and sediment quality, and the impacts of fishing on habitat.

Submerged aquatic vegetation is a critical component of estuarine habitat.

As resource managers move toward a more comprehensive ecosystem management plan, habitat suitability and restoration need to be defined and implemented. Examples of research tools that are used for management include habitat mapping and suitability modeling. Through assessment of the spatial and temporal variability of habitat, and pairing species' life history with current conditions of the ecosystem, scientists may further the understanding of habitat suitability, enabling scientists and managers to better predict fish populations and to aid management decisions.



Biological habitat and food availability
The surrounding biota (riparian forests, marshes, submerged aquatic vegetation beds, oyster reefs) provide refuge and food sources.

Water quality
Sediment and nutrient loads have a strong relationship with dissolved oxygen and phytoplankton (food) levels. Issues of concern also include toxicants and harmful algal blooms.

Substrate (structure)
Depending on the species, a specific substrate may be preferred for spawning or finding food (e.g., muddy bottom indicates filter feeders). Rocky or reef habitats may provide additional refuge or protection from predators.

Life history/species preferences*
Depending on the life stage of a species, its environmental preferences may vary greatly. The pairing of these biological, physical, and chemical preferences with knowledge about available habitat will foster greater understanding of population dynamics.

*Figure 1: A conceptual diagram of the components of an estuarine ecosystem that are considered habitat. *Life history/species preferences are not addressed in this newsletter.*

STEPS IN DETERMINING SUITABLE HABITAT

Determining habitat suitability consists of a number of steps in which the physical, chemical, and biological aspects of a system are combined to determine the suitability of that system for a particular species (Figure 2). First, the actual conditions of each parameter must be determined. This is usually accomplished by combining historical and current field data and observations into one map. Then, the actual conditions of a parameter are compared to research data about the preference and optimal conditions of the target species. Finally, actual and optimal conditions are combined into a map that illustrates where the target species can survive and flourish.

Using Chesapeake Bay as an example, habitat suitability is determined by mapping the bottom or substrate type, measuring water quality parameters and combining them into an index, and collecting samples of higher trophic level organisms. Substrate suitability varies between species and may be for refuge, spawning, or feeding. A variety of temperatures, dissolved oxygen levels, and benthic or phytoplankton indices (food) must also be incorporated to determine the probability of survival under multiple scenarios. Finally, the addition of fish survey information confirms or denies the suitability of habitat by determining the actual distributions of the target species at different times of year. Once all this information is compiled, it is possible to calculate a species' potential habitat and/or growth rate and incorporate it into ecosystem-based fisheries management plans.

Trawl surveys are one way to collect data about fish species.

