ATLANTIC COASTAL *Striped Bass* ROAD TO RECOVERY

1989

Publication Preparation

This publication was prepared by
fishery biologists Dave Deuel, Dave McDaniel, and Steve Taub.
Numerous other individuals
from a wide variety of organizations
contributed to this document.

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U. S. Department of the Interior
Fish and Wildlife Service

U. S. Department of Commerce
National Oceanic and Atmospheric Administration

Note: Part of the Striped Bass Study responsibility is an annual report to Congress summarizing activities undertaken since the study began in 1980. A limited number of these reports are available from either the National Marine Fisheries Service or the U.S. Fish and Wildlife Service.

1 INTRODUCTION

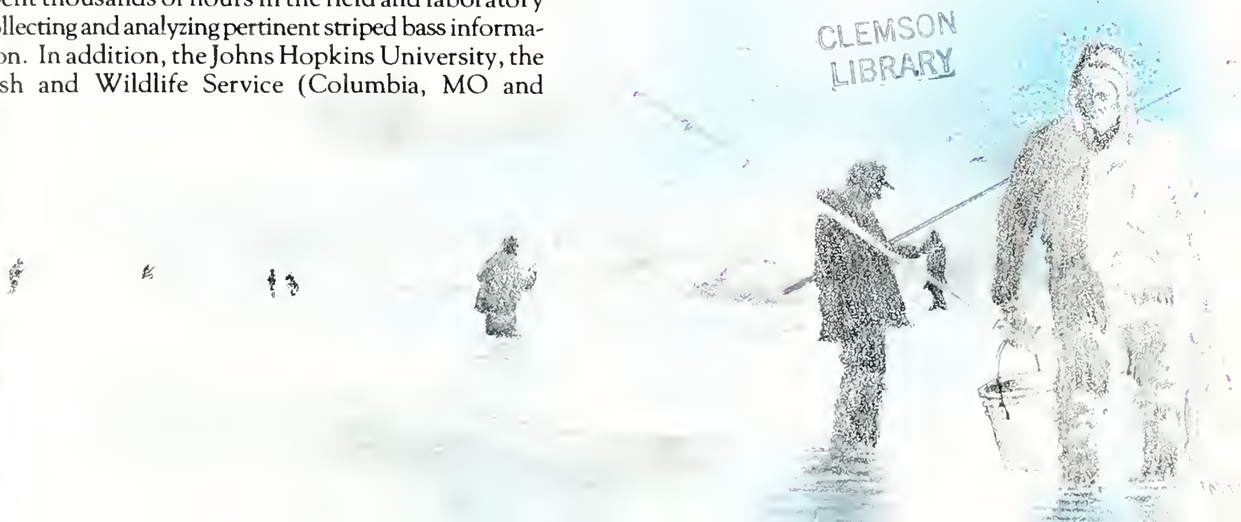
The striped bass, *Morone saxatilis*, historically has been one of America's most important recreational and commercial fishes. Commercial landings on the Atlantic coast from Maine to North Carolina in the 1960's through the mid-1970's ranged from 8 to 14 million pounds per year. Recreational harvests likely exceeded these commercial landings. A significant decline in striped bass landings began in the mid to late 1970's. Coincident with this decline, the production of young striped bass in Chesapeake Bay appeared to be decreasing. By the late 1970's, it was recognized that the species could not be managed properly without a better understanding of the factors controlling stock sizes. In response to this situation, the United States Congress amended the Anadromous Fish Conservation Act in 1979 to provide for an Emergency Striped Bass Study (Striped Bass Study) to explore the reasons for the decline, monitor the status of stocks, and evaluate the economic consequences.

Under the Striped Bass Study, the National Marine Fisheries Service was given primary responsibility to monitor the status of striped bass populations, while the U.S. Fish and Wildlife Service was to determine the factors responsible for the decline. Both agencies shared responsibility for a survey of the economic importance of recreational and commercial striped bass fisheries. These studies were to be carried out by the state and federal fisheries agencies and other institutions.

Atlantic coastal state natural resource agencies performed a significant amount of the work upon which this publication is based. These agencies spent thousands of hours in the field and laboratory collecting and analyzing pertinent striped bass information. In addition, the Johns Hopkins University, the Fish and Wildlife Service (Columbia, MO and Leetown, WV), and the National Marine Fisheries Service (Woods Hole, MA) provided much expertise.

The federal agencies responsible for the Striped Bass Study receive guidance from individuals with a wide variety of interests and expertise through an Emergency Striped Bass Study Planning and Coordination Group (Group). This Group meets semiannually to review the accomplishments and proposed future projects under the Striped Bass Study.

