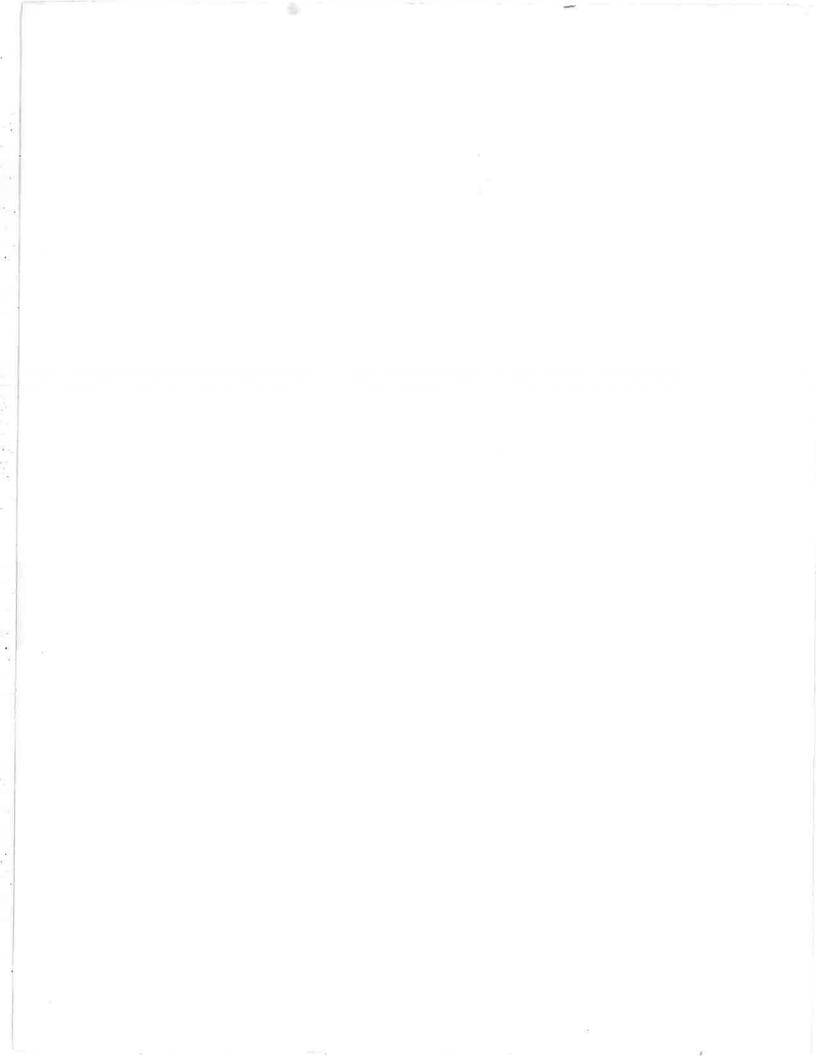
Habitat Requirements For Chesapeake Bay Living Resources

## Chesapeake Bay Program

Agreement Commitment Report



# HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES: A Report from the Chesapeake Bay Executive Council

Annapolis, Maryland January, 1988

## PARTORIS DELVIS VAR HILATTARINO AUG

#### JANUARY 1988

To link the health of specific species occupying various habitats to the water quality, the Implementation Committee recommended the formation of an ad hoc Living Resources Task Force to define habitat requirements for living resources. The Task Force spent two years developing and refining the <u>Habitat Requirements for Chesapeake Bay Living Resources</u> report, to establish a technical approach in setting regional habitat objectives for the Bay. The evolution of the Task Force into a permanent Living Resources Subcommittee strengthens the Chesapeake Bay Program's ongoing pledge to the Bay's threatened living resources.

The restoration and protection of the Chesapeake Bay's living resources, their habitats and their ecological relationships are a major focus of the 1987 Chesapeake Bay Agreement. The Agreement called for the adoption of "guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system," with the directive, "use these guidelines in the implementation of water quality and habitat protection programs." By adopting this Habitat Requirements for Chesapeake Bay Living Resources report as its own, the Chesapeake Executive Council begins fulfilling its strong commitment to restoring living resources.

The Habitat Requirements report will be used in conjunction with EPA Water Quality Criteria, State Water Quality Standards, and other information to help refine and improve living resources restoration and protection programs. It is recognized that the report is a dynamic document, and the Executive Council has directed the Implementation Committee to periodically update the report to account for new knowledge and research results regarding habitat requirements of living resources. To attain the goals of the 1987 Chesapeake Bay Agreement, a focused and concentrated effort must be made to restore and protect the habitats of our living resources so that the Chesapeake Bay may continue to be an economic and ecological treasure for future generations.

#### ADOPTION

We, the undersigned, adopt the report entitled Habitat Requirements for the Chesapeake Bay Living Resources, dated August, 1987, fulfilling our commitment "by January 1988, to develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs." We recognize that this report is a dynamic document and direct the Implementation Committee to periodically update the report to account for new knowledge and research results as regards the habitat requirements of living resources.

This report will be used as guidance, along with EPA Water Quality Criteria and State Water Quality Standards and other information, to help refine and improve Chesapeake Bay Agreement programs designed to provide for the restoration and protection of living resources, their habitats, and ecological relationships. An implementation strategy is being developed for these guidelines so that managers will have available suggested methods for incorporating the guidelines, as appropriate, into ongoing protection programs and to ensure that use of the guidelines is compatible with the protection, restoration, and enhancement of Chesapeake Bay living resources.

The Implementation Committee shall report to the Executive Council annually on the effectiveness of the guidelines, complemented by baywide assessments and management strategies, in helping meet the living resources goal stated in the 1987 Chesapeake Bay Agreement.

For the United States of America

For the District of Columbia

For the Commonwealth of Virginia

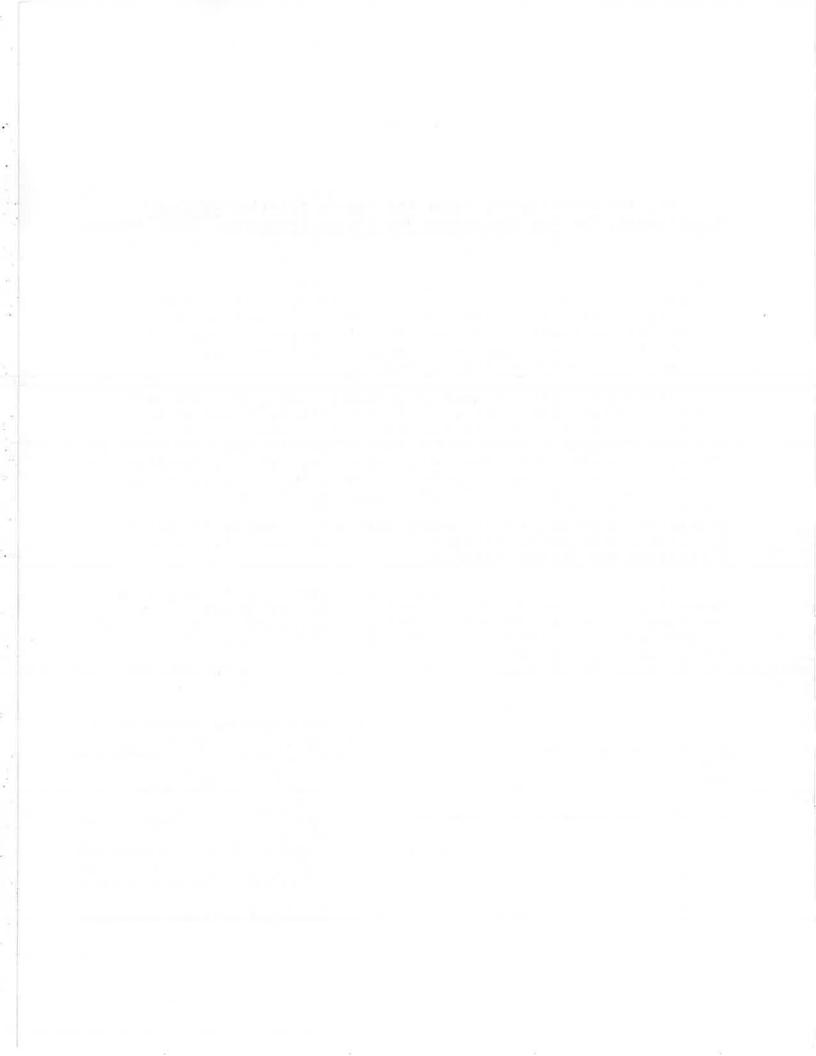
For the Commonwealth of Pennsylvania

For the State of Maryland

For the Chesapeake Bay Commission

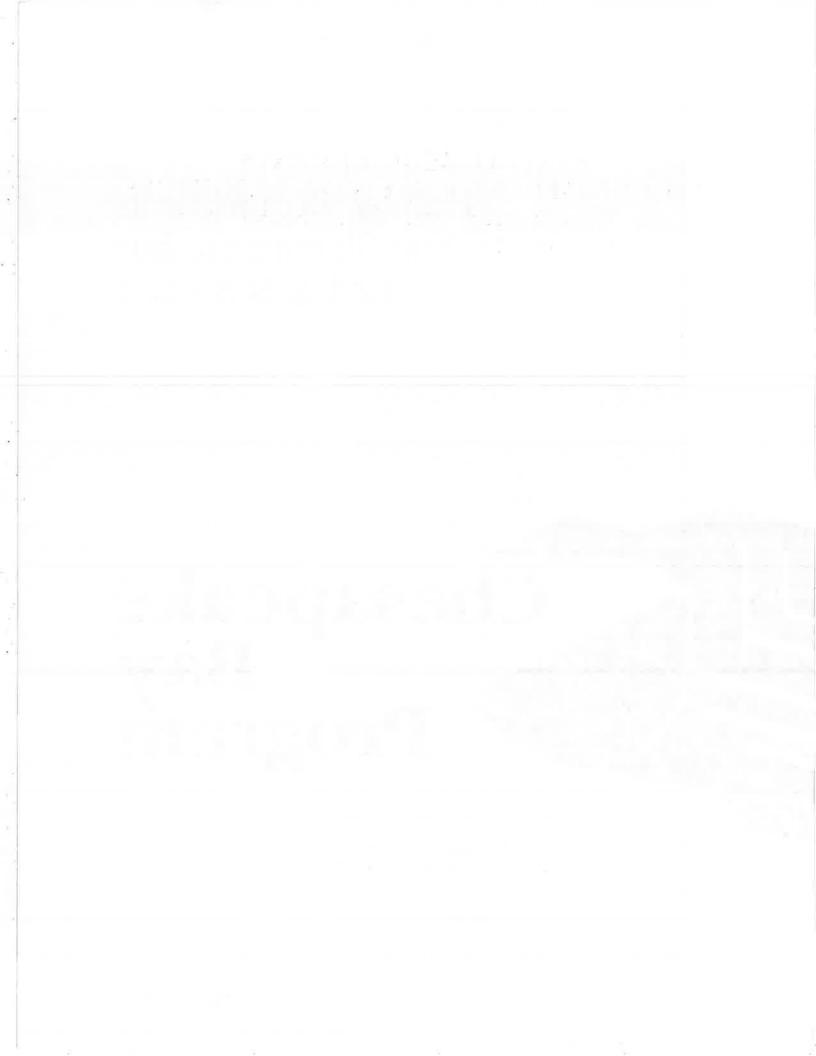
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Habitat Requirements For Chesapeake Bay Living Resources





# HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES: A Report from the Chesapeake Bay Living Resources Task Force

Annapolis, Maryland August, 1987

## 

#### **DISCLAIMER**

This report has been reviewed by the Living Resources Task Force of the Chesapeake Bay Implementation Committee and approved for publication by the Chesapeake Bay Program, U.S. Environmental Protection Agency. Approval does not signify that the contents necessarily reflect the view and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

1.

#### **ACKNOWLEDGEMENTS**

The Chairman of the Living Resources Task Force would like to acknowledge the participation and contributions of: the members and supporting staff of the Chesapeake Bay Living Resource Task Force; participants in the February Workshop on Habitat Requirements for Chesapeake Living Resources; the principal authors of the report, Steve Jordan, David Pyoas, and Charles Frisbee of the Maryland Department of Natural Resources and Bert Brun of U.S. Fish and Wildlife; the technical editor, Nina Fisher, Chesapeake Bay Program/Computer Sciences Corporation; and, the scientific editor, Bess Gillelan, Chesapeake Bay Program/Computer Sciences Corporation.

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#### KEY

m = meter C = celcius

ppt = parts per thousand

KD = light attenuation coefficient

TRC = total residual chlorine cm/s = centimeters per second

chlor. = chlorophyll

mg/l = milligrams per liter - equivalent to parts per million ug/l = micrograms per liter - equivalent to parts per billion

LC0 = lethal concentration - 0 percent mortality LC50 = lethal concentration - 50 percent mortality

um = micron

#### **FOREWORD**

The Living Resources Task Force, an ad hoc workgroup of the Chesapeake Bay Program, was charged by the Chesapeake Bay Implementation Committee to develop an approach to define habitat objectives for the living resources of the Bay. The objective of the Task Force in producing this report was to establish a technically defensible approach in setting regional habitat objectives for Chesapeake Bay by initially assembling habitat requirements for individual target species. The scope of this report places limitations on its utility as a planning document for Bay managers. It is intended, however, to summarize the results of the Task Force efforts to date and to provide the basis for future refinement of the habitat objectives approach. This document describes the results of ongoing efforts to identify critical habitat requirements for target species.

Within the context of this report, habitat is defined as the biotic and abiotic conditions upon which the living resources of the Bay depend. Abiotic conditions include factors such as water quality, substrate, circulation patterns, bathymetry, and weather; two dominant factors are salinity and depth. Biotic conditions are governed by variables such as vegetative cover, quality and quantity of prey species, species composition, population density, and primary productivity. The estuarine environment represents a wide range of these conditions which are dynamic in time and space. Although Bay species are tolerant of dynamic natural conditions, their habitats have been altered by man-induced activities; there is evidence that thresholds for tolerating adverse conditions have been exceeded. The Living Resources Task Force has attempted to identify the boundaries of tolerable conditions in the form of habitat requirements.

The report is constructed following the guidelines created to direct the development of living resources habitat requirements. The sections on the Chesapeake Bay ecosystem and the major physical factors affecting the Bay provide the structural framework for all subsequent discussions of the living resources. The representative living resources are a group of organisms that serve as indicators of the Bay's ecological condition. From this group, target species were selected as particularly important for the development of initial habitat requirements. The report includes a set of matrices outlining habitat requirements for critical life stages of the target species as well as range maps of these stages.

A scientific workshop, with invited participants from universities, research institutions, and state and federal agencies, was held to review the initial list of requirements and advise the Living Resources Task Force on critical life stages of the target species and seasonal and geographic distributions of the critical life stages. The workshop proceedings are contained in Appendix C: Report of the Workshop on Habitat Requirements for Chesapeake Bay Living Resources (Connery, 1987).

To guide subsequent efforts in linking living resources to habitat conditions, several recommendations for future tasks are proposed. These include expanding the habitat matrices to encompass requirements for food species on which the target

species depend, creating habitat matrices for other representative species, identifying species and population characteristics that could serve as indicators of the Bay's health, and encouraging Bay planners to incorporate habitat requirements into their environmental planning efforts.

This report will be utilized during discussions leading to the signing of the revised Chesapeake Bay Agreement in December 1987. Continued development of habitat and living resource goals will be part of the focus in the implementation of that Agreement.

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	Target Target Target Target Target	Species: Species: Species: Species: Species: Species: Species:	hickory shad (Alosa mediocris)  Yellow perch (Perca flavescens)  White perch (Morone americana)  Menhaden (Brevoortia tyrannus)  Spot (Leiostomus xanthurus)  Bay anchovy (Anchoa mitchilli)  Molluscan shellfish: American oyster	35 38 38	
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#### INTRODUCTION

Declines in stocks of finfish, shellfish, waterfowl and submerged aquatic vegetation in the Chesapeake Bay have prompted an unprecedented effort by the states and federal government to understand causes of the declines and to explore means of restoring and protecting these stocks. Studies completed in 1983 under the aegis of the Environmental Protection Agency concluded that the decline of important resources was due to deteriorating water quality, particularly nutrient enrichment and contamination by toxic metals and organic compounds (EPA, 1983).

Since 1983, most of the research and planning efforts for restoring and protecting the Chesapeake Bay has focused on documenting the present water quality of the Bay and refining strategies for reducing or preventing further increases in nutrient and contaminant loads. Strategies based primarily upon water quality, however, cannot necessarily ensure the restoration and protection of living resources. The most tangible warning signs of widespread environmental problems in the Bay have been shifts in the relative abundance of living resources. Therefore, living resources serve as excellent indicators of the Bay's recovery for Bay managers and the public.

The abundance and distribution of species within the Bay are related to many variables: climate, natural population cycles, reproductive potential, disease, predation, and the abundance and quality of food and habitat. Human activities impose another set of conditions which both directly and indirectly affect species abundance. Fishing, land and water uses, contaminant discharges, and physical habitat alterations can directly affect important species. Indirect impacts of these activities can result in disruption of food chains and perturbation of the ecological balance of the estuary.

In recognition of these principles, the Chesapeake Bay Program's Implementation Committee established the Living Resources Task Force (LRTF) to develop a living resource-based approach for defining habitat objectives for the Bay. The membership of the LRTF consisted of managers and scientists from federal and state agencies, private industry, and universities. series of meetings at both the managerial and technical levels, the Task Force outlined an approach to establish living resource objectives by first identifying habitat requirements for selected target species. The habitat requirements are intended to provide planners, managers, researchers, and modelers of the Bay with information on the minimum habitat quality needed by the target species and the plants and animals upon which the target species depend for These requirements can be used to estimate the feasibility, benefits and potential costs of maintaining and protecting an estuarine environment suitable for the successful reproduction and survival of living resources. Habitat requirements are not meant to be standards or criteria for wastewater discharge permitting or other types of regulatory activities, but they can be used to develop water quality standards for regions of the Bay that are defined in terms of living resource habitat rather than water use.

The relationship between the restoration or protection of living resources and requirements for protecting specified habitats requires clarification. Achievement of the proposed requirements will not necessarily directly result in the establishment of specific population or harvest levels for any of the targeted species. For example, total compliance with requirements for striped bass larvae may not result in an improvement of the annual juvenile index. However, the recovery of species which have declined in Chesapeake Bay and the reestablishment of a balanced ecosystem must be seen as the ultimate measures of success in restoring the quality of Chesapeake Bay. These goals will be unattainable unless certain minimum habitat requirements are achieved.

The Living Resources Task Force used the following sequential guidelines for developing the living resources habitat requirements described in this document:

- 1. Representative species for the Chesapeake Bay were identified for all trophic levels, including plankton, vegetation, benthic organisms, shellfish, finfish, and wildlife;
- 2. A smaller group of target species were identified for immediate development of habitat requirements. Criteria selecting the target species were based upon their commercial, recreational, aesthetic, or ecological significance and the threat to sustained production due to population decline or serious habitat degradation;
- 3. The critical life stages and critical life periods for the target species were identified;
- 4. Habitat requirement matrices for the targetted living resources and the species upon which they prey were developed and refined from current scientific literature and recent research findings;
- 5. Geographic areas of the Bay were defined where habitat requirements should be met in order to protect the reproduction and survival of the target species. These areas were based upon present distributions with consideration also given to historical distributions.

The guidelines were not set up to address issues of numerical population objectives or management of fish and game harvests. For most Chesapeake Bay species, neither the total population size nor the information needed to estimate stock sizes is available at present, so realistic objectives for population sizes cannot be set. While meeting habitat criteria may not ensure survival of a species in the face of exploitation, there can be no harvest in the absence of sufficient suitable habitat to support the species. The purpose of this first phase of the Task Force effort is to specify the quality and geographic distribution of Bay habitats necessary for the sustainable reproduction and long-

term survival of the target species. In the future, the living resources restoration efforts may also address such issues as:

- 1. Establishment of additional habitat requirements that support both prey of the target species and other representative species. Special attention should be paid to the planktonic and benthic communities as indicators of ecosystem stress and as support organisms for higher trophic levels;
- 2. Identification of those characteristics of living resource populations (e.g. distribution and abundance) or of Bay communities (e.g. diversity) that will serve as measures of the Bay's recovery or lack of recovery in response to management actions;
- 3. Provisions for refining programs for monitoring, living resources and habitat conditions, as well as water quality, and for using computer models of the Bay to predict the effects of actions to improve habitat conditions, such as nutrient reduction strategies;
- 4. Synthesis of habitat requirements into regional habitat objectives.

#### THE CHESAPEAKE BAY ECOSYSTEM

Public interest in the environment has centered directly on the Chesapeake Bay's aesthetic and economic values and indirectly on its ecological values. The success of economically-important finfish and shellfish is ultimately dependent on the primary producers of the Bay -- phytoplankton and other organisms that form the base of the Chesapeake's food chain. The animals, plants, and microbes of the Bay are interwoven by a complex of feeding, chemical, and physical interactions. Thus, successful restoration and protection of commercially, recreationally, and ecologically-important species are not solely dependent upon the physical and chemical integrity of habitats: the integrity of the trophic food web supporting these populations is crucial to resource survival and abundance.

Figure 1 is a network diagram of the summer, mesohaline Chesapeake Bay designed by Ulanowicz and Baird (1986). The network is presented as a prototype of the major trophic relationships and energy pathways in the Bay. It has been greatly simplified (in comparison to the real system) by grouping many species. It represents the general pattern of carbon flow (an indicator of food and energy) in the upper Chesapeake Bay during summer. Two basic pathways dominate the estuarine food web. The direct pathway leads from living plants to higher animals. The indirect, or detrital pathway leads from dead organic matter to lower animals then to higher animals. Tidal marsh, benthic, and submerged aquatic vegetation communities are strongly dominated by the detrital pathway.

The following discussion outlines the components of the Chesapeake Bay system and food web. Some of the primary producers of the Bay (plankton and aquatic vegetation) and primary and secondary consumers (benthic organisms, finfish, and waterfowl) are described in general terms.

#### **PLANKTON**

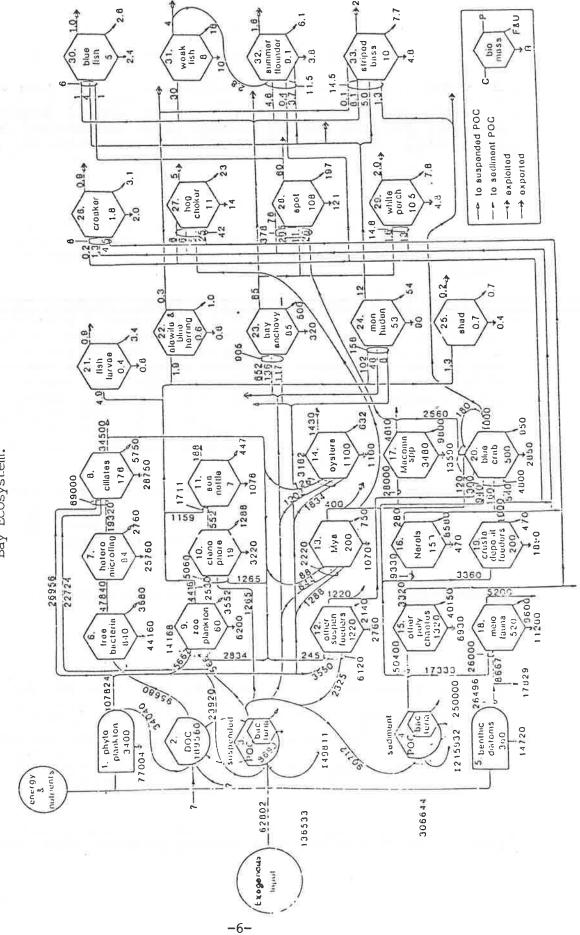
#### PHYTOPLANKTON AND BACTERIA

Phytoplankton are microscopic, usually single-celled plants, representing several divisions of algae. They constitute the base of the food chain; the major primary producers in Chesapeake Bay. Thus, phytoplankton play a fundamental role in the structure of the ecosystem. They are the major food source for a number of species including zooplankton, benthic suspension feeders, and fish. Bacteria are single-celled organisms that are responsible for tremendous amounts of carbon and nutrient-cycling processes (see Figure 1). As part of the detritus food chain, their role in decomposition of organic matter, particularly dead plankton cells, is a major causative factor of anoxia in bottom waters of the Bay.

