Introduction

Striped bass, *Morone saxatilis,* is a top predator in Chesapeake Bay and has been one of the most highly sought after commercial and recreational finfish of the region since colonial times. Its economic importance, throughout its Atlantic coastal range, contributed to overfishing in the 1970s and 1980s, and eventually provided the impetus to develop coastwide management measures. Under the Atlantic States Marine Fisheries Commission (ASMFC) management process, striped bass has made the most significant recovery of any coastal finfish species (ASMFC 2003). The striped bass coastal management program successfully rebuilt the Atlantic coast stock from a low of 20 million pounds (1985) to a high of 65.5 million pounds (2002) over a 15-year period (ASMFC 2005). The coastal stock is currently managed under a commercial quota and recreational harvest limits (ASMFC Amendment #6). Biological reference points (targets and thresholds) based on biomass and rates of fishing mortality are used to assess the status of the stock and a control rule has been adopted to prevent overfishing (Refer to ASMFC section for more details). In addition, a Chesapeake Bay (CB) Striped Bass FMP was developed in 1989 and amended in 1997. The CB FMP provided a comprehensive and coordinated approach by the Bay jurisdictions to manage the striped bass fishery.

The Chesapeake Bay plays a vital role in the life history of striped bass. It is the principal spawning and nursery area of striped bass along the Atlantic Coast. It is estimated that the Chesapeake Bay and its tributaries produce approximately 90% of striped bass that comprise coastal landings from southern Maine to North Carolina (Berggren and Lieberman 1978; Richards and Rago 1999). Habitat is a critical factor for supporting striped bass growth and survival and one of the focal points to an ecosystem approach to management (EAM). Within the Chesapeake Bay, striped bass utilize a wide variety of habitats depending on the season and its developmental stage. Striped bass are one of the top predators in the Chesapeake Bay food web and, therefore, are in competition with other predators for prey. Natural predators tend to stabilize natural systems and have the potential to influence species composition and the dynamics of ecosystems (Larkin 1979). Food availability is an important factor affecting abundance and growth in fish populations. As the abundance of striped bass has increased in the Bay, the amount of food needed to support the increased stock size and maintain the health of the stock may be compromised especially in regards to the availability of forage species (i.e., Atlantic menhaden, bay anchovy, river herring, etc.). Menhaden are an important source of food for striped bass and also support a major commercial fishery. In recent years, menhaden recruitment has been low. Two diseases, mycobacteriosis and ulcerative dermatitis, have appeared in the striped bass population causing body lesions, stunted growth, emaciation and internal nodules. These diseases may be indicative of a prey shortage. Consequently, the nutritional status of Chesapeake Bay striped bass is under evaluation.

The single-species approach to management has been effective in restoring the coastal striped bass population, but does not take into account how total removals affect the structure and function of the Chesapeake Bay ecosystem; how trophic interactions are impacted; or how the quality and quantity of habitat affects fish production. This ecosystem-based fishery management plan (EBFMP) for striped bass has been developed to guide the coordinated interagency management of sustainable striped bass fisheries in the Chesapeake Bay and its associated coastal waters. The striped bass EBFMP emphasizes the importance of Chesapeake Bay-related interspecies dependencies and habitat requirements, and encourages precautionary measures to ensure optimal fishery yields and a balanced ecosystem.

Ecosystem Based Fisheries Management in Chesapeake Bay

<u>Ecosystem vision statement</u>

The vision of Chesapeake Bay Program (CBP) ecosystem-based fisheries management plans (FMPs) is to manage fish and shellfish species in Chesapeake Bay based on their life history stages, forage preferences, trophic interactions, habitat utilization, and the hydrographic and physical parameters that influence their spatial and temporal distribution within Chesapeake Bay. Through ecosystem-based FMPs, CBP jurisdictions will develop management strategies and actions that consider species function within the ecosystem, and how habitat quality might affect the recovery or sustainability of the striped bass population. As data becomes available on multispecies interactions and ecosystem modeling becomes more refined, EBFMPs will be able to model species interactions more accurately. The EBFMPs should ultimately lead to the integration of information on land use and water-use impacts on stock structure and fish populations. Evaluating habitat utilization and development of habitat utilization indices relative to species productivity will be a useful component of the EAM. Chesapeake Bay jurisdictions will be able to strategically protect and restore essential fish and shellfish habitat to protect important fishery resources through informed and directed management measures. It is also envisioned that Chesapeake Bay Program EBFMPs, with their focus on restoring and protecting aquatic Bay habitats, will complement FMPs for Chesapeake Bay-dependent coastal species managed under the ASMFC, the Mid-Atlantic Fishery Management Council and the South Atlantic Fishery Management Council to support the national EAM.

<u>Why Ecosystem-based Fisheries Management?</u>

Many of the fish and shellfish that have supported Bay fisheries over the past three centuries have declined dramatically in abundance or productivity; in some cases, stocks economically collapsed during the 20th century. Fishing pressure, degraded aquatic habitat, and other anthropogenic modifications or stresses to the estuary and its watershed are the known or presumed causes of most long-term fishery declines. Given the importance of fishery resources, both economically and ecologically, the Chesapeake Bay Program (CBP) has adopted two important goals: the continuation of sustainable yields from "healthy" populations and the restoration of populations that are overfished or at low levels of abundance. Recognizing that sustainable fisheries are a function of balanced interactions among species, suitable water quality, and fish habitat in the Bay ecosystem, the CBP has adopted a plan to implement multi-species fisheries management in Chesapeake Bay during the first decade of the new millennium (CBP 2000). This challenging mandate has spurred efforts to develop ecosystem approaches that complement conventional fisheries management in the Bay and better integrate the Program's restoration activities using living resources as a driver.

Ecosystem Principles:

Under NOAA/STAC sponsorship, the Fisheries Ecosystem Plan (FEP) Technical Advisory Panel of regional experts on aquatic ecosystems developed a guidance document "Fisheries Ecosystem Planning in Chesapeake Bay" (February 2004) to support the Program's ecosystem approach to management (EAM). The FEP was adopted as an important component of developing ecosystem-based fishery management plans (EBFMP) by the Chesapeake Bay Program's Executive Council in November 2005. The FEP presents ecosystem-based management guidance and recommendations that were used to develop EBFMPs for the Chesapeake Bay. The following basic ecosystem principles are acknowledged:

- Diversity is important to ecosystem functioning.
- Components of ecosystems are linked.
- An ecosystem has thresholds and limits and when exceeded, can affect the structure and function of the system.
- Once thresholds and limits have been exceeded, changes may be irreversible.
- Ecosystems change with time.
- Ecosystem boundaries are open.
- The ability to predict ecosystem behavior is limited.
- Multiple scales interact within and among ecosystems.

The FEPs guiding principles emphasize the following key components: the quantity and quality of the managed species habitat; predator-prey or trophic interactions; the effects of fishing on the structure and function of the ecosystem; socio-economic influences; and external forces such as climatic change. In order to balance the key components of a fishery, the FEP stresses the need to develop and apply methods to monitor the key ecosystem components, to detect shifts in their condition, identify the causes of the shifts, and modify management practices in order to protect the resource if necessary (i.e., adaptive management).

How Ecosystem-based FMPs Differ from Single Species Plans

Ecosystem-based FMPs focus on the unique characteristics and interactions of Chesapeake Bay fish and shellfish species. The EBFMP is meant to be a responsive document that incorporates new information on fish stocks, trophic interactions and habitat effects to support management actions. As information becomes available through monitoring, modeling, and research projects, it will be incorporated into EBFMPs. The differences between single-species plans and ecosystem plans are mostly a matter of degree. The new plan uses an incremental process that starts with the individual species and adds a broader, more holistic perspective. Ecosystem-based FMPs consider the geographic boundaries and the population structure of the species. Since viable fish habitat is essential to an effective ecosystem approach, the plan includes a description of the spatial, environmental, and temporal extent of habitat; habitat requirements of the species and members of its immediate food web; sources of inputs degrading habitat; and comparisons between historic and existing habitat condition. Ecosystem-based FMPs also identify key predator- prey relationships and quantify trophic interactions, when possible. Estimates of total removals by commercial, recreational, and charter boat fisheries, including technical interactions such as bycatch and discards, are also included. Biological reference points (thresholds and targets), based on the best available scientific information, are defined for managing the stock. The remaining parts of the plan describe non-fisheries related human impacts; the impacts of fishery regulations on species in the immediate food web and the ecosystem as a whole; research recommendations; key uncertainties; externalities, such as climate change; and socioeconomic dimensions (Fisheries Ecosystem Plan, NOAA 2004).

Distribution/Geographic Range

Striped bass range from the St. Lawrence River in Canada to the St. Johns River on Florida's east coast and from the Suwannee River in western Florida to Lake Pontchartrain, Louisiana. The principal spawning and nursery areas of striped bass along the Atlantic Coast are the Chesapeake Bay and its tributaries, and secondarily the Hudson and Roanoke Rivers. In the Chesapeake Bay, striped bass may be found in all major tributaries of the Bay as well as in the Bay itself (Figure 5-1).

(1) add seasonal maps with distribution of eggs/larval stages; juveniles; adults and another map indicating coastal migrations; 2) diagram of life history stages and ecological processes)

For Chesapeake Bay striped bass management considerations, the watershed-to-mouth-of-the-Bay (WtM) unit, recommended in the FEP document, is the recognized boundary of influence. A significant component of striped bass life history occurs outside the Chesapeake Bay, including fishing pressure along the Atlantic coast. It is understood that the WtM area does not include the entire range of influence for striped bass management. However, it is recognized as the effective unit for the Chesapeake Bay Program's EAM. The Atlantic coast management group for striped bass is the Atlantic States Marine Fisheries Commission (ASMFC), a cooperative management framework for coastal jurisdictions.

Population Structure

A number of discrete striped bass populations are found along the Atlantic coast (Setzler et al 1980). During the spring, many of the major estuaries and river systems have spawning populations. The different estuarine populations school together forming "cohort" groups along the coast after the spawning season.

<u>Age structure</u>

One of the primary strategies for managing fish stocks is implementing size limits. Fishing generally selects for larger, older fish and has the potential to shift the spawning stock towards smaller, slower-growing individuals (Williams and Shertzer 2005). Old-growth age structure is important for maintaining long-term sustainable stocks (Berkeley et al. 2004). Striped bass are relatively long-lived and can reach age 29 (Secor et al. 1995). A long life span is generally a "bet-hedging" reproductive strategy that ensures individual success in spite of variable environmental conditions that may be detrimental to larval survival. In addition to longevity, a broad age distribution may also reduce variability in recruitment (Berkeley et al. 2004).

During the spawning season, the Maryland Department of Natural Resources conducts a spawning stock monitoring program that estimates relative abundance-at-age. This survey provides information on the age structure of the striped bass population in Maryland waters of the Bay and is used in the coast-wide stock assessments conducted by the ASMFC. The Maryland survey has been conducted since 1985 and employs multi-panel experimental drift gill nets. The survey records length distribution, age structure, average length-at-age (Figures x & x), and percentage of striped bass older then age 8 that are present on the spawning grounds. An index of spawning potential (ISP) for female striped bass, an age-independent measure of female spawning stock biomass (SSB) within the Chesapeake Bay, is calculated. The ISP varies by year and area (Table x). There is no reference level for age composition in the population since the survey began in the mid 1980's; a time period when the striped bass population was at a low point. The age structure is used more as a qualitative tool. If any problem is discerned, such as contracted age classes, it would trigger an ASMFC recommendation to address the issue under the adaptive management clause of Amendment #6. In general, a wide distribution of age classes indicates a healthy stock. Another positive indicator of age composition is a relatively high proportion of older females, as egg production increases with age.

Virginia conducts a spawning stock survey in the Rappahannock and James rivers. The gill net data for the James River began in 1994, and the pound net and gill net data from the Rappahannock began in 1991. Data are examined for diversity in age class structure.

Management Discussion Point
Evaluate the development of an ISP goal for the Bay.

<u>Reproduction</u>

Adults reach maturity at different ages based on sex. Males mature earlier with 100% maturity by age 3 (approximately 457mm or 18"). Females mature later with 50% maturity by age 6 (approximately 635-660 mm or 25-26") and 100% maturity by age 9 (approximately 812 mm or 32") (ASMFC 2004). Mature adults migrate to riverine spawning areas when the water temperature begins to increase in the spring. Striped bass spawn in the Chesapeake Bay from early to mid-April through the end of May, primarily in tidal freshwater areas just above the salt wedge. Spawning times may vary from year to year with annual temperature variations. Spawning activity (release of eggs and sperm) is triggered by a rise in water temperature. In the Chesapeake Bay, one to three spawning peaks may occur during each spawning season. Major spawning areas include the James, Pamunkey, Mattaponi, Rappahannock, Patuxent, and Potomac rivers on the Western Shore. Major areas at the head-of-the-Bay include the Susquehanna Flats, Elk River, Chesapeake and Delaware Canal; and the Choptank and Nanticoke rivers on the Eastern Shore. Currently, spawning areas in Maryland waters of the Bay are protected from harvest on a seasonal basis and are recognized as important habitat areas (map XX).

During spawning, multiple males surround a single female who broadcasts eggs into the swift water currents as the males release sperm. Older females are generally larger and have a higher fecundity. On average, an age 6 female produces 500,000 eggs while an age 15 female produces 3 million eggs (ASMFC 2004). There is no parental care of the offspring and the semi-buoyant eggs are carried downstream. Eggs and newly hatched larvae require sufficient turbulence, i.e., water flow, to remain suspended in the water column; otherwise, they settle on the bottom and are smothered by sediment. As the larvae grow, they move to progressively deeper levels of the water column and areas of higher salinity usually downstream. Most striped bass juveniles remain in their natal river until they reach 2-3 years of age and then begin their migration to the Atlantic coast.