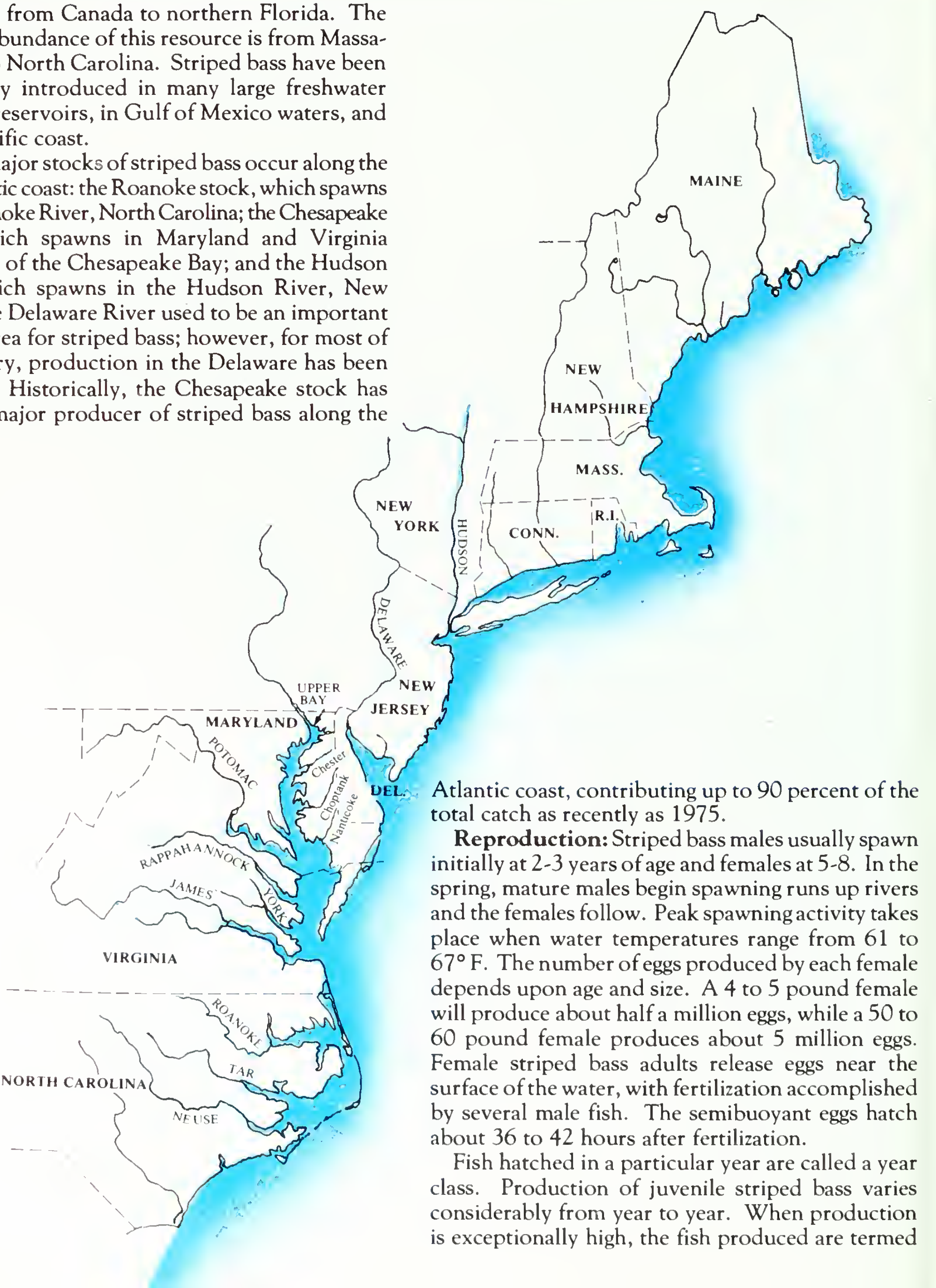
In 1987, the Group, recognizing that there was an abundance of recent research information about striped bass, requested that the information be summarized in a nontechnical publication for a general readership. This publication is a result of that request. It includes a summary of life history and fisheries management information on striped bass, and highlights major research studies on the Atlantic coast from 1980 to the present, with some earlier pertinent information also included. Although, some information in this report may be applicable to striped bass in other parts of its range such as the Gulf of Mexico, this report addresses Atlantic coastal stocks of striped bass. While focusing on research under the Striped Bass Study, this publication also provides information from additional studies by agencies and universities. Some pertinent articles are listed for further reference at the end of this report.



2 LIFE HISTORY

Distribution: Native stocks of Atlantic striped bass occur from Canada to northern Florida. The center of abundance of this resource is from Massachusetts to North Carolina. Striped bass have been successfully introduced in many large freshwater lakes and reservoirs, in Gulf of Mexico waters, and on the Pacific coast.

Three major stocks of striped bass occur along the mid-Atlantic coast: the Roanoke stock, which spawns in the Roanoke River, North Carolina; the Chesapeake stock, which spawns in Maryland and Virginia tributaries of the Chesapeake Bay; and the Hudson stock, which spawns in the Hudson River, New York. The Delaware River used to be an important spawing area for striped bass; however, for most of this century, production in the Delaware has been very low. Historically, the Chesapeake stock has been the major producer of striped bass along the Atlantic coast, contributing up to 90 percent of the total catch as recently as 1975.



Reproduction: Striped bass males usually spawn initially at 2-3 years of age and females at 5-8. In the spring, mature males begin spawning runs up rivers and the females follow. Peak spawning activity takes place when water temperatures range from 61 to 67° F. The number of eggs produced by each female depends upon age and size. A 4 to 5 pound female will produce about half a million eggs, while a 50 to 60 pound female produces about 5 million eggs. Female striped bass adults release eggs near the surface of the water, with fertilization accomplished by several male fish. The semibuoyant eggs hatch about 36 to 42 hours after fertilization.

Fish hatched in a particular year are called a year class. Production of juvenile striped bass varies considerably from year to year. When production is exceptionally high, the fish produced are termed a dominant year class. For striped bass, the occurrence of dominant year classes has resulted in record harvests in subsequent years. This factor is thought to have sustained the fisheries during the years of poor production throughout this century. While there appears to be both a 6 to 8 year and a 20 year periodicity of dominant year classes in striped bass, they are not always strongly pronounced. As striped bass are long-lived fish, females from a dominant year class can contribute as spawners for many years.

Growth and Development: Age and growth of fishes are of considerable interest to both scientists and anglers. Many factors, such as available food supply and environmental conditions, influence a fish's length and weight at a given age. There are some differences in the weight of male and female striped bass of the same age. Males are usually smaller than females at a given age. Fish weighing more than 30 pounds are usually females.

The striped bass is one of the largest members of the true bass family, and may live up to 30 years. In the marine environment, stripers weighing up to 30 pounds are common and some individuals are likely to achieve a length of more than four feet. The maximum known weight is a 125 pound commercially caught female taken from North Carolina waters in 1891. The all-tackle world sport record for striped bass is 78.5 pounds caught off Atlantic City, New Jersey, on September 21, 1982.

Striped bass at 2 years old, weigh about 3/4 of a pound and are 12 inches long; 4 years old, about 3 pounds and 20 inches long; 6 years old, about 10 pounds and 27 inches long; and 8 years old, about 18 pounds and 33 inches long. These data are general--there is significant geographic variation.

Although adult striped bass are hardy and adaptable fish, young stripers are vulnerable to natural predation and a host of environmental threats. Larval striped bass feed on small free-swimming plant and animal food items called plankton. Sufficient concentrations of acceptable food items must be available during the critical first several days of feeding. After a few weeks of growth, the diet shifts to small invertebrates, such as crabs and insects, and then eventually to small fish. Adult stripers tend to be

almost exclusively fish eaters and are voracious, opportunistic feeders. Striped bass generally feed at intervals rather than continuously, with peak feeding occurring at dusk and before dawn. Stripers also feed actively at night, as evidenced by recreational catches.