In the surface waters of the Bay, dissolved nutrients and sunlight are taken up by these photosynthetic organisms. Factors which control fluctu-

Components Of The Chesapeake Mesohaline Ecosystem During A Typical Summer. Standing Crops Are Indicated Within The Compartments In mgC m-2 And Schematic Representation Of Carbon Flows Among The 33 Principal The Indicated Flows Are In mgC m-2 summer-1. FIGURE 1.

Network Analysis of the Chesapeake # A 1986. Ulanowicz and Baird, Bay Ecosystem. Source:



ations in phytoplankton numbers, composition, and production are critical to the success or failure of higher trophic levels. The balance among photosynthesis, nutrient exchange and predation ultimately determines planktonic species composition. Large changes in nutrient and toxic loadings can also cause changes in the quantity and quality (size and species composition) of plankton communities in the system. There is growing evidence that a combination of factors, probably arising from the synergistic effect of point and nonpoint source discharges of toxics and nutrients, are causing a shift in species composition. This shift is reflected in high production of bacteria and minute phytoplankton species (favoring microzooplankton production) and may be related to reduced population numbers in the higher trophic levels of Oysters, for example, may grow more slowly in areas where nutrient enrichment has shifted phytoplankton species composition to smaller species which are not suitable as food.

#### **ZOOPLANKTON**

Zooplankton are swimming or floating animals that range from microscopic to jellyfish size. Many are important food for fish and other organisms. Zooplankton represent important primary consumers in the Chesapeake Bay food web, and thus function as a key link in the transfer of energy derived from phytoplankton, bacteria and detritius to higher trophic levels. Some zooplankton, particularly the mesozooplankton (medium-size), function as important and often critical links by supplying food to larval stages of many fish and shellfish species in higher trophic levels. The distribution of mesozooplankton and the phytoplankton upon which they feed is a function of salinity.

Jellyfish, including ctenophores (comb jellies) and sea nettles, prey on the smaller zooplankton and may influence summer planktonic populations and distributions. Microzooplankton, which are mostly single-celled protozoa, feed heavily on bacteria. The larvae of benthic animals and fish are also considered to be zooplankton. These larvae prey on smaller forms of plankton and may be consumed by larger animals. As the larvae develop, they may in turn consume other zooplankton.

#### **VEGETATION**

#### SUBMERGED AQUATIC VEGETATION

Submerged aquatic vegetation (SAV) is one of the Chesapeake Bay's most significant natural resources. In 1976, the decline of SAV was selected as one of the three major Bay problems (the only one directly focused on living resources) to be further researched. Since that time, SAV has remained at the forefront of public consciousness. It provides food and habitat for fish, numerous other aquatic organisms, and waterfowl. SAV remains a visible indicator of good water quality and the general ecological health of the Chesapeake Bay.

Several of the key species identified for detailed analysis in this effort require SAV (directly or indirectly) for food and/or habitat. Plants such as eelgrass (a common SAV species in mid to high salinity regions) and emergent

marsh grasses are major sources of primary productivity in the shallow waters of the Bay. In addition to being a direct food source for some consumers, organic detritus produced by decomposition of plant material provides food for other primary consumers such as small crabs, shrimp, selected fish and other detritivores.

Associations between SAV and finfish, shellfish, and waterfowl are well documented. The most important waterfowl wintering areas have been the most abundantly vegetated. Fish abundance in SAV communities in the upper Bay is high, indicating the importance of SAV for food and shelter. Lower Bay SAV beds serve as a primary blue crab nursery, sheltering large numbers of juvenile blue crabs throughout the year.

Because prey organisms use SAV habitats, predators may be attracted to the beds. Adult fish, such as striped bass and bluefish, may hunt invertebrate prey in SAV beds. Summer resident wading and shore birds seek prey in or near SAV beds.

SAV also functions as an important stabilizer for sediments. As turbid water circulates through SAV beds, sediments tend to settle out, resulting in clearer water and increased light transmittance. Direct uptake of nitrogen and phosphorus by SAV and its associated epiphytes also serves to buffer nutrient levels in the water during the spring and summer growing season. Decomposition of SAV releases nutrients back to the water column during the fall and winter when water column nutrient concentrations are lower.

#### TIDAL WETLANDS

The abundance of food and shelter provided by marsh grasses ensures a very favorable habitat for other members of this community. A host of invertebrates feed on decomposed plant material and, in turn, provide food for numerous species of higher animals. Another source of food is the dense layer of bacteria, algae, and microscopic animals that coats the stems of marsh plants. Decomposing plants and, to a lesser extent, dead animals are major food sources for the marsh dwellers. Therefore, the primary food web in the marsh environment is based on detritus. Tidal marshes are also important as physical habitat for estuarine species.

Salinity and frequency of tidal flooding are the most important factors in determining the types of plant and animal populations that inhabit a particular marsh. Freshwater marsh vegetation includes cattails, reeds, arrowarum, big cordgrass, wild rice, three-square, tearthumb and pickerel weed. Salt marshes of the mid and lower Bay are dominated by salt meadow cordgrass, saltgrass, and saltmarsh cordgrass. Irregularly flooded salt marshes have the fewest plant species and are dominated by needlerush.

Situated at the boundary between land and water, marshes absorb the erosive energy of waves and may also act as nutrient buffers, regulating the flow of local sources of nutrients into the Bay. Nutrients taken up by marsh vegetation are later slowly released into the Bay during decomposition. Marshes also protect the Bay ecosystem by trapping sediments that enter from streams or tidal flooding.

#### BENTHOS

The Chesapeake Bay supports an active community of organisms which live in association with bottom sediments or attached to solid substrate such as oyster shells, pilings, rocks, and shoreline structures. This assemblage, collectively known as the benthos, represents a major component of the Bay ecosystem. The benthos forms an important link between primary producers and higher trophic levels. Many benthic organisms are principal food sources for fish, waterfowl and crabs, while others are of direct economic importance (crabs, clams, oysters). Benthic organisms also play a significant role in the detrital pathway, breaking down organic matter. These decomposers are responsible for many key benthic processes, including nutrient recycling, sediment chemistry, and the depletion of dissolved oxygen.

The temporal and spatial distribution of benthic communities is determined primarily by chemical and physical factors (mainly salinity, depth, substrate, dissolved oxygen concentration, and temperature). The distribution and abundance of organisms composing benthic communities are, therefore, likely to respond to changes in water and sediment quality. Many benthic organisms live for 1-2 years or longer so that benthic communities are excellent indicators of an area's short and long-term trends in environmental quality. In addition, because benthic organisms past the larval stage are relatively immobile, they often complete much of their life cycles within welldefined regions of the Bay. As a result, benthic responses to changes in habitat quality are likely to be region-specific. As important intermediate links in the Bay's food web, benthic community responses to habitat changes are also likely to be representative of the responses of other living resources.

#### **FINFISH**

Finfish represent the majority of Chesapeake Bay nekton species. The trophic relationships of fish are diverse, depending on developmental stage, life histories, or physiological adaptations of different species. Most of the large fish species of the Bay like bluefish, striped bass, and sea trout, are temporary residents, living in the Bay for part of the year or only during certain stages of their life cycles to spawn or feed. Resident finfish, such as bay anchovies, hogchokers, and white perch, tend to be smaller in size. The spawning behaviors of Chesapeake Bay finfish place them into two main categories: ocean-spawning fish (spot, croaker, menhaden) and freshwater or estuarine-spawning fish (striped bass, herrings, shad).

Finfish occupy different trophic levels at specific stages of their lives. Most finfish initially feed on zooplankton and later turn to larger prey. The highest rates of survival of larval stages have been shown to correlate positively with the highest zooplankton densities. Thus, the success of species using the Bay as nursery grounds in its early life stages is dependent on the availability of certain types of plankton.

Finfish are represented by all consumer levels within the Bay's food web. Primary consumers, such as abundant schools of plankton-feeding menhaden, represent a major pathway from the primary producers directly to harvestable resources. Bluefish and striped bass are secondary or tertiary

consumers, feeding on smaller finfish. Finfish also serve as prey for other consumer-level species. The diets of many invertebrates, waterfowl, and some mammals are composed largely of fish.

#### WATERFOWL AND WILDLIFE

In addition to the Chesapeake Bay's importance as a source of valuable finfish and shellfish resources, the marshes and woodlands surrounding the Bay provide habitat for a variety of waterfowl, birds and other vertebrates.

The Chesapeake Bay is part of an important migratory path known as the Atlantic flyway. Most of the waterfowl reared between the western shore of Hudson Bay and Greenland spend some time in the marshes and on the waters of the Chesapeake Bay during their migrations. The Bay and the Delmarva peninsula provide some of the prime, most heavily used waterfowl wintering habitat along the Atlantic flyway.

Like finfish, bird species occupy all consumer levels of the food web. Some birds feed on primary consumers (such as mollusks), while other species feed on primary producers (plants). Birds feeding on secondary consumers, such as fish, are considered tertiary consumers; at the extreme edge of the food web, these high-level consumers (e.g. bald eagles) are often the first to be affected by disruption of the ecological integrity of the Bay.

#### CHESAPEAKE BAY HABITAT ZONATION

The variety of habitats within the Chesapeake can be classified using the two most basic factors controlling the distribution of Bay biota: water depth In this classification of Bay habitats, gradients of depth and and salinity. salinity can be divided into descriptive zones. Depths range from the deepest troughs and channels in the mainstem Bay to the intertidal shores and critical Salinity ranges from the tidal freshwater land areas bordering tidal waters. stretches of Bay tributaries and upper Chesapeake to the ocean-like water at the mouth of the Bay. Within these zones, many other physical and biotic factors such as sediment type, the presence of food and cover, the strength of waves and currents, water temperature, dissolved oxygen, and habitat contamination and disturbance control the distribution and abundance of living resources. A generic system of habitat zones, defined in terms of salinity and depth, offers a simplistic way to classify, describe, monitor, and manage living resources in Chesapeake Bay.

Brief descriptions of depth and salinity zones follow, along with examples of representative species in each zone.

#### **DEPTH ZONES**

#### **UPLAND SHORES**

A variety of vegetation types exists on the upland shores which are the terrestrial communities at elevations above the influence of tides. In many cases, the physical nature of these upland regions is heavily influenced by human activities, especially development and agriculture. Several species that depend upon Bay aquatic habitats also rely upon these terrestrial environments for food, cover, or nesting sites. Examples of these species include the bald eagle, Canada goose, river otter, beaver, and mink.

#### INTERTIDAL AND LITTORAL

The intertidal and littoral zones include areas with water depths of approximately 0.5 meters (m) or less. They are semi-aquatic habitats, covered periodically by tidal waters or washed by waves. These zones include marshes, sandy beaches, mudflats, and shoreline structures such as revetments and bulkheads. Representative species include marsh grasses, shorebirds, waterfowl, muskrats, many benthic species, and larval or juvenile stages of finfish and crabs.

#### SHALLOW WATER

The shallow water zone (to a depth of < 3 m) includes the uppermost waters over the surface of the entire Bay and its tidal tributaries as well as the bottom sediments in the shallow-water areas. Examples of important resident

organisms include submerged aquatic vegetation, waterfowl, shallow-water benthic species, crabs, and most juvenile finfish.

#### MID-WATER

The intermediate zone, with water depths between 3 and 6 m, includes the mid-layer of pelagic waters and the underlying sediments. Submerged aquatic vegetation is absent from all but the clearest waters at these depths. Oyster bars and softshell clam habitat are most common in this zone. Oyster bars support a specialized community of invertebrates, finfish and microorganisms. In the summer, finfish, crabs, and other invertebrates which would normally inhabit deeper water may be restricted to the intermediate zone by the availability of dissolved oxygen.

#### DEEP WATER

Deep pelagic waters of the Bay having water depths of > 6 m constitute habitat for most of the larger adult finfish. Many infaunal benthic species inhabit the underlying sediments. Seasonal depletion of dissolved oxygen in much of the Bay's deeper waters probably has limited the distribution of species that otherwise would depend on these habitats. Examples include adult striped bass, sciaenid finfish (croaker, spot, weakfish), flounder, sturgeon, and infaunal invertebrates such as Macoma clam.

#### SALINITY ZONES

The absolute geographic location of salinity zones varies greatly, influenced by freshwater discharge, tides, weather, and water depth. Each salinity zone includes the associated sediments and intertidal habitat.

#### TIDAL FRESH

The tidal fresh zone has salinities of < 0.5 ppt and includes the upper tidal reaches of all Bay tributaries and the area of the upper Bay known as the Susquehanna Flats. The tidal areas are critical spawning grounds for anadromous finfish, but otherwise support mostly freshwater species of finfish, invertebrates and plankton. Tidal fresh zone residents also include several species of freshwater marsh plants, submerged aquatic vegetation, as well as raptors, waterfowl, and upland wildlife.

#### **OLIGOHALINE**

The oligohaline zone, with a salinity range of 0.5 - 5.0 ppt, generally includes the middle reaches of tidal tributaries and a portion of the upper mainstem Bay, usually between the Susquehanna Flats and the mouth of the Patapsco. These areas support fresh and brackish water species of aquatic vegetation and are important nursery areas for anadromous finfish and spawning grounds for estuarine finfish. Benthic species diversity is at its lowest level in this zone, but some characteristic species (e.g. brackish-water clam (Rangia cuneata)) are dependent upon it and can be present in high densities. This zone is also characterized by high turbidity since it is a mixing

zone of freshwater flow on the surface and the heavier, saline water along the bottom.

#### **MESOHALINE**

The mesohaline portion comprises the most extensive salinity zone in the Chesapeake Bay and has salinities ranging from 5.0 to 18 ppt. Under average rainfall conditions, this zone encompasses the mainstem Bay from the mouth of the Patapsco to the area just south of the Potomac River mouth. The lower reaches of the major tributaries in the upper Bay are also mesohaline. Most of the Chesapeake Bay species of finfish, shellfish and benthic organisms, along with euryhaline (tolerant of a wide range of salinities) marine species, inhabit this zone.

#### **POLYHALINE**

Most of the polyhaline zone, with salinity ranging from 18 to 32 ppt., is found in the Virginia portion of the mainstem Bay. The lower reaches of the York and James rivers are also in this zone. Some marine finfish live solely in this segment of the Bay, although most of the estuarine finfish species are also present. Spawning and overwintering habitat for female blue crabs occurs within the polyhaline zone near the Bay mouth. Some benthic invertebrates such as the hard clam (Mercenaria mercenaria), the whelk or "conch" (Busycon spp.), and the oyster drill (Urosalpinx spp.), are generally restricted to this zone. Saltmarsh grass (Spartina spp.), eelgrass (Zostera sp.), and widgeongrass (Ruppia sp.) are typical in the polyhaline zone.

#### **SPECIES SELECTION**

#### REPRESENTATIVE LIVING RESOURCES

The following list of species or species associations was developed by the Living Resources Task Force to serve as an indicator of the Bay's ecological condition. Not all species are indicators of recovery; rather, the abundance of some are reflective of poor habitat conditions for less tolerant species. The list includes species of commercial and recreational importance and species which, due to their abundance, productivity, or distribution, are important in the flow and accumulation of energy through various trophic levels of the Chesapeake Bay ecosystem.

#### PHYTOPLANKTON ASSOCIATIONS:

#### Oligohaline

Winter/Spring

Cyclotella striata
Melosira granulata
Melosira islandica
Katodinium rotundatum
Cyclotella meneghiniana
Skeletonema costatum

#### Summer/Fall

Cyclotella striata
Merismopedia spp.
Microcystis aeruginosa
Gymnodinium spp.
Argetoceros spp.
Skeletonema costatum

#### Mesohaline

Winter/Spring

Skeletonema costatum Cyclotella striata Heterocapsa triquetra Certaulina pelagica Asterionella glacialis Asterionella japonica

Summer/Fall

Cyclotella striata Cryptomonas spp. Skeletonema costatum

### Summer/Fall (continued) Leptocylindrus minimus

#### Polyhaline

#### Winter/Spring

Skeletonema costatum
Leptocylindrus danicus
Asterionella glacialis
Cerataulina pelagica
Thalassiosira nordenskioldii
Thalassiosira rotula

#### Summer/Fall

Prorocentrum micans
Prorocentrum minimum
Heterocapsa triquetra
Cryptomonas spp.
Skeletonema costatum

#### **ZOOPLANKTON ASSOCIATIONS:**

#### Tidal fresh to oligonaline

Bosmina longirostris (Cladoceran)
Leptodora kindtii
Cyclops spp.
Mesocyclops edax
Diaptomus spp.
Tintinnids

#### Mesohaline to polyhaline

#### Winter

Cyanea capillata (lion's mane jellyfish)
Eurytemora affinis (copepod)
Acartia clausi (copepod)
Pseudocalanus spp.
Centropages hamatus
Temora longicornis
Neomysis americana
Sagitta elegans
Oithona spp.

#### Summer

Chrysaora quinquecirrha (sea nettle)
Mnemiopsis leidyi (ctenophore)
Podon polyphemoidese (cladoceran)
Evadne tergestina
Acartia tonsa (copepod)
Pseudodiaptomus coronatus
Labidocera aestiva
Parvocalanus crassirostris
Neomysis americana

Summer (continued)

Sagitta tenius

Scottolana canadenis (meiobenthic copepod)

Ectinosonia centicorne (meiobenthic copepod)

# SUBMERGED AQUATIC VEGETATION SPECIES:

Ruppia maritima (widgeongrass)

Zostera marina (eelgrass)

Vallisneria americana (wild celery)

Potamogeton pectinatus (sago pondweed)

Potamogeton perfoliatus (redhead grass)

# **EMERGENT AQUATIC VEGETATION SPECIES:**

Spartina alterniflora (salt marsh cordgrass)
Spartina cynosuroides (big cordgrass)
Spartina patens (salt meadow cordgrass)
Juncus roemerianus

# **BENTHIC ASSOCIATIONS:**

# Tidal fresh

Tubificidae (Limnodrilidae) Chironomidae Corbicula manilensis (Asian clam)

# Oligohaline

Rangia cuneata (brackish water clam) Scolecolepides viridis (polychaete worm)

# Mesohaline

Macoma balthica (Baltic clam)
Heteromastus filiformis (polychaete worm)
Streblospio benedicti (polychaete worm)
Leptocheirus plumulosus (amphipod)
Mya arenaria (soft-shelled clam)

# Polyhaline

Loimia medusa
Mulinia lateralis
Asabellides oculata
Sphiophanes bombyx
Mercenaria mercenaria (hard clam)
Maldanids
Tellinids
Nephtyiids
Phoxocephalids
Haustoriids

# Euryhaline

Callinectes sapidus (blue crab)

# Motile epifauna

Palaemonetes pugio (grass shrimp)
Gammarus gammarus (amphipod)
Crangon

Corophium Mysidacea

# Sessile epifauna

Balanus improvisus (barnacle)

Mytilis edulis Molgula spp. Bryozoa

Crassostrea virginica (American oyster)

Anemones

#### FINFISH SPECIES:

# Freshwater and Estuarine Spawners

Alosa sapidissima (American shad) Alosa pseudoharengus (alewife) Alosa aestivalis (blueback herring) Alosa mediocris (hickory shad) Anchoa mitchilli (Bay anchovy) Menidia menidia (Atlantic silverside) Morone saxatilis (striped bass) Morone americana (white perch) Perca flavescens (yellow perch) Acipenser oxyrynchus (Atlantic sturgeon) Acipenser brevirostrum (shortnose sturgeon) Fundulus heteroclitus (mummichog) Micropterus salmoides (largemouth bass) Pseudopleuronectes americanus (winter flounder) Trinectes maculatus (hogchoker) Cynoscion regalis (weakfish) Cynoscion nebulosus (spotted seatrout) Pogonias cromis (black drum)

# Ocean Spawners

Brevoortia tyrannus (menhaden)
Leiostomus xanthurus (spot)
Micropogonias undulatus (Atlantic croaker)
Sciaenops ocellatus (red drum)
Centropristis striata (black sea bass)
Paralichthys dentatus (summer flounder)
Pomatomus saltatrix (bluefish)
Anguilla rostrata (eel)

# WATERFOWL AND OTHER AQUATIC BIRD SPECIES:

Anas platyrhynchos (mallard) Anas rubripes (black duck) Aythya valisneria (canvasback) Aythya americana (redhead duck) Aix sponsa (wood duck) Ardea herodias (great blue heron) Florida caerulea (little blue heron) Butorides striatus (green-backed heron) Casmerodius albus (American egret) Egretta thula (snowy egret) Pandion haliaetus (osprey) Haliaeetus leucocephalus (bald eagle) Clangula heimalis (old squaw) Melanitta deglandi (white-winged scoter) Olor columbianus (tundra swan) Megaceryle alcyon (kingfisher) Anas acuta (northern pintail) Anas strepera (gadwall) Anas americana (American widgeon) Branta canadensis (Canada goose) Sterna albifrons (least tern) Haematopus palliatus (oystercatcher) Rynchops niger (black skimmer) spp. (dowitcher) Limnodromus Arenaria interpres (ruddy turnstone) Actitis macularia (spotted sandpiper)

# OTHER VERTEBRATE SPECIES:

Mustela vison (mink)
Lutra canadensis (river otter)
Ondatra zibethica (muskrat)
Castorcanadensis (beaver)
Caretta caretta (Atlantic loggerhead turtle)
Lepidochelys kempi (Atlantic ridley turtle)
Malaclemys terrapin (diamondback terrapin)

# TARGET SPECIES

The following list of target species, selected from the list of key representative species by the Living Resources Task Force, was reviewed by participants at the Habitat Requirements Workshop held on February 24, 1987. Selection criteria are outlined in the introduction of this document. Species grouped together with the symbol "\*" were determined to have habitat requirements similar enough to permit treatment as a group rather than as individuals.

# SUBMERGED AQUATIC VEGETATION:

Ruppia maritima (widgeongrass)

Zostera marina (eelgrass)

Vallisneria americana (wild celery)

Potamogeton pectinatus (sago pondweed)

Potamogeton perfoliatus (redhead grass)

# FINFISH:

Morone saxatilis (striped bass)

- \* Alosa aestivalis (blueback herring)
- \* Alosa pseudoharengus (alewife)
- \* Alosa sapidissima (American shad)
- \* Alosa mediocris (hickory shad)

Perca flavescens (yellow perch)
Morone americana (white perch)
Brevoortia tyrannus (menhaden)
Leiostomus xanthurus (spot)
Anchoa mitchilli (bay anchoy)

# SHELLFISH:

#### Molluscan

- \* Crassostrea virginica (American oyster)
- \* Mya arenaria (softshell clam)
- \* Mercenaria mercenaria (hard clam)

# Crustacean

Callinectes sapidus (blue crab)

# WATERFOWL AND OTHER AQUATIC BIRDS:

Aythya americana (redhead duck) Anas rubripes (black duck) Aythya valisneria (canvasback) Aix sponsa (wood duck)

- \* Ardea herodias (great blue heron)
- \* Florida caerulea (little blue heron)
- \* Butorides striatus (green-backed heron)
- \* Casmerodius albus (American (great) egret)
- \* Egretta thula (snowy egret)
- \* Pandion haliaetus (osprey)
- \* Haliaeetus leucocephalus (bald eagle)

# HABITAT MATRICES

The Living Resources Task Force, aware of the many limitations and gaps in the available information, has summarized minimum habitat requirements for selected target species. The abundance and diversity of the Bay's living resources are affected by several variables, many of which are not fully understood. If the recovery of species which have declined in the Chesapeake Bay and the reestablishment of a more balanced ecosystem are the ultimate measures of success, the achievement of certain minimum habitat requirements for specific regions in the Chesapeake Bay is an essential first step.

The following text and matrices summarize existing information on habitat requirements for the initial list of target species. For many species, reliable in situ water quality and habitat requirements are not known and numerous data gaps exist. In all instances, the Living Resources Task Force reviewed available laboratory and field studies which evaluated the tolerance of species to individual variables such as salinity, turbidity, dissolved oxygen, and toxics. Few studies dealt with the composite effects of water quality and habitat factors These variables are closely interrelated and a change in one on survival. variable often affects the relative tolerance to other factors. Water temperature, for example, is inversely proportional to dissolved oxygen. of respiration rise with increasing water temperature, animals can tolerate lower oxygen concentrations longer at lower temperatures. Toxic substances demonstrate similar interactions. In combination, these materials can exert either synergistic or antagonistic effects and their relative toxicity is generally inversely proportional to dissolved oxygen. When such interactions could clearly be identified, they have been noted in the text or accompanying matrices.

The matrices contain information available for the sensitivities of target species to toxic substances. The sensitivities have been included in the form in which they were reported in the literature (LC50, LC0, etc.). These should not be construed as levels of toxic materials that will necessarily protect the resources. Future efforts must address the interpretation of existing toxics data in the determination of specific habitat requirements.

The following sections describe the necessary requirements for each target species.