Stock Status

<u>Atlantic Coast</u>

From a coast-wide perspective, the estimated stock size of striped bass has increased since the early 1990's (Fig. xx ASMFC Total Abundance and Female SSB). The most recent population estimate (2005) was 65.3 million fish (ASMFC Striped Bass Technical Committee 2005). This estimate is approximately 10% higher than the average stock size for the previous five-year period. The female spawning stock biomass (SSB) along the Atlantic coast is estimated at 55 million pounds and is above the SSB target and threshold of 38.6 and 30.9 million pounds, respectively. The SSB estimate peaked in 2002 at 60.6 million pounds. An examination of population estimates by age group indicates that the abundance of age 13+ has increased over the last three years. Recruitment estimates of age 1 fish indicate an average class size for 2004.

The coastal striped bass stock is not overfished and overfishing is not occurring. Estimates of coastal fishing mortality (F) are calculated using a virtual population analysis (VPA) and results from striped bass tagging studies. Fishing mortality for 2004 is currently below the threshold F of 0.41 but above the target of 0.30. When calculating the estimates of F, the most recent year's estimate has the most uncertainly. Although the ASMFC Striped Bass Technical Committee agreed that the F in 2004 was below the threshold, they could not come to a consensus as to where the estimated F for 2004 was in relation to the target.

Once the coastal biological reference points were adopted, it was necessary to define what management steps would be taken if the targets and/or thresholds were met or if they were under the stated levels. A control rule for the Atlantic coastal striped bass stock was developed and adopted (Table 1). Both F and female SSB reference points will be used to assess the status of the coastal stock. If the current F exceeds the threshold, then overfishing is occurring and management steps will be taken immediately to reduce F. If F exceeds the target but is below the threshold, the Management Board will consider whether or not to implement steps to reduce F. If the current F is below the target F, no action is required. Similarly, if the female SSB estimate is below the threshold, the stock is considered overfished. The Management Board will take action to rebuild the stock. If SSB is above the threshold but below the target, no action is required. There is no intent to limit the population from expanding beyond the target level.

Table 1. ASMFC Amendment #6 Control Rule

	Fishing Mortality Rate	**Action**	**Female Spawning Stock Biomass**	**Action**
Target	F = 0.30 (coast) F = 0.27 (CB)	> Evaluate & possible take steps to reduce F < No further actions	38.6 million pounds	< Evaluate – no action required
Threshold	F = 0.41	> Take steps to reduce F	30.9 million pounds	< Take steps to rebuild the stock

Management Discussion Point
Explore the consequences of placing a limit on striped bass population expansion beyond the target SSB.

<u>Chesapeake Bay</u>

Both Maryland and Virginia conduct fishery independent and fishery dependent monitoring programs to assess the status of the stock and provide data to the Atlantic coast stock assessments. Under ASMFC Amendment #6, the Chesapeake Bay jurisdictions manage the striped bass fisheries at a target fishing mortality rate of 0.27. From the most recent ASMFC stock assessment (2004), the estimated Chesapeake Bay F was 0.16, below the target, and represents mortality during June 2003 to June 2004.

Juvenile striped bass seine surveys are conducted in Maryland and Virginia and document annual year-class success. These annual indices of relative abundance provide an indicator of future recruitment to the adult stock and long-term trends in young-of-the-year (YOY) abundance and distribution. In Maryland, juvenile striped bass have been sampled continuously since 1954 from four major spawning and nursery areas: the Potomac River, Head of Bay areas, Nanticoke Rive and the Choptank River (Durell and Weedon 2005). Beginning in 1993, the Maryland juvenile abundance has improved and recent indices have been above the target period average of 4.32 (Figure XX)

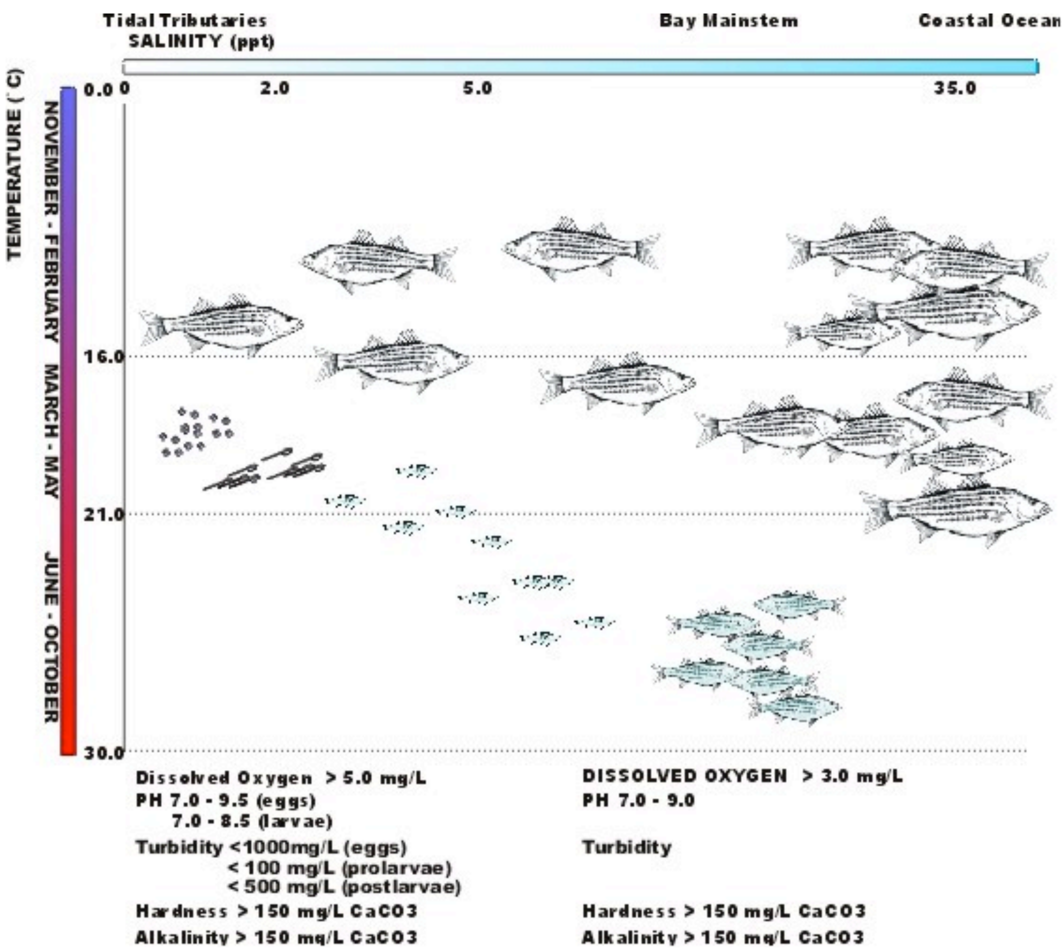
The Virginia Institute of Marine Science (VIMS) has conducted a juvenile striped bass seine survey from 1967 through 1973 and from 1980 until present (Austin et al. 2004). Striped bass recruitment in the Virginia portion of the Chesapeake Bay has been variable and above the historic average of 7.03 for the last few years (Figure xx). Years with moderate to extreme rainfall in the spring and subsequent lower salinities have led to extended nursery areas and stronger juvenile recruitment (Austin et al. 2004).

Age 1 indices have been developed from the Maryland survey data since 1991 and indicate an increasing trend in abundance. The average for the time series is 0.21. In 2004, the age 1 index was significantly higher at 0.55. (Durell et al. 2005)

Striped Bass Habitat in Chesapeake Bay

Chesapeake Bay is the primary spawning and nursery habitat for striped bass on the Atlantic Coast (Merriman, 1941; Raney, 1957). Habitat parameters within Chesapeake Bay are principal determinants of Atlantic striped bass stock year-class strength, determined by the end of the larval stage. Environmental variables also establish the distribution of adult striped bass within Chesapeake Bay, which may impact the rate of out-migration to the Atlantic Ocean and affect Bay and coastal fisheries. Striped bass habitat quality and quantity are affected by both human activities and climatic variation that influence the following environmental parameters: temperature, nutrient levels, productivity or density of prey, turbidity, river flow, dissolved oxygen, pH, salinity, and water toxins. The impact of habitat degradation and variability on both early and late life stages of striped bass in Chesapeake Bay is important to consider when managing the stock for a sustainable population, a functioning ecosystem, and economically sound fishery.

Habitat Utilization by Life Stage

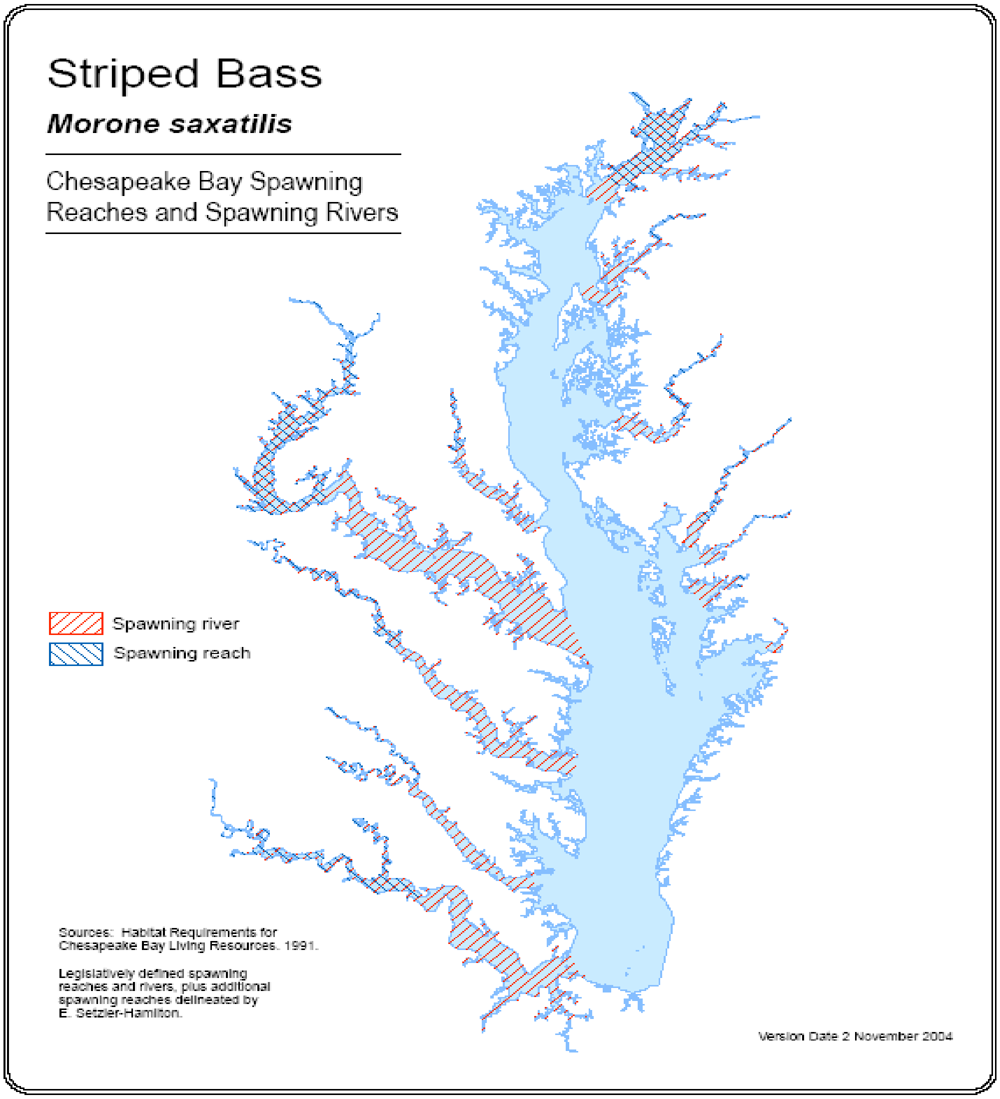


Spawning Adults and Eggs

Striped bass spawn primarily in tidal freshwater areas of Chesapeake Bay just above the salt wedge (salinity >0.5%) (Uphoff, 1989). Maryland's portion of the Chesapeake Bay, including its tributaries, is reported to produce more striped bass than all other propagation areas of North America combined (Vladykov and Wallace, 1952; Mansueti and Hollis, 1963). The lower Susquehanna River, once thought to be the major striped bass spawning area in the Chesapeake, has not contributed significantly to the reproduction of the stock during the past century. It is believed that changes in two important environmental factors, water flow and salinity, resulting from physical alterations to the striped bass migration route by construction of the Conowingo Dam and Chesapeake & Delaware Canal, affected a shift in spawning areas (Dovel and Edmunds IV, 1971). Major striped bass spawning areas within the Chesapeake Bay are illustrated in Figure XX.

Striped bass spawn in the Chesapeake Bay from the beginning of April through the first week of June at water temperatures ranging from 11-24^{o}C (Setzler et al., 1980). Peak spawning activity occurs from early-April to mid-May and has been observed at water temperatures from 14-19^{o}C (Setzler et al. 1980; Uphoff 1992). Peaks are triggered by a noticeable increase in water temperature and vary greatly from year to year (Shepherd 2000). Multiple peaks may occur during each spawning season, particularly when the spawning stock is comprised of several year-classes.