Migration: Striped bass are anadromous, the mature adults migrate from the ocean to spawn in brackish estuaries and freshwater rivers in early spring, and afterward return to the ocean and migrate along the coast. It is generally believed that most mature fish return to the river where they were hatched to spawn. Eggs hatch in fresh or slightly brackish water and the juvenile fish remain in estuaries near spawning areas. Some immature fish of both sexes migrate out of the estuary to join the coastal migratory population of mature fish.

Coastal striped bass generally have a northerly distribution in late spring and summer, occurring from the mid-Atlantic area to New England. There is a general southerly movement in the fall, with fish overwintering in deeper coastal waters or deep portions of the mouths of estuaries from New England to North Carolina. Striped bass from the Chesapeake Bay are the widest ranging stock while they are in coastal waters, occurring from North Carolina to eastern Canada. Fish from the Hudson River occur in coastal waters from Massachusetts to southern New Jersey. Tagging studies have shown that some Roanoke River fish may occur along the coast as far north as New York. In recent years, striped bass from the Roanoke River have been relatively restricted to Albemarle Sound and adjacent coastal waters, with only limited contributions to the coastal migratory stock. Little is known of the migratory patterns or distribution of the Delaware River stock.

3 MANAGEMENT PROGRAM

The Atlantic coastal striped bass fishery has a long history of management. Regulations were first implemented in New York in 1892 and most states had imposed some regulations by the late 1930's. In 1942, the Atlantic States Marine Fisheries Commission (ASMFC) was chartered by the United States Congress as a coastal interstate (Maine to Florida) compact. The ASMFC coordinates the development of fishery management plans through its member states, which are then responsible for implementing regulations. In 1942, the ASMFC recommended a coastwide 16-inch minimum size limit, based on a decline in commercial landings during the mid-1930's. While some states enacted regulations based on this recommendation, there were few additional regulations from the mid-1940's through the 1970's.

In 1981, the ASMFC published the Interstate Fisheries Management Plan for the Striped Bass (Plan). This comprehensive Plan was developed in response to the continued decline of striped bass in the 1970's and was adopted by member states of ASMFC to provide for uniform coastwide management regulations. The provisions of the Plan focused on size limits and spawning period closures as the means to reduce the harvest of striped bass. Subsequent amendments to the Plan recommended additional restrictions. The most recent amendment recommended a 33 inch minimum-size limit to further restrict the cath and to allow females of the Chesapeake Bay stock to spawn at least once before being caught.

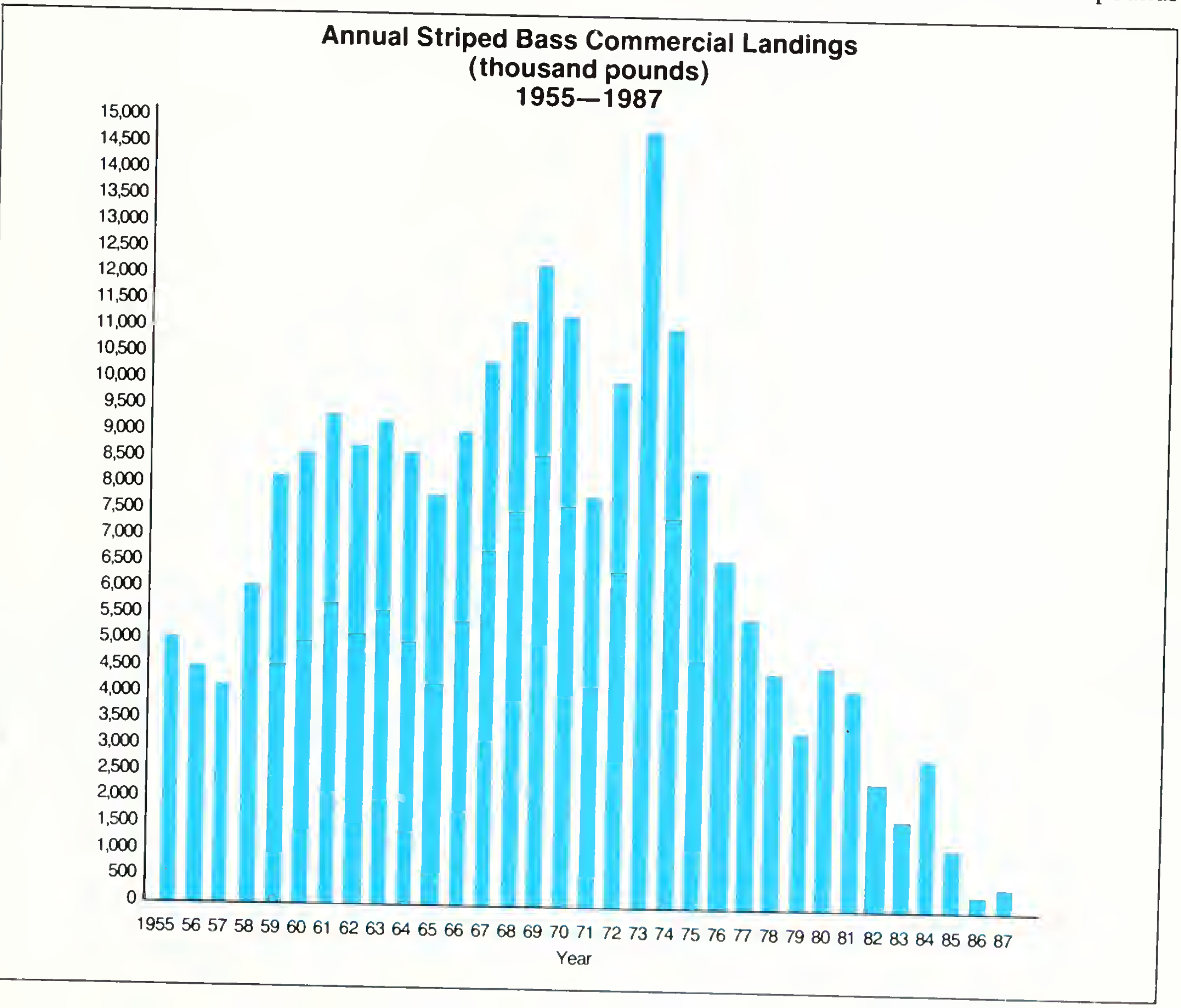
In 1984, the United States Congress passed the Atlantic Striped Bass Conservation Act (Act) to mandate coordinated interstate actions regarding the conservation of striped bass. This Act requires a federal moratorium on striped bass fishing in those states which have not adopted the recommended management measures of the ASMFC Plan, or that are not satisfactorily enforcing these measures. These sanctions have been effective in encouraging the states to implement the measures of the Plan and are resulting in protecting striped bass resources.