TARGET SPECIES GROUP: Submerged aquatic vegetation complex
Critical life stage: all life stages
Critical period: April-September

Five species of submerged aquatic vegetation (SAV), with tolerances spanning the full range of salinities found in Chesapeake Bay habitats, were

selected as members of the target species group. Widgeongrass (Ruppia maritima) and eelgrass (Zostera marina) are representative of both the meso-haline and polyhaline zones. Sago pondweed (Potamogeton pectinatus) and redhead grass (P. perfoliatus) are tolerant of oligohaline and mesohaline salinities. Wild celery (Vallisneria americana) inhabits tidal fresh and oligohaline waters.

Submerged aquatic plants are particularly appropriate as target species because of their key role in providing critical habitat for other species. An SAV bed provides cover for fish and invertebrates, food for waterfowl and reduces shore erosion and suspended sediment loads. Also, SAV is a good indicator of poor water quality due to its sensitivity to turbidity and nutrient enrichment.

Light penetration limits the depth at which SAV can survive and grow. In Chesapeake Bay, this depth is usually less than 2 m, although in less turbid water some SAV species may grow at depths of 6 m or more. Dense phytoplankton blooms and epiphytic growth, stimulated by high nutrient levels, can reduce the transmittance of light to SAV leaves. Shading reduces photosynthetic activity causing depletion of carbohydrate reserves required for growth, reproduction, and overwintering. In high salinity waters, nitrogen is generally a limiting nutrient. High nitrogen concentrations can cause phytoplankton blooms and epiphytic growth harmful to SAV. In the mesohaline zone, either nitrogen or phosphorus can limit algal growth. Levels of dissolved inorganic nitrogen greater than 0.14 mg/l and dissolved inorganic phosphorus greater than 0.01 mg/l are thought to be responsible for previous SAV declines, largely because of excessive epiphytic growth and high algal concentrations in surrounding waters (Stevenson, unpublished data).

Suspended sediment also can limit light penetration in the water column. Light attenuation coefficients (kd) for photosynthetically active radiation (400-700 nm wavelength) should not exceed 2.0/m, and total suspended solids should be less than 20 mg/l to promote reestablishment of SAV (Figure 2) (Stevenson, unpublished data) in mesohaline zones.

Substantial regrowth of SAV in the tidal fresh portion of the Potomac River has been attributed to recent reductions in phosphorus loadings from the Blue Plains sewage treatment plant. In freshwater at the head of the Bay, SAV grows well in the presence of high nitrate levels apparently because phosphate concentrations are low enough to limit phytoplankton growth. In these areas, SAV is able to obtain sufficient phosphorus from the sediments. Dense beds of some SAV species, however, can raise daytime pH levels high enough to cause chemical reactions which act to release phosphate from sediments, stimulating algal growth.

Herbicides, such as atrazine, can be harmful to SAV at concentrations in excess of 10 ug/L. Water column concentrations of this magnitude are likely to occur in localized shallow embayments directly affected by agricultural runoff.

Submerged Aquatic Vegetation Complex Species Critical life stage: All life stages Critical Life period: April - September Matrix of Habitat Requirements for

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	Secchi Depth (m)	Light Intensity (uE/m-2/s-1)	Ж (m-1)	Chlor. (ug/l)	DIN (1) (mg/l)	DIP (1) (mg/l)	Herbicides (ug/l)	强
Wild celery (Vallisneria anericana)	Silt-clay- sand	Littoral (<3m)	0-5	18-35	<20	1.0	Best at 100	[ ]	<15 (1)	<0.7-1.4 <0.01	<0.01	Mortality at 12 atrazine	6-9
Sago pondweed (Potamogeton pectinatus)	Mud better than sand	Littoral (Sm)	0-12	15-35	<b>5</b> 00	1.0	Best at 350	1.7-2.0	<15 (1)	<0.14	<0.01	250 diquat or paraquat controls	6-9
Redhead grass   Potamogeton   perfoliatus	Mud, some organics	Littoral (Sm)	2-19	15-35	20	1.0	Best at 230	1.7-2.0	4.5	<0.14	<0.01	SignIficantly reduced photosynthesis at > 50	6-9
Widgeongrass (Ruppia maritima)	Prefers sand	Littoral (<2m)	2-60	20-26	<b>2</b> 0	1.0	Best at 236	1.7-2.0	<15	<0.14	<0.01	[]	6-9
Eelgrass (Zostera marina)	Usually sand	Littoral (0.25-1.5m)	5-35	8-30	<15	1.25	Best at 220	Ξ	<10	[]		Mortality at 100-1000 ug/l afrazine	6-9

(1) Stevenson (unpublished data) (2) Orth and Webb (unpublished data)

# TARGET SPECIES: Striped bass (Morone saxatilis) Critical life stage(s): larval, juvenile Critical life period: April to June

# **BACKGROUND**

There have been numerous literature reviews and synopses dealing with striped bass biology (e.g. Richkus, 1986; Setzler-Hamilton, 1980; Westin and Rogers, 1978; and Hildebrand and Schroeder, 1928). The reader is referred to these publications for a more thorough account of their life history.

# SPAWNING AND RANGE

Striped bass spawn during the spring in tidal fresh or brackish waters. The principal spawning and nursery areas of striped bass along the Atlantic Coast are found in the Chesapeake Bay and its tributaries (Merriman, 1941) and the Hudson and Roanoke rivers (Kaumeyer and Setzler-Hamilton, 1982).

Within the Chesapeake Bay basin, major spawning areas include: the James, Pamunkey, Mattaponi. Rappahannock, Patuxent, and Potomac rivers on the western shore; the head of the Bay with the Susquehanna Flats, Elk River, Chesapeake and Delaware (C & D) Canal; and, the Choptank and Nanticoke rivers on the Eastern Shore (Mansueti and Hollis, 1963; Speir, Personal Communication, 1987).

Spawning activity is apparently triggered by a rise in water temperature. Spawning times may vary from year to year due to annual temperature variations. In the Chesapeake Bay, 1 to 3 peaks occur during each spawning season with the major peak occurring any time during the last half of April or the first week of May (Kaumeyer and Setzler-Hamilton, 1982; Grant and Olney, 1982). Research has suggested that freshwater flow (both velocity and volume) is related to successful spawning (Kaumeyer and Setzler-Hamilton, 1982; Bayliss, 1982).

## TROPHIC IMPORTANCE

Adult and copepodite copepods and cladocerans are the major food items of larval striped bass. Setzler-Hamilton et al. (1981) reported that rotifers and Eurytemora affinis copepodites are the dominant prey for first-feeding striped bass larvae in the Potomac River. Larval striped bass from 6 to 13 mm consume copepodites, adults of cyclopoids and other copepods. The diet of larvae  $\geq$  14 mm consists almost entirely of adult copepods (Kaumeyer and Setzler-Hamilton, 1982). Westin and Rogers (1978) provided a comprehensive list of food items for striped bass at various life stages.

# **TOXICITY**

Of all the species examined in this report, striped bass has been studied the most with respect to its sensitivity to toxic chemicals. This section summarizes selected striped bass bioassays and highlights conflicting data.

Matrix of Habitat Requirements for Striped bass (Morone saxatilis) Critical life stage: larval, juvenile Critical life period: April - June

Target Species	Zone	Salinity (ppt)	Temp. (C)	Metals (mg/l)	DO (mg/l)	Insecticides (ug/l)	甁.	TRC (mg/l)	Flow (m/s)	Alkalinity (mg/l)	Total Hardness (mg/l)
Striped bass (Morone saxatilis)	Water column demersal (1)	0-5 (1)	16-19	Cadmium LC0 0.001 Copper sulfate LC0 0.10 Cupric chloride LC0 0.10 Zinc chloride LC0 0.10	Tolerate 4.5-20 (2) Optimum (2) 6-12	Malathion <14 Chlordane (2) <2.4 2,4,5-T <10	Optimum 7.5 - 8.5	(see text for narrative requirements)	(3)	>20 (2)	200-250
- 25-				Other metals of concern: Diss. Al							
rne i species:											
Cyclops nauplii and copepodites Copepods Cladocera (sididea) Copepods:											
	(1) Westin and Rogers (1978) (2) Kaumeyer and Setzler-Hamilton (1982) (3) Fay et al. (1983)	Rogers (197 nd Setzler-H 183)	78) Jamilton (19	82)							
	Refer to Appendix A for more specific toxicity values.	lix A for m	ore specific	toxicity values.							

Hall (1984) reported that water quality data from an on-site toxicity experiment on the Nanticoke River implicated that aluminum toxicity was induced by low pH. According to Richkus (1986), striped bass exhibited "no detectable effect" from aluminum concentrations of 200 to 400 ug/l at about pH 7. However, a pH of 6.5 or less with aluminum concentrations in the range of 25 to 100 ug/l caused significant mortality dependent upon the life stage of the striped bass (Richkus, 1986). O'Rear (1972) compared the relative toxicity of copper and zinc on embryos. Copper was more toxic, with a 48 hr LC50 value of 0.74 ppm. Hughes (1973) tested the tolerance of larval striped bass to cadmium, copper, and zinc. Cadmium was the most toxic. Larval striped bass experienced 50% mortality when exposed to 0.001 ppm of cadmium chloride for 96 hr (Kaumeyer and Setzler-Hamilton, 1982).

Data indicate that levels of total residual chlorine (TRC), while not necessarily lethal, may have significant sublethal effects on striped bass. For example, striped bass larvae exhibited significantly shorter body lengths after eggs were exposed to 0.15 ppm of total residual chorine. Kaumeyer and Setzler-Hamilton (1982) report that striped bass eggs exhibit 50% and 100% reduction in hatch rate when exposed to 0.19 and 0.43 ppm of TRC, respectively.

Lethal concentrations of toxic substances at various stages of the striped bass life history have been summarized by Richkus, 1986; Westin and Rogers, 1978; DiNardo et al., 1984; Emergency Striped Bass Study, 1984; and, Bonn et al., 1976.

Appendix A contains additional information on the sensitivity of striped bass for a selected group of toxic substances.

TARGET SPECIES: Alewife (Alosa pseudoharengus)
Critical Life Stage(s): egg, larval
Critical Life Period: Early April to mid-June

TARGET SPECIES: Blueback herring (Alosa aestivalis)
Critical Life Stage(s): egg, larval
Critical Life Period: Early April to end of May

#### **BACKGROUND**

This profile covers the life history and environmental requirements of the blueback herring (Alosa aestivalis) and the alewife (Alosa pseudo-harengus), since their distributions overlap and their morphology, ecological roles, and environmental requirements are similar. The alewife and blueback herring are anadromous species found in riverine, estuarine, and Atlantic coastal habitats, and have occurred historically throughout the Chesapeake Bay region (Hildebrand and Schroeder, 1928). Since the early developmental stages of the blueback herring, alewife, and hickory shad (Alosa mediocris) are difficult to separate and the spawning seasons and locations overlap for all these species, the matrix developed for both species also is applicable to the hickory shad.

# SPAWNING AND RANGE

The spawning locations and seasons of blueback herring and alewife overlap considerably. Blueback herring usually do not ascend streams as far as alewives (Hildebrand and Schroeder, 1928; Scott and Crossman, 1973). Blueback spawn in both fresh and brackish water in rivers and ponds (Davis, 1973; Hildebrand, 1963). However, Loesch and Lund (1977) reported that blueback herring preferred spawning in fast-flowing waters with hard substrates. Alewife often spawn in slower-moving waters (Wang and Kernehan, 1979). Because spawning by blueback herring is more site-specific than for alewife, dams and alteration of blueback spawning sites may be more detrimental to their population.

The spawning period for these two species is also very similar. Blueback spawning occurs from late April to early May in the Potomac River (Hildebrand, 1963). Alewives spawn from early April through mid-May (Wang and Kernehan, 1979).

Smith (1971) observed blueback spawning at water temperatures of 19-24 degrees C, but Wang and Kernehan (1979) reported slightly lower spawning temperatures (15.0-22.0 degrees C). Alewives spawn at water temperatures from 12.0-22.5 degrees C (Wang and Kernehan, 1979). Alewife eggs hatch at temperatures ranging from 12.7-26.7 degrees C (Atlantic States Marine Fisheries Commission, 1985). Klein and O'Dell (1987) report that the optimum temperature range for river herring larvae is 16-24 degrees C.

#### TROPHIC IMPORTANCE

The river herrings, blueback herring and alewife, are seasonally abundant fish feeding chiefly on zooplankton, particularly copepods (U.S. Corps of Engineers, 1984). The larvae for these two species consume primarily zooplankton and relatively small cladocereans and copepods (U.S. Fish and Wildlife Service, 1983). Juveniles and adults consume fish, crustacean and insect eggs, as well as adult insects; young fish may also constitute a portion of the diet when available (U.S. Corp of Engineers, 1984).

# **ENVIRONMENTAL CONDITIONS**

The LC50 of total residual chlorine (TRC) for blueback herring eggs ranges from 0.20-0.32 ppm (U.S. Fish and Wildlife Service, 1983). Eggs exposed to 84 mg/l of TRC reached early embryo stages but failed to develop further. Larvae from eggs exposed to sublethal concentrations of total residual chlorine were all deformed. Concentrations of 36 mg/l TRC produced 100% mortality in 1-day old larvae (U.S. Fish and Wildlife Service, 1983). Ammonia, nitrites and any form of reduced nitrogen are toxic. Nitrogen and phosphorus can indirectly affect food production and induce anoxic conditions (Connery, 1987).

Auld and Schubel (1978) found that suspended sediments at concentrations of 100 ppm or less had no significant effect on the hatch rate of alewife or blueback herring eggs. Research suggests that water flow created by shear, power plant uptake, pressure drop, and dam turbines is critical to the reproduction and survival of river herrings (Connery, 1987).

Matrix of Habitat Requirements for Alewife (Alosa pseudoharengus) Critical life stage: egg, larval Critical Life period: April to mid-June

Suspended Solids (mg/l)	50		
DO (mg/l)	>5.0		
丟	6.5-8.5 (2)		
Turbidity (NTU)	දු ල		
Temp. (C)	Eggs: 12.7-26.7 (2) Larvae: 16 - 24 (2)		
Salinity (ppt)	0-5 (optimum) (1)		
Substrate	Sand, gravel with 75% silt *critical for eggs and spawning (3)		
Target Species	Alewife (Alosa pseudoharengus)	PREY SPECIES:	L Zooplankton  Cladocerans  Copepods
	2		

(1) Kaumeyer and Setzler-Hamilton (1982)(2) Klien and O'Dell (1987)(3) FWS/DBS-82/11.9 October 1983

Matrix of Habitat Requirements for Blueback herring (Alosa aestivalis)
Critical life stage: egg, larval
Critical Life period: early March to the end of May

TRC (mg/l)	40.20 (3)	
DO Suspended Solids (mg/l)	95	
DO (mg/l)	\$\infty \times \	
强	6.5-8.5 (2)	
Turbidity (NTU)	§ €	
Temp.	Eggs: 12.7-26.7 (2) Larvae: 16 - 24 (2) (2)	
Salinity (mt)	0-5 (optimum) (1) r-Hamilton (1982) 87) October 1983	
Substrate	Sand, gravel with 0-5 (optimum) 75% silt *critical (1) for eggs and spawning (3) (3) (3) (1) Kaumeyer and Setzler-Hamilton (1982) (2) Klien and O'Dell (1987) (3) FWS/DBS-82/11.9 October 1983	
Target Species	Blueback herring (Alosa aestivalis) Zooplankton Cladocerans Copepods	

TARGET SPECIES: American shad (Alosa sapidissima)
Critical Life Stage(s): egg, larval
Critical Life Period: Mid-April to early June

TARGET SPECIES: Hickory shad (Alosa mediocris)
Critical Life Life Stage(s): egg, larval
Critical Life Period: April to June

## **BACKGROUND**

Historically, shad have inhabited virtually all rivers feeding the Chesapeake Bay (Kaumeyer and Setzler-Hamilton, 1982). Currently, shad population numbers are extremely low in Maryland waters, and shad fishing is banned (Jones et al., 1978; Kaumeyer and Setzler-Hamilton, 1982). There is still a commercial shad fishery in Virginia tributaries, however.

# SPAWNING AND RANGE

Spawning runs may begin as early as February, but are most frequent in April. Characteristic spawning and nursery grounds for shad are tidal freshwaters in estuaries and rivers; however, some shad can tolerate moderate salinities (Stagg, 1985; Kaumeyer and Setzler-Hamilton, 1982). Successful hatches have been reported at salinities ranging from 7.5 ppt at 12.0 degrees C to 15 ppt at 17 degrees C. No eggs hatched at a salinity of 22.5 ppt (U.S. Fish and Wildlife Service, 1986).

Shad spawning areas vary in depth and substrate. Shad seem to prefer areas dominated by shallow water or broad flats with sand or gravel bottoms (U.S. Fish and Wildlife Service, 1986). Sufficient water current velocities are required to keep the shad eggs suspended in the water column. Preferred velocities in spawning waters range from 30.5 to 91.4 cm/sec (U.S. Fish and Wildlife Service, 1986). Exposure of the eggs to suspended sediment concentrations as high as 1,000 mg/l did not affect hatching success (Auld and Schubel, 1978), but larval mortality was high at suspended sediment concentrations greater than 100 mg/l for 96 hours (U.S. Fish and Wildlife Service, 1986).

# **ENVIRONMENTAL CONDITIONS**

Eggs hatch in 12 to 45 days at 12 degrees C and in 6 to 8 days at 17 degrees C (Bigelow and Schroeder, 1953). Maximum survival of eggs and larvae occurs at 15.5-26.6 degrees C (U.S. Fish and Wildlife Service, 1986). Temperatures of 7-9 degrees C were reported to be lethal to eggs and larvae and temperatures of 20.0-23.4 degrees C caused extensive larval abnormalities (U.S. Fish and Wildlife Service, 1986). The LD50 for acid pH was 5.5 and it was 9.5 for basic pH (U.S. Fish and Wildlife Service, 1986). Larval shad LD50 for low dissolved oxygen (DO) ranges from 2.0-3.5 ppm, depending on the population. Mortality of eggs was 100% at DO levels below 1.0 mg/l (U.S. Fish and Wildlife Service, 1986). Larvae exhibit significant signs of stress when exposed to a DO level of 3.0 mg/l, and many died at 2.0 mg/l (Chittenden, 1969). A DO level of > 5.0 ppm is considered optimum (Chittenden, 1969; Wang and Kernehan, 1979).

Matrix of Habitat Requirements for American shad (Alosa sapidissima) Critical life stage: egg, larval Critical Life period: mid-April to early June

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	Hd	DO (mg/l)	Suspended Solids (mg/l)	
American shad (Alosa sapidissima)	[ ]	Egg: 7.5-15.0 at 12-17 C (3)	Egg: 15.5-26.6	\$ Q	6.5-8.5 (2)	χØ	<50	
		Larvae: 0-5 (1)	Larvae: 15.5-26 (3) 16-25 (2) (See text for narraive requirements)	ur- ents)				
DDEV CDECIES. (3)								
Midge larvae Midge pupae Cyclopoid copepods								
Dapma puex								
	(1) Kaumey (2) Klien an (3) FWS ha Biologic	<ol> <li>Kaumeyer and Setzler-Hamilton (1982)</li> <li>Klien and O'Dell (1987)</li> <li>FWS habitat suitability index publications Biological Report 82(11.45) 1986</li> </ol>	n (1982) publications 986					

Matrix of Habitat Requirements for Hickory shad (Alosa mediocris) Critical life stage: egg, larval Critical Life period: April to June

Substrate Salinity (ppt)	Egg: 7.5-15.0 at 12-17 C (3)	Larvae: 0-5 (1)				,
Temp. (C)	Egg: 15.5-26.6	Larvae: 15.5-26 (3) 16-25 (2) (See text for narrative requirements)				
Turbidity (NTU)	<b>5</b> 0 (2)	nar- sments)				
Hď	6.5-8.5 (2)					
DO (mg/l)	X &					
Suspended Solids (mg/l)	<50					

 Kaumeyer and Setzler-Hamilton (1982)
 Klien and O'Dell (1987)
 FWS habitat suitability index publications Biological Report 82(11.45) 1986 Larvae remain near the spawning grounds, usually a short distance downstream. Young remain in the nursery area until water temperatures begin to decrease in the fall. The downstream migration begins at a water temperature of approximately 21.1 degrees C (Wang and Kernehan, 1979). All young have left the nursery grounds by the time the temperature reaches 8.3 degrees C (Wang and Kernehan, 1979).

# TROPHIC IMPORTANCE

Shad larvae consume cyclopoid copepods, midge larvae, midge pupae, and Daphnia pulex (U.S. Fish and Wildlife, 1986).

# ADDITIONAL INFORMATION

For a concise overview see Boreman (1981); for a detailed study of the life history of shad see Mansueti and Kolb (1953). Reports by Cooper (1984), Richkus and DiNardo (1984), and Davis (1973) respectively provide thorough reviews on the status of Atlantic coast shad, all anadromous alosids of the eastern United States, and shad life history information for Virginia waters.

TARGET SPECIES: Yellow perch (Perca flavescens)

Critical life stage: egg, larval

Critical life period: first year of life

# SPAWNING AND RANGE

Yellow perch make vertical temperature-dependent migrations and inshore, upstream spawning migrations. The spawning period lasts from March to April in shallow tidal and non-tidal freshwater. Spawning occurs in low velocity currents (< 5 cm/s). The species is common where debris or vegetation are present. Eggs are gelatinous and semibuoyant (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1983; and, Wang and Kernehan, 1979). In the Chesapeake Bay, yellow perch habitat is situated between the upstream limit of tidal freshwater to mid-mesohaline salinity zones. Spawning activity has been reported in low salinity waters up to 2.5 ppt in the Severn River (Wang and Kernehan, 1979). Hildebrand and Schroeder (1982) observed yellow perch from Havre de Grace, Maryland to Lewisetta, Virginia. The fish tend to migrate toward the shorezone in summer and into deeper waters in winter (U.S. Corps of Engineers, 1984).

# TROPHIC IMPORTANCE

The principal foods of young yellow perch in freshwater consists of insects and small crustaceans (U.S. Corps of Engineers, 1984). Adults feed on soft-bodied fish, minnows, and anchovies, as well as isopods, amphipods, shrimp, crabs, insect larvae, and snails (U.S. Corps of Engineers, 1984; Hildebrand and Schroeder, 1928).

Matrix of Habitat Requirements for Yellow perch (Perca flavescens) Critical life stage: egg, larval Critical Life period: first year of life

Suspended Solids (mg/l)	>500, reduced larval survival (1)		
Cover	Vegetation, submerged trees, SAV (3)		
Hd	6.5-8.5 (2) (2) ity)		
Flow (cm/s)	Larvae 6.5 (<9.5mm) (7 unable to maintain position in current velocity) >2.5 (3)		
DO (mg/l)	<u>12</u> (2)		
Turbidity (NTU)	89		1983)
Temp. (C)	Tolerate 10-19		S-82/10.55
Salinity (ppt)	Tolerate 0.5 (1) Optimum 16-19 (1)		nilton (1982) vice (FWS/DB
Zone	Demersal (see text for narrative requirement) (3)		d Serzler-Han Dell (1987) d Wildlife Ser
Substrate	Egg: sand or sand & gravel mixture  Larvae; silt dominant, backwater and marsh areas (3)		<ul> <li>(1) Kaumeyer and Setzler-Hamilton (1982)</li> <li>(2) Klein and O'Dell (1987)</li> <li>(3) U.S. Fish and Wildlife Service (FWS/DBS-82/10.55 1983)</li> </ul>
Target Species	Yellow perch (Perca flavescens)	PREY SPECIES: Copepod nauplii Cyclopoid copepods Cladocerans Diaphanosoma	

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#### OTHER SENSITIVITIES

Yellow perch inhabit slow-flowing tidal rivers containing vegetation, submerged trees or pilings. Data suggest that yellow perch abundance decreases with increasing turbidity (U.S. Fish and Wildlife Service, 1983). They are able to tolerate low dissolved oxygen levels and remain active even under winter ice. However, laboratory and field studies determined that dissolved oxygen levels from 0.2-1.5 mg/l are lethal to yellow perch. A dissolved oxygen level of 5 mg/l was determined as the optimum lower limit (U.S. Fish and Wildlife Service, 1983).

TARGET SPECIES: White perch (Morone americana)
Critical life stage(s): egg, larval
Critical life period: first year of life

# **BACKGROUND**

White perch are found throughout the Chesapeake Bay and C&D Canal and have been reported in marine waters north of Chesapeake Bay. White perch are considered anadromous, but non-migratory resident populations do occur.