Fertilized eggs are spherical (about 1.6 mm in diameter), non-adhesive, and semi-buoyant (Mansueti, 1958). Eggs are slightly denser than water and sink slowly towards the bottom from the moment they are released into the water column. Albrecht (1964) stated that a velocity of 1 ft/sec in fresh water is required for optimal egg suspension and rates of survival. Fish (1959) has shown that newly deposited eggs require a vertical water movement of 1.25 mm/min to keep them suspended. Eggs that fall to the bottom perish. Striped bass eggs hatch from 29 (at 22^{o}C) to 80 hours (at 11^{o}C) after fertilization (Funderburk et al., 1991).



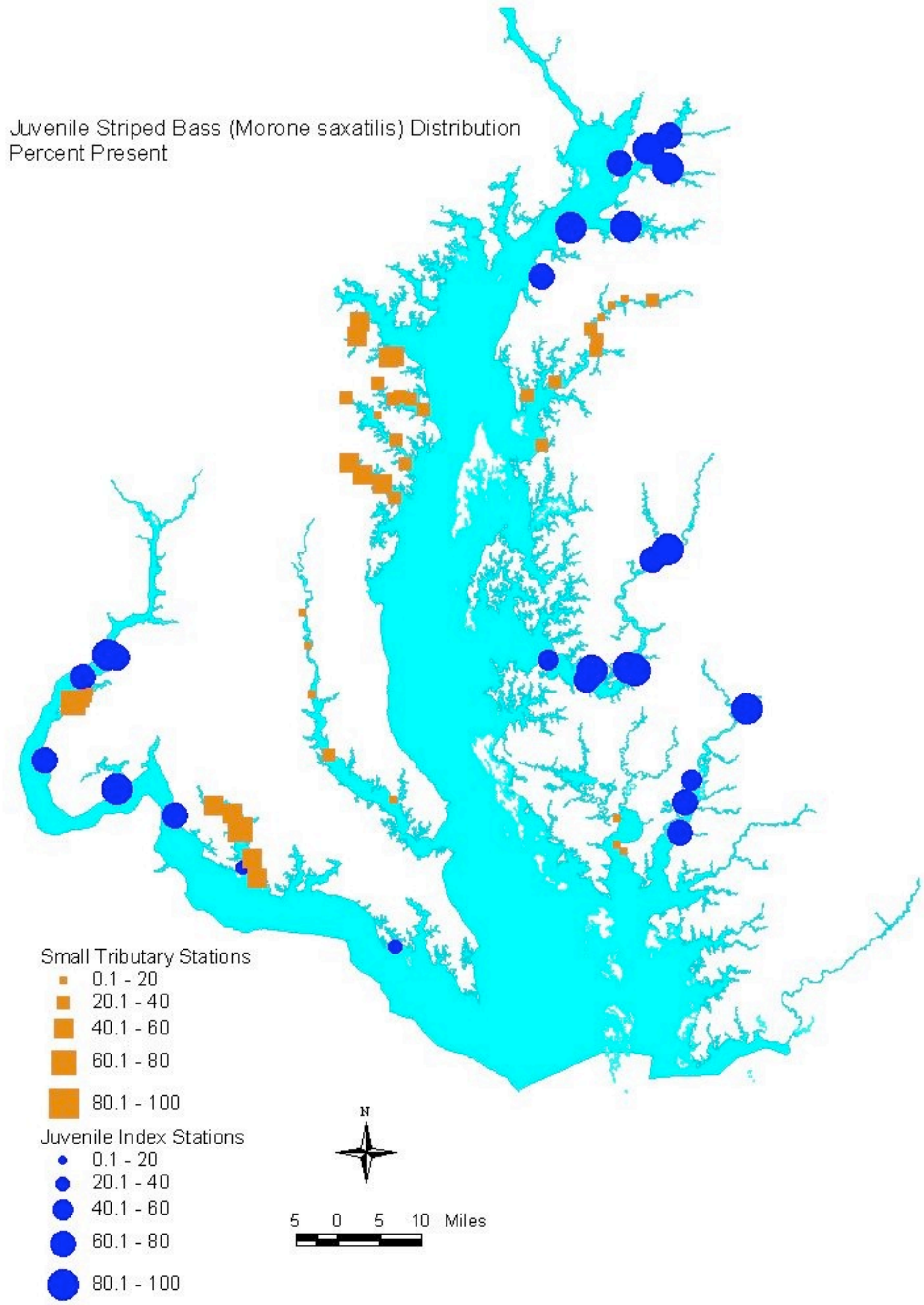
<u>Larval Stage</u>

The larval stage is believed to be the most critical. Larval survival rates determine juvenile numbers and year-class strength (Polgar, 1977; Goodyear et al., 1985; Uphoff, 1989). There are three stages of larval development, including: yolk-sac larvae, finfold larvae, and post-finfold larvae (Hill, 1989). Yolk sac larvae range from 2.0 - 3.7 mm (TL) at hatching and are planktonic, requiring sufficient turbulence to keep them from settling to the bottom where they would be smothered by sediment (Barkuloo, 1970). Newly hatched larvae most often occur in open water. Larvae remain in this stage of development until the yolk sac is absorbed, typically 2-9 days post-hatch.

As larvae grow they are found progressively deeper in the water column (Mihursky et al., 1981 and Houde et al., 1988). The finfold phase lasts for about 11 days and fish usually reach a length of 12mm. The last phase is the post-finfold larvae, which last for about 20 to 30 days, and reach a length of 20 mm (Bain, 1982). While at first it is necessary for the larvae to reside in turbulent waters to maintain position in the water column, the larvae quickly become motile (Doroshev, 1970). By 13 mm (TL), larvae begin forming schools and move upstream. Finfold and larger larvae have been collected in mid-channel areas near the bottom. Occurrence of finfold larvae varies with the time of day and the depth of the river (Hill, 1989).

Young-of-the-Year

Striped bass larvae begin metamorphosis to the juvenile stage at about 20 mm (Setzler-Hamilton, 1981), and are considered juveniles once their fins are fully developed. As juveniles grow, during their first summer and autumn (NMFS 1981), they move progressively downriver into higher salinity, near-shore, shoal areas less than 6-feet deep (1.8 m) (Boreman and Klauda, 1988; Boynton et al., 1981; Setzler-Hamilton, 1981).



<u>Subadults and Adults</u>

Large numbers of sexually immature and mature striped bass reside in the Chesapeake Bay year-round, comprising the Chesapeake Bay resident stock. Surveys conducted by the MDNR indicate that striped bass ages 3-12 typically comprise the resident stock (MDNR, 1995). Most of these fish are pre-migratory and will join the coastal migratory stock upon reaching maturity. Immature females that join the coastal migratory stock do not return to the Chesapeake Bay until they are sexually mature and ready to spawn (Kohlenstein, 1981). Rates of sexual maturation appear to be related to latitude or ambient temperatures; fish from southern waters generally mature at an earlier age than those from regions to the north (Funderburk et al., 1991). Complete recruitment of females to the spawning stock may not occur until ages 7 or 8 (MDNR, 1987).

Striped Bass Migration

The migratory behavior of striped bass is complex with seasonal movements and locations of the fish related to age, sex, maturity, and natal river. In addition, there is considerable variation in the migratory behavior patterns of fish of the same age, sex, and maturity. Despite these differences, certain behavior patterns are common. Generally, sexually immature fish of both sexes remain in their natal estuary until about age 2. After age 2, most females and some males begin to leave the estuary and undertake seasonal coastal migrations (Funderburk et al., 1991). Merriman (1941) found that about 90% of the striped bass collected in the coastal waters off of Long Island and New England were females, while males were more common in collections from Delaware Bay, the Roanoke River, and the Albemarle Sound of North Carolina.

During April and May, immature female striped bass, ages 2-3, begin to migrate out of the Chesapeake Bay to the coasts of the mid-Atlantic and New England states. Later in the spring and through the fall, larger, mature striped bass migrate northward from the Bay. Migration estimates made by Dorazio et al. (1994) indicate that during the spring-fall, larger striped bass are more likely to migrate from spawning areas of the Chesapeake Bay to coastal areas north of Cape May, NJ than are smaller fish. This study found that nearly all tagged fish larger than 100 cm TL migrated from the Chesapeake Bay to the northern region. Most of these larger fish were females. Merriman (1941) concluded that because males mature at an earlier age and a smaller size than females, fewer males participate in the northward migration. Kohlenstein (1981) determined that few young males leave the Chesapeake Bay and approximately one-half of the 3-year-old females migrate to coastal waters. Smaller proportions of age-2 and age-4 females migrate from the Chesapeake Bay.

Quantity of Habitat

Essential fish habitat is defined in the Magnuson-Stevens Fishery Conservation and Management Act as the "waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Striped bass is an estuarine-dependent coastal migratory species that depends on many Chesapeake Bay habitat types during its lifecycle. In this context, all of the Chesapeake Bay and its tributaries represent essential fish habitat for striped bass. Because restoration funding is limited, targeting habitat restoration efforts might more effectively focus on habitat areas of particular concern (HAPC) (NOAA 2001), i.e., provide protection to those areas that critically impact the stock and species health.

HAPCs require special consideration for protection and restoration, either because of the severity of their degradation or their importance to critical processes within a species' life cycle (NOAA 2004). Striped bass spawning and nursery grounds (shown in Figure XX) are HAPCs in Chesapeake Bay because these habitats directly influence year class strength, which is primarily determined by the impact of environmental variables on larvae. Eggs and larvae are the most-sensitive life stages to poor habitat quality (Rose et al., 1993), which further warrants focusing particular attention to their habitat needs. Because the Chesapeake Bay is the largest spawning and nursery area for Atlantic striped bass, these areas are not only critical to the Chesapeake Bay ecosystem and the fisheries it supports, but also to coastal fisheries.

Habitat quantity is affected primarily by changes in water quality, rendering some areas uninhabitable to striped bass. Suboptimal habitat conditions may cause stress to the animal, leading to disease, decreased growth rate, low body weight, and mortality. Specific habitat needs of striped bass life stages are summarized in Table XX. These parameters are affected by many variables, including anthropogenic impacts and climate variability.

The high volume of hypoxic water in the Bay in conjunction with rising summer temperatures is thought to contribute to an 'oxygen-temperature squeeze,' limiting the suitable habitat for striped bass in the Bay (Price et al. 1985). Low dissolved oxygen is a persistent problem in Chesapeake Bay, limiting striped bass habitat availability to an extent influenced by seasonal and annual variability. Deoxygenation can be caused by a combination of factors, including nutrient loading and low wind forcing resulting in diminished mixing of the water column. As nutrient concentrations increased in many areas of the Bay and its tributaries in the past 50 years, greater deoxygenation of the deep channel in the mid and upper bay has occurred. The volume of Chesapeake Bay bottom waters containing 0.5 ml oxygen/liter or less was about 15 times greater in July 1980 than in July 1950 (Price et al. 1985). Since 1984, the Chesapeake Bay Program has led an effort to decrease nutrient levels in the Bay, which has resulted in some important reductions in recent years (Boesch et al. 2001).

Coutant and Benson (1987) suggested that limitations of adult summer habitat in Chesapeake Bay may be just as critical to maintenance of the coastal striped bass populations as spawning and nursery areas. This study identified a potentially critical adult habitat area in Chesapeake Bay in the vicinity of the Bay Bridge that had relatively cool water temperatures (<25°C) in summer and provided refuge from high temperatures for adults and subadults during the summer months. This habitat area stretches from Tilghman Island, about 35 km south of the Bay Bridge, to Rock Hall, about 20 km north of the bridge. Coutant and Benson (1987) suggest that perhaps the water in a shallow sill that cuts off the deep bay channel near the mouth of the Rappahannock River may, under some climate conditions, reach temperatures that limit striped bass emigration from the Bay, making summer thermal refugia in the Bay even more critical.

Quality of Habitat

Striped bass stock productivity is ultimately determined by the quality of the available habitat (Rago, 1991). The year-class strength of striped bass, like most other fish populations, is determined by the end of the larval stage (Chadwick, et al. 1977). The major determinant of larval survival in striped bass is extrinsic, density-independent, environmental conditions, and not merely the abundance or fecundity of the spawning stock (Ulanowicz and Polgar, 1980; Uphoff, 1989; Logan, 1985; Cooper and Polgar, 1981). Environmental variables that affect survival of striped bass larvae include: temperature, productivity or density of prey, nutrient levels, turbidity, river flow, dissolved oxygen, pH, salinity, and water toxins. Land use impacts that affect these variables include: wetlands destruction, riparian buffer removal, increasing impervious surface and sedimentation from construction, overuse of fertilizer and pesticides, and burning of fossil fuels. Habitat quality is also affected by variation in climate.

Land Effects and Impervious Surface

Urbanization and industrialization significantly contribute to the physical degradation of coastal areas, eutrophication, and increased contaminant loads (Pearce 1991). Land is converted to impervious surface (IS) mainly through development, i.e., paved roads and buildings. As a result of IS, the volume and intensity of runoff during rain events increase and impact aquatic habitat. Runoff leads to physical instability of streams and increased amounts of erosion and sedimentation. Runoff from IS is usually warmer than water from forested areas or other porous land and, therefore, a source of thermal pollution. Runoff also transports a wide variety of nutrients contributing to algal blooms, hypoxia, and anoxia; toxic metals; and detrimental organic compounds (Beach 2002).