The ASMFC Plan is being revised to incorporate new striped bass information and to develop management strategies to be used when stocks recover. Decisions on specific management actions will rely in part on results of the Striped Bass Study. In recent years, management decisions have been guided by research conducted under the Striped Bass Study and management needs have provided direction for certain research activities. However, future management actions will continue, among other things, to restrict the commercial and recreational catch to prevent overfishing.

4 RESEARCH PROGRAM

In 1980, the Striped Bass Study began by identifying possible causes of the decline, and outlining an action plan and a research program to address these causes. Possible causes identified were excessive fishing, habitat deterioration, contaminants, effects of industrial development, and an extended sequence of natural events inhibiting production of dominant year classes. In addition to research conducted under the Striped Bass Study, other studies have been carried out by state fisheries agencies and university researchers. Many of the studies are interrelated. For example, in tagging striped bass for migration studies, samples are taken for age and growth determinations, and/or for stock identification. A description of striped bass research by topic, including those studies funded under the Striped Bass Study, as well as other related studies follows.

Harvest: While commercial landings fluctuated widely since the 1930's, landings generally increased through the early 1970's. Since the mid-1970's, commercial landings declined from a record high of 14.7 million pounds in 1973 to 2.4 million pounds in 1982, and further declined to 0.4 million pounds



in 1987. However, a large part of the decline since 1982 resulted from restrictions on the commercial fishery, including moratoria in Maryland and Delaware and coastwide minimum-size limits.

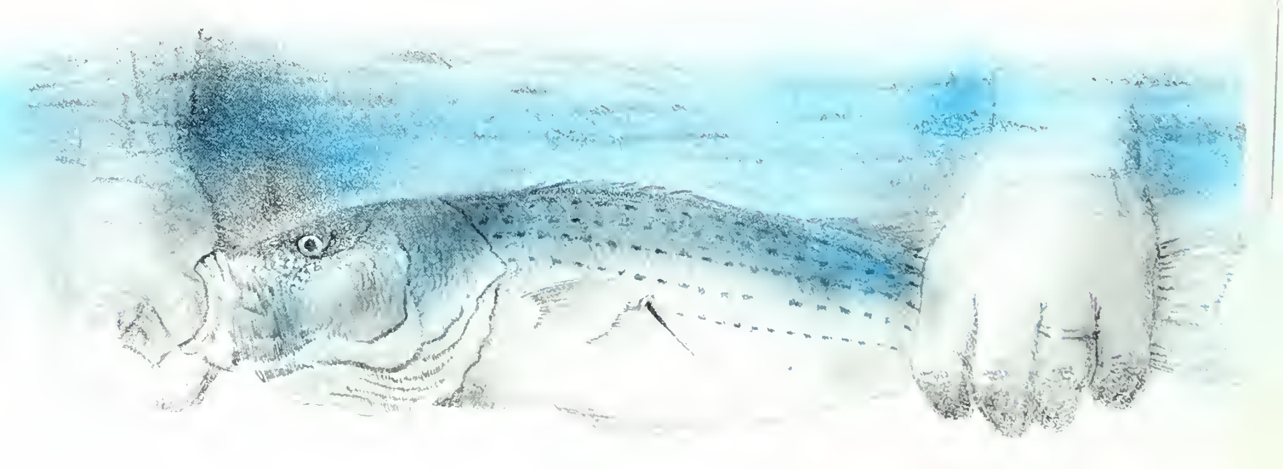
The recreational fishery for striped bass experienced declines similar to the commercial fishery due to reduced numbers and restrictions on harvest. The total catch by recreational fishermen from Maine through North Carolina declined from 2.0 million fish in 1979 to about 0.6 million fish in 1983–1985. The catch increased to 1.4 million fish in 1986 and 0.9 million in 1987, probably reflecting the abundance of the 1982 and subsequent year classes. One consequence of the 33 inch minimum-size limit and creel limits imposed on striped bass has been an increase in the proportion of the total recreational catch that is released alive. In 1986 and 1987, about 90 and 94 percent respectively of the total recreational catch of striped bass was released alive. This likely reflects a high proportion of the catch being under the minimum-size limit or exceeding the allowed creel limit, and demonstrates the effectiveness of existing regulations in conserving striped bass. However, the amount of delayed mortality resulting from fish caught and released is not known.

Fishing Mortality: The harvest of striped bass by the recreational and commercial fisheries increased through the 1960's and early 1970's. Fishing mortality or the percentage of the striper population actually caught, increased during the 1970's. The last known dominant year class in the Maryland portion of the Chesapeake Bay occurred in 1970, making possible the record commercial catch in 1973. In the absence of a subsequent dominant year class and with a continued high fishing mortality, the abundance of Chesapeake Bay stocks declined severely. Sampling programs begun in 1982 have revealed relatively few fish from year classes prior to 1982 in the Chesapeake Bay and very few females on the spawning grounds. These findings suggest that mortality of striped bass spawned in the Chesapeake Bay during the 1970's was high enough to remove most of them from the population by 1982.

Estimates of total mortality rates for the Chesapeake Bay striped bass from the 1970 year class were from 60 to 93 percent per year for males and 45 percent per year for females. As a result, female striped bass in Chesapeake Bay are comprised mainly of year classes that are not yet fully mature.

High catch levels of 12 to 14 inch striped bass in the Chesapeake Bay in the 1960's and the early 1970's severely reduced the number of females reaching sexual maturity. Females from the dominant 1970 year class continued to occur on the spawning grounds in Maryland through the early to mid 1980's (ages to 15 years old). Females from 4 to 10 years of age, however, were virtually absent. The particulary high fishing mortality of young males in the Chesapeake Bay is supported by the sex ratios of striped bass sampled in the coastal fishery. During the late 1970's and early 1980's, the ratios of females to males was about 10 to 1, indicating a very high mortality of males prior to migrating from the Bay. In 1985 and 1986, with the protection afforded by the size limits and the Maryland moratorium, the ratio changed to slightly more than one female per male.