#### SPAWNING AND RANGE

White perch move upriver in the spring into the shorezone of tidal fresh waters to spawn (U.S. Corps of Engineers, 1984). In the Chesapeake Bay, spawning occurs from April to June. Spawning has been observed in December when appropriate climatic conditions occurred (Hildebrand and Schroeder, 1928). The species prefers spawning over shoal hard bottoms (e.g. sand or gravel) with currents. During their first year, juveniles remain in soft-bottomed, shallow, freshwater nursery areas, preferably in vegetated zones. Juveniles larger than 25 mm in total length begin inshore-offshore movements in response to light levels. Low temperatures cause white perch to move into deeper waters. Wintering populations are found in the deeper channels and holes in the upper Bay and tributaries. White perch in the Bay system are thought to consist of isolated subpopulations indigenous to each tributary.

Adult white perch are found in salinity zones of 5-18 ppt; however, they prefer to spawn at salinities less than 4.2 ppt (U.S. Fish and Wildlife Service, 1983; U.S. Corps of Engineers, 1984). Osmotic regulation is disrupted in eggs deposited in water of salinities  $\geq$  10 ppt. Larvae can tolerate salinities in the range of 0-8 ppt (U.S. Fish and Wildlife Service, 1983).

#### TROPHIC IMPORTANCE

The white perch is a generalized feeder and is benthophagus or piscivorous depending upon food availability, age and season (U.S. Fish and Wildlife Service, 1983). Larvae prey upon zooplankton. Fish, crustaceans, annelids and insect larvae are taken during juvenile and adult stages (Hildebrand and Schroeder, 1928). The fry are consumed by larger prey fish such as bluefish

Matrix of Habitat Requirements for White perch (Morone americana) Critical life stage: egg, larval Critical Life period: first year of life

Target Species	Substrate	Salinity (ppt)	Temp (C)	Hd	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Zone
White Perch (Morone americana)	Compact silt, sand, mud, clay (2)	Tolerate 0-8 Optimum 0-1.5	Tolerate 11-30 Optimum 12-20	8.5 (4)	% <b>€</b>	0 <del>5</del> 0 (4)	4.70 (4)	Subsurface waters (3)
PREY SPECIES: Rotifers Copepod nauplii Cladoceran: Bosmina E. affinis Cyclopid copepods Daphnia								
	(1) Kaumeyer and Setzler-Hamilton (1982) (2) FWS/DBS-82/11.7 1983 (3) Wang and Kernehan (1979) (4) Klien and O'Dell (1987)	er-Hamilton (1º 1983 (1979) 987)	982)					

(Cont'd)
Matrix of Habitat Requirements for
White Perch (Morone americana)
Critical life stage: egg, larval
Critical life period: first year of life

Critical life period: TIISt year of life  TRC Herbicides Metals (mg/l) (mg/l)	LC5 0.15 2,4-D LC50 Cupric chloride (1) 55.5 (1) LC5 0.023 Mercuric chloride LC5 0.004 Nickel chloride LC5 0.037 Silver nitrate LC5 0.017 (1)		<ol> <li>Kaumeyer and Setzler-Hamilton (1982)</li> <li>FWS/DBS-82/11.7 1983</li> <li>Wang and Kemehan (1979)</li> <li>Klien and O'Dell (1987)</li> </ol>
Insecticides (mg/l)	DDT LC50 - 8.00 Dieldrin LC50 - 10.0		<ol> <li>Kaurneyer and Setzler-Ham</li> <li>FWS/DBS-82/11.7 1983</li> <li>Wang and Kernehan (1979)</li> <li>Klien and O'Dell (1987)</li> </ol>

and striped bass (Hildebrand and Schroeder, 1928; U.S. Fish and Wildlife Service, 1983; U.S. Corps of Engineers, 1984).

TARGET SPECIES: Menhaden (Brevoortia tyrannus)
Critical life stage(s): juvenile
Critical life period: April to October

# SPAWNING AND RANGE

Juvenile menhaden are found in upper Chesapeake Bay tributaries from late May through November. Kaumeyer and Setzler-Hamilton (1982) report that juveniles were found in the Potomac River in March and April and in the upper Bay from late May through late June and in November. April through October is generally the peak time of abundance in the upper Chesapeake Bay. During the post-larval stage, menhaden tend to accumulate at the fresh/salt-water interface in the upper Bay region. Juveniles in the upper Bay begin to emigrate, generally after their first summer, from the freshwater interface into the mesohaline zone (U.S. Corps of Engineers, 1984; Kaumeyer and Setzler-Hamilton, 1982). Larger fish are found in the deeper waters down the Bay. Sub-adults leave the estuary with the adults in October; however, some overwintering occurs in Chesapeake Bay (U.S. Corps of Engineers, 1984; Kaumeyer and Setzler-Hamilton, 1982).

Spawning and early larval development occur in continental shelf waters of the Atlantic. Menhaden are estuarine dependent, utilizing the estuary both as a nursery for juveniles and as adult feeding ground during the summer months (Bigelow and Schroeder, 1953; Reintjes, 1969; and U.S. Corps of Engineers, 1984). Reintjes (1969) observed eggs and small larvae in Long Island Sound, Narragansett Bay, and Chesapeake Bay, but suggested that spawning in these areas made minor contributions to total population numbers.

# TROPHIC IMPORTANCE

Menhaden represent a major energy link between plankton directly to the large piscivores. Where menhaden are present in dense schools, their filter-feeding can be a primary control over local plankton abundance. According to Ulanowicz and Baird (1986), the summer diet of menhaden in the mesohaline part of Chesapeake Bay consists of zooplankton (65%), phytoplankton (5%), and unspecified organic particulates (29%).

TARGET SPECIES: Spot (Leiostomus xanthurus)

Critical life stage(s): juvenile

Critical life period: Early April to early November

#### SPAWNING AND RANGE

The spot is a demersal, marine spawning fish. Spawning activity on the continental shelf adjacent to the Chesapeake Bay was reported to occur during late fall and winter (Kaumeyer and Setzler-Hamilton, 1982). Some adults may

Matrix of Habitat Requirements for Menhaden (Brevoortia tyrannus) Critical life stage: juvenile Critical Life period: April to October

	1		1		cal Line park		
Target Species	Zone	Salinity (ppt)	Temp.	FE.	DO (mg/l)	Pathogens	
Menhaden (Brevoortia tyramus)	Pelagic or open water	tolerate 0-34 optimum 0-15 (2)	10-30 (4)	6.5-8.5 (3,4)	3,4)	Fungal parasites	
PREY SPECIES: (1)							
Phytoplankton Zooplankton Particulate Corganic material							
				8 <b>2</b> 6			
74							
	(1) Ulanowicz (2) Kaumeyer (3) Klein and 1 (4) U.S. Corp.	<ol> <li>Ulanowicz and Baird (1986)</li> <li>Kaumeyer and Setzler-Hamilton (1982)</li> <li>Klein and O'Dell (1987)</li> <li>U.S. Corps of Engineers (1984)</li> </ol>	(ton (1982) 84)				

Matrix of Habitat Requirements for Spot (Leiostomus xanthurus)
Critical life stage: juvenile
Critical Life period: early April to early November

lids.						
Suspended Solids (mg/l)	0. (3)					
DO (mg/l)	X @					
H	6.5 - 8.5					
Turbidity (NTU)	<b>%</b> &					
Temp. (C)	Tolerate 6.3-32.5 (2)					
Salinity (ppt)	Tolerate 0.32 optimum 0.5 (2)					
Substrate	Bottoms dominated by grasses and filter-feeding clams (4)					
Target Species	Spot (Leiostomus xanthurus)	PREY SPECIES: (1)	Nerels spp. Other polychaetes Macoma spp.	Ostracods Copepods		

(1) U.S. Fish and Wildlife Service (FWS/DBS-82/11.3 (1983)(2) Kaumeyer and Setzler-Hamilton (1982)(3) Klien and O'Dell (1987)(4) Wang and Kemehan (1979)

spawn twice a year (U.S. Fish and Wildlife Service, 1982). Kaumeyer and Setzler-Hamilton (1982) suggested that adult spot do not survive after they spawn.

Post-larval and juvenile spot spend much of their lives in estuaries (U.S. Fish and Wildlife Service, 1982). Post-larval spot inhabit Chesapeake Bay from early April through early November (Hildebrand and Schroeder, 1928). In the Maryland portion of the Bay, spot larvae and young juveniles congregate in the oligohaline zone, although when population densities are high, some young move into tidal freshwater, shallow marshes, and drainage ditches (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1982). In the lower Bay, spot larvae and young juveniles are found in mesohaline and polyhaline tidal marshes. Spot are common near grass beds and over muddy substrates (U.S. Fish and Wildlife Service, 1982). In Chesapeake Bay, adults are found in mesohaline to polyhaline salinity zones (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1982). Spot leave the Bay as water temperatures decline in the fall (Wang and Kernehan, 1979).

Fish in their second or third year of life do not penetrate very far into the estuary, and are abundant only in the lower Virginia portion of the Bay (U.S. Corps of Engineers, 1984). Adult spot habitat in the Chesapeake is defined as mid-mesohaline to polyhaline areas with depths to 6 m overlying soft sediment bottoms (U.S. Corps of Engineers, 1984).

## TROPHIC IMPORTANCE

Juvenile spot primarily consume benthic invertebrates including: ostracods, copepods, and polychaetes (U.S. Fish and Wildlife Service, 1982). Approximately 93% of the summer diet consists of polychaetes; most of the remainder is *Macoma* spp. (Ulanowicz and Baird, 1986). Spot are preyed upon by large gamefish and also harvested by sport and commercial fisheries. Spot represent a significant link in the transfer of energy from the detritivores and primary consumers eaten by spot in the Bay to its predators in the waters of the adjacent continental shelf (U.S. Corps of Engineers, 1984).

TARGET SPECIES: Bay anchovy (Anchoa mitchilli)

Critical life stage(s): larval

Critical life period: May to September

#### **BACKGROUND**

Bay anchovy has been observed in virtually all open waters throughout the Chesapeake Bay from the tidal fresh to the polyhaline zone; the C & D Canal and Havre de Grace down to Lynnhaven Roads, Virginia (Wang and Kernehan, 1979; Hildebrand and Schroeder, 1928). Anchovy larvae are pelagic and are also found over a wide salinity range (Wang and Kernehan, 1979; Hildebrand and Schroeder, 1928). According to Wang and Kernehan, (1979) the larvae move upstream to low salinity regions after hatching, with the highest concentrations of larvae observed at salinities of 0-7 ppt salinity. The U.S. Corps of Engineers (1984) reported larvae at salinities of 3-7 ppt. Larvae were found 40 miles above brackish water in Virginia (Wang and Kernehan, 1979) and in the Potomac River in freshwater near Bryans Point, about 12 miles below Wash-

Matrix of Habitat Requirements for Bay anchovy (Anchoa mitchilli) Critical life stage: larval Critical Life period: May to September

Temp. (C)	15.0- 30.0		
Salinity (ppt)	0.7		Wang and Kernehan (1979)
	Pelagic		Wang and
Zone	Pe		

ington, D.C. (Hildebrand and Schroeder, 1928). Anchovy larvae also occur large numbers throughout the lower Chesapeake Bay (Olney, 1983).

#### SPAWNING AND RANGE

The Bay anchovy spawning season occurs from May to September in the Chesapeake Bay (Wang and Kernehan, 1979). Spawning is pelagic and occurs in the Chesapeake Bay at salinities ranging from 1-22 ppt (U.S. Corps of Engineers, 1984; Wang and Kernehan, 1979). Spawning also occurs at the Chesapeake Bay mouth where salinities are typically 25-28 ppt (Olney, 1983). Wang and Kernehan (1979) reported that spawning activity in the Delaware Bay occurs between 15 degrees C and 30 degrees C with peak activity occurring at 22-27 degrees C. They also reported peak egg densities occur at salinities of 12-13 ppt in Chesapeake Bay. In the upper Chesapeake Bay, larvae are observed in shallow shore areas where the salinities range between 3-7 ppt (U.S. Corps of Engineers, 1979).

## TROPHIC IMPORTANCE

Anchovies feed primarily on mysids and copepods (Hildebrand and Schroeder, 1928). In overlapping ranges, Bay anchovy larvae are reported to compete with alosid larvae for copepods (U.S. Corps of Engineers, 1984; Hildebrand and Schroeder, 1928). The anchovy is a year-round resident, and an important forage fish of the Chesapeake (U.S. Corps of Engineers, 1984). During the summer, in the mesohaline portion of Chesapeake Bay, anchovies consume large quantities of phytoplankton (13%), zooplankton (72%), and organic detritus (15%) (Ulanowicz and Baird, 1986).

# ADDITIONAL INFORMATION

The larval stage is considered the most sensitive life stage for the Bay anchovy. The larvae have been observed to congregate at the surface waters of the oligohaline zone. Crowding has been observed as anchovies move into the narrower oligohaline areas of tributaries. Concentration of larvae in the surface waters may cause localized overpopulation which possibly resulting in a reduction in year class abundance (U.S. Corps of Engineers, 1984).

# TARGET SPECIES GROUP: Molluscan Shellfish

American oyster (Crassostrea virginica)
Critical life stage(s): larval, spat and adult
Critical life period: entire life cycle

Soft clam (Mya arenaria)

Critical life stage(s): larval

Critical life period: May - October

Hard clam (Mercenaria mercenaria) Critical life stage(s): egg and larval Critical life period: first year of life

#### **BACKGROUND**

American oysters, soft clams, and hard clams are prominent members of the benthic community in Chesapeake Bay and contribute substantially to the economy of the region. Oysters have recently experienced severe declines in abundance. Soft clams in the Chesapeake Bay have also decreased in abundance in recent years in the Bay. Intense fishing pressure, loss of habitat, and water quality degradation have been blamed for declines in the abundance of these species. Hard clams, however, have maintained more stability in population numbers, primarily due to greater market demand for surf clams and ocean quahogs in the mid-Atlantic region.

# SPAWNING AND RANGE

All Chesapeake oysters are subtidal, whereas their southern counterparts are often intertidal. American oysters prefer a firm substrate: pilings, hard rock bottoms, and substrates firmed with the oyster shells of previous generations. Soft clams in the Chesapeake inhabit shallow subtidal (10 m) estuarine waters to intertidal areas in the oligohaline through the polyhaline zones. Hard clams are euryhaline marine species sensitive to salinities below 12 ppt, and thus are only found in the lower Bay from the mesohaline through the polyhaline zone (12-32 ppt). Although found in a variety of substrates including mud, hard clams prefer a firm bottom. They favor a mixture containing sand or shell which provides points of attachment for juveniles as well as protection from many predators.

The American oyster in the Chesapeake Bay spawns in the summer when water temperatures exceed 15 degrees C. Heavy spawning is likely to occur at Sperm and eggs are released into the water where fertil-22-23 degrees C. ization occurs, producing free-swimming larvae. The duration of the larval stage varies with temperature, lasting sometimes as few as 7 to 10 days, but most often between 2 to 3 weeks before the larvae set and became sessile Soft clams and hard clams, like most other bivalve mollusks, spawn when a critical temperature occurs. In the Chesapeake, soft clams spawn in the spring when water temperature reaches 10 degrees C and spawning may be repeated in the fall when water temperature falls to 20 degrees C. eggs develop into planktonic trochophore larvae in about 12 hours. remain in the water column for about 6 weeks during the fall. spring rate of larval development is caused by temperatures at the warmer end of the soft clam's spawning temperature range. Setting of soft clams, therefore, may occur twice in the same year. Frequently, however, heavy predation on the spring set by blue crabs and bottom-feeding fish results in unsuccessful recruitment. Hard clams spawn at temperatures of 22-24 degrees C. egg development occurs between 20-35 ppt salinity. At salinities below 17.5 ppt, larvae fail to metamorphose and growth of juveniles ceases. Optimal temperatures for larval growth range between 18 and 30 degrees C. ceases at oxygen concentrations below 2.4 mg/l.

#### TROPHIC IMPORTANCE

The American oyster is an epibenthic suspension feeder, ingesting a variety of algae, bacteria, and small detrital particles, most within a range of 3-35 um. Capture efficiency decreases rapidly at particle sizes < 3 um. Particles filtered but not ingested by the oyster are eliminated as pseudofeces. Fecal and

pseudofecal material is important in sediment production and deposition, providing sites for remineralizing bacterial action, and as a food source for deposit feeders. The hard shell provides a substrate for numerous epifaunal organisms such as barnacles and mussels. These characteristics make the oyster an important member of the benthic community throughout the Chesapeake Bay. Oysters, especially in the juvenile stages, are subject to heavy parasitism and predation by many organisms include protozoans, crabs, snails, and flatworms.

Both soft and hard clams are also important benthic species in the Bay. Both species are infaunal suspension feeders, ingesting small detrital particles and phytoplankton, as well as bacteria and microzooplankton in the case of Mya spp. Adult soft clams burrow deeply, feeding through a long extensible siphon. Juveniles, burrowing less deeply, often fall prey to finfish, blue crabs and waterfowl. Commercial harvesting of adults reduces adult populations and exposes juveniles to predation before they can burrow back into the sediment. Hard clams favor shallow burrows and are also preyed upon by fish, crabs, and waterfowl, particularly during the juvenile stage. Also of commercial importance, the hard clam populations in the Bay suffer from irregular recruitment and are strictly limited to higher salinity regions.

# OTHER SENSITIVITIES

Oysters are sensitive to both turbidity and sedimentation. Excessive sediment deposition smothers adults and prevents setting of spat. The observation that the upstream limit of producing oyster bars has shifted downstream several miles in historic times is evidence of the impact of sedimentation. Adult feeding rates are depressed at suspended solids concentrations above 24 mg/l and feeding ceases at concentrations above approximately 50 mg/l. Soft clams are vulnerable to sediment disturbances since they are slow reburrowers. As such, they are impacted by harvesting practices, waves, currents and bioturbation. Regrowth of SAV would benefit these bivalves by reducing the amount of sediment resuspension and the resulting turbidity.

Areas of good circulation produce better setting and survival of young oysters. Most oysters in the Chesapeake are found in areas less than 10 m deep in which circulation patterns promote adequate levels of dissolved oxygen. Soft clams are also impacted by anoxia which restricts their distribution to shallow waters less than 10 m in depth.

Oyster diseases, notably Haplosporidium nelsoni ("MSX") and Perkinsus marinus ("dermo"), have caused significant mortality in the lower Bay. The organisms causing these diseases require the higher salinities of the lower Bay to proliferate. The devastating oyster diseases, MSX and dermo, may not be restricted by salinity. Infection rate may be related to the oyster's cellular responses to salinity. In the Choptank River, at salinities < 13 ppt, MSX has been observed.

Temperatures of 32.5 degrees C or greater are lethal to adult soft clam limiting intertidal distribution in the species' southern range. For oysters, soft clams, and hard clams, it is generally agreed that food availability is another significant factor dictating their survival. Foods of critical sizes are needed for the different life stages; with the cell sizes generally ranging from 3-35 um.

Matrix of Habitat Requirements for American oyster (Crassostrea virginica) Critical life stage: larval, spat, adult Critical Life period: entire life cycle

Salinity (ppt)	5-35						
Suspended Solids Sa (mg/l)	<35 (adult activity reduced above 24) (3)						
DO (mg/l)	>2.4 (2)*					al Report 82(11.65)	ature not known.
Zone pH	Subidal (1) 6.8-8.5 (2)					(1) U.S. Fish and Wildlife Service Biological Report 82(11.65) (2) Kaumeyer and Setzler-Hamilton (1982) (3) Jordan (1987)	*Critical DO should be higher when temperature exceeds 25 degrees C. Exact requirements not known.
Substrate	Firm substrate, pilings, hard rock bottom, shells (1)					(1) U.S. Fish and (2) Kaumeyer and (3) Jordan (1987)	*Critical DO sho exceeds 25 degr
Target Species	American oyster (Crassostrea virginica)	PREY SPECIES:	Phytoplankton size range: 3-35 microns				

Matrix of Habitat Requirements for Softshell Clam (Mya arenaria) Critical life stage: larval Critical Life period: May to October

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Alkalinity (mg/l)	DO (mg/l)	됬	TRC (mg/l)	Herbicides (ug/l)	Metals (mg/l)
Softshell clam (Mya arenaria)	Sand, sand-mud, sand-clay (2)	Shallow intertidal and sub- tidal (2)	>10.5 (1)	Mean temps during larval setting are: Spring=19.4-21.9 Fall=19.6-13.9 (2)	(3)	% <b>⊕</b>	8-5.9	LC0 0.05	Chlordane <2.4 (2)	LC50's for 168-hr Cu, .035 Cd, .150 Zn, 1.55 Pb, 8.80 Mn, 3.00 Ni, 50.00 (3)
PREY SPECIES: Microzooplankton Phytoplankton										
	<ol> <li>FWS Habitat Suitability Index Publica</li> <li>Kaumeyer and Setzler-Hamilton (1982)</li> <li>EPA Quality Criteria for Water 1986</li> </ol>	tat Suitability and Setzler-H ity Criteria fo	/ Index Public familton (198; r Water 1986	<ol> <li>FWS Habitat Suitability Index Publications Biological Report 82(11.68) 1986</li> <li>Kaumeyer and Setzler-Hamilton (1982)</li> <li>EPA Quality Criteria for Water 1986</li> </ol>	ероп 82(11.6	8) 1986				

Matrix of Habitat Requirements for Hard clam (Mercenaria mercenaria) Critical life stage: egg, larval Critical Life period: first year of life

ita Al

Target Species Substrate Zone	Hard clam Shell, sand, Mesohaline, mud (1) polyhaline mercenaia)  PREY SPECIES: Phytoplankton size range: 3-35 microns  Detritus	
Salinity (ppt)	[17]	
Temp. (C)	18-30 (1)	
DO (mg/l)	×2.4 (1)	
Hd (l/gm)	6.8-8.5	
Metals (mg/l)	Silver nitrate LC5 021 Cupric chloride LC5 018 Mercuric chloride LC5 005 Nickel chloride LC5-1.11 Zinc chloride LC5 068 LC5 068	
Alkalinity (mg/l)	20 (2)	
Insecticides (mg/l)	Aldrin LC0041 Toxaphene LC0-<.025 (1)	
Chlorinated Hydocarbons (mg/l)		

(1) Kaumeyer and Setzler-Hamilton (1982) (2) EPA Quality Criteria for Water 1986

TARGET SPECIES: Blue crab (Callinectes sapidus)
Critical life stage: larval, pre-molt, post-molt
Critical life period: June - October

#### **BACKGROUND**

Blue crabs are found from the mouth of the Bay to tidal fresh areas. There are distinct differences in the ranges of males and females. During the summer months, males are found from freshwater to the polyhaline zone, although they occur in the greatest numbers in salinities of 3-15 ppt. Maximum numbers of females occur down Bay at salinities of 10 ppt to ocean salinities. When air temperatures drop below 10 degrees C, adult crabs leave shallow, inshore waters and seek deeper areas where they bury themselves and remain in a state of torpor throughout the winter.

#### SPAWNING AND DISTRIBUTION

After mating, females migrate south in the Bay toward higher salinity waters. The timing of egg hatching is seasonally dependent. If mating occurs during spring, then the first egg mass, or sponge, may hatch in July. Most females mate during the late summer season in July, August, or September, with hatching delayed until the following summer. A female may also produce two or more egg sponges later in the summer. Blue crab spawning appears to be concentrated at the mouth of Chesapeake Bay in the channel region between Cape Henry and Cape Charles where salinities are near oceanic.

McConaugha et al. (1981) examined seasonal, horizontal and vertical distribution of blue crab larvae in the mouth of the Chesapeake Bay and nearshore waters. Only early stage zoeae (mainly Stages I-III) and megalopae were found in the Bay mouth, while all zoeal stages and megalopae were present in abundance offshore. They concluded that larval development occurs in the rich coastal waters and recruitment back to the estuary occurs in the post-larval or juvenile stages.

Juvenile crab migration up the Chesapeake Bay and its tributaries begins in August. Male and female juvenile crabs apparently have different migratory patterns. Miller et al. (1975) reported that juvenile crabs, predominantly males, move into the Chesapeake and Delaware Canal area in late spring. This distribution of sexes is quite unlike the sex distribution of juvenile crabs in the lower Bay, around Tangier Sound, suggesting there is a separation of the sexes at an early stage which is probably due to differences in migratory behavior.