Runoff can affect fish and their habitats in a number of ways. Thermal pollution and persistent hypoxic conditions can shift fish distribution (Rudolph et al. 2003) and affect reproduction especially during spring spawning runs. Chemicals transported by runoff into aquatic habitats can disrupt reproductive function by mimicking hormones (Colburn and Thayer 2000). Chemicals can also accumulate in fish and impact human consumption. The Maryland Department of the Environment (MDE) has issued fish advisories because of excessive concentrations of PCBs and organochlorine pesticides.

A variety of studies have documented the degradation of freshwater ecosystems when IS in a watershed exceeds 10% (Cappiella and Brown 2001; Beach 2002). The Center for Watershed Protection has developed an impervious cover model that expresses the relationship of fluvial stream quality to IS. This model supports the concept of a “10% rule,” i.e., crossing this threshold leads to impairment of freshwater stream function and deterioration of the system. The model further describes watersheds with 11-25% IS as impacted and those with more than 25% as unable to support freshwater aquatic life. Impacts of IS on fish communities in estuarine systems are limited although fish response to urban land-use has been measured (Limburg and Schmidt 1990; Carmichael et al. 1992). The strong negative relationship between IS and freshwater systems and the 10% rule may not be as dominant in estuarine and oceanic systems. The response may not be as strong because ocean water and large volumes of freshwater input (such as the Susquehanna and Potomac rivers) may dilute the effect of upsteam inputs and push IS thresholds higher (McGinty et al. 2005).

Maryland DNR Fisheries Service has been evaluating the use of impervious surface reference points (ISRPs) as a tool for fisheries management. Developing ISRPs begins with determining the functional relationship between IS and water quality, primarily dissolved oxygen (DO), and a species population response (i.e., abundance, distribution, mortality, recruitment success, growth, etc.) (McGinty et al. 2005). Using DO as a response variable is ideal for fish since they require well-oxygenated water. The level of DO provides insight into both the metabolic state of the fish and the pollution status of a waterbody (Limburg and Schmidt 1990). A strong relationship between IS and DO was found in the Chesapeake Bay tributaries. The results of the 2005 sampling season indicate a negative relationship between mean bottom DO and percent IS in a watershed. A bottom DO of 5 mg/L occurs at 4% IS and 3 mg/L at 10% IS. Bottom DO and the relative abundance of target species reached a plateau between 3.0 and 5.0 mg/L (McGinty el al. 2005). Shifts in habitat use due to changes in bottom DO were not detected.

Based on the IS results from 2005, the following fisheries management framework is proposed. In systems with low IS (less than 5%), fish habitat would generally be considered unimpaired and management actions regulating fishing morality or age at entry into the fishery would be appropriate. In systems with a medium IS (between 5% and 10%), habitat loss would likely have a negative effect on population dynamics. Management would need to compensate for habitat loss and implement more restrictive harvest measures or change land use practices and increase pollution control. In systems with a high IS (>10%), successful preservation or restoration of finfish stocks by traditional fisheries management measures would be unlikely, i.e., a sustainable harvest strategy would be ineffective due to habitat loss (McGinty et al. 2005).

Management Discussion Points

Develop quantitative habitat-based reference points based on IS for estuarine watersheds to evaluate the impact of development on fish communities.

Use estuarine and marine IS targets and thresholds for county and state growth planning, watershed based strategies and actions, and finfish habitat management (how degraded habitats influence fish production).

Establish watershed management guidelines for incorporating an ecological component into landscape planning that will result in improved aquatic/fish habitat conditions.

Promote research on what methods have an impact from stream to tidal tributary to bay.

Insert diagram of impervious surface throughout Bay (<5, 5-10, >10%) here

Insert diagram with the following elements:

- Road and Building Construction: Changes in water flow; High levels of nutrients and sediment in the water, leading to low dissolved oxygen;
- Stream channelization, dams and other flow obstructions, and increased impervious surface: Changes in water flow
- Building too close to the stream bank: Diminished riparian vegetation;
- Burning fossil fuels (power plants, vehicles), wastewater treatment plant overflow, over-use of fertilizers, herbicides, and pesticides, industrial waste dumping, acid mine drainage: pH reduction; Water toxins (harmful algae toxins, chlorine, heavy metals, oil, acid, pesticides, herbicides and fungicides, greenhouse gases, radioactive wastes);
- Power plants: thermal pollution.
- Wastewater Treatment Plant Overflow
- Agriculture, Golf Course, and Yard Over-usage of Fertilizers, Pesticides, Herbicides, and Fungicides
- Stormwater Run-off of nutrients, toxics, and sediment

Insert a box including the following here:

What you can do to reduce impacts on striped bass and other Bay organisms:

1. Limit your vehicle fuel usage:
   - Use your car, boat, RV as little as possible
   - Buy an energy efficient vehicle
2. Limit your home fuel usage:
   - Buy energy efficient appliances
   - Install a thermostat that can regulate temperatures in your home based on when you are there (when you are not home, increase the temperature setting in the winter and increase the temperature setting in the summer)
   - Try to acclimate yourself to temperatures in your home that are lower in the winter and higher in the summer than you might otherwise be accustomed to
   - Consider supplementing your traditional home heating system with an efficient supplemental heating source
   - Turn off lights when you are not in a room
   - Use energy-efficient lightbulbs
3. Limit fertilizer, pesticide, and herbicide usage:
   If it is not needed, don't use it; If it is needed, only use that amount that is necessary. When fertilizer usage is necessary, consider using organic fertilizer (composted manure) instead of synthetic chemical fertilizer. Be aware that some chicken litter includes toxic metals such as arsenic and other potentially toxic substances.
4. Limit new development:
   - Consider renovating an old building instead of building a new one
   - Do not build within 100 feet of a waterway
   - If your property is beside a waterway, maintain the natural riparian buffer (plants within 100 feet of the bank) or plant a buffer if one does not exist
5. Limit the amount of water that runs off of your property by installing rain barrels or rain gardens

6. Limit your usage of treated water:
   - Consider replacing your lawn with native plants that require less watering and fertilizer
   - Use rain water to water your plants instead of tap water
7. If you have a septic system, make sure that it has been upgraded so that it will not leak or overflow.
8. Promote smart growth in your county or town/city:
   - Be aware of those areas that require protection and restoration and do not build there
   - Promote green building practices in your area
   - Participate in your county/city planning process

Table XX summarizes water quality conditions favorable to the survival of striped bass at different life stages. Although survival may occur outside these limits, the organisms may be stressed. (REFERENCE?)

TABLE XX - HABITAT REQUIREMENTS FOR STRIPED BASS LIFESTAGES

Life Stage	Temperature (°C)	Salinity (ppt)	pH	Hardness (mgL^{-1} CaCO3)	Alkalinity (mgL^{-1} CaCO3)	Dissolved Oxygen (mgL^{-1})	Turbidity (mgL-1)
Egg	12 - 23	0 - 8	7.0 - 9.5	>150	>150	>5.0	<1000
Optimum	14 - 20	>0.5					
	18 - 21	2 - 10					
Prolarva	12 - 23	0 - 15	7.0 - 8.5	>150	>150	>5.0 (at 18 °C)	<100
Optimum	18 - 21	1 - 3					
		3 - 7					
Postlarva	12 - 23	0 - 15	7.0 - 8.5	>150	>150	>5.0 (at 18 °C)	<<500
Optimum	15 - 22	3 - 7					
Juvenile and Adult	10 - 27	0 - 16	7 - 9	>150	>150	>5.0	0 - 10 (clay/silt)
	14 - 21	<12					0 - 2000 (fine sediment)

<u>Environmental Variables that Determine Habitat Quality for Striped Bass:</u>

- Water Temperature:
  Striped bass eggs and larvae show significant increases in mortality when exposed to rapidly changing water temperatures (Schubel et al., 1976). Temperatures at or below 12°C are considered lethal to striped bass eggs and have been a suspected cause of high egg mortality (Funderburk et al., 1991; Rose et al., 1993). The variability in temperature in striped bass spawning habitat in the spring and summer is somewhat unpredictable and spawning females are thus unable to

determine a time of spawning that would guarantee optimum temperature conditions for their offspring. Therefore, striped bass are highly fecund and spawn over a broad period to ensure that some of the larval cohorts will encounter favorable conditions for survival and growth (Secor and Houde, 1995).

Adult striped bass have a strong tendency to avoid water temperatures >25^{o}C (Coutant, 1985; Matthews et al., 1989). This can affect migration patterns as well as suitable spawning habitat. When climate change or human impacts cause temperature increases above this threshold, suitable habitat for striped bass migration and spawning are limited.

Discharge of heated waters from power plants or other industrial facilities is called thermal pollution. In Chesapeake Bay tributaries, thermal pollution affects egg, larval, and juvenile development, can cause mortality (Dorfman, 1974), and can alter the timing of spawning events, thus limiting chances for successful spawning. A sharp rise in temperature may cause premature spawning activity (Farley, 1966), while a sudden drop in temperature can cause cessation of all spawning activity (Boynton et al., 1977).

- Salinity:

  Low salinity waters promote higher egg and larval survival than freshwater (Albrecht, 1964; Seltzer et al. 1980). Juvenile striped bass migrate to more saline portions of the estuary after exceeding 70mm TL (Mihursky et al., 1976). Adult striped bass readily acclimate to changes in salinity by adjusting the osmotic pressure within their bodies, enabling them to survive in low to moderate salinity tributaries, moderate salinity bay waters, and high salinity ocean waters.

- Dissolved Oxygen:

  Dissolved oxygen is critical for egg and larval survival. Turner and Farley (1971) found that a reduction in the dissolved oxygen level reduces survival of striped bass eggs and larvae; that hatching time is slightly longer in low DO concentrations; and that the longer striped bass eggs are exposed to low oxygen concentrations, the lower the percentage survival. Klyashtorin and Yarshombek (1975) found that striped bass of 0.3-22 g could survive at a DO level of 4.0 – 4.5 mg/L, but that at this minimum level, motor activity is restricted, food consumption is lowered, energy expenditure is increased for respiration, and growth rate is reduced. Adult striped bass typically avoid waters with low dissolved oxygen. Chittenden (1971) concluded that low DO concentrations in the freshwater tidal areas of the Delaware River had eliminated this area as a striped bass spawning area. Adult striped bass can tolerate higher temperatures with higher oxygen saturation than with reduced oxygen levels (Meldrim et al., 1974).

- pH:

  Funderbunk et al. (1991) reported that a pH of 7.0 to 8.5 is sufficient for survival of striped bass larvae and juveniles and an instant change of 0.8 - 1.0 units caused high mortality. Studies at the Columbia National Fisheries Research laboratory indicate that a pH of 6.5 is toxic to 19-day old striped bass larvae after 7 days of exposure and an addition of 0.1 mg/l aluminum (Al) at pH 6.5 killed all 19-day old striped bass after 5 days of exposure in soft water (Mehrle et al., 1982). Soft water has very low levels of dissolved calcium, magnesium, and other divalent metal ions, giving it low buffering capacity and making it subject to pH crashes. Laboratory tests have revealed that exposure of larval striped bass (<50-days old) to pH <+6.0 causes rapid mortality and that the toxicity of total aluminum increases with decreasing pH. Metals become soluble at low pH levels, increasing their toxicity to larval fishes (Peterson et al, 1982). The striped bass life stages most sensitive to low pH are: early cleavage, newly hatched, and early feeding larvae (Peterson et al, 1982). The toxicity of low pH declines after 50-80 days of age (Buckler et al., 1987). Increased water hardness and increased salinity reduce the toxic effects of low pH and inorganic contaminants (Palawski, et al., 1985; Rago, 1991).

- Sediment:

High levels of suspended sediment can smother striped bass eggs and larvae (Burkaloo, 1970). Shoreline construction projects, channel dredging, increased impervious surface from urbanization, and a reduction in stabilizing vegetation can contribute to stream turbidity problems. Runoff in rivers with inadequate riparian buffer zones can increase concentrations of suspended solids in the water column to the point of reduced larval feeding efficiency (200-500 mg/l) (Breitburg, 1988) and survival (500 and 1,000 mg/l (Auld and Schubel, 1978). Urbanization that causes changes in stream hydrology can functionally effect flows and cause high rates of stream erosion. Increased energy associated with extended periods of elevated flow from stormwater settling ponds causes erosion rates to increase.

Auld and Schubel (1978) showed that turbidities greater than 1000 mg/L caused egg mortality, and levels greater than 500 mg/L caused larval mortality. Turbidity levels over 350 mg/L have been shown to block the entry of spawning adults into river systems (Radtke and Turner, 1967). Adult striped bass have been observed to avoid areas of total dissolved solids greater than 180 mg/L (Farley, 1966; Murawski, 1969).

- Nutrients:

Elevated nutrient levels in Chesapeake Bay cause increased respiration of benthic organisms and oxygen consumption of decomposing matter; this in turn lowers levels of dissolved oxygen in deeper waters (Officer et al, 1984), resulting in increased anoxic and hypoxic areas of the Bay. This along with rising surface temperatures in summer can limit available habitat for striped bass. Increased levels of nutrients can also change phytoplankton assemblages that can alter food web dynamics. Such phytoplankton changes could result in lower abundance of preferred striped bass forage fish in the Bay. Limited food resources may increase the likelihood and prevalence of poor body condition and disease in striped bass (Hartman and Margraf, 2003).

- Flow:

  Sufficient water flow is necessary in order for larvae to maintain position in the water column prior to developing motility (Doroshev, 1970).
  Altered flow can affect migration of juveniles by changing current speed, water temperature, pH, salinity, and other aspects of local water quality. Periods of high rainfall have been shown to reduce pH, elevate levels of aluminum and other toxic metals, and increase toxicity of water in striped bass nursery areas (Hall et al, 1985).