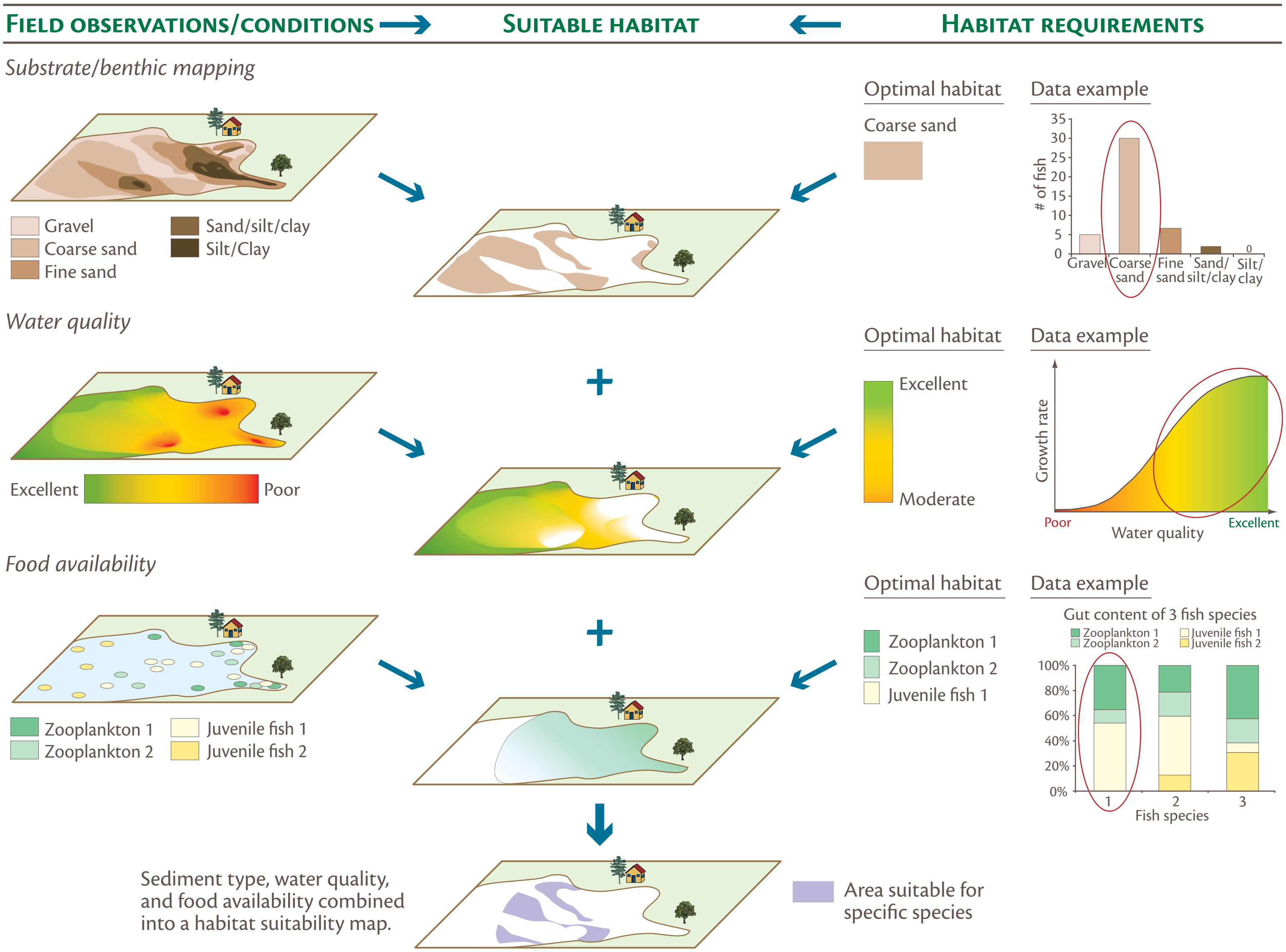


Figure 2: A hypothetical illustration of how habitat suitability is determined for a target species. Field observations, habitat requirements, and data examples are illustrative and do not represent real data.

CURRENT KNOWLEDGE: COLLECTING DATA FOR HABITAT SUITABILITY MODELS

Although the theory behind habitat suitability modeling is relatively well understood, the research and field work to support the models can be limited. For example, the current state of baseline data collection and scientific research on preferences for substrate, water quality, and food availability varies widely for individual species, as well as between ecosystems. The following examples from Chesapeake Bay illustrate the methods already in use as well as the gaps in knowledge that will need to be addressed in the future.

Subsrate/benthic mapping

Substrate types are mapped using a variety of techniques such as shipboard acoustics, video, aerial photography, and satellite remote sensing (Figure 3). The method employed depends on conditions such as water clarity and depth. Collection of core and grab samples can refine the broader-scale data, contributing further insight into sediment characteristics, pollutants, and organic content.

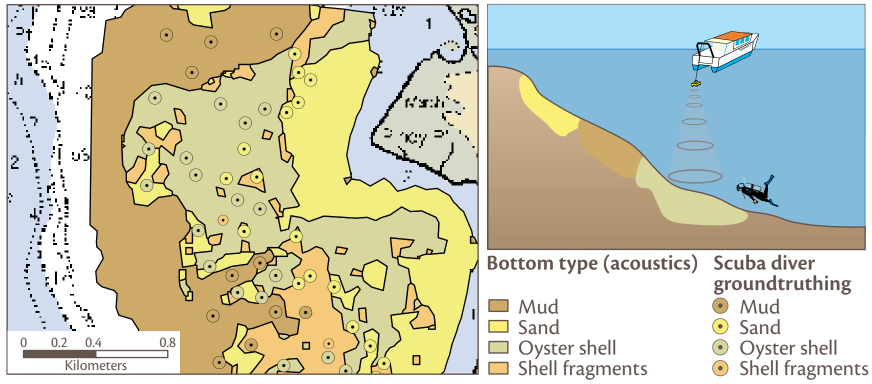


Figure 3: Acoustic equipment maps bottom type in the Chester River, with grab samples verifying the acoustic data. This data is used to construct maps of historic oyster beds. Data: NOAA Chesapeake Bay Office.

Water quality assessment

Every species has specific requirements for water quality parameters such as dissolved oxygen, salinity, pH, temperature, and clarity. Water quality is monitored by multiple groups around Chesapeake Bay, on a variety of spatial and temporal scales for different parameters. Additionally, some of the data is then interpolated over the entire Bay, which gives a more detailed description of available habitat for different species (Figure 4).