# **GROWTH**

Blue crab growth is regulated by water temperature. Growth occurs from late April to mid-October when temperatures are above 15 degrees C (Van Engel et al., 1973). They grow by shedding their hard shells (molting). Molting is a major physiological event of crustacean life history. Blue crabs molt frequently during the early juvenile stages (7-10 days). The periodicity decreases with age and size. The premolt and postmolt phases are periods of high metabolic activity; therefore, the animal may be more susceptible to

Matrix of Habitat Requirements for Blue crab (Callinectes sapidus) Critical life stage: larval, premolt, post-molt Critical Life period: June - October

environmental stress during these periods. The crabs reach adult size (130 mm or larger) while on the "nursery grounds," brackish water habitats in the tributaries and mainstem of the Bay.

# TROPHIC IMPORTANCE

Blue crabs are generally considered omnivorous. The zoeae and megalopae prey primarily upon zooplankton. The megalopae will also feed upon pieces of fish or shellfish and aquatic plants (Van Engel, 1958). Juvenile and adult blue crabs are also omnivorous, feeding on benthic macroinvertebrates, small fish, aquatic vegetation and associated fauna, and dead organisms (Lippson et al., 1979). The blue crab is known to prey on young quahogs and seed oysters under experimental conditions. It will also prey on oyster spat, newly set oysters and clams, or young oysters if other food is unavailable (Van Engel, 1958; Shea et al., 1980). It follows that the blue crab may be a major factor in the control of benthic populations (Shea et al., 1980).

TARGET SPECIES: Canvasback (Aythya valisineria)

Critical Life Stage: nestling

Critical Life Period: March - June

#### **BACKGROUND**

The canvasback is a diving duck, often descending several meters in search of food. It breeds on the North American prairies and migrates only when water becomes too cold in its summer range. Chesapeake Bay populations have been reduced from a peak of almost 400,000 canvasbacks, to averages of 250,000 in the 1950s and generally less than 70,000 in the 1980s. Before hunting reforms in 1918, canvasbacks, an international delicacy, were slaughtered in the thousands by market hunters.

Canvasbacks have adapted with success from their earlier dependence on and preference for wild celery and other submerged aquatic vegetation. These ducks now depend on Rangia and Macoma clams, snails, insects, worms and small crustaceans as a substantial portion of their diet. This dietary change has made them less desirable table fare, but canvasbacks are still much prized by hunters.

TARGET SPECIES: Redhead duck (Aythya americana)
Critical Life Stage: nestling
Critical Life Period: March - June

# **BACKGROUND**

The redhead's principal breeding grounds are the North American prairies, where habitats have been reduced. Most redheads migrate to the Gulf of Mexico coast, but in the 1950s as many as 118,800 were estimated in the Chesapeake Bay during January 1956. The 1980s populations have averaged about 3,500. This duck's exceptionally large salt glands enable it to spend much

Matrix of Habitat Requirements for Canvasback (Aythya valisneria) Critical life stage: wintering Critical Life period: November - March

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (mg/l)	Secchi Depth (m)	Light Intensity (uE/m-2/S-1)	KD (m-1)
Canvasback Duck (Aythya valisneria)	N.L.	N.L.	N.L.	N.L.	N.L	[ ]	N.L.	N.L.
PREY SPECIES:								
Wild celety (Vallisneria americana)	Silt-clay sand	Littoral (3m)	0 - 5	18 - 35	<20	1.0	Best at 100	
Sago pondweed (Potamogeton pectinatus)	Mud better than sand	Littoral (3m)	0 - 12	15 - 35	8	1.0	Best at 350	1.7 - 2.0
Redhead grass (Potamogeton perfoliatus)	Mud, some organics	Littoral (3m)	2 - 19	15 - 35	<sup>2</sup> 20	1.0	Best at 230	1.7 - 2.0
Widgeongrass (Ruppia maritima)	Prefers sand	Littoral (<2m)	2 - 60	20 - 26	20	1.0	Best at 236	1.7 - 2.0
Eelgrass (Zostera marina)	Usually sand	Littoral (0.25-1.5m)	5-35	8 - 35	<15	1.25	Best at 220	[ ]
Baltic clam (Macoma balthica)	All substrates; best in mud	Intertidal; Subtidal to 15m	2 - 19		[ ]	[ ]	N.L.	N.L.
Brackish-water clam (Rangia cuneata)	Mud/sand mix	Intertidal; Subtidal to 5m	0 - 18	8 - 32	Ξ		N.L.	N.L.
Crustaceans Insects Small fish	(1) Stevenson (unpublished data) (2) Orth and Moore (unpublished data)	npublished data ore (unpublished	) d data)					

(Cont'd)
Matrix of Habitat Requirements for
Canvasback (Aythya valisneria)
Critical life stage: wintering
Critical Life period: November - March

•				•			
Target Species	DIN (1) (mg/l)	DIP (1) (mg/l)	Herbicides (ug/l)	Metals Ch (mg/l)	Chlorophyll a (1,2) (ug/l)	DO (mg/l)	Hď
Canvasback (Aythya valisneria)	N.L.	N.L.	N.L.		N.L.	N.L.	N.L.
PREY SPECIES: Wild celery (Vallisneria americard)	<0.7-14	<0.01	Mortality at 12 atrazine	[ ]	<15	N.L.	6-9
Sago pondweed (Potanogeton pectinatus)	<0.14	<0.01	250 diquat or paraquat controls		<15	N.L.	6 - 9
Redhead grass (Potamogeton perfoliatus)	<0.14	<0.01	Signficantly reduced photosynthesis at 50	[ ]	<15	N.L.	6 - 9
Widgeongrass (Ruppia maritima)	<0.14	<0.01		Ξ	<15	N.L.	6-9
Eelgrass (Zostera marina)	Ξ	[ ]	Mortality at 100 - 1000 atrazine		<10	N.L.	6-9
Baltic clam (Macoma balthica)	[ ]	[ ]	Ξ	Accumulates metals; toxicity not known	Ξ		N.L.
Brackish-water clam (Rangia cureata)	Ξ	[]		[ ]	[]	Withstands anoxia for days. Intolerant of air exposure	[ ]
Crustaceans Insects Small Fish		(ast) bod-iliman, wood	(e)			•	

(1) Stevenson (unpublished data) (2) Orth and Moore (unpublished data)

Matrix of Habitat Requirements for Redhead Duck (Aythya americana) Critical life stages: All life stages Critical Life period: April - September

FOOD ITEMS:   Silt-clay   Littoral   0-5   18-35   <20   1.0   Best at 100   [ ]	Target Species Redhead duck (Aythya americana)	Substrate N.L.	Zone N.L.	Salinity (ppt) N.L.	Temp. (C) N.L.	Turbidity (mg/l) N.L.	Secchi Depth (m)	Light Intensity (w/E/m-2/S-1) N.L.	(m-1)	_ !
Valisneria   Sago pondweed	FOOD ITEMS:		:	•	,					
Sago pondweed (Potamogeton Pectinatus)         Mud better than sand (3m)         Littoral (3m)         0-12         15-35         <20	Wild celery (Vallisneria americana)	Silt-clay sand	Littoral (3m)	65	18-35	<20	1.0	Best at 100		
Mud, some         Littoral         2-19         15-35         <20         1.0         Best at 230           Organics         (3m)         5-60         20-26         <20         1.0         Best at 236           Prefers sand         (<2m)         5-60         20-26         <20         1.0         Best at 236           Usually sand         0.25-1.5         5-35         8-35         <15         Best at 220		Mud better than sand	Littoral (3m)	0-12	15-35	<b>2</b> 0	1.0	Best at 350	1.7-5	2.0
Prefers sand (<2m) 5-60 20-26 <20 1.0 Best at 236   Usually sand 0.25-1.5 5-35 8-35 <15 1.25 Best at 220	Redhead grass (Potomogeton perfoliatus)	Mud, some organics	Littoral (3m)	2-19	15-35	<b>2</b> 00	1.0	Best at 230	1.7-2	0
Usually sand 0.25-1.5 5-35 8-35 <15 1.25	Widgeongrass (Ruppia maritima)	Prefers sand	(2m)	2-60	20-26	<b>~</b>	1.0	Best at 236	1.7-2	0:
Crustaceans Insects Small fish	Eelgrass (Zostera marina)	Usually sand	0.25-1.5 m	5-35	8-35	<15	1.25	Best at 220	_	
	Crustaceans Insects Small fish									

(1) Stevenson (urpublished data) (2) Orth and Moore (urpublished data)

(cont'd)
Matrix of Habitat Requirements for
Redhead Duck (Aythya americana)
Critical life stage: All life stages
Critical Life period: April - September

Target Species	Chlor.	NIO .		Herbicides	Metals
Redhead duck (Aythya americana)	N.L.	N.L.	N.L.	N.L.	N.L.
FOOD ITEMS:					
Wild celery (Vallisneria americana)	<15	<0.7-	<0.01	Mortality at 12 atrazine	
Sago pondweed (Potamogeton pectinatus)	<15	<0.14	<0.01	250 diquat or paraquat controls	
Rechead grass (Potamogeton perfoliatus)	<15	<0.14	<0.01	Significantly reduced photosynthesis at 50	
Widgeongrass (Ruppia maritima)	<15	<0.14	<0.01	[]	[.]
Eelgrass (Zostera marina)	<10			Mortality at 100-1000 atrazine	[.]
Crustaceans Insects Small fish					
				*	
	(1) Stevenso (2) Orth and	(1) Stevenson (unpublished data) (2) Orth and Moore (unpublished data)	data) shed data)		

of its wintering time in waters at or near ocean salinity. Entire winters may be spent on the water.

The food of the redhead consists largely of vegetation, more so than other diving ducks. Sago pondweed, wild celery, widgeongrass and other submerged aquatic plants are the favored items. A small percentage of insects, mollusks, other invertebrates, and small fish are also eaten.

TARGET SPECIES: Black Duck (Anas rubripes)
Critical Life Stage: nestling
Critical Life Period: April - July

# **BACKGROUND**

The Chesapeake Bay's population of black ducks has dwindled in recent years, from an estimated 200,000 overwintering in 1955 to less than 50,000 in the mid-1980s. For this reason, more severe hunting restrictions have been placed upon the species.

Black ducks pair in the autumn. Typically in April, the female lays from 7 to 12 eggs in simple, hollowed-out, pine needle-lined nests. In the Chesapeake Bay area, isolated islands and marshes are the favored breeding places. Though wary of people and other intruders such as predators, which include raccoons, crows and gulls, almost half the nests are usually destroyed. A second clutch of eggs is then usually laid.

Black ducks feed on animal foods more than most other dabblers. Favored items are snails, mussels, clams, small crustaceans and immature insects. Pondweeds (*Potamogeton* spp.), widgeongrass, eelgrass, smooth cordgrass, wild rice and bulrushes are plant food items which, along with corn, are consumed when available.

TARGET SPECIES: Wood duck (Aix sponsa)
Critical Life Stage: nestling
Critical Life Period: April - July

# **BACKGROUND**

Wood ducks are at the northern edge of their wintering range in the Chesapeake area, but can breed successfully, given proper habitat. Breeding habitat should include 10 acres of isolated wetlands with at least 50 percent cover, while wintering habitats may be less dependent on size given the adults' greater sociability and mobility. Typical habitat consists of secluded freshwater swamps and marshes providing plenty of downed or overhanging trees, shrubs, and flooded woody vegetation. Areas inhabited by beaver often provide good wood duck habitat. Cavity nesting sites are important for wood ducks, in order to provide safety from predators such as raccoons.

Adults are largely herbivorous, typically feeding on nuts and fruits from woody plants, aquatic plants and seeds. Their diet does include some insects

Matrix of Habitat Requirements for Black Duck (Anas rubripes) Critical life stage: nestling Critical Life period: April - July

					Critical Life period: April - July	a: April - July				
Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Secchi Depth (m)	Cover	Light Intensity (uE/m-2/s-1)	Metals (mg/l)	Herbicides (ug/l)	
Black duck (Anas rubripes) PREY SPECIES:	[]	N.L.	N.L.	N.L.	1.0 - needs intertidal feed- ing areas	Marsh vegetation	N.L.	Lead shot ingested	Ξ	
Wild celery (Vallisneria americana)	Silt-clay- sand	Littoral (3m)	0.5	18-35	1.0	N.L.	Best at 100		Mortality at 12 atrazine	
Sago pondweed (Potamogeton pectinatus)	Mud better than sand	Littoral (3m)	0-12	15-35	1.0	N.L.	Best at 350	[ ]	250 diquat or paraquat controls	
Redhead grass (Potamogeton perfoliatus)	Mud, some organics	Littoral (3m)	2-19	15-35	1.0	N.L.	Best at 230	[]	Significantly reduced photosynthesis at >50	
Widgeongrass (Ruppia maritima)	Prefers sand	Littoral (<2m)	2-60	20-26	1.0	N.L.	Best at 236	[]		
Smartweeds (Polygonum spp.)	[ ]	[ ]	[ ]	N.L.	N.L	N.L.	[]	[ ]	[ ]	
Rice cutgrass (Leevsia oryzoid)	[ ]	[ ]	[]	N.L.	N.L	N.L.	Ξ	[ ]	[ ]	
Cordgrass (Spartina alterniflora)	[]	[ ]	Ξ	N.L.	N.L.	N.L.	[ ]	[ ]	[]	
Salt marsh snail (Melampus	[ ]	[ ]		[ ]	N.L.	Ξ		[ ]	[ ]	
bidentatus)	(1) Stevenson (Unpublished data) (2) Orth and Moore (Unpublished data)	Unpublished oore (Unpul	l data) olished data)							

(cont'd)
Matrix of Habitat Requirements for
Black Duck (Anas rubripes)
Critical life stage: nestling
Critical Life period: April - July

N.L.	6-9	6-9	6-9	6-9	N.L.	N.L.	N.L.	N.L.	
N.L.	<0.01	<0.01	<0.01	<0.01	N.L.	N.L.	N.L.	N.L.	
N.L.	<0.7- 1.4	<0.14	<0.14	<0.14	N.L.	N.L.	N.L.	N.L.	
N.L.	<15 (1)	<15 (1)	<15 (1)	<15 (1)	N.L.	N.L.	N.L.	N.L.	l data) Nished data)
N.L.		1.7-2.0	1.7-2.0	1.7-	N.L	N.L	N.L	N.L	(Unpublished
N.L.	<b>20</b>	<sup>20</sup>	CZ0	250	N.L.	N.L.	NL	N.L.	(1) Stevenson (Urpublished data) (2) Orth and Moore (Unpublished data)
Black duck (Anas rubripes) PREY SPECIES:	Wild celery (Vallisneria americana)	Sago por (Potamo)	Redhead grass (P. perfoliaus)	Widgeongrass (Ruppia maritima)	Smartweeds (Polygonum spp.)	Rice cutgrass (Leevsia oryzoides)	Cordgrass (Spartina alterniflora)	Salt marsh snail (Melampus	ordentalus)
	N.L. N.L. N.L. N.L. N.L.	N.L. N.L. N.L. N.L. N.L. N.L. N.L. (1) 1.4 <0.01	M.L. N.L. N.L. N.L. N.L.  -20 [ ] <15 <0.7 <0.01  -17 <15 <0.14 <0.01  2.0 (1)	Black duck	Black duck	Black duck	Black duck (Anus rubripes)	Black duck (Anas rubripes)	Black chuck

Matrix of Habitat Requirements for Wood Duck (Aix sponsa)
Critical life stage: wintering
Critical Life period: November to March

Wood Duck (Aix sponsa)  PREY SPECIES:  Arrow-arum (Pelaruha viv ginica)  Giant burreed (Sporagemian eurycarpun)  Colars (Polygoraum spp.)  Potamogeton spp.)  N.L. 0  Oaks (Quercus spp.)  Notamogeton spp.)  N.L. 0-12  Nuss Aquatic invertebrates Fruits Insects		Target Species	Cover	Salimity (ppt)	Critcal Life period: 140 v
PREY SPECIES:  Arrow-arum (Pedandra virginica)  Giant burreed (Sparaganium eurycarpum)  Tearthumb (Polygonum app.)  Oaks (Quercus app.)  Potamogeton spp.  N.L.  Nuss Aquatic invertebrates Fruits Insects		Wood Duck (Aix sponsa)	Needed for young	NT	
Arrow-arum (Pelandra virginica)  Giant burreed (Sparaganium eurycarpum)  Tearthumb (Polygonum sup.)  Oaks (Quercus sup.)  Potamogeton sup.  Nus.  Nus. Aquatic invertebrates Fruits Insects		PREY SPECIES:			
Giant burreed (Sparagonium eurycarpum)  Tearthumb (Polygonum syp.) Oaks (Quercus spp.) Potamogeton spp. Nus. Aquatic invertebrates Fruits Insects	5"	Arrow-arum (Peltandra virginica)	KL	•	
Tearthumb N.L. (Polygonam spp.) Oaks (Quercus spp.) Potamogeton spp. Nuss Aquatic invertebrates Fruits Insects	-5	Giant burreed (Sparaganium eurycarpum)	NT	•	
rates N.L.	9-	Tearthumb (Polygonum app.)	NT	•	
on app. N.L.		Oaks (Quercus spp.)		•	
Nuts Aquatic invertebrates Fruits Insects		Potamogeton spp.	NT	0-12	
		Nuts Aquatic invertebrates Fruits Insects			

(1) U.S. Fish and Wildlife Service (unpublished data)

and aquatic invertebrates. During the egg laying period, adult wood duck hens have high protein and calcium requirements, satisfied mainly through an invertebrate diet. Young ducklings up to 6 weeks of age also ingest a high percentage of invertebrates, chiefly insects.

TARGET SPECIES: Great blue heron (Ardea herodeas)
Critical Life Stage: nestling
Critical Life Period: May-July

# **BACKGROUND**

Habitat for the great blue heron includes wooded areas suitable for colonial nesting and wetlands within a specified distance (e.g. 1 kilometer) of a heronry where foraging can occur. The heronry area itself can be an acre or two in size, but is preferably isolated. Most great blue heron colonies in the Bay area are located in riparian swamps with trees tall enough for nest placement at 5 to 15 m above ground. Other wading bird species may coexist in a great blue heronry. Four eggs are typically laid by the adult female, with an incubation period of four weeks.

Great blue herons feed alone or occasionally in flocks. Feeding usually occurs during the day, but occasionally takes place at night. Both still-hunting and stalking techniques are used to hunt for fish which is their main prey. Herons also eat frogs, lizards, snakes, small birds, mammals, and insects. Usually, feeding is limited to clear waters less than 0.5 m in depth, with firm substrate. Contaminants in the food chain have been documented as a problem, especially dieldrin and DDE and possibly other organochlorines, which cause eggshell thinning.

TARGET SPECIES: Great (American) egret (Casmerodius albus)
Critical Life Stage: nestling
Critical Life Period: June - August

# **BACKGROUND**

Habitat needs of the great heron are similar to those of the great blue heron; a heronry area preferably isolated, with good roosting trees and a foraging area close by. Fresh, brackish and salt water marshes are all used for foraging.

Three or four eggs, incubating in about 24 days, are typically produced. The large nests can be from 6 to greater than 15 meters high, located in large trees near the water. Crows and vultures may prey on the eggs when left unattended. The young of the year sometimes wander northward before migrating southward for the winter.

The food of the great egret consists of small fish from the shallow waters, as well as frogs, lizards, small snakes, crustaceans, mollusks and insects. The depth of water in which foraging takes place is usually less than 25 cm.

Matrix of Habitat Requirements for Great blue heron (Ardea herodeas)
Critical life stage: nestling
Critical Life period: May to July

Target	Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (mg/l)
Great blue heron (Ardea herodeas)	ue heron rodeas)	Firm better	Intertidal, shallow	N.L.	N.L.	Estuarine	N.L.	0.5	[ ]	[]
PREY S	PREY SPECIES: (1)									
	Atlantic silversides (Menidia menidia)	Prefer hard, vegetated- Needed for eggs, young	Intertidal	Tolerate 1-34 Prefer 3-14	Juveniles: Tolerate 3-31 Prefer 18-25		>5.0	Ξ	[ ]	<b>Endrin</b> <0.05
9 1 Mummichog 1 (Furdulus heterocliu	ımmichog ındulus heteroclitus)	Prefer mud	Intertidal	0-30	[ ]	[]	>5.0	[ ]	8	Endrin <10 (2)
Stripec (Fundu	Striped killfish (Fundulus majalis)	Prefer sand	Intertidal	1-30			>5.0	[ ]	3	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mann Amphibians	Repüles Insects Crustaceans Small mammals Amphibians	16								
		(1) U.S. Fish and Wildlife Service (unpublished data) (2) Eisler (1986) lists toxicity information on 118 toxicants	nd Wildlife Ser 5) lists toxicity	vice (unpubli	shed data) on 118 toxica	ints				

Matrix of Habitat Requirements for Great egret (Casmerodius albus) Critical life stage: nestling Critical Life period: June to August

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants

# TARGET SPECIES: Little blue heron (Florida caerulea) Critical Life Stage: nestling Critical Life Period: June - August

#### **BACKGROUND**

The little blue heron breeds in the Chesapeake Bay area, but winters to the south. This heron's habitat includes fresh and salt water marshes where it seeks to avoid human activity. The heronry is typically situated in dense vegetation on or near a secluded small water body, often far inland from the larger marsh.

Food for little blue herons consists of minnows, crustaceans, insects such as grasshoppers, small frogs, lizards and worms. The little blue heron is an active feeder. Organochlorine residues have probably found their way into tissues and eggshells, but resulting physiological problems have not been noted.

TARGET SPECIES: Green heron (Butorides striatus)
Critical Life Stage: nestling
Critical Life Period: June - August

#### **BACKGROUND**

The green heron breeds in the Chesapeake Bay area and winters further to the south. Habitat for the green heron consists of either fresh or saltwater marsh. This heron appears to be more tolerant of human activity than some other heron species. The green heron nests singly or in small colonies, unlike the large heronries of other species. Their nests are not necessarily located near the water. Four to five eggs are usually laid, with incubation taking 17 days.

Food of the green heron includes minnows, tadpoles, water insects and their larvae, and crustaceans. They occasionally feed in the uplands where prey includes worms, insects such as crickets and grasshoppers, snakes and small mammals.

TARGET SPECIES: Snowy egret (Egretta thula)
Critical Life Stage: nestling
Critical Life Period: June - August

#### BACKGROUND

The snowy egret breeds in the Chesapeake Bay area and winters to the south. Both fresh and saltwater marshes are typical habitats for the snowy egret. Large rookeries, preferably in isolated sections of a marsh, are favored. Nests usually range in height from 3 to 6 meters in small trees.

Matrix of Habitat Requirements for Little blue heron (Florida caerulea) Critical life stage: nestling Critical Life period: June-August

Metals Ch (mg/l) Hy [ ] En (2) End (2) End
Chlorinated Hydrocarbons (ug/l)  [ ]  Endrin < 1.0 (2)  Endrin < 0.3 (2)

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants.

Matrix of Habitat Requirements for Green Heron (Butorides striatus)
Critical life stage: nestling
Critical Life period: June-August

	Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (ug/l)
	Green heron (Butorides striatus)	Firm better	Intertidal	N.L.	N.L.	Tidal, nontidal wetlands	N.L.	0.25	[]	[]
	PREY SPECIES: (1)									
-	Atlantic silversides (Menidia menidia)	Prefer hard, vegetated- Needed for eggs, young.	Intertidal	Tolerate 1-34, Prefer 3-14	Juveniles: Tolerate 3-31, Prefer 18-25		>5.0	_		Endrin <0.05
-65 <b>-</b>	Mummichog (Fundulus heteroclius)	Prefer mud	Intertidal	0-30	[]	Ξ	>5.0	[]	(2)	Endrin <10 (2)
	Striped killfish (Fundulus majalis)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
	Reptiles Insects Crustaceans Small mammals Amphibians									
		(1) U.S. Fish and Wildlife Service (unpublished data) (2) Eisler (1986) lists toxicity information on 118 toxicanis	1 Wildlife Ser ) lists toxicity	vice (unpublis information	shed data) on 118 toxicar	is				

Matrix of Habitat Requirements for Snowy Egret (Egretta thula) Critical life stage: nestling Critical Life period: June to August

Secchi Metals Depth (mg/1) (m)	0.25		[ ] (2)	[ ] (2)	
DO (mg/l)	N.L.	>5.0	>5.0	>5.0	
Flow (cm/s)	Tidal, nontidal	:: e	[ ]	[ ]	
Temp. (C)	N.L.	Juveniles: Tolerate 3-31, Prefer 18-25	[ ]	[ ]	
Salimity (ppt)	Ŋ.	Tolerate 1-34 Prefer 3-14T	0-30	1-30	
	ব্র	द्भ	ন্ত	-	
Zone	Intertidal	Intertidal	Intertidal	Intertidal	
Substrate Zone	Snowy egret (Egretta thula) PREY SPECIES: (1)	Prefer hard, Intertice vegetated- Needed for eggs, young.	Prefer mud Intertiö	Prefer sand Intertida	

(1) U.S. Fish and Wildlife Service (unpublished data) (2) Eisler (1986) lists toxicity information on 118 toxicants

The snowy egret usually produces 4-5 eggs which incubate in about 18 days. Both parents share in nesting chores. Food consists of small fish, insects, crayfish, small snakes, frogs and lizards.