- Toxicants:

  Buckler et al. (1987) determined that the response of larval and juvenile striped bass to toxic acidic conditions and inorganic contaminants decreases with age. Slow growth rates can increase the time of exposure of larval fish to water toxins (Ware, 1975). Factors contributing to decreased growth rates include: reduced food abundance, inadequate nutrition, low water temperatures, and stress from poor water quality. Abrupt changes in salinity, that may occur with heavy rain events and high stormwater influx, can cause osmoregulatory stress in striped bass larvae, which increases their sensitivity to contaminants (Buckler et al, 1987).

  Three classes of environmental contaminants have been studied intensely for their impact on striped bass, including: monocyclic aromatic hydrocarbons (benzene), chlorinated hydrocarbons (PCBs), and residual chlorine from water treatment plants, present in the form of hypochlorous acid, hypochlorite ions or as dissolved elemental chlorine. Chronic exposure to sub-lethal levels of benzene has been shown to limit the ability of juvenile striped bass to locate and consume food items, resulting in decreased body fat and total weight (Korn et al., 1976). Mehrle et al. (1982) found elevated levels of PCBs, arsenic, lead, selenium, and cadmium in Chesapeake Bay were correlated with decreased vertebral strength, stiffness (extent of elasticity), toughness (energy absorbed at bone failure), and stress tolerance in young of the year striped bass. Residual chlorine has been shown to cause decreased hatching rate of striped bass eggs and mortality of eggs and larvae (Middaugh et al., 1977; Morgan and Prince, 1977).

- Riparian Vegetation:

  Diminished riparian vegetation limits filtration of nutrients, sediment, and contaminants from waters prior to stream entry; the ability of the tree canopy to regulate the water temperature of streams; entry of leaf litter that contribute to the aquatic food chain; as well as the contribution of woody debris that can help dissipate flow energy and bank erosion (Booth et al., 1996; Booth and Jackson, 1997). Resulting increased stormwater runoff can cause dramatic changes in stream flow, water temperature, and channel geomorphology (Poff, et al., 1997). These changes can result in decreased distribution and abundance of riverine species and the ecological integrity of the system as a whole (Power et al., 1995; Resh et al., 1988; Poff, et al., 1997).

Management Discussion Points

Promote free-flowing streams: Reject the building of any new dams or stream obstructions, stream channelization, or other projects that would significantly alter water flow.

Develop habitat-based reference points in spawning and nursery areas for habitat requirements, including temperature, salinity, pH, DO, turbidity, nutrient, sediment, riparian buffer, and toxics levels.

Establish a habitat assessment program for spawning and nursery areas to include monitoring of temperature, salinity, pH, DO, turbidity, nutrient, sediment, riparian buffer, and toxics levels.

Determine indicators of habitat health: e.g., resiliency, species diversity, spatial and temporal variability, patchiness

Climate

Since the beginning of the 19th century, there has been an upward trend in global temperatures with a concurrent rise in ocean temperatures. Increases in global temperature have been linked to increased levels of atmospheric carbon dioxide and other gases (Casselman 2002). Understanding the dynamics of climate change on fishery resources is a complex process that involves population biology, interactions with the ecosystem and human behavior (Magnuson 2002). In addition, analyzing climate trends are highly dependent on time scale. What is observed using short-term trends can mask long-term trends. Scales of time used to assess signals from ice cover extend over thousands of years whereas the time frame for relating climate to fish population trends are more limited since data sets usually span only 25 to 50 years. Even with this limitation, inter-year and inter-decadal variability can provide some insight into what fish managers should consider under warmer climate conditions.

Responses to climate dynamics have already been documented for tidal wetlands, chemical and biological cycles in lakes, biodiversity, and biogeographic limits (McGinn 2002). Results indicate that climate change can affect life history patterns of aquatic organisms and their habitats. Impacts on fish populations include changes in productivity and changes in distribution. Changes in productivity are likely to be manifested as changes in biomass and fishery yields (Shuter el al. 2002). Examining climatic factors in relationship to fish population dynamics could help explain variability in stock size and improve management advice.

One of the primary factors affecting fish population dynamics and productivity is temperature. Temperature directly affects a number of physiological processes in fish, mainly, spawning, development, age at maturity, and growth (Casselman 2002). In recent years, warmer temperature extremes have been more pronounced. In the Great Lakes Basin, temperature associations explained between 12% and 36% of the variance in year-class strength, thus tracking the effects of climate change on fish populations (Casselman

2002). Depending on the temperature requirements for a particular species, warming trends could either have a negative or positive effect. Fish that prefer warmer water conditions could expand their range. The northwest Atlantic Ocean demersal and pelagic fish study (Murawski 1993) provides evidence that thermal conditions in the ocean have changed with a concurrent shift in fish species composition towards more tropical species.

There is evidence that biological reference points (targets and thresholds) used to direct fishery management are sensitive to climate changes especially aspects of fish population dynamics like growth, reproduction, and mortality (Brander 2004). One example of the effects of climate change on fish population dynamics is larval cod (*Gadus morhua*) and the seasonal timing and abundance of plankton in the North Sea (Beaugrand et al. 2003). The survival of larval cod is dependent on plankton. When the North Atlantic Oscillation (NAO), the atmospheric pressure gradient between Iceland and the Azores, is increasing it is associated with increasing sea temperatures and changes in winds, rainfall and other factors that affect plankton availability. The higher NAO results in reduced recruitment and ultimately leads to a reduction in the ability of the cod stock to withstand fishing pressure. As a result, expected yield and recruitment of North Sea cod are different under high and low NAO conditions (Brander and Mohn 2004). Biological reference points that were used to set fishing levels before climatic impacts can become compromised and hinder sustainability. Targets and thresholds will need to be adaptive, i.e., adjusted or changed relative to climatic effects and other environmental impacts.

Management Discussion Points:
Adjust biological reference points (targets and thresholds) to account for the effects of climatic change and adopt a mechanism to modify them to account for future changes.

Establish harvest targets that preserve the natural buffering characteristics of individual stocks (consider longevity, diverse age structure, migration pathways)

Modeling Question
How do increases in temperature affect the growth rate potential and subsequent production of top predator biomass in CB?

Further Analysis
Examine the effects of spring water temperature in the Chesapeake Bay on the temporal and spatial synchrony of phytoplankton and zooplankton production. Has there been a shift in production due to increasing temperatures? How does zooplankton abundance relate to juvenile fish abundance?

Are there any climate-sensitive species/stocks? Monitor them to provide early warning of climate impacts.

Conduct vulnerability assessments of individual fish stocks to thermal changes with the objective of ordering existing stocks in terms of those most likely to benefit and those most likely to suffer under climate change. Include vulnerability of critical habitats.

In the Chesapeake Bay, increases in mean sea level height range from 3.1 mm (Baltimore Harbor) per year to 7.0 mm (Chesapeake Bay Bridge Tunnel, VA). The Chesapeake region has a higher rate of increase, more than double the global rate, because of two factors: geologic land subsidence and groundwater extraction (Stevenson 2002). A continued increase in sea level rise has the potential to negatively impact every coastline and marsh areas. The Chesapeake region has been stressed by marsh losses from a number of other factors. Aerial and satellite data indicate more than 50% of the marshes have been degraded. Eroding marshes contribute to increasing turbidity, increasing wave power and decreasing SAV.

Management Discussion Points:
Identify and distinguish between areas that are critical to protect and areas that are capable of withstanding continued use.

Regional differences in fish production have been demonstrated along the west coast, indicating regional analyses are necessary. Use a zonal approach within the Bay??

Trophic Interactions

The striped bass population in Chesapeake Bay has shown an increasing trend since the removal of the fishing moratorium in 1995. The increase in abundance of this top predator has likely impacted abundance of forage fish in the Bay. Concurrent decreases in the menhaden population due to coastal reduction fisheries and environmental impacts have significantly impacted the amount of available forage for top predators in the Bay (Kahn 2004; Jacobs et al. 2004). Menhaden have historically comprised a large proportion of the striped bass diet, but have contributed relatively less in recent years due to decreased population abundance. Uphoff (2003) reported that menhaden abundance in Chesapeake Bay is at a historic low. The interactions between predator and prey not only significantly impact abundance of fish stocks, but also impact the health of populations. In recent years, disease, parasitic infection, and low body weight have frequently been observed in the Chesapeake Bay striped bass population. It is likely that limited prey availability has lead to low body weight and stress, causing depressed immune function and susceptibility to disease (May et al. 2004).

Menhaden populations in the Bay have exhibited low levels of recruitment in recent years, likely due to a combination of climate change (Wood et al., 2004), environmental degradation, and fishing pressure. As menhaden have become less prevalent, striped bass have changed their food preferences and prey upon other available species. Uphoff (2003) calculated predator-prey ratios, indicating that the proportion of age 0-2 Atlantic menhaden per striped bass decreased by 20% from 1982 to 1998.

Overton et al. (2000) determined that from 1955 to 1970, menhaden contributed the highest relative biomass to the striped bass diet in Chesapeake Bay when compared to other prey species: menhaden (48%), followed by gizzard shad (15%), bay anchovy (11%), and blue crab (7%). However, by 1998, the striped bass diet, combined across all age classes, had shifted: gizzard shad contributed the highest portion of biomass to the striped bass diet (28%), followed by menhaden (20%), blueback herring (13%), and blue crab (1%) (Overton et al., 1999). Although percent composition of diet varies significantly depending on the year, season, age-class, gear-type, and location of striped bass sampled, the shift in diet composition from menhaden to other prey species is evident from results of several studies and indicative of a decline in availability of this preferred striped bass forage species.

Environmental factors such as salinity and substrate structure are important determinants of striped bass diet composition (Boynton et al, 1981). These environmental factors change with varying habitat and climate. Cooper et al (1998) noted that mysid consumption by 160mm TL striped bass larvae decreased as the salinity of the water decreased. Booth and Gary (1993) reported that more blue crabs were found in stomachs of striped bass that were caught in the higher salinity waters of the lower Chesapeake Bay than of those caught in the lower salinity waters of the upper Chesapeake Bay.

The structure of the feeding areas also plays a role in the foraging habits of the striped bass. Boynton et al (1981) found that the feeding success rate of juvenile striped bass was significantly greater in near-shore areas than in open water areas. This may be due to a higher density of appropriately sized prey items in the near-shore areas as opposed to the open water areas examined.

Management Discussion Point:
Develop a forage fish index for adult striped bass.

<u>Modeling Need:</u> Use the EwE model, the ASMFC multispecies VPA model, and other trophic models to determine:

1. What are the long-term consequences[1] to striped bass, its competitors (weakfish and bluefish) and its major prey species (menhaden, bay anchovy, polychaetes, mysid shrimp, isopods/amphipods, blue crabs) of the recent ASMFC proposal to cap the Chesapeake Bay menhaden fishery at 105,000 tons? of capping the Chesapeake Bay menhaden fishery at 130,000 tons, as proposed by industry? of capping the Chesapeake Bay menhaden fishery at 190,000 tons, a level that apparently was harvested for a series of years in the 1980s-1990s? of reducing menhaden fishing in Chesapeake Bay to 70,000 tons? of reducing menhaden fishing in Chesapeake Bay to 0 tons?

2. Rather than caps on the Chesapeake Bay menhaden fishery, what would be the consequences to striped bass, its competitors (weakfish and bluefish) and its major prey species (menhaden, bay anchovy, polychaetes, mysid shrimp, isopods/amphipods, blue crabs) of changing the fishing mortality rate on menhaden, i.e., a fishing effort regulatory approach, rather than a quota allocation (e.g., 50% of present; 150% of present, etc.)?

3. What would be the consequences to striped bass, its competitors (weakfish and bluefish) and its major prey species (menhaden, bay anchovy, polychaetes, mysid shrimp, isopods/amphipods, blue crabs) of increasing (or decreasing) the fishing mortality rate on striped bass in Chesapeake Bay by 25%, 50%, 100%? weakfish in Chesapeake Bay by 25%, 50%, 100 bluefish in Chesapeake Bay by 25%, 50%, 100%?

4. What would be the consequences to to striped bass, its competitors (weakfish and bluefish) and its major prey species (menhaden, bay anchovy, polychaetes, mysid shrimp, isopods/amphipods, blue crabs) of holding the total mortality rate of Chesapeake Bay menhaden constant, but varying the fishing mortality rate to account for potential predator demand? (This scenario may need critical thought and discussion since F will vary as predator abundances shift. Can EwE deal with this? It is responsive to the Collie and Gislason 2001 suggestion that forage fishes are best managed by controlling total mortality).

5. What are the consequences to striped bass, its competitors (weakfish and bluefish) and its major prey species (menhaden, bay anchovy, polychaetes, mysid shrimp, isopods/amphipods, blue crabs) of changes in Chesapeake Bay water quality that reduces or increases chl-a levels by 50%, 100%? (Runs that Howard showed us on 8 Sept suggest that there is a strong and linear response of all higher trophic levels to a change in level of primary production. Is it realistic?)

6. What are the consequences of capping the striped bass population at current levels and increases of 25% and 50% on the balance of predators and prey (weakfish, bluefish, menhaden, bay anchovy, croaker, spot, mysid shrimp, polychaetes, isopods/amphipods, blue crabs)?

[1]Consequences to be measured as changes in biomass, numbers, recruitment levels, etc. For menhaden, it is especially important to see trends in YOY fish and in older age classes.