The Hudson River stock has not experienced a decline in recent years. This could have resulted



from the fact that the commercial fishery in the Hudson River has been closed since 1976 due to excessive levels of a contaminant known as PCB. PCB is an abbreviation for a manufactured liquid chemical mainly used in the generation of electricity. Striped bass captured in research surveys of overwintering and spawning stocks have consisted mainly of 4-8 year old fish, with an age range from 2 to 16 years of age. Estimated annual total mortality (fishing and natural mortality) rates were under 42 percent.

For the Roanoke River stock, it appears there was excessive fishing mortality and habitat problems during the 1970's. The commercial catch is now composed primarily of 2 year old fish, with few fish older than 4 years of age. The age composition of the females on the spawning grounds in the Roanoke River reflects heavy fishing pressure, with few females over 4 years old.

Sexual Maturity: Until recently, females were believed to begin spawning at age 3, the majority maturing at age 4, and all spawning by age 6. Important recent studies suggest that very few females mature at age 3 and only a small percentage of age 4 females spawn. At age 6, only about one-half of the females have spawned for the first time. Females may be age 7 or 8 years old before they have all spawned. Some males reach sexual maturity at age 2, most at age 3, and all are mature by age 4.

The age of maturity for female striped bass was a key factor in the recent management efforts to restore the Chesapeake Bay stocks. A 33 inch minimum-size limit was deemed appropriate to protect 95 percent of the females of the 1982 year class and subsequent year classes of the Chesapeake Bay stock until 95 percent of the 1982 females had spawned once. This size limit was based on earlier maturity data and assumed that by age 6 all females were mature. The recent information on maturity of females would result in a lower percentage of females being protected to maturity and probably would result in a slower recovery rate for the Chesapeake Bay stocks. However, as the 1982 year class females become 7 and 8 years old in 1989 and 1990, nearly all should spawn. This increase in the size of the spawning population should result in increased juvenile production.

Stock Composition and Identification: Striped bass from the Hudson River, Delaware River, Chesapeake Bay and the Roanoke River are believed to be of different stocks. While their ranges overlap, they are believed to be reproductively separated, thus having genetic differences. Stocks are identifiable by structural or biochemical differences which may be measured. However, the accuracy of the methodology to detect separate stocks is not absolute.

The harvest of striped bass from coastal waters removes fish from the various stocks. The proportion of fish harvested in a particular area from each stock varies over time and season. This variation results from the relative abundance of the stocks, seasonal migrations, and the age and sex composition of the stocks. Prior to the decline of the Chesapeake Bay stock, about 90 percent of the fish along the coast were of Chesapeake Bay origin, 7 percent from the Hudson River stock, and 3 percent from the Roanoke River stock. However, after the decline, Chesapeake Bay and Hudson River stocks contributed about equally to the coastal fishery, with insignificant contributions from the Roanoke River stock.

Recent efforts to rebuild the Chesapeake Bay stock required a severe reduction in fishing while this stock was in the Chesapeake Bay and along the coast. A knowledge of the geographic and seasonal distribution of Chesapeake Bay fish stocks in coastal areas is necessary to develop an effective management strategy.

Several techniques to separate stocks have been pursued. One technique measures differences in proteins occurring in eye lenses. Results from fish sampled along the northern coast showed substantial variability in stock composition. Because eye lens protein analysis requires killing the fish, careful handling of samples, is slow, and is relatively expensive, three new approaches to stock identification are being developed.

Juvenile Indices: Juvenile production of striped bass is measured annually using beach seine or trawl surveys during the summer and fall in striped bass nursery areas The average number of juvenile striped bass collected per seine haul is used to calculate the relative abundance of young-of-the-year striped bass. This is called the juvenile index. The juvenile indices calculated from surveys in different nursery areas are not directly comparable to each other due to the differences in sampling methods and geographic locations, but these indices are important in identifying trends. This information, combined with adult stock data is used to guide management decisions.

The Maryland juvenile index, begun in 1954, shows several dominant year classes through the

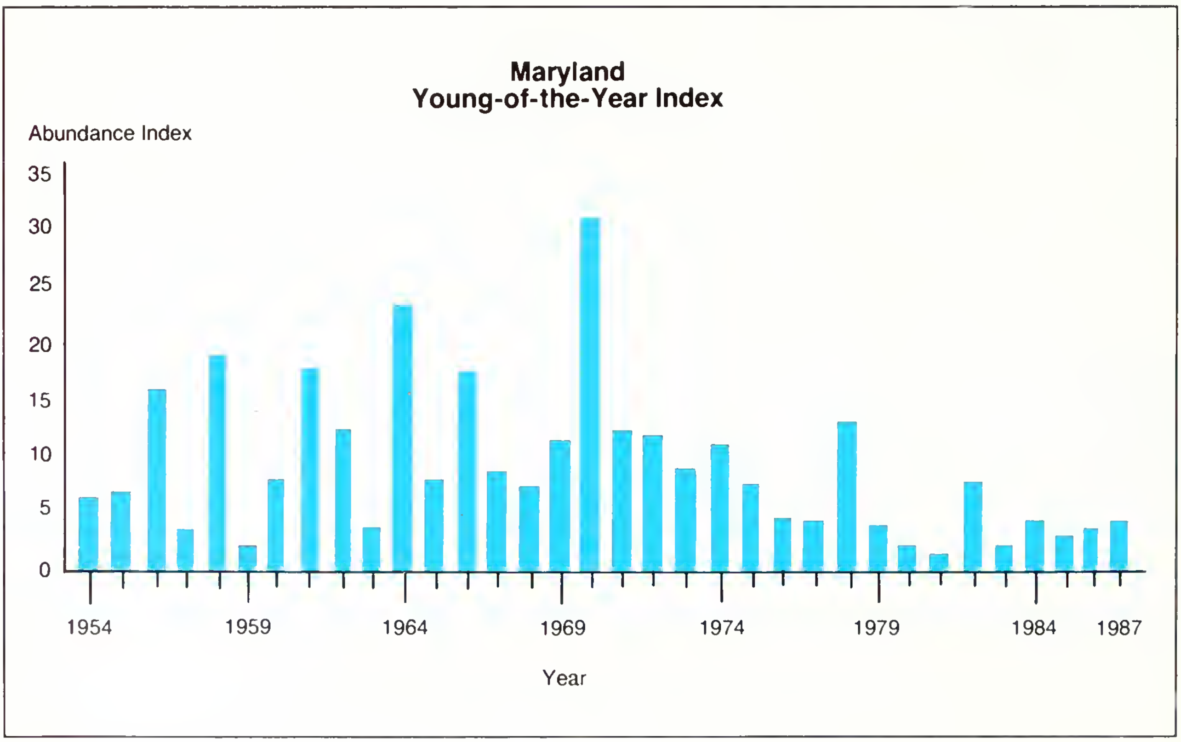
1960's with the last dominant year class in 1970. During this period, total commercial landings were high, as well as sport catches. The decrease in landings since the early 1970's is consistent with low juvenile indices and the absence of dominant year classes since 1970. In 1987, the Maryland striped bass juvenile index was 4.8, a slight improvement over the 1986 index of 4.1. The 1987 index is well below the historic average value of about 8.