(a)

Animal	Minimum oxygen requirements (mg l^{-1})
Striped bass	5 - 6
American shad	5
Yellow perch	5
Hard clam	5
Blue crab	3
Bay anchovy	3
Spot	2
Worms	1

(b)

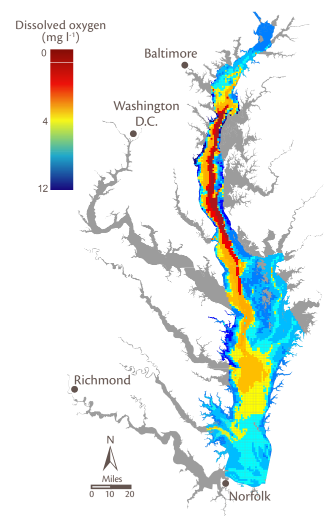


Figure 4: (a) Dissolved oxygen requirements for different species in Chesapeake Bay. Data: Chesapeake Bay Program. (b) Map of summer minimum dissolved oxygen in 2005. Data: Chesapeake Bay Program.

Biological habitat and food availability

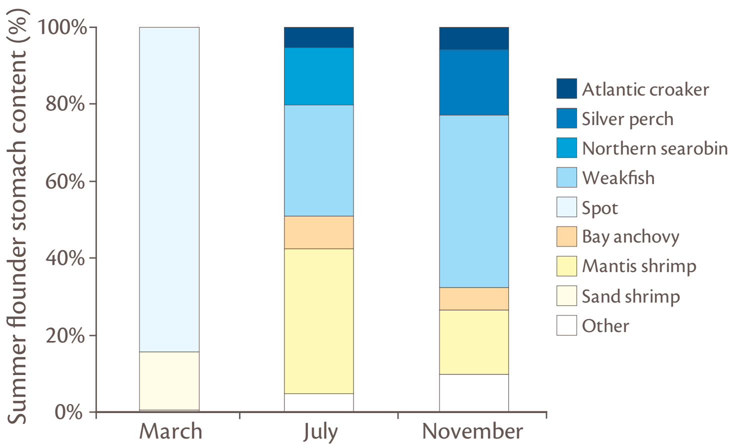


Figure 5: Diet composition from summer flounder trawl surveys. Data: Virginia Institute of Marine Science.

Determination of food source availability is a critical habitat assessment component. Trawl surveys may be used to investigate species' diet composition, which may vary depending upon available prey (Figure 5). A benthic index of biotic integrity (IBI), measuring water quality in reference to living organisms and food source availability for higher predators, is also used as an indicator of benthic biodiversity. In addition to these general methods of assessing the biological environment, research may include more specific factors for particular species. This is the case with yellow perch, which depend upon the shade of a shoreline forest to survive and spawn.

The biological component of habitat assessment is in much need of increased spatial and temporal coverage. Currently, there are few near-shore and shallow-water species distribution surveys. The current program in Chesapeake Bay is limited mostly to the mainstem of the Bay and therefore leaves entire species and seasonal movements out of the assessment.

HABITAT SUITABILITY MODELING FOR BAY ANCHOVY IN CHESAPEAKE BAY

Xinsheng Zhang, Lowell Bahner, Bob Wood, and Ed Houde

The bay anchovy is one of the most important forage fish in Chesapeake Bay. This small, abundant fish feeds on the Bay's zooplankton populations and, in turn, is an important prey species for many other ecologically and economically important predator fish species, such as striped bass (Figure 6). Due to this link between zooplankton and higher trophic levels, understanding the factors that influence bay anchovy abundance is critically important for scientists and natural resource managers. To this end, scientists from the Cooperative Oxford Laboratory collaborated with researchers from the National Oceanic and Atmospheric Administration (NOAA) and the University of Maryland Center for Environmental Science (UMCES) to construct a habitat suitability model for the bay anchovy. This model uses data on environmental factors (temperature, oxygen, and zooplankton) to calculate how suitable the Bay is as anchovy habitat, as indicated by how fast an anchovy would grow in any location throughout the Bay (Figure 7). Preliminary results suggest that hypoxia can limit optimal bay anchovy habitat, particularly in summer and in the deep water portions of the middle Bay. The annual Bay-wide growth rates that the model calculates closely follow annual abundance surveys of bay anchovies conducted throughout the Bay. This indicates that the model has the potential to be a very useful tool for managers to understand how environmental factors, including anthropogenic factors (such as pollution), influence the ecology of Chesapeake Bay on a variety of spatial scales.

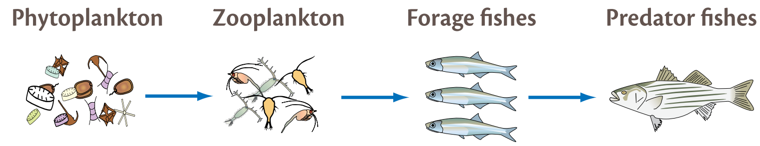


Figure 6: Bay anchovy is a link between plankton and higher trophic levels.