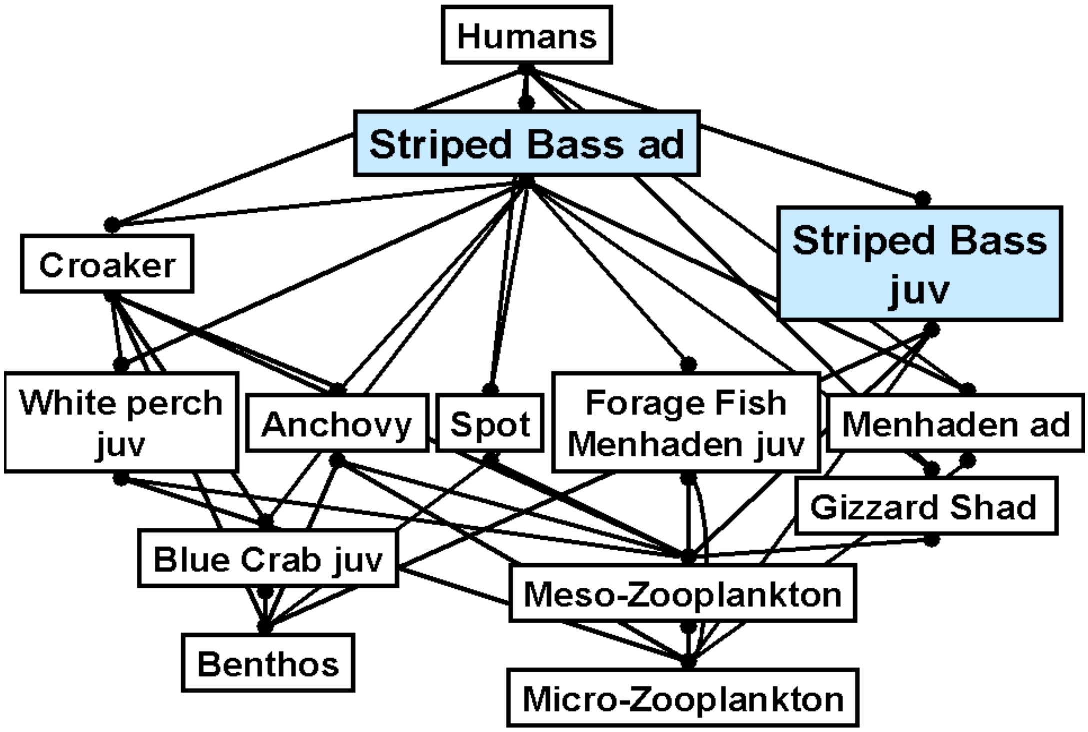


Figure 1. Subweb of striped bass.

Striped Bass Diet Composition by Life Stage

The diet of striped bass, *Morone saxatilus*, varies throughout the lifecycle. Striped bass begin as planktivorous larvae and gradually switch to a predominantly piscivorous diet as adult fish.

<u>Larval Stage Feeding Habits</u>

Once striped bass eggs hatch, the larvae require 2 – 9 days for the mouth to fully form. During this time, larvae receive nourishment from a yolk sac located on their ventral surface. At 5-9 days post-hatch and 5 mm (TL), striped bass larvae begin feeding on microscopic zooplankton found in inshore areas (Funderburk et al., 1991). Larvae feed primarily on copepodite, adult copepods and cladocerans. Typically, the calanoid copepod, *Eurytemora affinis*, is a major prey item during April. Major foods in late-May and early-June are the copepods, *Acartia tonsa* and Cyclops spp., and the cladocerans, *Bosmina longirostris* and Daphnia spp. (Funderburk et al., 1991; Uphoff, 1989). During this period, larger forms of zooplankton, such as *Siphonophora*, *Medusae*, and *Chaetognatha*, may prey upon striped bass larvae.

Early larvae require relatively high prey densities for successful feeding, as muscular coordination is not fully developed. During feeding, striped bass larvae pass their mobile, planktonic prey repeatedly in order to aim and strike at the prey successfully. Nine-day-old larvae have been observed to strike successfully at concentrations of 15,000 Cyclops nauplii and copepodites per liter. By the 11th and 12th day, when the air bladder of the striped bass larvae has filled, the prey concentration may be reduced to 2,000 and 5,000 per liter (REF).

As the larvae grow, they select progressively larger zooplankton prey items, such as *Mysidopsis* and *Gammarus*, until they attain a size of approximately 100 mm Total Length (TL). At this point, the striped bass larvae begin to include larval fish as a dietary component. This time frame also corresponds to the transition to the juvenile stage.

<u>Juvenile Feeding Habits</u>

Young-of-the-year (age-0) striped bass are flexible, non-selective feeders. Diet composition of age-0 striped bass is highly dependent on prevailing salinity patterns and dissolved oxygen levels, which vary significantly by season, spatial area, and with climate flux. Success of this developmental stage in the Chesapeake Bay and Hudson River estuaries is thought to determine year-class strength of the Atlantic stock.

Juvenile striped bass will commonly consume larval fish, *Crangon septemspinosa*, mysids, larger species of amphipods, and polychaetes. They will also consume insect larvae, turbellarians, cumaceans, phantom midges, and members of the fish lice genus, *Argulus* as the opportunity arises (Dunning et al, 1997). While invertebrate prey items typically outnumber fish prey items significantly, fish prey items contribute heavily towards the total weight of stomach contents.

The MDNR Striped Bass Survey and VIMS Chesapeake Bay Trophic Interaction Laboratory conducted a diet analysis of juvenile striped bass caught in the Maryland portion of the Chesapeake Bay in both 2004 and 2005, which indicated the relative importance of various prey types to the age-0 striped bass diet in this region. The percent of Relative Importance (%IRI) is used as a standard assessment of dietary importance and takes into account frequency of occurrence, relative numerical abundance, and relative weight contribution of each prey item. IRI% was as follows in 2004 for major prey type categories of age-0 striped bass: 53% crustaceans, 34% insects, 7% fish, and 6% other arthropods, worms, mollusks, and miscellaneous material (MDNR, 2004). In 2005, IRI% shifted between the same prey categories, while crustaceans remained the dominant prey category, fish replaced insects as the second most important diet category: 61.1% crustaceans, 19.6% fish, 13.6% insects, and 5.6% miscellaneous material, worms, and mollusks (MDNR, 2005). Chironomids, or midges, and amphipods were the two individual prey types of greatest importance in both years. Other important individual prey types were polychaete worms and larval fish.

Reports from other regions of the Bay indicate a difference in relative importance of juvenile striped bass prey types, supporting the concept that they are non-selective feeders. In a study of age-0 striped bass in three Virginia rivers of the Chesapeake Bay, the majority of the diet was comprised of fish, decapods, mysids, polychaetes, and amphipods (Markle and Grant, 1970). A study in Potomac River reported insect larvae, polychaetes, larval fish, mysids, and amphipods as primary prey items (Boynton, et al, 1981). On the lower James River, leptodorids, copepods, insect pupae, fish, and insect larvae were determined to be the major prey (Rudershausen and Loesch, 2000). Although these studies are not directly comparable, given that they employed various gear types and study methodologies, the variety of major prey types reported for this one life stage indicates that young-of-the-year striped bass prey upon available items of sufficiently small size.

As juvenile striped bass grow larger, they eat a higher proportion of fish as prey. Manooch (1973) examined the stomach contents of juvenile striped bass of 125 – 304mm TL in Albemarle Sound, North Carolina and found that they fed primarily on Clupeids and bay anchovy with some predation on blue crabs and penaeid shrimp. Markle and Grant (1970) noted that in Virginia tidal rivers, once striped bass reach 70mm, they began feeding on larger invertebrates and fish if they are available.

<u>Adult Feeding Habits</u>

Walter and Austin (2003) studied adult, migratory striped bass diet composition in 1997 and 1998 throughout the Chesapeake Bay and its tributaries. Striped bass between 458mm and 1151mm TL were sampled by hook and line (bait omitted), gill net, fyke net, and otter trawl. Table Z shows the variation in diet by season and salinity zone. Overall, clupeid fishes dominated the adult diet and menhaden, in particular, accounted for 44% of the weight and occurred in 18% of the stomachs. Hartman (1993) reported that the striped bass diet is composed of an increasingly higher percentage of menhaden with age, rising from 33% at age 1 to 66% at age 6. Other prey species are seasonally important to striped bass in Chesapeake Bay.

Table Z. Large Striped Bass (458-1151 mm TL) Diet Composition in Chesapeake Bay (Walter and Austin, 2003)

Season	Location	Main Prey Types
March, April, May	Tidal fresh/oligohaline spawning areas (reduced feeding intensity)	Gizzard shad, white perch, anadromous herrings
Spring (before and after spawning)	Mesohaline (high feeding intensity)	Menhaden, croaker, white perch, blue crab +for smaller fish (458-710mm): bay anchovy, juvenile spotted hake +for larger fish (711mm and above): anadromous herrings
Fall	Mesohaline, polyhaline (high feeding intensity)	Menhaden (53-58%); spot, croaker, and weakfish (combined 23-31%) +for larger fish (711mm and above): summer flounder (15%)

		+for smaller fish (458-710mm): butterfish (4%); gizzard shad (11%); *In September, blue crabs contributed 70% of diet by weight

Dominant Piscivore Interactions in Chesapeake Bay

Striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), and weakfish (*Cynoscion regalis*) are the dominant piscivores in Chesapeake Bay (Hartman and Brandt 1995). Piscivore production in the Chesapeake is highly dependant on only a few prey species. In general, young predators feed primarily on bay anchovy until they become large enough to feed on Atlantic menhaden, spot, and croaker (Hartman and Brandt 1995). Atlantic menhaden become increasingly important in the diets of larger and older predatory fish in Chesapeake Bay. The consumption of high amounts of Atlantic menhaden from summer to fall corresponds with estimates of peak biomass of this prey species in the mid-Chesapeake (Luo and Brandt 1993). Atlantic menhaden are extremely important to annual production of striped bass and bluefish in the Chesapeake Bay because much of the annual growth of these predators occurs when menhaden dominate their diet (Hartman and Brandt 1995).

Seasonal as well as ontogenetic differences in prey preference are apparent for all three species. Chesapeake Bay piscivores feed predominantly upon prey associated with pelagic trophic pathways, except for young striped bass (Age-0 and Age-1), which feed on benthic resources until mid-summer at age-1 (Hartman and Brandt 1995). During spring and summer, an increase in benthic prey occurs for age-2 and older striped bass and age-1 and older weakfish and bluefish. Seasonally restricted use of benthic prey (spot, croaker) is most pronounced in older cohorts, excepting age-0 striped bass that feed on benthic sources (invertebrates) year-round and age-0 bluefish that feed exclusively on pelagic sources.

Hartman and Brandt (1995) found that bluefish and weakfish have the highest between-species overlap in diet, followed by striped bass and bluefish, and striped bass and weakfish. Highest overlaps within a species were usually found among older cohorts. The degree of dietary overlap varied seasonally. Overlap was generally found to be lower in May-August than September-April.

Hartman and Brandt (1995) found that most annual growth of Chesapeake Bay piscivores occurs in the second half of the year, after mid-July. Striped bass annual weight gain appears to decline with age in Chesapeake Bay. Bluefish grow rapidly during their stay in the estuary, with all age groups increasing in weight from day of first capture in late-May to the time they leave the estuary in October. In general, age-0 bluefish grow exponentially throughout the year and age-1 and age-2 bluefish more than double in weight while in the Chesapeake. Weakfish exhibit variability in weight-at-age, due to the fact that they are batch spawners, spawning from May through August in Chesapeake Bay (Szewdlmayer, et al 1990). Weakfish grow rapidly during their time in the estuary (May – October). Age-0 weakfish grow exponentially, while age-1 fish increase in size by about 6-fold while in the Chesapeake Bay, averaging 42g in spring and 250g in fall (Hartman and Brandt, 1995).

Table . Shifts in Diet Composition of Dominant Piscivores in Chesapeake Bay (Hartman and Brandt, 1995)

Species	Age-0	Age-1	Age-2+
Striped Bass	polychaete worms, gammarids, grass shrimp, and mysids July-August, Nov-Dec: Above food items plus juvenile naked gobies	invertebrates for first half of year, with increasing contribution of fish in the second half of the year: Jan/Feb: gammarids, siphons from softshell clams; Mar-April: gammarids and mysids; May-Dec: bay anchovies and Atlantic menhaden	fall/winter: predominantly Atlantic menhaden; spring/summer: predominantly age-0 spot, age-1 and older white perch, and polychaetes
Weakfish	predominantly bay anchovies, with some mysids in July/August	predominantly Atlantic menhaden and spot, with some mysids in May-August	predominantly Atlantic menhaden and spot, with some mysids in May-August
Bluefish	predominantly bay anchovies, but by September/October Atlantic menhaden contributed approximately 1/3 of the diet by weight	predominantly Atlantic menhaden, but in July-August spot and croaker compose the majority of the diet	predominantly Atlantic menhaden, but in July-August spot and croaker compose the majority of the diet

Management Discussion Point:
Manage top predator (striped bass, bluefish, weakfish) population levels for XX ratio.

Fishery Statistics

<u>Overall</u>

The total Atlantic coast harvest of striped bass in 2004 was approximately 5.2 million fish and above the average (1997-2003) of 4.36 million fish (Figure x). The 2004 harvest was about 33.3% larger than the harvest in 2003. The recreational fishery accounted for 72.5% of the total 2004 catch (landings + discards). The Virginia recreational fishery harvested the largest proportion (19.6%) of the catch compared to the other Atlantic coastal states. Maryland landed 13.2% of the total. The commercial harvest and discards accounted for the remaining 27.5% of the total coastal harvest.