Juvenile production by the Roanoke River stock in 1987 was a record low with a juvenile index of 0.06. Nine of the 10 lowest indices for the 30 year series have occurred in the last decade. While a geographic shift in the nursery area in recent years may have resulted in the index being an underestimate of juvenile production, other information on the Roanoke stock indicates that the stock is severely depressed.

The Virginia juvenile index has generally increased since 1980, with the index values for the three major nursey areas (James, York, and Rappahannock Rivers) exceeding their respective long-term averages. Similarly, the 1987 juvenile index of 60.7 for the Hudson River is the highest value for the time series. Production in the Hudson River, although low in 1985 and 1986, has indicated high recruitment since 1980.

Abundance of Year Classes: The reasons for the occurrence of dominant year classes of striped bass are not well understood. The deposition of an exceptionally large number of eggs, resulting from a high number of spawning females, may be a factor. However, there is evidence that suggests that some dominant year classes have been produced when the number of spawning females was low. Most likely, dominant year classes result when survival of eggs and larval fish is highest as a result of favorable environmental conditions. Waterflow, temperature, turbidity, salinity, and other factors impact on survival of eggs and larval striped bass. If one or more of these factors is adverse during the spawning season, survival is limited.

Besides leading to a decline in harvest, the absence of a dominant year class in the Maryland portion of the Chesapeake Bay stock since 1970 has adversely affected the spawning population. The 1970 year class represented 60 percent, 75 percent, and 55 percent of the spawning population in 1974, 1975, and 1976, respectively. By 1982, there were few fish on the spawning grounds and the 1970 and



older year classes were still contributing the majority of spawning females. Since 1984 there has been a resurgence in the abundance of males, but females remain scarce. However, in 1987, the 1982 year class females appeared as the most abundant year class on the spawning grounds.

Monitoring of Adult Striped Bass: Sampling the age, size, and sex composition of a spawning stock of striped bass is one means of monitoring the condition of the stocks. This information is also used in estimating mortality rates, forecasting the future condition of the fishery, and in developing and evaluating management options. Ideally, samples taken to obtain age, size, and sex information should be unbiased; that is, fish of each age, size, and sex would occur in the sample in proportion to their actual occurrence throughout the population. Since the early 1980's, regulations on the commercial striped bass fishery have resulted in samples of the commercial catch no longer being representative of the population. To obtain vital information on striped bass stocks including size, age, and sex, several states have scientific sampling programs which do not rely on sampling fish from the commercial fishery. These efforts also include tagging of fish and obtaining samples for stock identification and contaminant analysis. A major sampling effort off Long Island is of particular importance in determining characteristics of the coastal fishery. Striped bass from both Chesapeake Bay and Hudson River stocks move past Long Island in the fall, and fish of a wide size range are present. Annual sampling provides information needed to monitor changes in the stocks over time and to assess the effectiveness of management measures.

In Maryland, sampling adult striped bass on the spawning grounds in the early to mid-1980's revealed a virtual absence of females between 4 and 10 years of age. This indicated that mortality of females was high enough to preclude virtually all reproduction. Females present were primarily those from the 1972 and older year classes. By now, only a few of these fish remain. For males, the spawning stock was dominated by 2 and 3 year old fish, with age 5 and older fish infrequently taken on the spawning grounds.

As the stocks rebuild because of catch restrictions and other management measures, the age composition of the adult stock will change. Females of younger year classes, combined with older ones, will result in an increased number of female spawners each year. For this to occur, protection afforded striped bass by existing management measures must be continued. After stocks recover, there will be a continued need to monitor characteristics of the adult stocks and of the fish harvested in order to provide information for management decisions.

Population Modeling: Modeling helps assess fishery management options and provides projections on potential rates of population recovery. A specific model has been developed for striped bass to help determine the maximum allowable fishing mortality rates. This model predicts the maximum fishing mortality rate permissible for a given set of length limits, and predicts the relative allocation of yield under that given set of minimum size limits.

Contaminants: Variations in striped bass year classes are an intrinsic part of their biology. When "strong year classes" failed to materialize during the late 1970's, fishery managers began to suspect that something was wrong. Pesticides, herbicides, fertilizers and heavy metals were all proposed as potential sources of mortality of early life stages, particularly eggs and larvae. Coupled with possible influences of acid rain, contaminants were suggested as a significant cause of the decline in striped bass. However, even though contaminants were proposed as a key factor, the available data were insufficient to be conclusive.

Research on contaminants has been pursued both in the laboratory and in the field. Tests have shown that striped bass larvae are among the most acid sensitive fishes. Exposure of fish less than 50 days old to pH below 6.0 caused rapid mortality. (The pH of distilled water, which is neutral, is 7.0. This is 10 times less acidic than a pH of 6.0). The toxicity of aluminum and other inorganic contaminants generally increases as pH decreases. Thus, these contaminants may be important factors in early life stage survival in those spawning grounds characterized by low alkalinity and temporary depressions in pH. Aluminum levels as low as 50 parts per billion could be toxic to young fish at a pH below 6.5.

To evaluate survival of striped bass in their natural spawning habitats, a complementary series of experiments have been conducted since 1984. Experiments showed that the Nanticoke River water was toxic to larvae in 1984. On-site controlled experiments demonstrated higher survival in a mixture of river and well water, than river water alone. The results indicated that a toxic component was present in the river water. Laboratory toxicity studies, which duplicated the water quality conditions (pH, aluminum, and hardness) of the

Nanticoke River in 1984, resulted in mortality rates remarkably consistent with field observations that year. Decreased survival was also observed when young bass were exposed to a contaminant mixture (containing aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) at concentrations similar to those measured in the Choptank River in 1983.