TARGET SPECIES: Bald eagle (Haleaeetus leucocephalus)
Critical Life Stage: nestling
Critical Life Period: late-January to mid-June

### **BACKGROUND**

The southern bald eagle is still endangered but has been making a comeback in the Chesapeake Bay area -- it was estimated that 136 pairs occupied nests in 1986. The bald eagle breeds in the Bay area and a select number migrate south in autumn. Others remain in congregations in areas such as Caledon State Park, VA, on the Potomac River.

Habitat for the bald eagle is typically close to the water, where tall trees provide good perching places for the bird to observe prey. The bald eagle avoids human activities and it will usually not vigorously defend a nest.

Two to three eggs are produced, laid in a large nest up to 7 feet high by 7 feet across. The nest may be 60 feet or more above ground placed in large trees. About 35 days are required for incubation of eggs.

Food of bald eagles consists primarily of fish, which is often found dead by the birds. Other dead animals may also be taken. The bald eagle will also take other prey alive such as ducks, and small to medium mammals. The problem of organochlorine pesticide residues which caused eggshells to thin and hatch success to be reduced has been minimized.

TARGET SPECIES: Osprey (Pandion halaetus)
Critical Life Stage: nestling
Critical Life Period: April to mid-July

# **BACKGROUND**

The Chesapeake Bay region supports over 1,500 nesting pairs of ospreys. Ospreys always live near the water, roosting in large trees and building large, bulky, stick-nests in trees or on poles or platforms. The osprey can learn to tolerate human disturbance near its nest. After the breeding and rearing season is complete, the birds migrate to tropical wintering grounds.

Ospreys feed almost exclusively on live fish taken from near-surface waters. Nearly every common Chesapeake Bay species of fish has been recorded in the osprey's diet. Situated at the top of the food chain, ospreys experienced trouble with accumulated organochlorine pesticide residues of DDT and dieldrin some years ago. The problems of thinned eggshells and poor hatch rates experienced at the time, have apparently been rectified, and the birds are doing well in the Bay.

Matrix Habitat Requirements for Bald Eagle (Haliaeetus Ieucocephalus)
Critical life stage: nestling
Critical life period: late January to mid-June

Target Species	Cover	Salinity	Temp.	Metals	D0	М	Turbidity	Systemoded collide	
		(ppt)	(C)		(mg/l)	•	(DTV)	(mg/l)	
Bald Eagle (Haliaeetus leucocephalus)	Quiet area near water, with tall trees	N.L.	N.L.	lead shot ingested: 11.3 ppm in kidney is	N.L.	N.L.	N.L.	N.L.	
PREY SPECIES:				fatal.					
Striped bass (Morone saxatilis)	[]	0-5(1)	16-19	*	6-12	7-8*	[ ]	[]	
American shad (Alosa sapidissima)		0-15 (2,3)	15.5-26	[ ]	>5 (4)	6.5-8.5 (4,5)	<50 (4)	<50 (5)	
Menhaden (Brevoortia tyramus)	[ ]	0-15 (2)	10-30		>5 (4,6)	6.5-8.5 (4,6)	[ ]	[]	
Alewife (Alosa pseudoharengus)	[ ]	0-5*	16-25		%	6.5-8.5 (4)		~50	
White Perch (Morone americana)		*8-0	12-20*	[ ]	>5 (4)	6.5-8.5 (4)	<50 (4)	<70 (4)	
Yellow Perch (Perca flavescens)	SAV, Sub- merged trees	0-0.5	10-19	[ ]	>5 (4)	6.5-8.5	<50 (4)*	<500 (1)*	
Carrion Small mammals Turles Birds	* See target species habitat requirement matrices for more detailed information.  (1) Westin and Rogers (1978)  (2) Kaumeyer and Setzler-Hamilton (1982)  (3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986  (4) Klein and O'Dell (1987)  (5) Connery (1987)  (6) U.S. Corps of Engineers (1984)  (7) Wang and Kernehan (1979)	pecies habitat requi d Rogers (1978) and Setzler-Hamili itat suitability inde O'Dell (1987) s of Engineers (198 Kernehan (1979)	rement mab con (1982) x publicatio 44)	rices for more	detailed infor Report 82(11.	nation. .45) 1986			

(Cont'd)
Matrix of Habitat Requirements for
Bald Eagle (Haliaeetus leucocephalus)
Critical life stage: nestling
Critical Life period: April to mid-July

Target Species	Substrate	Zone	Flow (m/s)	Alkalinity (mg/l)	Pathogen	Metals (mg/l)	Insecticides (mg/l)
Bald Eagle (Haliaeetus leucocephalus)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:							
Striped bass (Morone sæatilis)	Ξ	Water column demersal	0.3- 5.0 (1)	>20	[ ]	*	*
American shad (Alosa sapidissima)	[]	[ ]	Ξ,	[]	[]	Ξ	[ ]
Menhaden (Brevoortia tyramus)	=	Pelagic or open waters	[]	[ ]	Fungal parasites	[ ]	[ ]
Alewife (Alosa pseudoharengus)	Sand, gravel w/75% silt	Ξ			[ ]	[ ]	[ ]
White Perch (Morone americana)	Compact silt, sand, mud clay	Subsurface waters (7)	[ ]	[]	[]	*	DDT LC50 - 8.0 Dieldrin LC50 - 10.0
Yellow Perch (Perca flavescens)	* ,	Demersal*	[]	Ξ			[ ]
	* See target species habitat requirement ma (1) Westin and Rogers (1978) (2) Kaumeyer and Setzler-Hamilton (1982) (3) FWS Habitat suitability index publicat (4) Klein and O'Dell (1987) (5) Connery (1987) (6) U.S. Corps of Engineers (1984) (7) Wang and Kerneham (1979)	ies habitat requogers (1978) d Setzler-Hami suitability ind Dell (1987) 77 f Engineers (15 rneham (1979)	irement matr Iton (1982) ex publicatio	* See target species habitat requirement matrices for more detailed information.  (1) Westin and Rogers (1978)  (2) Kaumeyer and Setzler-Hamilton (1982)  (3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986  (4) Klein and O'Dell (1987)  (5) Connery (1987)  (6) U.S. Corps of Engineers (1984)  (7) Wang and Kerneham (1979)	nformation. 2(11.45) 1986		

Matrix of Habitat Requirements for Osprey (Pandion haliaetus) Critical life stage: nestling Critical Life period: April to mid-July

	Target Species	Cover	Salinity (ppt)	Temp.	TRC (mg/l)	DO (mg/l)	Hd	Turbidity (NTU)	Suspended Solids (mg/l)
	Osprey (Pardion haliaetus) PREY SPECIES:	i u	ż	i Z	i Z	j Z	N.L.	N.L.	
	Striped bass (Morone stratilis)		0-5(1)	16-19	*	7-6*	[]	Ξ	
-70	American shad (Alosa sapidissima)		0-15 (2,3)	15.5-26		>5 (4)	6.5-8.5 (4.5)	<50 (4)	<50 (5)
_	Menhaden (Brevoortia tyrannus)	[]	0-15 (2)	10-30	[ ]	>5 (4,6)	6.5-8.5 (4,6)	[ ]	_
	Alewife (Alosa pseudoharengus)		0-5*	16-25		χ	6.5-8.5 (4)		00 00 00 00 00 00 00 00 00 00 00 00 00
	White Perch (Morone americana)		*8-0	12-20*	0.15	>5 (4)	6.5-8.5 (4)	<0 (4)	<70 (4)
	Yellow Perch (Perca flavescens)	SAV, Sub- merged trees	0-0.5	10-19		>5 (4)	6.5-8.5	<50 (4)	<500 (1)

<sup>\*</sup> See target species habitat requirement matrices for more detailed information.
(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986
(4) Klein and O'Dell (1987)
(5) Connery (1987)
(6) U.S. Corps of Engineers (1984)
(7) Wang and Kernehan (1979)

(Cont'd)
Matrix of Habitat Requirements for
Osprey (Pandion haliaetus)
Critical life stage: nestling
Critical Life period: April to mid-July

Target Species	Substrate	Zone	Flow (m/s)	Alkalinity (mg/l)	Pathogen	Metals (mg/l)	Insecticides (mg/l)	
Osprey (Pandion haliaetus)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	
PREY SPECIES:								
Striped bass (Morone saxailis)		Water column demersal	0.3- 5.0 (1)	>20	[]	*	*	
American shad (Alosa sapidissina)			[]	Ξ			Ξ	
Menhaden (Brevoortia tyrannus)	[]	Pelagic or open waters			Fungal parasites	[]	Ξ	
Alewife (Alosa pseudoharengus)	Sand, gravel w/75% silt		[ ]	Ξ		[]	Ξ	
White Perch (Morone americana)	Compact silt, sand, mud clay	Subsurface waters (7)	[ ]	[]	Ξ	*	DDT LC50 - 8.0 Dieldrin LC50 - 10.0	
Yellow Perch (Percaflavescens)	*	Demersal*		[]	[ ]	[ ]		
	*See target species habitat requirement mat (1) Westin and Rogers (1978) (2) Kaumeyer and Setzler-Hamilton (1982) (3) FWS Habitat suitability index publicati (4) Klein and O'Dell (1987) (5) Connery (1987) (6) U.S. Corps of Engineers (1984) (7) Wang and Kerneham (1979)	ies habitat requiogens (1978) ad Setzler-Ham t suitability inc Dell (1987) 37) of Engineers (1	irement mati ilton (1982) iex publicati 984)	*See target species habitat requirement matrices for more detailed information.  (1) Westin and Rogers (1978)  (2) Kaumeyer and Setzler-Hamilton (1982)  (3) FWS Habitat suitability index publications Biological Report 82(11.45) 19  (4) Klein and O'Dell (1987)  (5) Connery (1987)  (6) U.S. Corps of Engineers (1984)  (7) Wang and Kerneham (1979)	*See target species habitat requirement matrices for more detailed information.  (1) Westin and Rogers (1978)  (2) Kaumeyer and Setzler-Hamilton (1982)  (3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986  (4) Klein and O'Dell (1987)  (5) Connery (1987)  (6) U.S. Corps of Engineers (1984)  (7) Wang and Kerneham (1979)			

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(2) Blueback herring	FWS/OBS 82/11.9 1983 20 pp.
Alewife	FWS/OBS 82/10.58 1983 17 pp.
(3) American shad	Biological Report 82(10.88) 1985 27 pp.
Hickory shad	Biological Report 82(11.45) 1986 15 pp.
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(4) Yellow perch	FWS/OBS 82/10.55 1983 32 pp
(5) White perch	FWS/OBS 82/.11.7 1983 10 pp.
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FWS/OBS - 82/11.19 1984 13 pp.

Soft shell clam

Hard shell clam

Kaumeyer and Setzler-Hamilton. 1982.

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Habitat Suitability Index Models:

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# APPENDIX A:

TOXICITY OF SUBSTANCES TO STRIPED BASS LARVAE AND JUVENILES

Adapted from Westin and Rogers. 1978.

Synopsis of Biological Data on the Striped Bass, Morone saxatilis (Walbaum) 1972. University of Rhode Island, Marine Technical Report 67, Kingston, RI

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-TABLE 1TOXICITY OF SUBSTANCES TO STRIPED BASS LARVA

SUBSTANCE	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
Acriflavine	5.0 (NA)	Hughes (1973)
Aldrin	0.01 (NA)	Hughes (1973)
Amifur	10.0 (NA)	Hughes (1973)
Butyl ester of 2,4-D	0.15 (NA)	Hughes (1971)
Cadmium	0.001 (NA)	Hughes (1973)
Chloride	1000 (NA)	Hughes (1973)
Chlorine	0.20 (NA)	Morgan & Prince (1977)
	0.40-0.07 incipient	
Copper	0.05 (NA)	Hughes (1973)
Copper	0.31 (0.12-3.08)	0'Rear (1971)
Copper sulfate	0.1 (NA)	Hughes (1971)
Dieldrin	0.001 (NA)	Hughes (1973)
Diquat	1.0 (NA)	Hughes (1973)
Diuron	0.5(NA)	Hughes (1973)
Dylox	5.0 (NA)	Hughes (1971)
Ethyl parathion	2.0 (NA)	Hughes (1971)
Formaldehyde	10.0 (NA)	Hughes (1973)
НТН	0.5 (NA)	Hughes (1971)
Iron	4.0 (NA)	Hughes (1973)
Karmex	0.5 (NA)	Hughes (1971)
Malachita green	0.05 (NA)	Hughes (1973)
Methylene blue	1.0 (NA)	Hughes (1973)
Methyl parathion	5.0 (NA)	Hughes (1971)
Potassium dichromate	100 (NA)	Hughes (1971)
Potassium permanganate	1.0 (NA)	Hughes (1971)
Roccal	0.5 (NA)	Hughes (1973)
Rotenone	0.001 (NA)	Hughes (1973)
Sulfate	250 (NA)	Hughes (1973)
Tad-Tox	5.0 (NA)	Hughes (1973)
Terramycin	50.0 (NA)	Hughes (1973)
Zinc	0.1 (NA)	Hughes (1973)
Zinc	1.18 (0.25-2.46)	U. kear (19/1)

a All 4-7 day-old larvae from Moncks Corner, South Carolina, tested at 21 C, except O'Rear (1971) which were tested in 14-19 C range, Morgan & Prince (1977) not specified, and Middaugh et al. (1977) at 18 C.

- c 48-hour TLm
- d 96-hour LCo
- e 24-hour TLm

b NA = not available (i.e., neither given nor calculatable).

-TABLE 2
TOXICITY OF SUBSTANCES TO JUVENILE STRIPED BASS

SUBSTANCE	TEST TEMP C	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
Abate Achromycin Acriflavine Aldrin	13 21-22 21 13 21 20	1.0 (NA) 190 (153.2-235.6) 27.5 (NA) 16.0 (14.7-17.4) 0.0072 (0.0034-0.0152 LCo 0.075 (NA) 0.010 (NA)	Korn & Earnest (1974) Kelley (1969) Hughes (1973) Wellborn (1971) Korn & Earnest (1974) Hughes (1973) Rehwoldt et al. (1977)
Amifur Ammonium hydroxide	21	LCo 30.0 (NA) 1.9-2.85 1.4-2.8	Hughes (1973) Hazel et al. (1971)
Aquathol	21	610 (634–795)	Wellborn (1971)
Bayluscide	21	72 hr. 1.05 (0.94-1.18)	Wellborn (1971)
Benzene	17.4 16	10.9 ul/l (+0.02)	Meyerhoff (1975)
Butyl ester of	21	5.8 ul/l 3.0 (NA)	Benville and Korn (1977)
2,4-D	20	70.0 (NA)	Hughes (1971) Rehwoldt et al. (1977)
Cadmium	21	0.002 (NA)	Hughes (1973)
Carbaryl	17	1.0 (NA)	Korn & Earnest (1974)
Casoron	21	6,2000 (5,210-7,378)	Wellborn (1971)
Chlordane	15	0.0118 (0.0057-0.024)	Korn & Earnest (1974)
Chloride	21	5000 (NA)	Hughes (1973)
Chlorine	18	0.04 incipient	Middaugh et al. (1977)
Cooling Tower	4.5-6.0	>4.0X	Texas Instruments (1974)
Blowdown and	18.5-26.0		
Power Plant		w/o CL2, 3.6X	
Chemical Discharge		(3.81X - 3.4X)	
Co-Ral	21	62 (53–73)	Wellborn (1971)
Copper	21	0.05 (NA)	Hughes (1973)
Coppor gulfata	17	4.3 (NA)	Rehwoldt et al. (1971)
Copper sulfate	21 21–22	0.15 (NA)	Hughes (1971)
	21-22		Kelley (1969)
Cutrine	21	0.62 (0.54-0.71) 0.1 (NA)	Wellborn (1969)
DDD	17	0.0025 (0.0016-0.004)	Hughes (1973)
DDT	17		Korn & Earnest (1974) Korn & Earnest (1974)
	_ ,	0.00084)	Rolli & Earliest (1974)
Dibrom	13	A = 1A A A A A	Korn & Earnest (1974)
Dieldrin	14	•	Korn & Earnest (1974)
		0.00334)	mozn w Barnest (17/4)
	21		Hughes (1973)
Diquat	21		Hughes (1973)
	21		Wellborn (1969)
Diuron (Karmex)	21		Hughes (1973)

-TABLE 2 (cont.)-

SUBSTANCE		96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
Dursban	13	0.00058 (0.00035-	Korn & Earnest (1974)
Dylox	21	0.00097) 2.0 (NA) 5.2 (4.2-8.0)	Hughes (1971) Wellborn (1969)
Endosulfan	16	0.0001 (0.000048- 0.00021)	Korn & Earnest (1974)
Endrin	17	0.000094 (0.000045- 0.00019)	Korn & Earnest (1974)
E.P.N.	18	0.60 (0.025-0.150)	Korn & Earnest (1974)
Ethyl parathion	21 15	1.0 (NA) 0.0178 (0.0048- 0.0657)	Hughes (1971) Korn & Earnest (1974)
Fenthion Formaldehyde	13 21 21–22 21	0.453 (0.216-0.955) 15 (NA) 20 (15.4-26) 18 (10-32)	Korn & Earnest (1974) Hughes (1973) Kelley (1969) Wellborn (1969)
Heptachlor HTH	13 21	0.003 (0.001-0.006) 0.25 (NA)	Korn & Earnest (1974) Hughes (1971)
Instant Sea as (Cl)	21	LCo 17000 (NA)	Hughes (1973)
Iron Karmex (Diuron)	21 21	6.0 (NA) 6.0 (NA) 3.1 (2.5-3.9)	Hughes (1973) Hughes (1971) Wellborn (1969)
Lindane	21 13	0.40 (0.35-0.46) 0.0073 (0.0045-0.0119)	Wellborn (1971) Korn & Earnest (1974)
Malachite green	21	0.2 (NA) 24 hr. 0.30 (0.27-0.33)	Hughes (1973)
Malathion	21 13	0.24 (0.20-0.29) 0.014 (0.013-0.015)	Wellborn (1971) Korn & Earnest (1974) Rehwoldt et al. (1977)
Methoxychlor Methylene blue Methyl parathion	20 15 21 21	0.039 (NA) 0.0033 (0.0021-0.0051) 12.0 (NA) 4.5 (NA)	
nethyl parathion	13 20	0.79 (0.17-1.40) 14.0 (NA)	Korn & Earnest (1974) Rehwoldt et al. (1977)
MS-222	21-22 22-28	31.5 (25.6-37.5) 24 hr. 50.0 (NA)	Kelley (1969) Tatum et al. (1965)
MS-222 with 20 o/oo	21–22	31.5 (26.6-37.5)	Kelley (1969)
Nickel Oil field brine (as Cl)	17 21	6.2 (NA) LCo 16600 (NA)	Rehwoldt et al. (1971) Hughes (1968)
Potassium dichromate	21	75 (NA)	Hughes (1971)
Potassium permanganate	21 21-22	4.0 (NA) 2.6 (2.17-3.12)	Hughes (1971) Kelley (1969)

-TABLE 2 (cont.)-

SUBSTANCE	TEST TEMP C	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
	21	2.5 (2.1–2.9)	Wollham (1060)
Polyotic	21	>1818 (NA)	Wellborn (1969) Wellborn (1969)
PMA	21-22	1.1 (0.84-1.44)	
Quinaldine	21-22	4.5 (3.82–5.45)	Kelley (1969)
Quinatume	22-28	24 hr. 22.0 (NA)	Kelley (1969)
Quinaldine with	21-22	5.0 (3.86-6.65)	Tatum et al. (1965)
20 0/00	21-22	3.0 (3.80-0.03)	Kelley (1969)
Reconstituted	21-22	35 o/oo (NA)	Kelley (1969)
sea water		(0.00)	110110)
Roccal	21	1.5 (NA)	Hughes (1973)
Rotenone	21	LCo 0.001 (NA)	Hughes (1973)
Simazine	21	0.25 (0.17-0.36)	Wellborn (1969)
Sodium nitrilo-	20	5500 (NA)	Eisler et al.
triacetic acid			(1972)
Sulfate	21	3500 (NA)	Hughes (1973)
Syndet Ch	20	4.6 (NA)	Eisler et al.
			(1972)
Syndet Ga		8.7 (NA)	Eisler et al. (1972)
Tad-Tox	21	10.0 (NA)	Hughes (1973)
Terramycin	21	75.0 (NA)	Hughes (1973)
	21-22	170 (140.5-205.7)	Kelley (1969)
	21	178 (144–221)	Wellborn (1969)
		165 (147–185)	Wellborn (1971)
Toluene	-16	7.3 ul/l	Benville & Korn (1977)
Toxaphene	17	0.0044 (0.002-0.009)	Korn & Earnest (1974)
m-xylene	16	9.2 (8.3-10) ul/l	Benville & Korn (1977)
Zinc	21	0.1 (NA)	Hughes (1973)
	17	6.7 (NA)	Rehwoldt et al. (1971)
2, 4, 5, T	20	14.6 (NA)	Rehwoldt et al. (1977)

a Unless specified otherwise

b NA = not available (i.e., neither given nor calculatable)

c Range of 96-hour TLm in freshwater, 33% sea water, and sea water (95% C.I. given for percent mortality at 0, 40, 60, 80, and 100%).