Maryland commercial watermen harvested 50.8% of the total followed by Virginia (16.3%) and the Potomac River Fisheries Commission (10.1%) (Munger et al. 2005). For the commercial fishery, most of the harvest in the Chesapeake region was on fish between the ages of 3 and 7. For the recreational fishery, the greatest mortality was on ages 3, 4, and 8 (41.8%)

Striped bass commercial and recreational harvests from the Chesapeake Bay have been increasing since the removal of the moratorium in 1990. Maryland's commercial striped bass harvest is managed under a quota system with a separate allocation each for the Chesapeake Bay and the Atlantic coast. As the striped bass stock has increased over the years, the annual quota has increased. The Maryland commercial striped bass fishery is currently capped at 1231 participants. Each licensee is required to annually declare his/her intent to harvest striped bass to remain on the list of eligible fishermen. A special striped bass commercial fishing permit is required to land fish. Allowable gear types in Maryland are gill net, hook and line, pound net, or haul seine. Each gear type has an allowable quota and season. Attrition occurs through failure to declare intent for two consecutive years or failure to renew the commercial fishing license. The number of fishermen declaring intent has varied slightly from year to year. During 2004, the Maryland commercial fishery harvested 446,980 striped bass weighing 1.78 million pounds. Total commercial effort was estimated at 7,192 days. The Maryland recreational quota was 2.5 million pounds.

Since 1990, the striped bass fishery in Virginia has been managed under a two-quota system, one for the Chesapeake Area and another for the Coastal area. In 2004, the commercial quota for the coastal area was 184, 853 pounds and the Chesapeake area quota was 1.36 million pounds. The quotas are managed by an individual transferable quota system (ITQ) that allows for intra-annual transfers of allotments (VMRC 2005). A total of 474 commercial harvesters from the Chesapeake area and 36 harvesters from the coastal area participated in the 2004 fishing season. The Virginia recreational quota was 1.5 million pounds.

The Chesapeake Bay is allowed a spring trophy quota for the recreational fishery. Each year the Bay jurisdictions propose a new quota that must be approved by ASMFC. The cap on the trophy fishery is based on the number of age 8+ fish. The quota for 2005 was 40,624 fish. If the spring fishery goes over the allotted quota, the overage is subtracted from the following year's quota.

Ecological Effects of Fishing

From an ecosystem perspective, fishing removes biomass and can affect the structure and function of the Chesapeake Bay ecosystem. Fishing is size selective and has the potential to select for smaller, slower-growing individuals. Striped bass management is focused on maintaining a target spawning stock biomass and not exceeding a biomass threshold. These biological reference points have been determined to provide adequate recruitment, i.e., keep the population at a level that is not limited by insufficient egg or larval production. Research suggests that age structure combined with spatial distribution of spawning and recruitment, is as important as spawning biomass in supporting sustainable population levels (Berkeley et al. 2004).

Disease (section under development)
STRIPED BASS HEALTH & DISEASE (M.M.McBride 02/10/06)

I. NUTRITIONAL STATUS
   a. Increased Striped Bass Population
   b. Observations/Indications
      i. Skinny (menhaden rich in oils)
      ii. Today 3-6 year old resident striped bass weigh 10-15% less than they did in the 80s
   c. Forage Fish
      i.
   d. Competition for Forage/Shifts in Diet
   e. Outlook
   f. Management Options

II. MYCOBACTERIOSIS
   a. What is Mycobacteriosis
   b. Origin/Source
   c. Prevalence
      i. Inside Chesapeake Bay
      ii. Outside Chesapeake Bay
   d. Effect on Striped Bass Health
   e. Effect on Human Health
   f. Effect on Fishing Industry
   g. Monitoring Efforts
   h. Management Outlook
   i. Management Options

III. TOXIC CONTAMINANTS (TOXICANTS)
   a. Toxicants Found in Striped Bass
   b. Sources
      i. Point Sources
      ii. Non-point Sources
   c. Concentrations/Trends
      i. Inside Chesapeake Bay
      ii. Outside Chesapeake Bay
   d. Effect on Striped Bass Health
   e. Effect on Human Health
      i. Fish Consumption Advisories
   f. Effect on Fishing Industry
   g. Monitoring Efforts
   h. Management Outlook
   i. Management Options

IV. ULCERATIVE DERMATITIS

V. HARMFUL ALGAL BLOOMS
   a. What are HABs?
   b. Origin/Source
   c. Prevalence/ Occurrence
      i. Inside Chesapeake Bay
      ii. Outside Chesapeake Bay
   d. Effect on Striped Bass Health
   e. Effect on Human Health
   f. Effect on Fishing Industry
   g. Monitoring Efforts
   h. Management Outlook
   i. Management Options

VI. RESPONSE TO HYPOXIC CONDITIONS
   a. Endocrine Disruptors
   b. Reproduction

VII. OTHER HEALTH & DISEASE ISSUES
   a. Harmful Algal Blooms

VIII. RECOMMENDATIONS

Mycobacterium

Synopsis of Atlantic Coast Management
Summary of Amendment 6
The Atlantic States Marine Fisheries Commission (ASMFC) and the Interstate Fisheries Management Program (ISFMP) are responsible for the oversight and management of coastal fishery resources, including the striped bass fishery, conducted by the fifteen Atlantic coast states (Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida). As part of the responsibilities charged to the ASMFC under the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA), the ASMFC produced the Interstate Fishery Management Plan for Atlantic Striped Bass (October 1981) under their Interstate Fishery Management Program (ISFMP). The plan is periodically amended to incorporate new technologies, research, and methods. Amendment 6 to the Fishery Management Plan was adopted by the ASMFC in February 2003.

General requirements of Amendment 6 to the Interstate Fishery Management Plan for Striped Bass include setting a fishing mortality target level, introducing a threshold and target female Spawning Stock Biomass, requiring a female Spawning Stock Biomass survey, requiring a Juvenile Abundance Index survey, and requiring the compilation of non-fisheries derived information to be used for conservation efforts. Amendment 6 also requires the collection of additional fisheries-dependent and fisheries-independent data and addresses the potential for bycatch of protected species. The management measures adopted by the Management Board under Amendment 6 shall be maintained by the states for three-year periods unless a target or threshold is violated.

The fishing mortality (F) rate is calculated from the VPA and tagging data and will be compared to the fishing mortality target and the fishing mortality threshold in order to determine if the stock is overfished or if steps need to be taken in order to reduce the fishing mortality. The current fishing mortality threshold is set at 0.41 and the fishing mortality target is set at 0.27 for the Chesapeake Bay and 0.30 for the coastal waters of Maryland and Virginia. Overfishing occurs when the fishing mortality threshold is exceeded and would result in the Management Board taking action to reduce the fishing mortality. If the fishing mortality exceeds the fishing mortality target, the Management Board will consider steps to take to reduce the fishing mortality. Additionally, the commercial striped bass fishery will have a maximum coastal allocation of 131,560 pounds that can be landed from Maryland coastal waters and a maximum coastal allocation of 184,853 pounds that can be landed from Virginia coastal waters.

The female spawning stock biomass (SSB) is designed to ensure a minimum amount of sexually mature females in the population that is based on the estimated biomass of sexually mature females of 1995 when the striped bass stocks were declared restored. The female SSB threshold is 30.9 million pounds or greater and a female SSB target of at least 38.6 million pounds is adopted by Amendment 6. Should the female SSB fall below the female SSB threshold, the Management Board would take actions to increase the female SSB. The female SSB will assessed via an annual female spawning stock survey that will consist of the current gill net survey of the Upper Chesapeake Bay and Potomac River in Maryland and the spring pound net survey of the Rappahannock and James Rivers in Virginia.

An annual juvenile abundance survey from striped bass nursery areas in the Chesapeake Bay and its tributaries will be required from both Maryland and Virginia. The survey protocol must remain consistent throughout the period that a particular index is to be used and the index must be validated.

Conservation efforts should be designed to preserve existing striped bass spawning and nursery areas within state waters, improve the quality and extent of those areas, and avoid activities that may negatively impact striped bass success. Efforts should also consist of identifying historical and current spawning and nursery, identifying those areas that may be reclaimed, establish striped bass essential habitats that restrict human activities that negatively impact striped bass success. State natural resources departments should coordinate with state and federal agencies that determine water quality standards in order to incorporate striped bass water quality needs, and coordinate with those state and federal agencies that are responsible for reviewing impact statements and permit applications for activities that may negatively impact striped bass success.

The Maryland and Virginia fisheries dependent data that is required under Amendment 6 pertains to the Commercial, Recreational, and For-Hire striped bass fisheries. Data will be collected on: catch and effort, permit and vessel registration, biological , bycatch/release and protected species, strandings and entanglements, and social and ecological data. These data will be collected through add-ons of surveys and mandatory

forms already in place. Specific details of the ACCSP data collection program may be found in: The Program Design of the Atlantic Coastal Cooperative Statistics Program, second edition, November 2004.
Survey components of the ACCSP data program that are specific to the commercial fisheries may be found in Sections 3.A, 3.D, 4.D, 5.C.1, and 6.A. Specific data elements required of the commercial fisheries surveys may be found in the following tables of the ACCSP report:

The management tools provided for by Amendment 6 should assist fisheries managers in obtaining a minimum level of sexually mature striped bass at or below a target fishing mortality rate which will provide the potential for a quality and economically viable recreational, for-hire, and commercial striped bass fishery program.

Table #. Estimates of Atlantic coastal striped bass commercial landings[1] (1950-2004), recreational catch[2] (1981-2004), and combined commercial and recreational removals (1950-2004) for each ASMFC member-State (including State, Coastal and Federal waters). Plus, percent taken by each ASMFC state of total striped bass commercial landings, recreational catch, and combined commercial and recreational. Data: Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD

Atlantic Coastal States Managed by ASMFC	Total Commercial Landings (MT) 1950-2004	% Total Coastal Commercial Landings 1950-2004	Total Recreational Catch (MT) 1981-2004	% Total Coastal Recreational Catch 1981-2004	Total Commercial Landings & Recreational Catch Combined 1950-2004	% Combined Total Commercial Landings & Recreational Catch 1950-2004
Maine	5.3	< 0.01	1,103.3	1.16	1,108.6	0.46
New Hampshire	54.5	0.04	731.7	0.77	786.2	0.33
Massachusetts	13,839.2	9.45	18,095.4	18.98	31,934.6	13.22
Rhode Island	2,849.1	1.95	5,209.8	5.47	8,058.9	3.34
Connecticut	188.6	0.13	4,666.4	4.90	4,855.0	2.01
New York	16,344.4	11.17	19,133.2	20.07	35,477.6	14.69
New Jersey	4,415.4	3.02	18,003.7	18.89	22,419.1	9.28
Pennsylvania	0.0	0.00	0.0	0.00	0.0	0.00
Delaware	2,087.8	1.43	1,341.2	1.41	3,429.0	1.42
Maryland	55,949.6	38.22	10,280.8	10.78	66,230.4	27.41
Virginia	32,739.1	22.37	10,706.0	11.23	43,445.1	17.98
North Carolina	17,887.2	12.22	5,985.1	6.28	23,872.3	9.88
South Carolina		0.00	46.7	0.05	46.7	0.02

Georgia	12.8	0.01	11.0	0.01	23.8	0.01
Florida		0.00	11.7	0.01	11.7	< 0.01
Total	146,373.0	100.00	95,326.0	100.00	241,699.0	100.1

1-Landings = Fish that are landed and sold domestically by U.S. fishermen.
2-Catch = Fish caught but not necessarily brought ashore.
Total landings by state include confidential data and will be accurate, but landings reported by individual species may, in some instances, be misleading due to data confidentiality. Landings are reported in pounds of round (live) weight.
Estimates of recreational catch not available before 1981.

Research recommendations

(To be determined by Plan Review Team)

Relevant Jurisdictions and User Groups

Chesapeake Bay Program
The Chesapeake Bay Program (CBP) began to develop FMPs for selected finfish and shellfish within the framework of the 1987 Chesapeake Bay Agreement, setting a schedule for adoption of FMPs for individual species. Presently, the Fisheries Management Planning and Coordination (FMPC) Workgroup of the Living Resources Subcommittee has completed 15 plans that encompass 21 species; the Chesapeake Executive Council has approved these plans. Chesapeake Bay FMPs provide compatible, coordinated management for the conservation and wise use of the Bay's fishery resources. The CBP does not hold regulatory authority, however, and compliance by Bay states remains voluntary.

Nine of the 14 most valuable species fished in the Bay are not year-round residents. These species are managed under ASMFC, or joint ASMFC/MAFMC, SAFMC, regulatory authority (Table 1). Although CBP has no management authority over seasonal Bay residents that range along the coast, the states do have jurisdiction when these migrants move within their boundaries. Management of migratory species by the hierarchy of responsible agencies is critical since these species represent a vital component of the Bay's culture and economy.

Atlantic States Marine Fisheries Commission
The focus of ASMFC activities centers on management of coastal migratory species. The commission emerged from an agreement in 1942 by 15 Atlantic coastal states (Maine through Florida, including Pennsylvania) to participate in cooperative management and conservation of shared coastal fishery resources within state waters (inland waters and state territorial seas) (Figure 2). Each state has three representatives on the commission: the director for the state's marine fishery management agency; a state legislator or

designee; and an individual appointed by the state governor who represents fishery interests. The commission's main policy arenas include: interstate fisheries management; research and statistics; habitat conservation; sport fish restoration; and law enforcement. The ASMFC operates under authority of the Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Fisheries Act), which became law in 1993. The act brings together the ASMFC and its member states, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service in a cooperative management process, and provides a mechanism to ensure Atlantic coastal state compliance with conservation measures included in ASMFC-approved FMPs. Prior to the passage of this act, state implementation of ASMFC FMPs was voluntary, except for striped bass. Today, all ASMFC states must comply with conservation provisions of an FMP, or face a moratorium imposed by the Secretary of Commerce on fishing for, or landing, the managed species within waters of that state.