No single contaminant has been consistently observed at levels toxic to striped bass larvae. The larvae appear to be sensitive to a wide array of toxic chemicals known to be present in spawning areas of the Chesapeake Bay. The chance of a simultaneous combination of high acidity and aluminum causing toxicity that limits production of striped bass in some of the spawning grounds in the Chesapeake Bay in some years seems to be well established. In 1986, tests in the Potomac River showed low survival for 10-day-old larvae. Mortality was attributed to high levels of inorganic contaminants, especially aluminum, cadmium, and copper and to sudden drops in temperature. In contrast, 3 years of studies in the Upper Bay region have failed to demonstrate any significant toxic conditions.

Both laboratory and field experiments indicate that low pH can significantly increase early life mortality of striped bass. To test whether low pH has actually contributed to the decline of striped bass, particularly since 1970, it is necessary to demonstrate either a decreasing pH trend in spawning rivers, or an increase in the frequency of low pH events during spawning periods or both. An exhaustive survey of available data on striped bass spawning habitats from North Carolina to the Hudson River revealed that no statistically significant changes in the frequency or magnitude of extreme pH events were noted for Chesapeake Bay striped bass spawning habitats since 1970. In the Choptank River extreme pH events were relatively common both before and after 1970. In the York, James, and Potomac Rivers extreme pH events were infrequent or absent. There is no evidence of a systematic change in frequency or magnitude of extreme acidity events in any Chesapeake Bay spawning rivers. Where changes might have occurred, the historical monitoring programs were inadequate to detect all but extremely large changes in the frequency and magnitude of pH events. The major spawning grounds in the Potomac River and upper Bay region, which historically dominated production in Maryland, are more alkaline with characteristically higher pHs.

Research thus far has laid a firm foundation for testing the effects of contaminants on striped bass recruitment. The key mortality factors are known, proven methods for testing mortality have been developed, and some of the rivers where high mortality is likely have been identified. What is not known is how important the contaminant-related mortality is for striped bass recruitment. In recent years, since the spawning stock has been so small, the resulting low recruitment cannot be ascribed to either low egg deposition or contaminants.

In the next few years, the opportunity to test the second part of the hypothesis will be available--namely, that decreases in water quality have contributed to the decline. If future year classes remain small, even when the adult spawning stock is large, then the toxicity argument would be more easily supported. In view of the high historical variability in young-of-the-year survival, it will be several years before strong inferences can be made.

Stocking for Restoration: It is important to determine if stocking will provide significant positive results in aiding recovery of striped bass populations to the Bay. The striped bass restoration program provided that an intensively managed program of stocking young striped bass would be implemented with the first stocking in 1985. These stockings are designed as an aid to restoration and are being evaluated for that purpose, as opposed to put-grow-take augmentation of the wild striped bass population. The Fish and Wildlife Service, Maryland Department of Natural Resources, Virginia Department of Game and Inland Fisheries, and two large utility companies are the major cooperators. The decision to stock was made because: (1) there has been no strong year class in Maryland providing good recruitment since 1970; (2) spawning success in the Upper Bay, a traditionally good location, has been weak in recent years; and, (3) there has been a notable scarcity of mature female striped bass on the spawning grounds.

With only a few exceptions, all fish stocked are tagged and all genetic parent stocks are kept separate. These fish stocking operations of striped bass in Chesapeake Bay are rigidly controlled and managed for applied research purposes. Tag return information is vital to enable fishery managers to determine the survival and movement of stocked fish.

During the 3-year period, 1985–1987, 1.4 million juvenile striped bass were tagged and released in Chesapeake Bay waters. As of fall, 1988, approximately 2,500 tags have been recovered, mostly from

Chesapeake Bay. Recaptures from outside Chesapeake Bay have come from along the Atlantic coast as far north as Massachusetts. Movements have been noticeably northward. It is too early to tell whether or not stocking will have a significant impact on restoring Chesapeake Bay striped bass.

Economic Studies: Striped bass have supported valuable recreational and commercial fisheries along the Atlantic coast for many years. The precipitous decline in the harvest of striped bass during the 1970's had a significant adverse economic impact, consequently Congress required an economic study be conducted to quantify the magnitude of the impact. Results of the 1980–1982 study indicated that the economic benefits generated from the 1980 commercial and recreational harvest of striped bass were still substantial, even for the relatively low stock levels during that year. For the ten coastal states from Maine to North Carolina, a total net economic value of about $12 million was generated. Approximately 75% of this total was associated with recreational catch while the other 25% came from commercial harvest.

In addition to the net benefits generated for the economy in general, the striped bass fisheries produced important income and employment opportunities in the coastal areas. The 1980 commercial and recreational striped bass fisheries resulted in $90 million in direct expenditures in the coastal areas of the 10 states. These expenditures generated a total direct and indirect contribution of over $200 million in economic output and employment for over 5,600 people. The findings of this study indicated that, had the striped bass stocks remained at the 1974 level, the striped bass fishery would have supported an additional $200 million in economic activity and 7,000 jobs in 1980.

Other Research Areas: Since 1980, investigators have examined several other factors which might have contributed to the decline in striped bass stocks. Results indicate that predation on striped bass eggs and larvae, and an increased abundance of competing species have not been identified as a cause of lowered striped bass production. Similarly, a lack of appropriate food for larval striped bass does not appear to be a limiting factor.

In 1983, a virus was isolated from striped bass undergoing high mortalities in a hatchery. The identification of this virus, infectious pancreatic necrosis, (IPN), led to studies which showed that while striped bass may become infected with IPN, they act only as carriers and do not die from the disease. Neither IPN, nor any other disease, is suspected of having been a primary cause of declines of striped bass.