#### APPENDIX B:

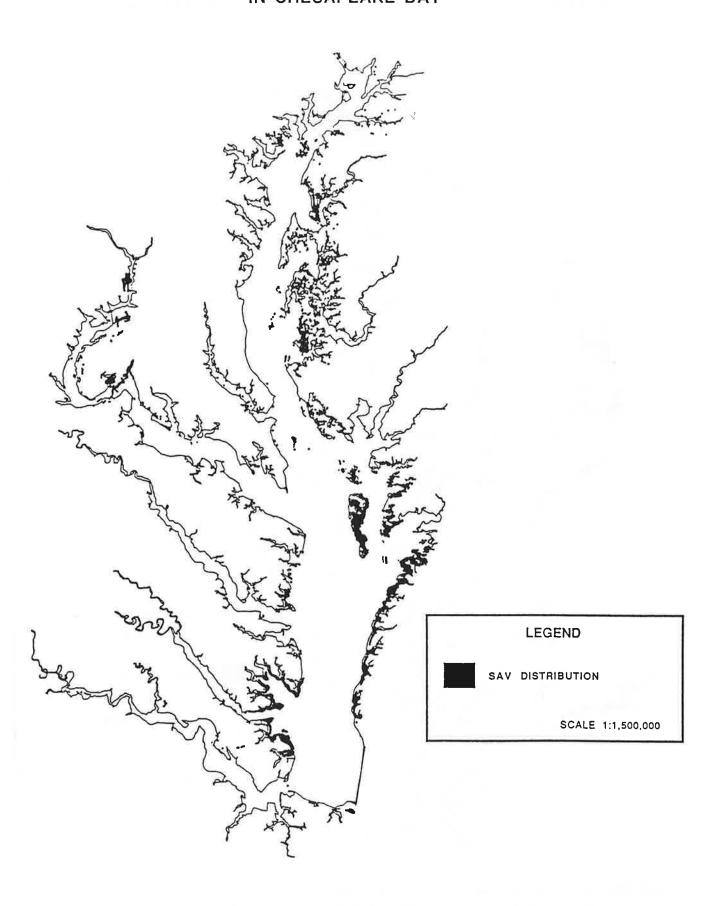
HABITAT DISTRIBUTION MAPS OF CRITICAL LIFE STAGES OF THE TARGET CHESAPEAKE BAY LIVING RESOURCE SPECIES

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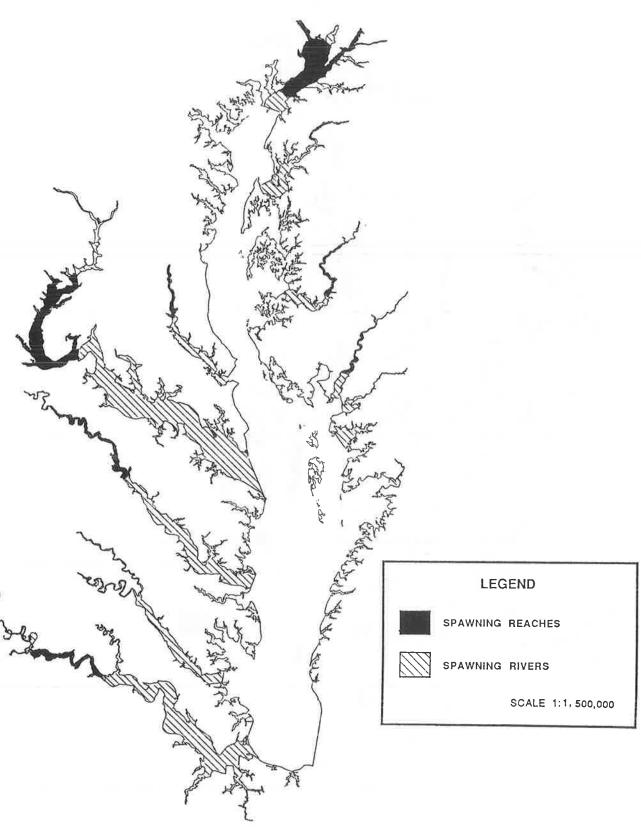
### List of Habitat Distribution Maps for the Critical Life Stages of the Target Chesapeake Bay Living Resource Species

- 1. 1986 Distribution of Submerged Aquatic Vegetation in Chesapeake Bay
- 2. Striped Bass (Morone saxatilis): Habitat Distribution of Legislatively Defined Spawning Reaches and Rivers in Chesapeake Bay
- 3. Blueback Herring (Alosa aestivalis): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 4. Alewife (Alosa pseudoharengus): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 5. American Shad (Alosa sapidissima): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 6. Hickory Shad (Alosa mediocris): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 7. Yellow Perch (Perca flavescens): Habitat Distribution of Spawning Areas in Chesapeake Bay
- 8. White Perch (Morone americana): Habitat Distribution of Spawning and Nursery Areas in Chesapeake Bay
- 9. Menhaden (Brevoortia tyrannus): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 10. Spot (Leiostomus xanthurus): Habitat Distribution of Nursery Areas in Chesapeake Bay
- 11. Bay Anchovy (Anchoa mitchelli): Habitat Distribution of Spawning and Nursery Areas in Chesapeake Bay
- 12. American Oyster (Crassostrea virginica): Habitat Distribution of Seed Areas and Suitable Substrate in Chesapeake Bay
- 13. Softshell Clam (Mya arenaria): Habitat Distribution in Chesapeake Bay
- 14. Hard Clam (Mercenaria mercenaria): Habitat Distribution in Chesapeake Bay
- 15. Blue Crab (Callinectes sapidius): Summer Habitat Distribution of Females and Spawning Areas in Chesapeake Bay
- 16. Blue Crab (Callinectes sapidius): Summer Habitat Distribution of Males in Chesapeake Bay
- 17. Blue Crab (Callinectes sapidius): Winter Habitat Distribution of Females in Chesapeake Bay
- 18. Blue Crab (Callinectes sapidius): Winter Habitat Distribution of Males in Chesapeake Bay
- 19. Canvasback (Aythya valisneria): Distribution of Wintering Populations
- 20. Redhead Duck (Aythya americana): Distribution of Wintering Populations
- 21. Black Duck (Anas rubripes): Distribution of Wintering Populations
- 22. Wood Duck (Aix sponsa): Distribution of Wintering Populations
- 23. Colonial Waterbirds: Habitat Distribution of Nesting Populations in Chesapeake Bay
- 24. Osprey (Pandion halaetus) and Bald Eagle (Haliaeetus leucocephalus): Habitat Distribution of Nesting Populations in Chesapeake Bay

### 1986 DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN CHESAPEAKE BAY

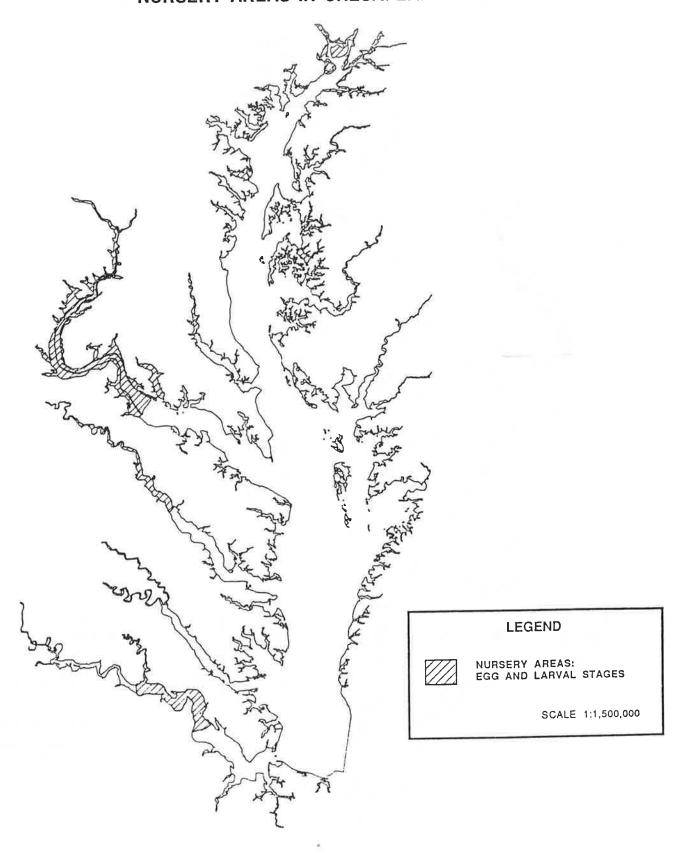


### STRIPED BASS (Morone saxatilis): HABITAT DISTRIBUTION OF LEGISLATIVELY DEFINED SPAWNING REACHES AND RIVERS

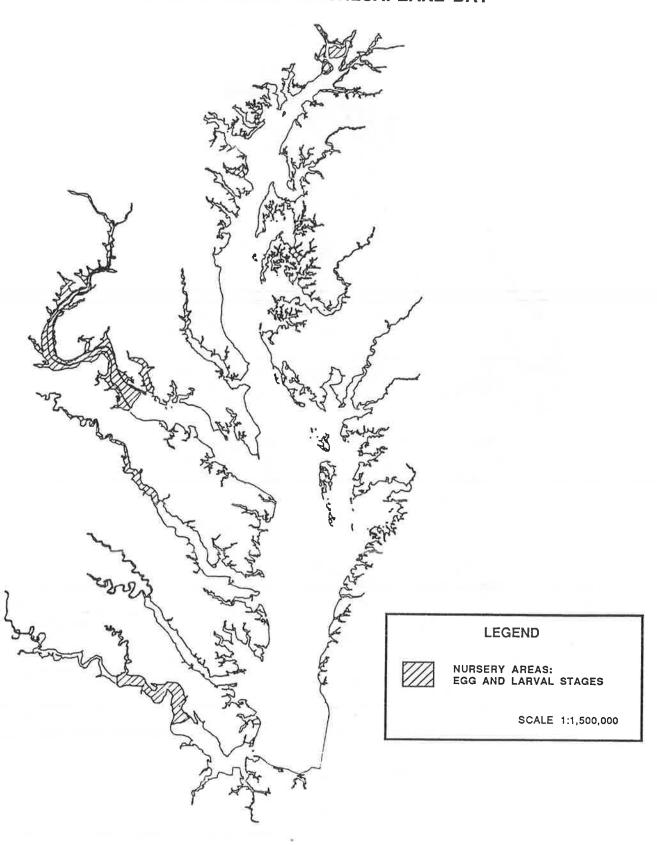


SOURCES: Code of Maryland Regulations 08.02.05.02
Virginia Marine Resources Commission Regulation 450-01-0034
FIGURE 2

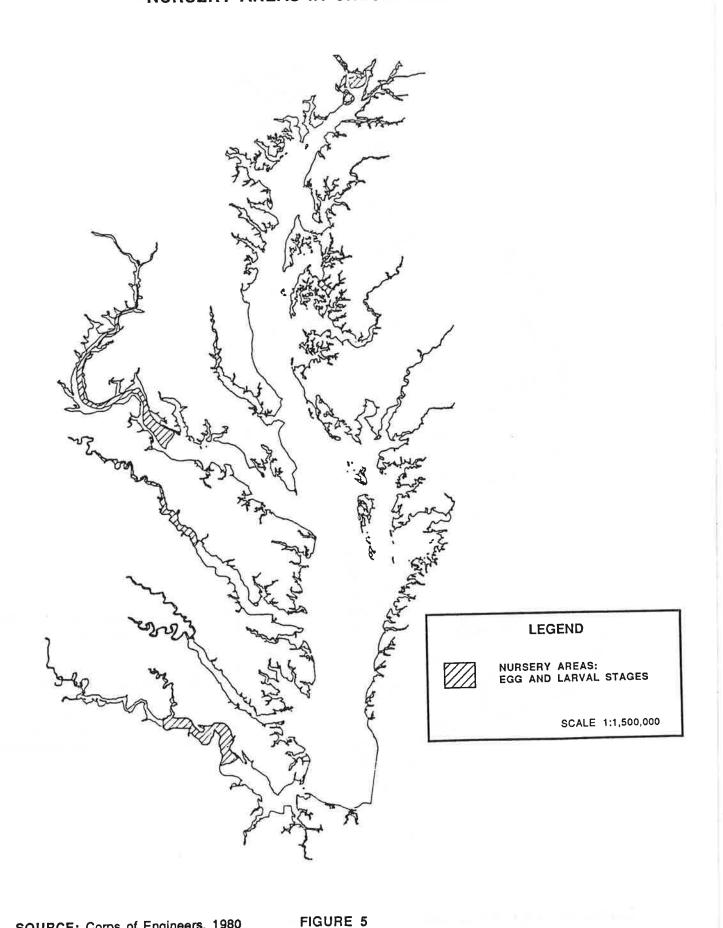
# BLUEBACK HERRING (Alosa aestivalis): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



## ALEWIFE (Alosa pseudoharengus): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY

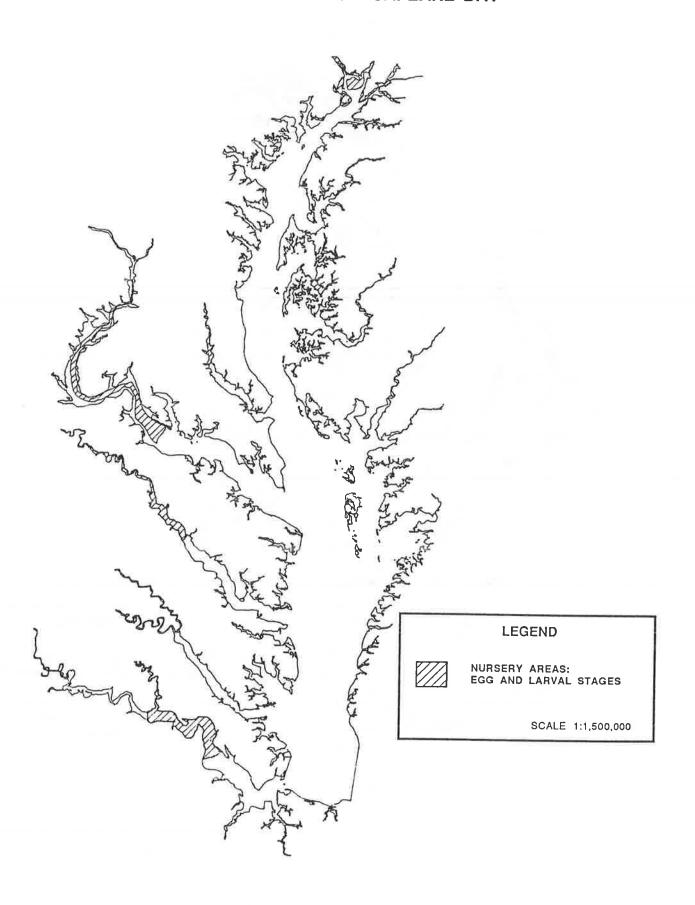


## AMERICAN SHAD (Alosa sapidissima): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY

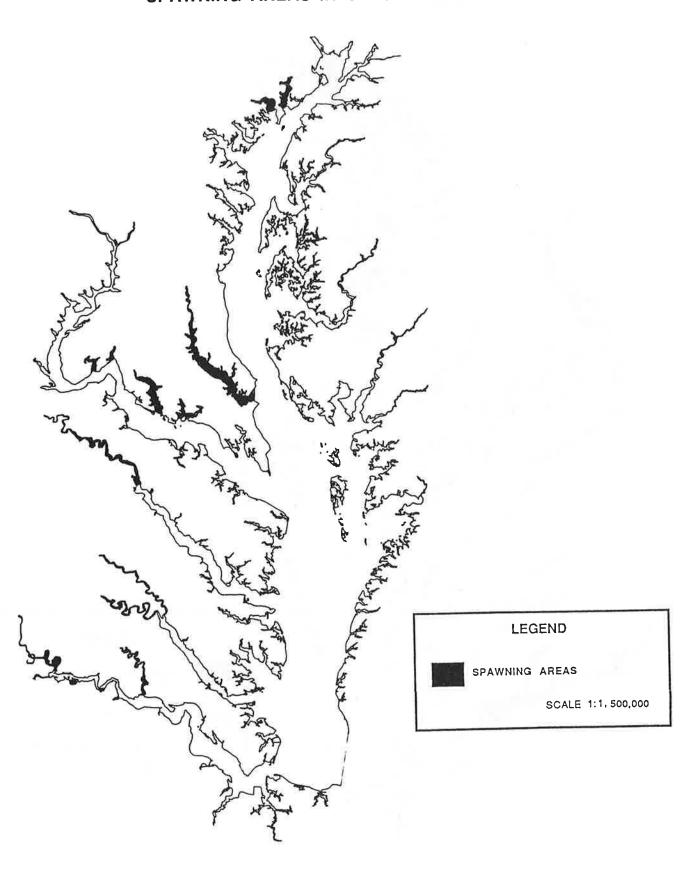


SOURCE: Corps of Engineers, 1980

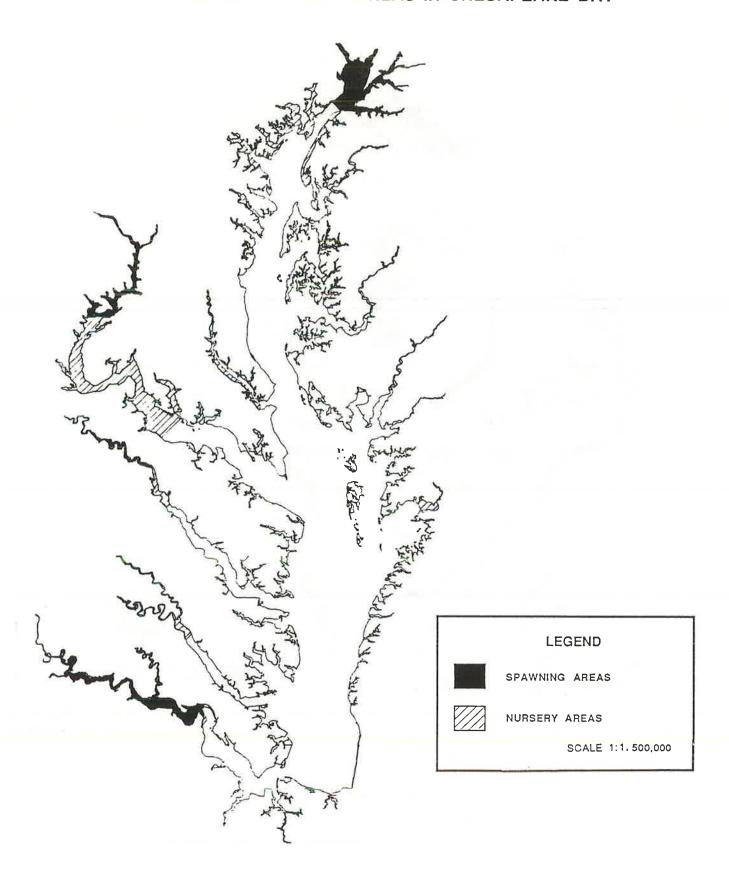
### HICKORY SHAD (Alosa mediocris): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



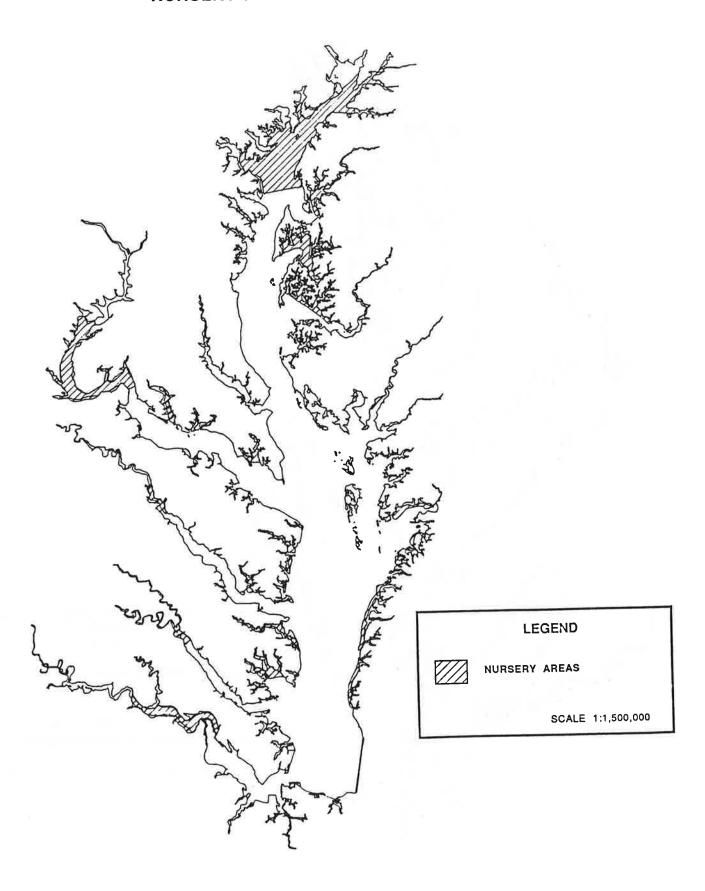
### YELLOW PERCH (Perca flavescens): HABITAT DISTRIBUTION OF SPAWNING AREAS IN CHESAPEAKE BAY



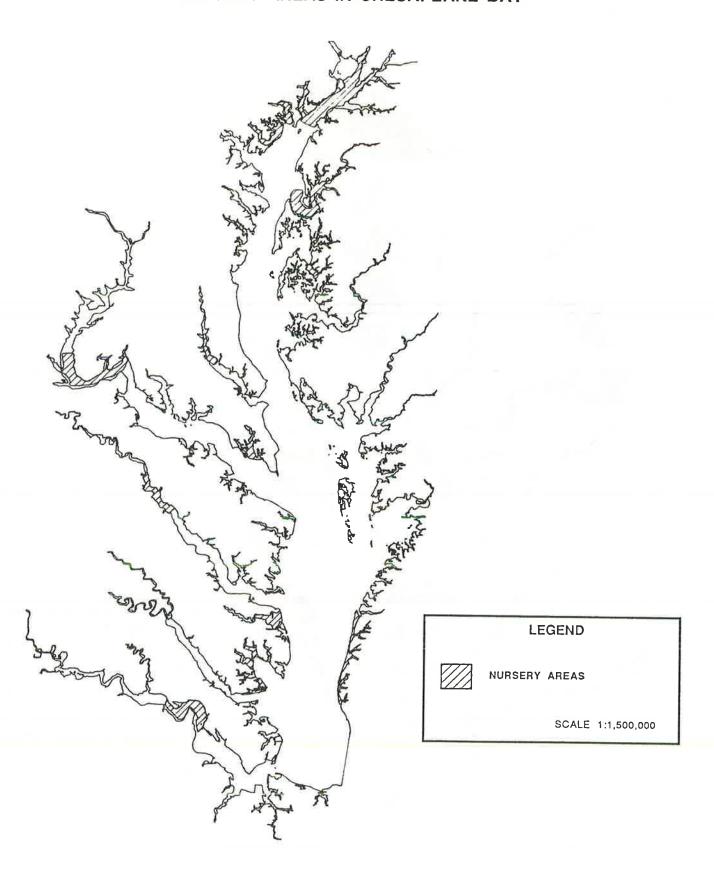
### WHITE PERCH (Morone americana): HABITAT DISTRIBUTION OF SPAWNING AND NURSERY AREAS IN CHESAPEAKE BAY



### MENHADEN (Brevoortia tyrannus): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



### SPOT (Leiostomus xanthurus): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 10

# BAY ANCHOVY (Anchoa mitchilli): HABITAT DISTRIBUTION OF SPAWNING AND NURSERY AREAS IN CHESAPEAKE BAY

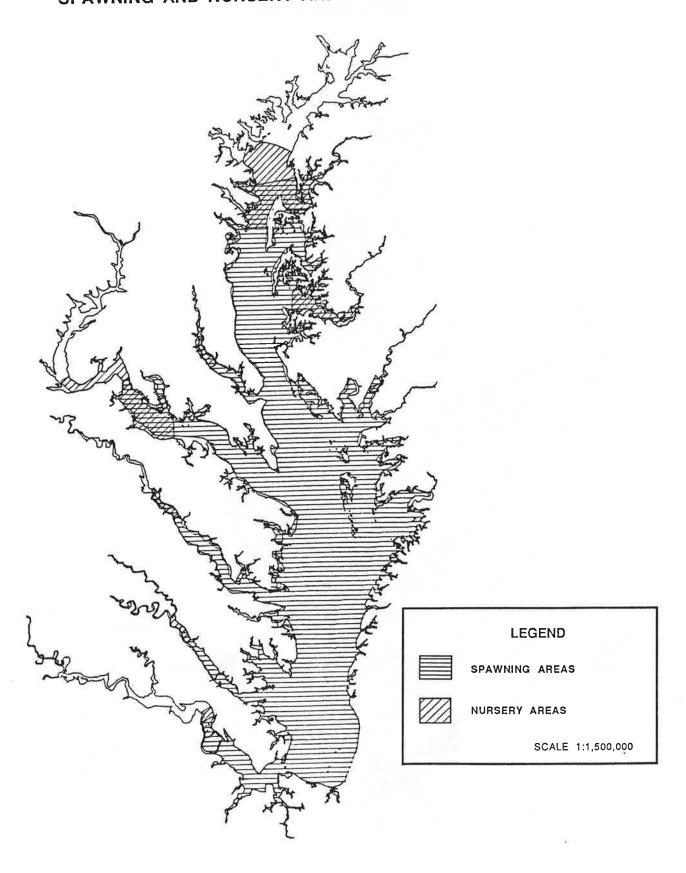
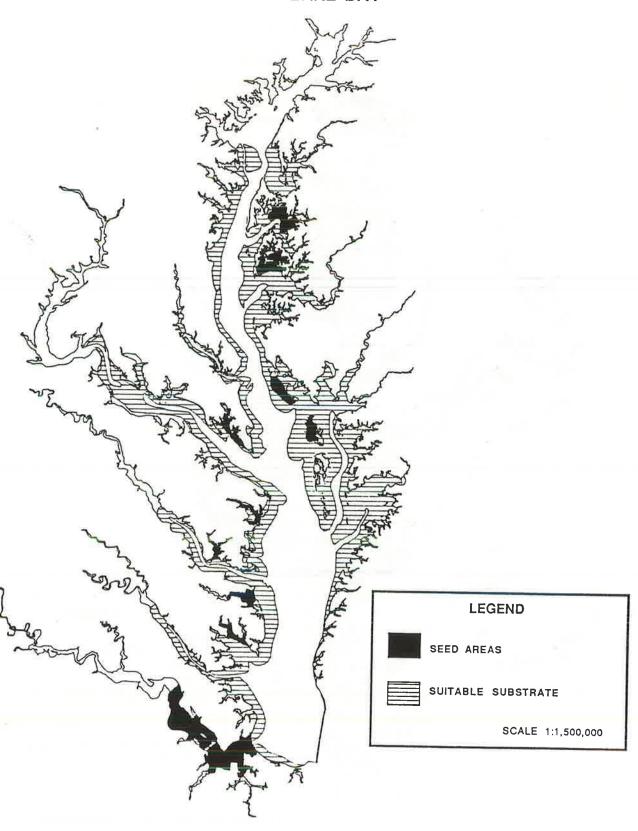
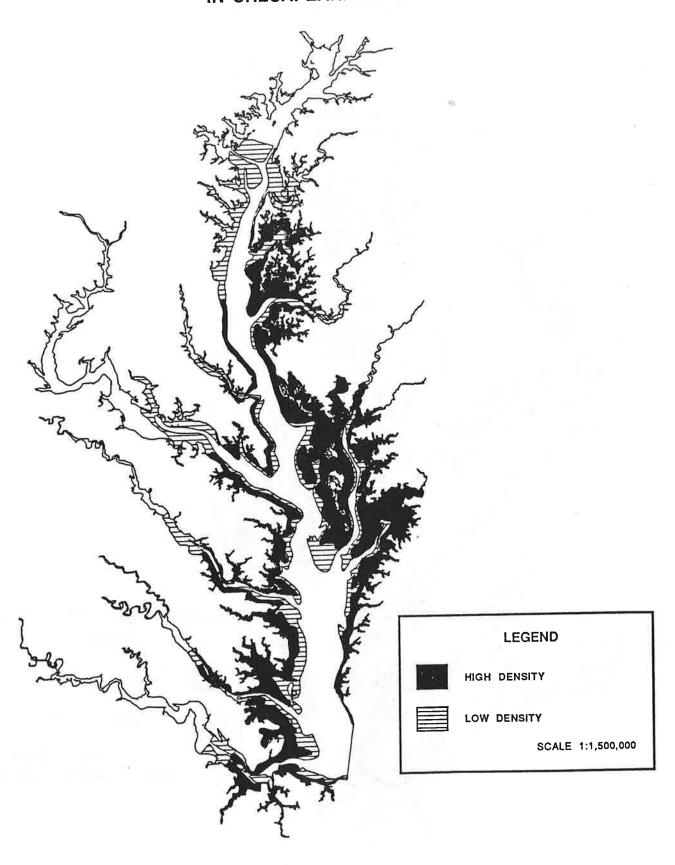