<u>Regional Management Councils Established Under the Magnuson Act</u>
The Magnuson Fishery Conservation and Management Act (MFCMA) of 1976 established authority to manage U.S. fisheries within the U.S. EEZ (extending from three nautical miles offshore to 200 nautical miles) and created eight regional councils to manage the living marine resources within this zone (Figure 2). The MFCMA was enacted principally to control and reduce heavy foreign fishing, promote the development of a domestic fishing fleet, and link fishing communities more directly to the management process. The geographical range for several Chesapeake Bay fished species extends into management regions of the Mid-Atlantic and South-Atlantic Fisheries Management Council jurisdictions:

<u>Mid-Atlantic Fisheries Management Council (MAFMC)</u>
The MAFMC is responsible for conservation-based management of fisheries in federal waters (the EEZ), which occur primarily off the mid-Atlantic coast (Figures 2 & 2b). States with voting representation on the mid-Atlantic council include New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and North Carolina (North Carolina is represented on both the mid-Atlantic and south-Atlantic councils). Black sea bass, bluefish, and summer flounder are Chesapeake Bay species under joint MAFMC and ASMFC management authority.

<u>South-Atlantic States Fisheries Management Council (SAFMC)</u>
The SAFMC establishes conservation measures to ensure the viability of marine resources in federal waters off the coasts of North Carolina, South Carolina, Georgia, and East Florida to Key West (Figures 2 & 2c). Its FMPs are designed to produce optimum yield while preventing overfishing. Red drum and Spanish and king mackerels are Chesapeake Bay species under joint SAFMC and ASMFC management authority.

<u>New England Fisheries Management Council (NEFMC)</u>
The NEFMC jurisdiction extends from Maine to southern New England. Some NEFMC-managed species range to the mid-Atlantic, while striped bass (managed by ASMFC) ranges as far north as Canada (Figures 2 & 2a). Notably, the council has developed and implemented the Northeast Multispecies (Groundfish) FMP that covers a complex of thirteen species. None of NEFMC's managed fisheries, however, has relevance to Chesapeake Bay.

<u>Commercial Fishermen</u>
Commercial fisheries for striped bass operate in 8 of the 14 jurisdictions regulated by the Commission's FMP. The largest commercial landings are from Maryland, Virginia, Massachusetts, Potomac River Fisheries Commission, and New York. Predominant gear types in the commercial fisheries are gillnets (anchored, drift, or stake), pound nets, and hook and line.

<u>Recreational Fishermen</u>
Since 1979, the first year of the Marine Recreational Fisheries Statistics Surveys (MRFSS), the recreational harvest of striped bass has ranged from 28-73 percent of the total harvest. However, the MRFSS estimates of harvest are not considered reliable until 1981. Following the re-opening of the fishery in 1990, the recreational harvest has grown from a low of 2.2 million fish in 1990 to a high of 17.1 million fish in 2000 (a greater than 677% increase). In 2000, states with the largest proportion of recreational harvest were Maryland, New Jersey, Virginia, New York, and Massachusetts. Predominant gear types in the recreational fisheries are hook and line (anglers) and charter boats. catch and release

<u>Other Stakeholders</u>
Major stakeholders in the striped bass fishing industry, other than participants in commercial and recreational fisheries (including charter boats), primarily fall into the economic dimension, meaning sales and salaries associated with:

- Seafood distributors
- Restaurants
- Grocery stores
- Seafood markets.

To consider major stakeholders from an ecosystem-based perspective expands this list to include:

- Fishery managers (ASMFC, CBP, MD DNR, VMRC, PRFC, DC F&W)
- Bay State departments of environmental management (VA DEQ, MDE, etc.)
- State departments of conservation and recreation
- Environmental advocacy groups
- Scientific researchers
- Bay residents (General Public with a vested interest in the well being of Bay and its fisheries, i.e., water quality and ecosystem health).

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Figure x. Mean length (mm TL) by year for male striped bass sampled from spawning areas of the Upper Chesapeake Bay, April/May, 1985-2005. Error bars are 95% confidence intervals. (MDNR Striped Bass Project)

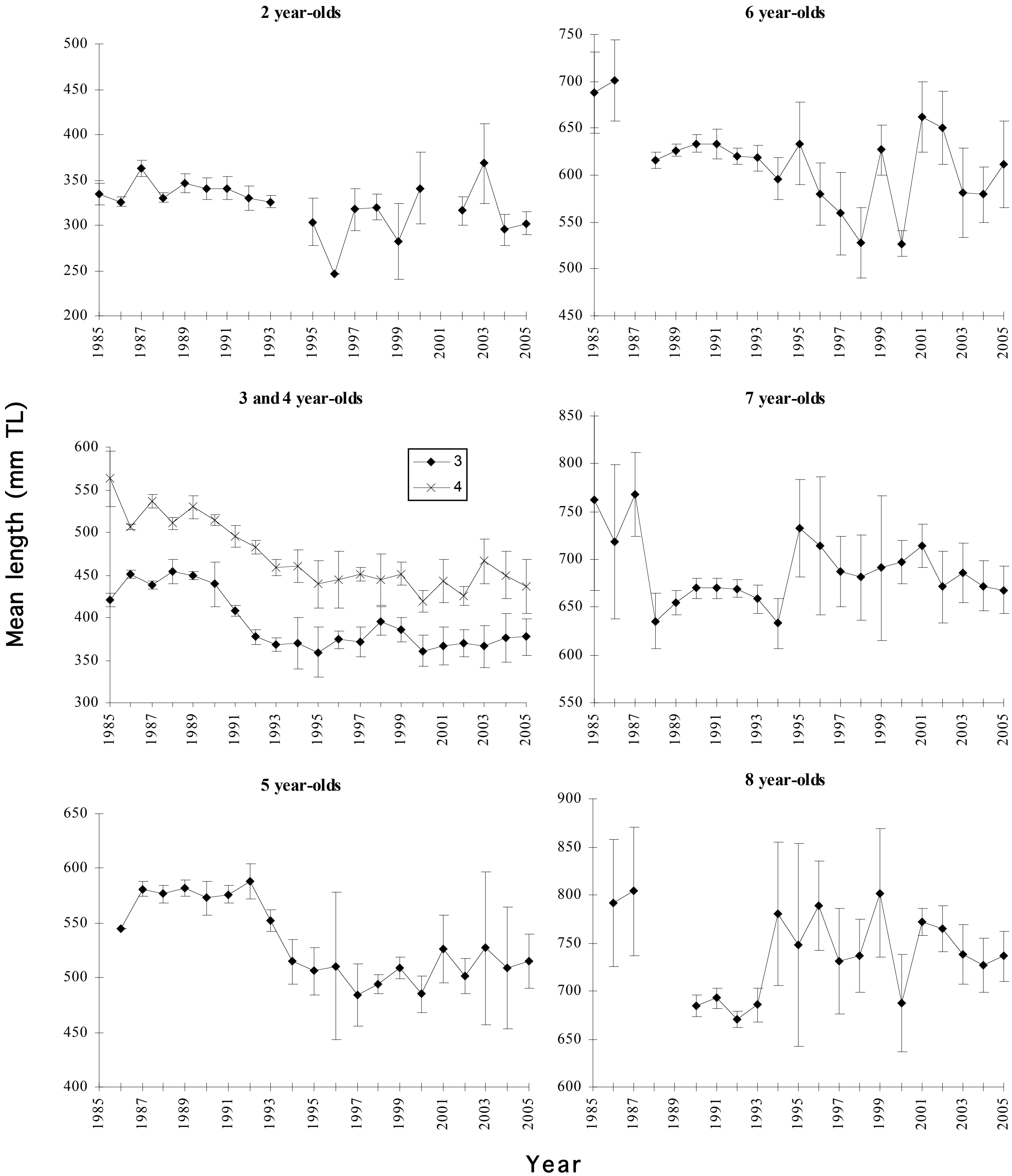
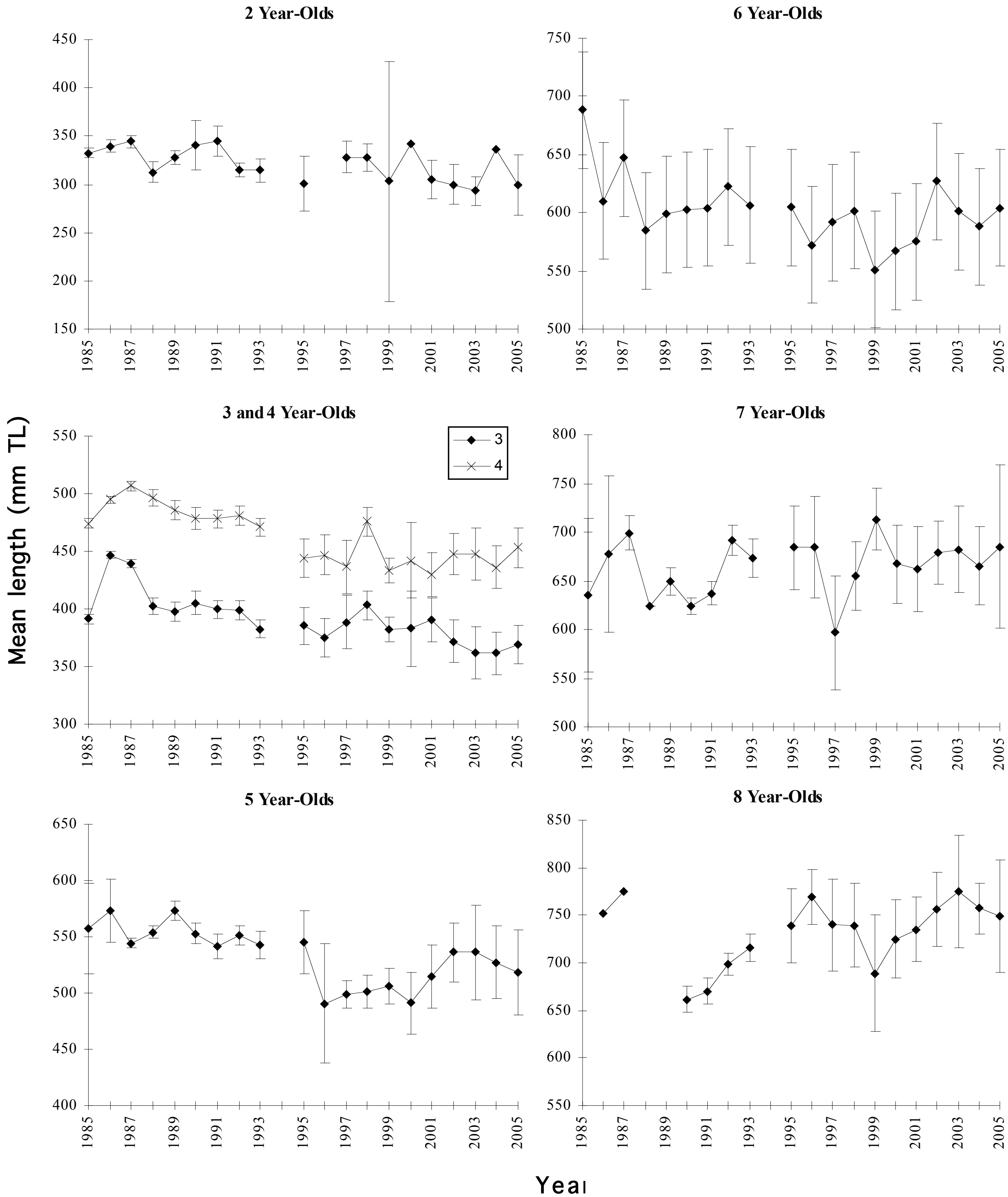


Figure x. Mean length (mm TL) by year for male striped bass sampled from spawning areas of the Potomac River, March/May, 1985- 2005. Error bars are 95% confidence intervals. (MDNR Striped Bass Project)



Note: The Potomac River was not sampled in 1994.

Table. Index of spawning biomass by year, for female striped bass ≥500 mm TL sampled from spawning areas of the Chesapeake Bay during March, April and May, 1985-2005. The index is selectivity-corrected CPUE converted to biomass using parameters from a length-weight regression (MDNR Striped Bass Project).

Year	Upper Bay	Choptank River	Potomac River
1985	64.93	290.97	25.9
1986	151.95	129.67	45.7
1987	400.49	195.89	88.84
1988	250.32	309.27	63.60
1989	120.29	597.86	80.54
1990	98.42	899.29	62.52
1991	109.38	1010.60	138.65
1992	274.95	689.89	379.35
1993	278.52	1014.32	420.88
1994	87.26	449.78	Not Sampled
1995	547.66	Not Sampled	293.77
1996	347.87	1225.66	391.57
1997	256.89	Not Sampled	369.58
1998	157.41	Not Sampled	216.98
1999	161.44	Not Sampled	275.19
2000	169.91	Not Sampled	301.76
2001	490.21	Not Sampled	273.23
2002	266.39	Not Sampled	380.74
2003	566.24	Not Sampled	118.46
2004	389.76	Not Sampled	578.78
2005	469.74	Not Sampled	196.11