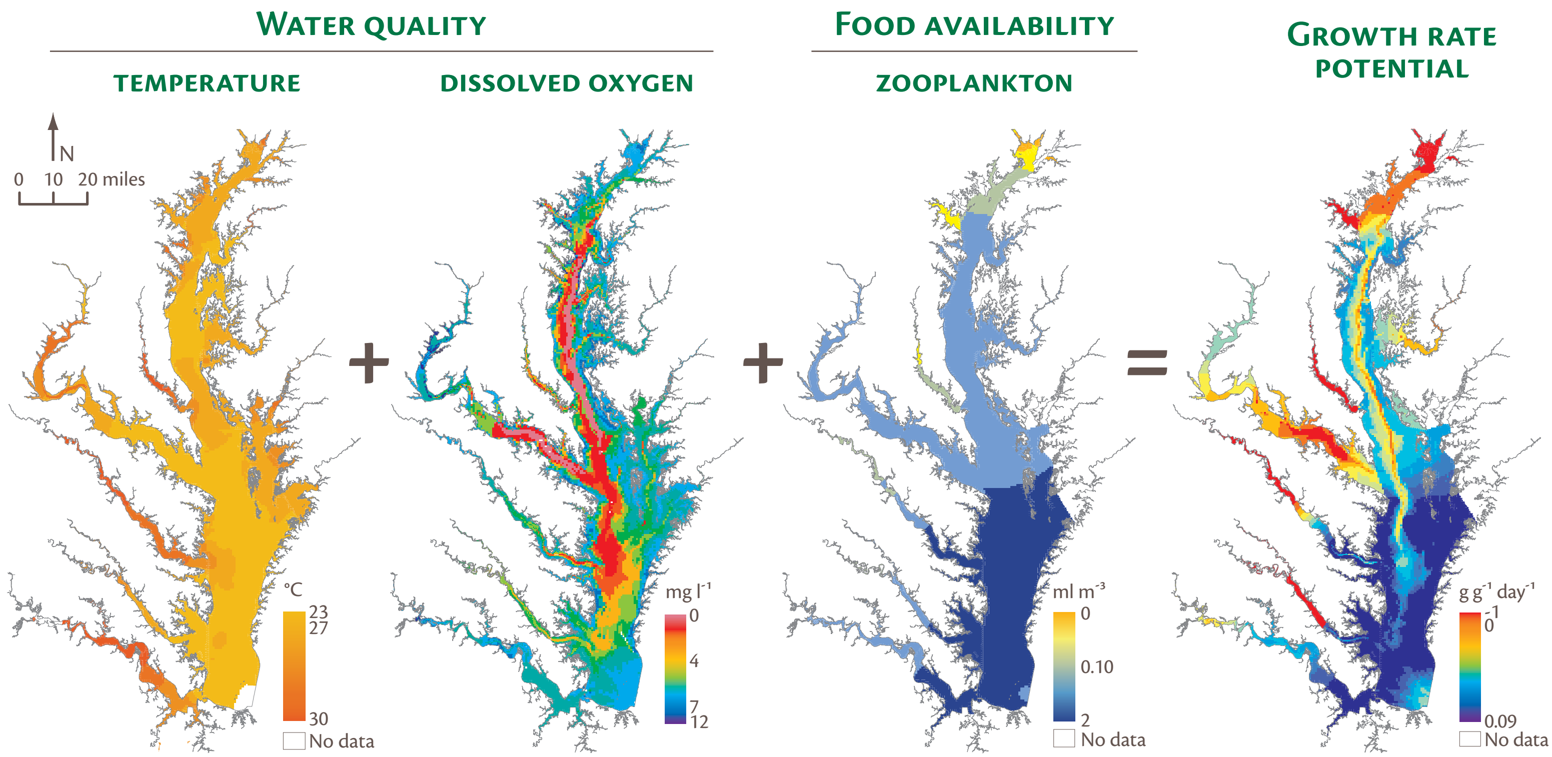


Figure 7: Representative distributions of surface water temperature, bottom dissolved oxygen, and averaged zooplankton biomass. Modeled bay anchovy growth rate potential through the water column of Chesapeake Bay during summer determined by combining temperature, dissolved oxygen, and zooplankton.

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Further information and references:

- Habitat suitability modeling: Xinsheng Zhang, xinsheng.zhang@noaa.gov
- Benthic mapping: NOAA Chesapeake Bay Office, http://chesapeakebay.noaa.gov
- Water quality data:
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  - Chesapeake Bay Multispecies Monitoring and Assessment Program, http://www.fisheries.vims.edu/multispecies/
- [1]Miller et al. 1989. *Fisheries* 14(6):22-38