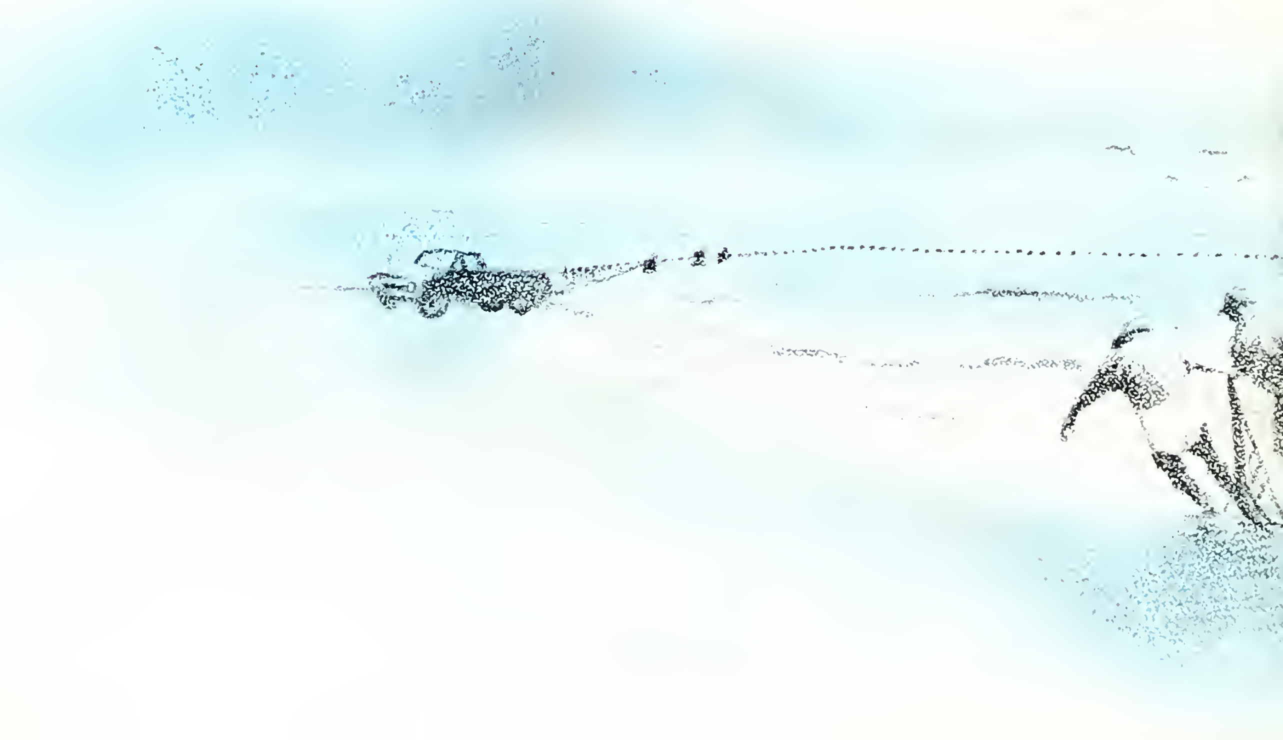
Summary: The research programs under the Striped Bass Study have provided increased knowledge of striped bass life history. Much of this information has been used to help make management decisions. Research under the Striped Bass Study has demonstrated that excessive fishing mortality rates, or overfishing, was a major cause of the decline in the striped bass stocks in the 1970's. Other studies have shown decreased survival of eggs and larval striped bass from various contaminants in some rivers in some years. Future research and monitoring studies should continue to provide information on the status of the stocks for use by fishery managers.

5 OUTLOOK FOR THE FUTURE

The future of the stocks will depend on management techniques which control fishing mortality and re-establish conditions, such as improved water quality, which foster successful reproduction and subsequent recruitment to the harvestable stock. To date, management efforts have focused on reducing fishing mortality, a practical, short-term solution to help rebuild the stocks. Experimental stocking is also being conducted to determine if stocking will augment the depleted stocks. While there are efforts underway to improve water quality, most are of a long-term nature and will take time to contribute to the success of striped bass restoration.

The past high mortality of striped bass of all ages, but in particular the excessive harvest of young fish, has resulted in few fish reaching sexual maturity. The consequence of these high harvest levels was a reduction in the number of female spawners. The 33 inch minimum size limit is protecting females of the 1982 and subsequent year classes of Chesapeake Bay stocks. This limit has ensured that many more fish will reach maturity and provide recruits to the stocks. This size limit may soon be increased to afford more protection. Future management strategies must continue to control the harvest levels to ensure adequate numbers and age distribution of spawning females.

Historically, the striped bass fisheries have been supported by dominant year classes. Without adequate management, these population cycles result in severe fluctuations in annual harvest levels. Management strategies need to be implemented when the stocks recover in order to spread the harvest of dominant year classes over a longer time period.



Adequate egg production alone will not guarantee adequate recruitment to the stock. Survival of striped bass eggs and larvae is extremely variable and is believed to be caused by naturally occurring and man-influenced fluctuations in environmental conditions. This premise is supported, in part, by the occurrence of dominant year classes. Striped bass spawn in areas where human activities frequently contaminate water, thus compounding natural variability in egg and larval survival. Adverse water quality during spawning and nursery periods lowers survival and may prevent the occurrence of dominant year classes.

In recent years, reduced numbers of females and an absence of younger females on the spawning grounds have reduced total egg production. Younger females spawn later in the season than older ones. Additionally, egg and larval survival may not be uniform throughout the spawning period. If conditions favorable for survival occur infrequently and for short time periods, juvenile production can depend heavily on the number of eggs produced during those favorable periods. Obviously, juvenile production can be increased by increasing the number of female spawners. In 1986 and 1987, the 1982 year class females were the most abundant year class on the spawning grounds in Maryland. If in the next few years the 1982 and subsequent year class females continue to be abundant on the spawning grounds, the stock should increase substantially. Ultimate recovery, however, depends on the ability of these year classes to reproduce successfully, an integral part of which probably is the success of efforts to reduce contaminants in spawning and nursery areas.

While minimum size limits control the harvest of younger fish, they allow unrestricted harvest of legal size fish. Future management must provide for an adequate spawning stock size. This suggests that fishing mortality must be controlled through additional measures such as creel limits, and seasonal and area closures. While the 33 inch minimum size limit may be altered after recovery, additional management measures need to be imposed to restrict the harvest. The history of implementing and evaluating fishery management actions shows that protective measures are needed after recovery.

Research studies have identified the probable major factors involved in the decline of striped bass populations. Likewise, this research has also enabled fishery managers to sharply focus their efforts on those specific issues that will maximize the likelihood of restoring Atlantic coastal striped bass stocks.

6 ADDITIONAL READINGS

For readers who desire additional , related information, the following references are recommended. Local librarians can assist in securing these items.

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Photos: Live striped bass, Virginia Institute of Marine Science; Large mounted striped bass, and small striped bass in hand, Paul Perra, Atlantic States Marine Fisheries Commission; Field photograph, Fish and Wildlife Service photo by Wes Dixon. **Artwork:** Robert J. Savannah.

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