FIGURE 11

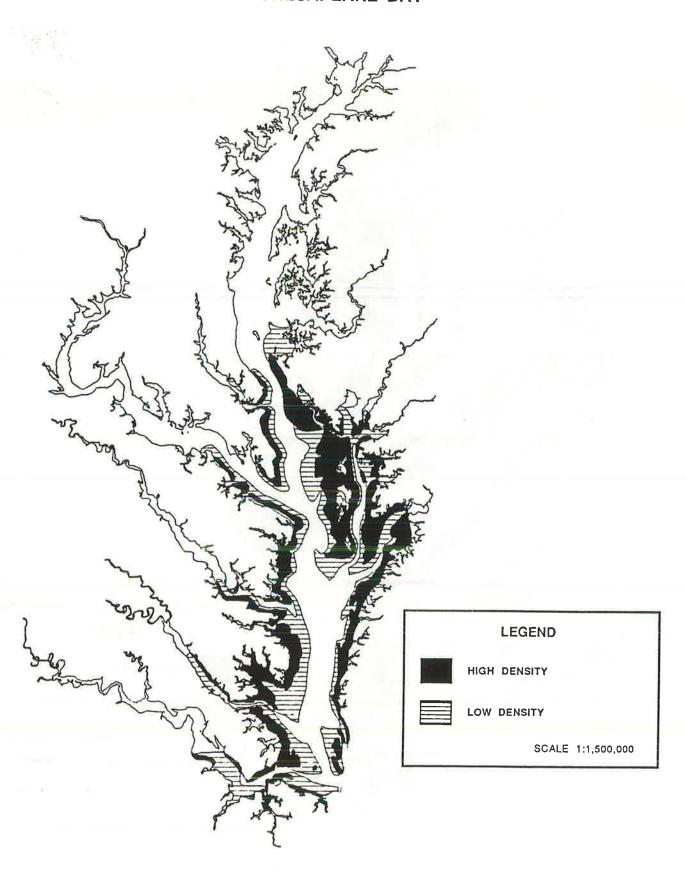
# AMERICAN OYSTER (Crassostrea virginica): HABITAT DISTRIBUTION OF SEED AREAS AND SUITABLE SUBSTRATE IN CHESAPEAKE BAY



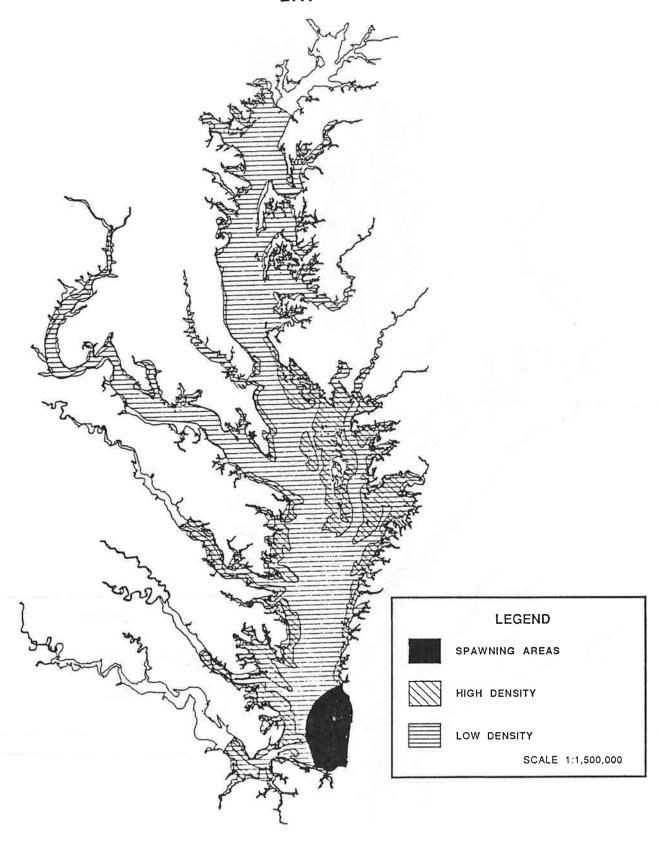
# SOFTSHELL CLAM (Mya arenaria): HABITAT DISTRIBUTION IN CHESAPEAKE BAY



#### HARD CLAM (Mercenaria mercenaria): HABITAT DISTRIBUTION IN CHESAPEAKE BAY

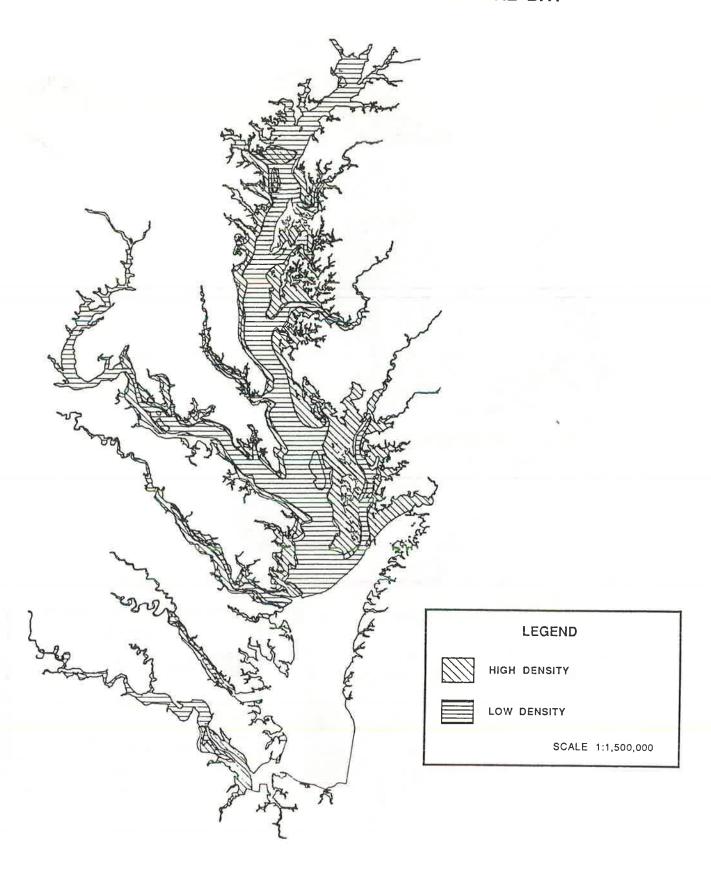


BLUE CRAB (Callinectes sapidus) : SUMMER HABITAT DISTRIBUTION OF FEMALES AND SPAWNING AREAS IN CHESAPEAKE BAY

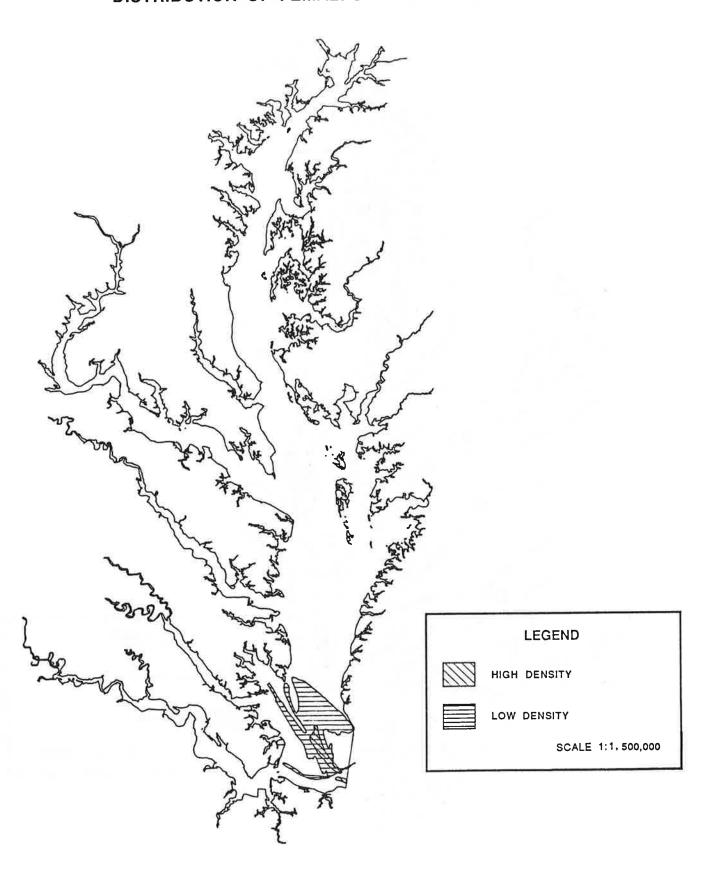


SOURCE: Corps of Engineers, 1980 FIGURE 15

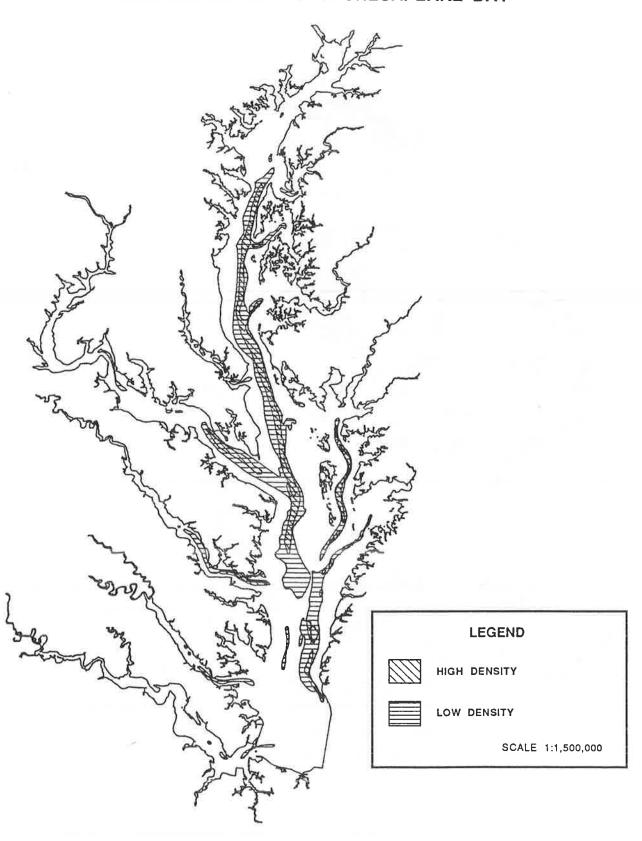
### BLUE CRAB (Callinectes sapidus): SUMMER HABITAT DISTRIBUTION OF MALES IN CHESAPEAKE BAY



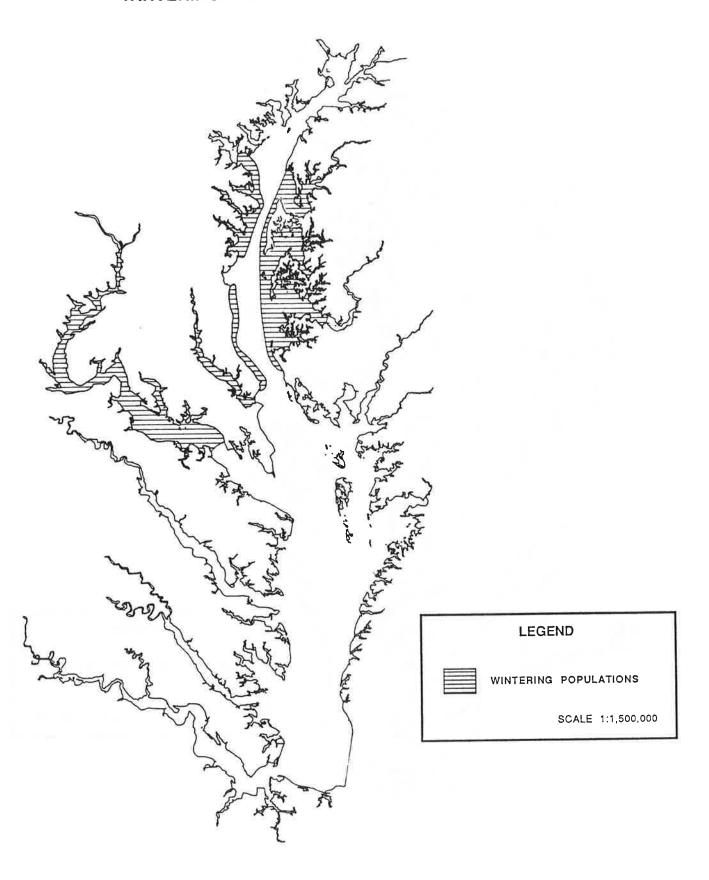
### BLUE CRAB (Callinectes sapidus): WINTER HABITAT DISTRIBUTION OF FEMALES IN CHESAPEAKE BAY



### BLUE CRAB (Callinectes sapidus): WINTER HABITAT DISTRIBUTION OF MALES IN CHESAPEAKE BAY

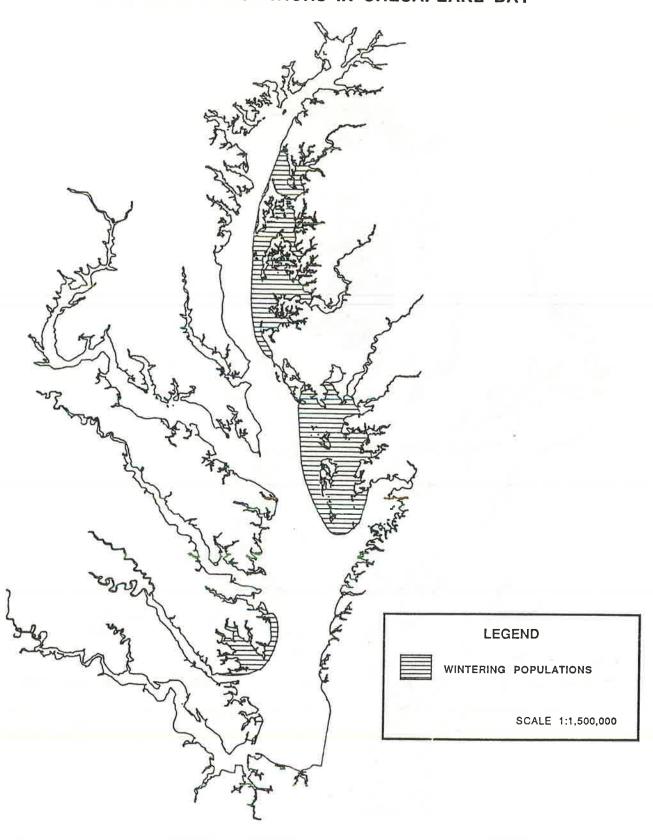


### CANVASBACK (Aythya valisneria): DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY

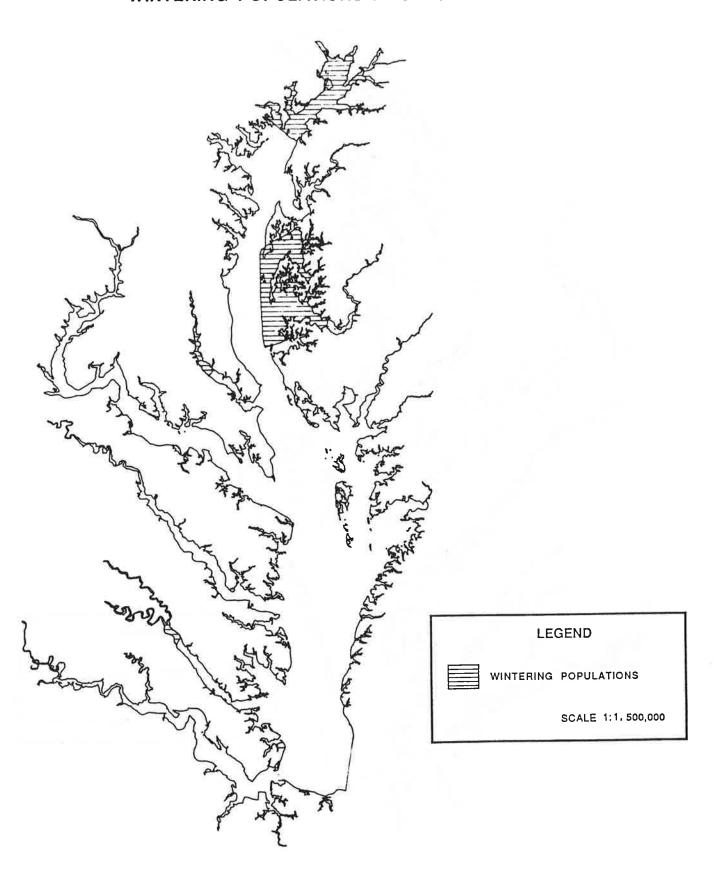


SOURCE: USFWS unpublished data

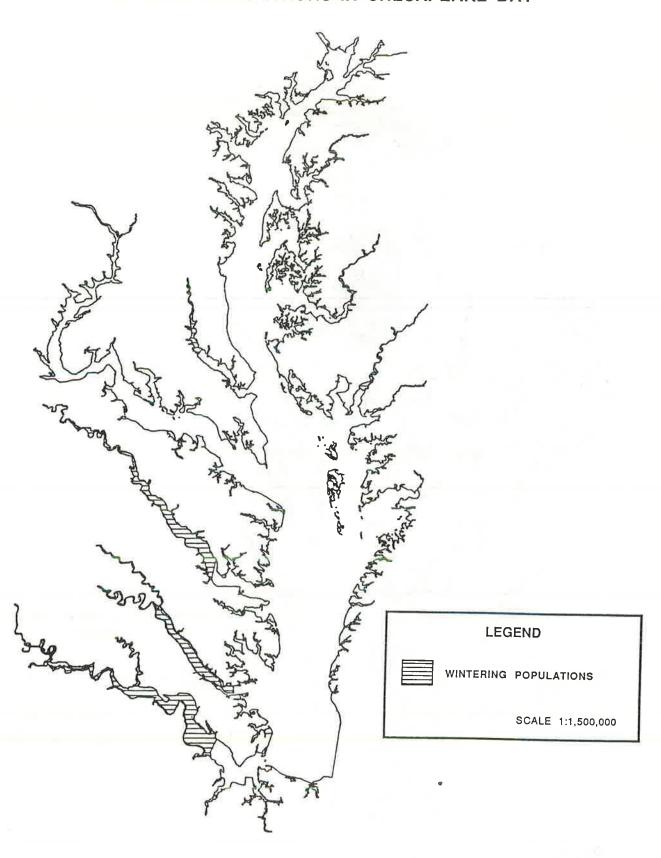
### REDHEAD DUCK (Aythya americana): DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



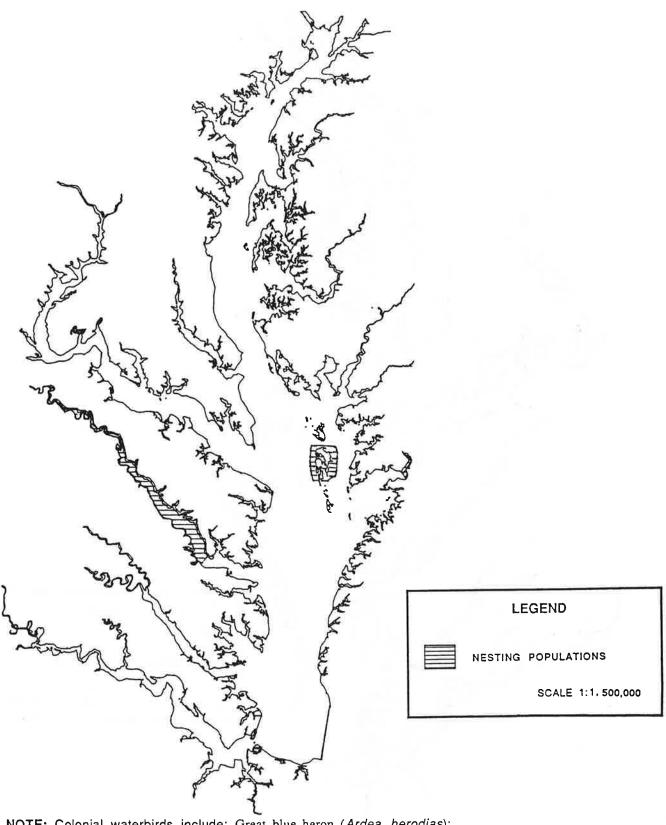
### BLACK DUCK (Anas rubripes): DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



### WOOD DUCK (Aix sponsa): DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



### COLONIAL WATERBIRDS: HABITAT DISTRIBUTION OF NESTING POPULATIONS IN CHESAPEAKE BAY



NOTE: Colonial waterbirds include: Great blue heron (Ardea herodias);

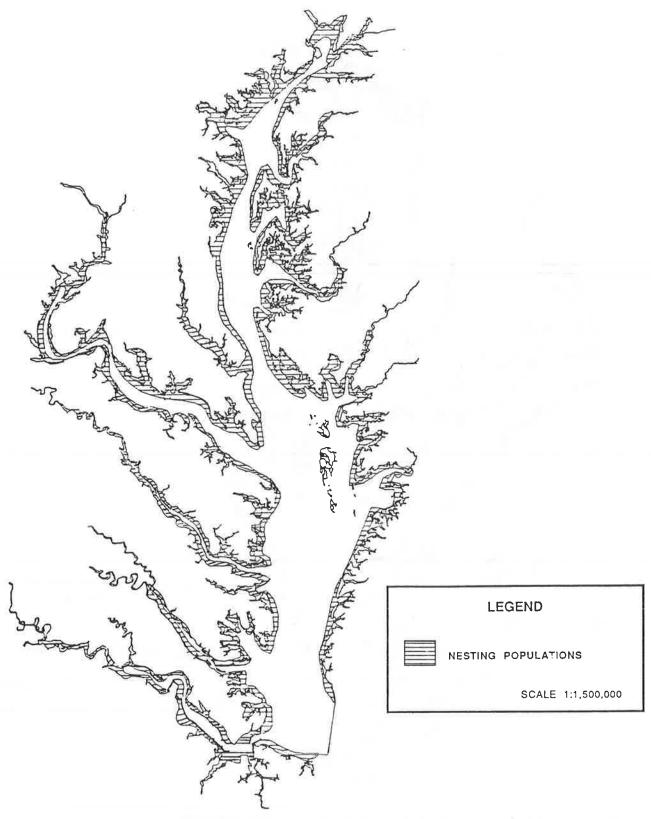
Little blue heron (Florida caerulea); Green-backed heron (Butorides striatus);

Snowy egret (Egretta thula); American or great egret (Casmerodius albus)

Scattered nests may occur in many other wooded, secluded areas of Bay tributaries.

SOURCE: USFWS unpublished data FIGURE 23

# OSPREY (Pandion haliaetus) AND BALD EAGLE (Haliaeetus leucocephalus): HABITAT DISTRIBUTION OF NESTING POPULATIONS IN CHESAPEAKE BAY



NOTE: Bald eagle nests, roosts and feeding areas are generally found within one mile of the riverine and estuarine shoreline in the Bay system. Occasionally, lakes and reservoirs are used. Some bald eagles remain in the Bay area year round.

SOURCE: USFWS unpublished data

FIGURE 24

\*U. S. GOVERNMENT PRINTING OFFICE: 1988-520-467:00087